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Influence of discontinuity the glue-line and selected technological factors on the shear strength of glued joints.

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Abstract: *Influence of discontinuity the glue-line and selected technological factors on the shear strength of glued joints.* The main aim of this work is determine the effect of discontinuity glue-line and the selected factors on the static shear strength wood joints. Tested joints were created by gluing beech wood and beech wood with MDF by PVAC adhesive. Discontinuity glue-line was created in view of the reduction glue amount at 75% and 50% of the value recommended by the manufacturer. The values of shear strength of the discontinuous glued-line (point and line) were compared with the strength of the joint with continuous glued-line. Factor affecting strength of adhesive joint was also open time of bonding. The analysis of results show that it is possible to create the discontinuous glued-line with a reduced amount of adhesive by 25%, wherein the strength properties of joints, taking into account examined factors falling only minimally compared to the continuous glued-line formed by the adhesive manufacturer's recommendations.

Keywords: glued joint, discontinuity of glue-line, technological factors of gluing, shear strength of the glued joints

INTRODUCTION:

Knowledge about the mechanical properties of structural joints are the basis on which is the basis for constructing furniture. The joints are critical points in the design. These locations are the most common cause of damage of structure due to the changes in local properties of the bonded elements. Glued joints form a significant group of joints in furniture and building structures which are applied structural adhesive joints connecting structural components and technology glue joints, connecting materials for creating components. When applying adhesives to followed technological procedures, safety regulations and rules for the use overwritten by the manufacturer in order to achieve properties that adhesives offer. If we are to address the impact of reducing the amount of glue and selected factors must always be in view of the strength glued joints, consequently, the safety of products.

Based on the theory of gluing it is possible to determine the basic conditions of gluing, namely: the right choice attached material and adhesive, suitable structural design, suitable surface coatings, compliance with the modalities for bonding, creating suitable conditions and other physico-chemical form solid bonds. The quality and strength adhesive joints affected by several factors such as the type and characteristics of the adhesive, the type of wood and its mechanical and physical properties, conditions of bonding (pressure, pressing time, pressing temperature), types of joints and the environment in which the product is used and others. The type of wood influences the bond strength due to the density; porosity and containing other substances that contain tree species. In the work (Pekař, 2007) was tested shear bond strength of some domestic and exotic wood species, this selection of trees to guarantee the density range. The highest average strength achieved samples with higher density. In the case of indigenous plants have been stronger bonded specimens of beech trees as spruce. For the gluing process it is

usually required moisture of material of 8-12% over the cross section. Effect of moisture material to be glued and adhesive type has been examined in work (Follrich et. al, 2010). The experiment results showed that the bonding strength of samples with a moisture content of 25% did not fulfil the standards set by the value of the fortress. In the work (Ramazan, 2006) was tested influence the thickness of the adhesive bonded joints. The results have shown a relationship between the thickness and adhesive strength. The largest average strength of 6.94 MPa was obtained at a thickness of 0.18 mm. With increasing thickness of the adhesive strength decreased. The smallest average strength was achieved at a thickness of 0.48 mm, at this thickness, the average strength of 39.48% compared to 0.18 mm thickness.

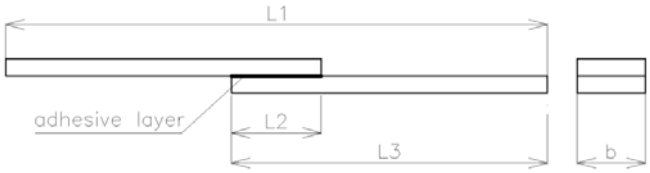
MATERIALS AND METHODS

Test specimens were made from straight fibers beech boards with a nominal density of 700 $kg.m^{-3}$ ± 50 $kg.m^{-3}$ and a humidity of 12% ± 1% and MDF with density 750 $kg.m^{-3}$. For the purposes of gluing samples were used one component copolymer dispersion adhesive Technobond D3. On the basis the verification tests we have created 11 test files of glued solid beech and 11 test files glued combination of beech and MDF. The files contain the 10 test specimens (Figure 1). In the files will change the amount of applied adhesive, changing the type of glue line. Test samples were glued with various opened time. The contact surface of the beech samples was 6 cm^2, the contact surface samples glued beech and MDF was 4 cm^2. The specific parameters of bonded files are listed in table 1.

