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STIFFNESS AND LOAD CAPACITY OF BISCUIT CORNER JOINTS

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SYNOPSIS. The paper presents the examinations concerning the effect of dimensions of a biscuit joint on the stiffness and load capacity of a corner joint in case construction. Variable factors were: the thickness of boards, the dimension and the number of biscuits in the joint. Moreover, the values of load capacity of joint were related to peak values of normal and tangential stresses in the face member of joint.

KEY WORDS: corner joint, biscuit joint, stiffness, load capacity, stresses, particleboard

INTRODUCTION

Corner joints in case constructions made of wood-based panels can be produced by different joints out of which dowel joints are nowadays most widely used. Among other joints a biscuit joint, which is more and more frequently used by furniture designers, deserves our particular attention. Despite that this joint has not been sufficiently examined with respect to its strength. It was paid attention to in the research made by among other Albin et al. (1987) as well as Swaczyna and Piekacz (1996), but this was mainly comparative examination allowing to classify joints as regards load capacity. The relationship of mechanical properties of the joint to its dimensions was not described in them, however. Therefore, at the Institute of Technology of Kazimierz Wielki University investigations were carried out to determine the influence of the dimensions of the biscuit joint on the load capacity and stiffness of the corner joint in case construction made of particleboard.

MATERIALS AND METHODS

Investigations were carried out using specimens of the corner joint, being an element of typical case furniture (Fig. 1). Plate elements, made of a non-laminate,

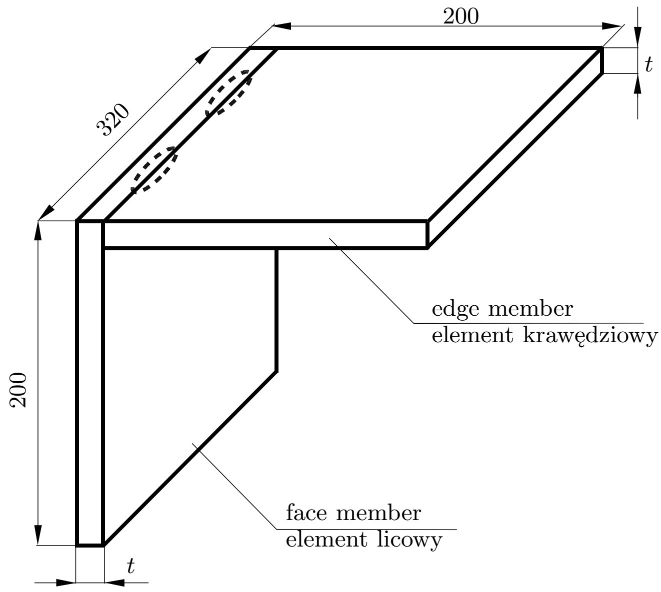

Fig. 1. Construction of biscuit joint
Rys. 1. Budowa połączenia kątowego o złączu lamelkowym

three-layer particleboard, were joined by means of a beech biscuit “lamello” settled by using 0.1 mm glue line. There were used commercially available biscuits of three different sizes, marked as ‘0’, ‘10’ and ‘20’. The precise sizes of biscuits were presented in Table 1. A variable factor was also the number of biscuits in a joint. Due to a specimen’s dimension it was possible to insert 2 and 3 biscuits.

Table 1. Dimensions of biscuits used in the joint
Tabela 1. Wymiary zastosowanych w złączu lamelek

Type of biscuit Typ lamelki	Thickness Grubość [mm]	Length Długość [mm]	Width Szerokość [mm]
‘0’	3.8	48	15
‘10’	3.8	54	19
‘20’	3.8	60	23

The two most popular thicknesses of particleboards: 16 and 18 were taken into consideration, whose physical and mechanical properties are presented in Table 2. A complete plan of tests was assumed, including all combinations of type and number of biscuits and thicknesses of particleboard. All specimens were assembled with polyvinyl acetate emulsion Racoll 25 Express. Fifteen replications were made for each investigative combination. Total number of specimens was equal to 180.

The specimens were loaded, which resulted in closing the arms of the joint (Fig. 2). The examination of the stiffness of the joint was conducted through determining the relative rotation angle of the joint arms γ, being the result of the

Table 2. Properties of particleboard used in the investigation
Tabela 2. Właściwości płyt zastosowanych do badań

Property of particleboard Właściwość płyty wiórowej	Tickness of particleboard Grubość płyty wiórowej			
	16 mm		18 mm	
	mean value wartość średnia	standard deviation odchylenie standardowe	mean value wartość średnia	standard deviation odchylenie standardowe
Density [kg/m^3] Gęstość [kg/m^3]	641	11.7	690	6.7
Moisture content [%] Wilgotność [%]	7.8	0.63	8.1	0.72
Bending strength [MPa] Wytrzymałość na zginanie [MPa]	14.7	1.45	13.2	1.20
Modulus of elasticity [MPa] Moduł sprężystości [MPa]	2 920	158.3	2 770	116.1

action of the bending moment M in the corner of the joint. In the examination, the loads were used that ensured linear dependence of joint deformation on bending moment. For particular investigative combination, the increment of force ΔP ranged from $P_d = 30$ N to $P_d = 120$ N. The specimens were loaded four times with the forces of values from P_d to P_g, measuring the increment Δf in relative move of the edge member. The average value of this increment from the last three measurements was obtained. Based on it, the increment $\Delta\gamma$ [rad] of relative rotation of the joint arms was calculated.

Rigidity coefficient k, being a measure of joint stiffness, was calculated from the formula (1):

$$k = \frac{\Delta M}{\Delta\gamma} = \frac{\sqrt{2}}{2} \cdot \frac{\Delta P}{\Delta\gamma}(a - t) \tag{1}$$

where: k – rigidity coefficient of the joint [Nm/rad],
ΔP – loading increment [N],
$\Delta\gamma$ – rotation angle increment [rad],
a – length of arm joint [m],
t – thickness of particleboard [m].

The determining of the load capacity was made using the same specimens, measuring the value of the $P_{\max}$ force, for which the destruction of the joint took place. This force causes the appearance of the maximal bending moment $M_{\max}$ in the corner of the joint, which was recognised as the measure of the bending load capacity of the joint.

$$M_{\max} = \frac{\sqrt{2}}{2} P_{\max}(a - t) \tag{2}$$