Table 1: Technological parameters of glued files for determining shear strength of adhesive joint

The file number	Bonded material	Type of glue-line	The amount of applied adhesive (g/m^2)	Open time of gluing (s)	Reduction in adhesives consumption (%)
1.	beech-beech	full-area	120	30	0
2.	beech-beech	full-area	120	300	0
3.	beech-beech	point	90	30	25
4.	beech-beech	point	60	30	50
5.	beech-beech	line	90	30	25
6.	beech-beech	line	60	30	50
7.	beech-beech	point	90	300	25
8.	beech-beech	point	60	300	50
9.	beech-beech	line	90	300	25
10.	beech-beech	line	60	300	50
11.	beech-beech	full-area	150	30	0
12.	beech-MDF	full-area	120	30	0
13.	beech-MDF	full-area	120	300	0
14.	beech-MDF	point	90	30	25
15.	beech-MDF	point	60	30	50
16.	beech-MDF	line	90	30	25
17.	beech-MDF	line	60	30	50
18.	beech-MDF	point	90	300	25
19.	beech-MDF	point	60	300	50
20.	beech-MDF	line	90	300	25
21.	beech-MDF	line	60	300	50
22.	beech-MDF	full-area	150	30	0

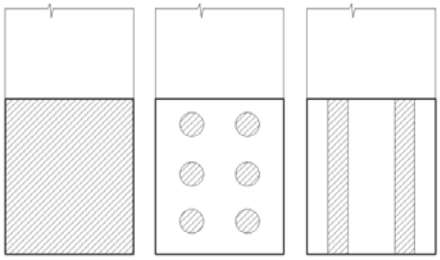
Compressed samples were conditioned 24 hours at 20 °C and a relative humidity of 20%. Shear strength is tested on Schroeder LabTest 4050.



Specimen dimensions		
The material of test samples:	**beech-beech**	**beech-MDF**
L1 length of the test specimen (mm)	**170 ± 2**	**180 ± 2**
L3 length of adherent (mm)	**100 ± 2**	**100 ± 2**
L2 lapping length (mm)	**30 ± 2**	**20 ± 2**
b width of the test specimen (mm)	**20 ± 0,2**	**20 ± 0,2**

Figure 1: Shape and dimensions test samples

Figure 2. shows the glue-line types; fig. 3 shows the principle of testing wood specimens.



a) b) c)

Figure 2: The type of glue spread for the glue-line
a) full-area glueline, b) point glueline, c) line glueline

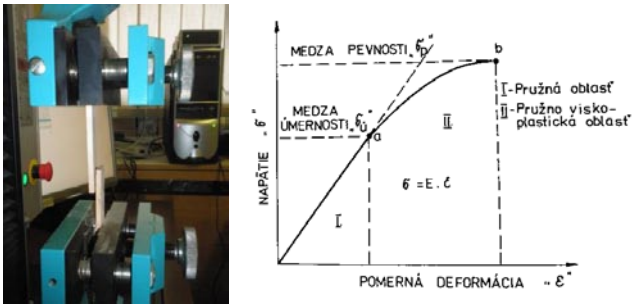


Figure 3: Test principle and working diagram during the test

The methodology of work is aimed at detecting the static shear strength glue-line, and the impact has been studied: the type of material discontinuity glue-line, open time bonding and quantity of glue. Bonding strength was calculated from equation (1):

$$\sigma = \frac{F}{S} \tag{1}$$

where:

σ – strength of glued joint (MPa)
F – the ultimate strength force (N)
S – bonding surface (mm^2) - for beech samples 600 mm^2 for a sample of beech + MDF 400 mm^2.

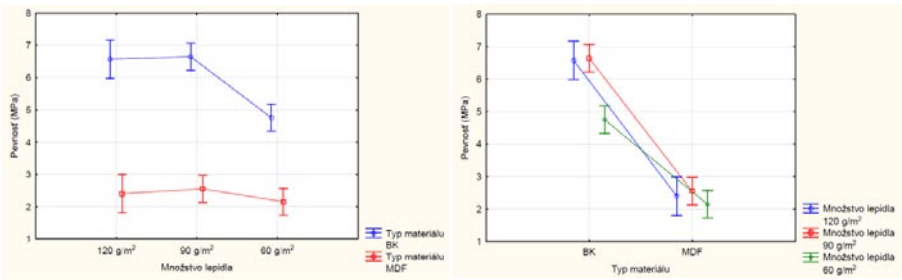
RESULTS

On the basis of the measured values can be concluded that the greatest strength had samples with full-area glue spread. Lower strength as a full-area glue spread reached a point adhesive application and the minimum strength has a linear adhesive application. According to the table 2 it can be argued that the impact of factors such as the type of material and quantity of applied glue have a statistically significant effect on the value of the shear strength test specimens (Šaržík, 2015).

Table 2: Basic table of multi-factorial analysis of variance - the impact of the type of material and quantity of adhesive applied to the shear strength of the joint

Efekt	Jednorozměrné testy významnosti pro Pevnosť (MPa) Sigma-omezená parametrizace Dekompozice efektivní hypotézy				
	SČ	Stupně volnosti	PČ	F	p
Abs. člen	3139,642	1	3139,642	1713,114	0,000000
Typ materiálu	591,600	1	591,600	322,801	0,000000
Množstvo lepidla	59,515	2	29,757	16,237	0,000000
Typ materiálu*Množstvo lepidla	27,506	2	13,753	7,504	0,000726
Chyba	355,546	194	1,833		

The change in the shear strength of test pieces with different amounts of applied glue is shown in fig. 4. In the both cases of type glued material is achieve the highest shear strength of the test sample with an amount of glue 90 g/m^2.The increased strength of the glue spread 90 g/m^2 compared with the quantity of 120 g/m^2 could be caused by discontinuity glue-line (scatter coating) compared with full-area glue spread. In case of point glue spread was glue area thicker compared with full-area glue spread. The adhesive was concentrated in six points (areas) compared with full-area glue spread. The minimum strength of the sample reached with amount of glue of 60 g/m^2.



a) b)

Figure 4: The changes of shear strength – influence of materials and different amount of adhesive on the shear strength

Test specimens created by gluing beech; surface of connection **400 mm²**			Test specimens created by gluing beech+MDF; surface of connection **600 mm²**		
The file number	Average values of **F_{max} (N)**	Average values of **σ_{max} (N)**	The file number	Average values of **F_{max} (N)**	Average values of **σ_{max} (N)**
1	***3502,27***	***8,76***	**12**	***1134,05***	***2,84***
2	1755,36	4,39	**13**	785,32	1,96
3	**3335,94**	**8,34**	**14**	**1177,11**	**2,94**
4	2621,34	6,55	**15**	1026,59	2,57
5	3065,97	7,66	**16**	1096,05	2,74
6	2402,71	6,01	**17**	1035,43	2,59
7	2309,28	5,77	**18**	975,43	2,44
8	1507,73	3,77	**19**	775,67	1,94
9	1917,89	4,79	**20**	827,28	2,07
10	*1072,17*	*2,68*	**21**	*593,77*	*1,48*
11	4145,45	10,36	**22**	1248,67	3,12

Evaluation of factor type of glue spread.

The evaluation of the measured values shows that the strength of the joints made with full-area glue spread with open times of 30 seconds and the glue spread amount of 120 g/m^2 was averaged 8.76 MPa. After reducing the amount of adhesive to 25% e.g. to 90 g/m^2 as disconnected glue-line strength of the joint is reduced to an average of 8.34 MPa, this means reduction of the strength by about 5%. In the creation liner discontinuous glue-line of the same parameters as point glue-line showed reduction shear strength in the average at 7.66 MPa, i.e. a difference 13%. By reducing the amount of adhesive to 50% i.e. to 60 g/m^2 to reduce the average shear strength for point glue-line to 6.55 MPa (decrease of 25%), and the liner glue-line to 6.01 MPa (decrease of 32%). Discontinuous point glue-line is on average 9% higher than the average strength of a liner glue-line. If we compare the test pieces with an open time of 300 seconds, created from full-area glue spread with a discontinuous glue spread, the test samples created with the full-area glued spread by the glue amount of 120 g/m^2 amounted to an average strength of 4.39 MPa. The test samples with point glue spread for which reduce the amount of adhesive to 90 g/m^2 amounted an average strength of 6.01 MPa. These samples amounted 27% greater strength than samples with full-area glue spread. Samples with liner glue-line amounted to average strength of 4.79 MPa, i.e. 9% greater strength than full-area glue spread. The reduction of adhesive at 50% i.e. to 60 g/m^2, samples with point glue spread have reached average strength of 3.77 MPa. It means that they have 15% less strength than samples with full-area glue spread. Shear strength of samples with line glue spread is 2.68 MPa which represents about 39% less strength than samples with full-area point glue spread. Comparing the of the discontinuous glue-line, i.e. samples with a point glue spread amounted to an average of 23% greater strength than samples with the line glue spread of the joint (Šaržík, 2015).

Evaluation of factor type of bonding material:

In all cases, of test pieces of glued solid beech achieve greater results than the test specimens created by gluing beech and MDF. Test specimens created by gluing beech - MDF amounted to an average strength of around 58% less than for test samples of glued solid beech.

Evaluation of factor of gluing open time:
The test specimens were glued with an open time of 30 and 300 seconds. Test specimens made of solid beech with an open time of adhesive 300 seconds were about 48% lower average strength than the test samples glued with adhesives open time 30 seconds. Test specimens created of beech and MDF with an open adhesive time 30 seconds reached at approximately 28% greater average shear strength than specimens with an open time of 300 seconds.

Evaluation of factor the amount of applied adhesive:
The quantity of applied adhesive has decreased from 120 g/m^2 to 90 g/m^2 and 60 g/m^2. Samples with an open time of adhesive 30 sec and by reducing the quantity glue about 25% of the average strength was reduced by approximately 8.5%. Reducing the amount of 50% of the average strength was reduced by about 28.5%. Samples with an open time of 300 seconds, and reducing the amount of adhesive applied on 25% of increase the strength of the average of 17%. The samples with reduced amount of applied adhesive about 50% of the strength were reduced by an average of 27% (Šaržík, 2015).

CONCLUSIONS**:**

- The greatest impact on strength of glued joint was the type of material to be glued and adhesive open time. The samples made of solid beech achieve greater strength than samples created by gluing beech and MDF. The reason for the low strength of glued joint is less cohesion of the surface layer of samples with MDF as was cohesion of the adhesive itself and the adhesion at the interface MDF - glue. Damage was most common in the surface layer of MDF.
- With increasing open time is reduced strength of glued joint.
- Significant effect on strength of the joint has a discontinuity glue-line. In this case, point glue spread achieves greater strength than linear glue spread.
- With regard to reducing the amount glue it is not a direct correlation between reducing the amount of adhesive and consequently a reduction in bond strength.
- The curing time of joint also has a relatively important role in bond strength. After a period of 24 hours curing adhesive bond was 20% less than the strength of adhesive bond with curing time of 7 days.

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Streszczenie: *Wpływ nieciągłości połączeń klejowych i wybranych czynników technologicznych na wytrzymałość na ścinanie połączeń klejowych*. Głównym celem pracy jest ocena wpływu nieciągłości połączeń klejowych i czynników pobocznych na wytrzymałość na ścinanie połączeń klejowych. Połączenia wykonywano na próbkach bukowych oraz MDF przy użyciu kleju polioctanowinylowego. Nieciągłość spoiny zapewniano przez obniżanie naniesienia do 75% i 50% wartości rekomendowanych przez producenta. Wartości porównano z próbkami o spoinie ciągłej. Czynnikiem wpływającym na jakość spoiny okazał się też czas otwarty. Wykazano że da się obniżyć ilość kleju o 25% bez znaczącego wpływu na jakość sklejenia.

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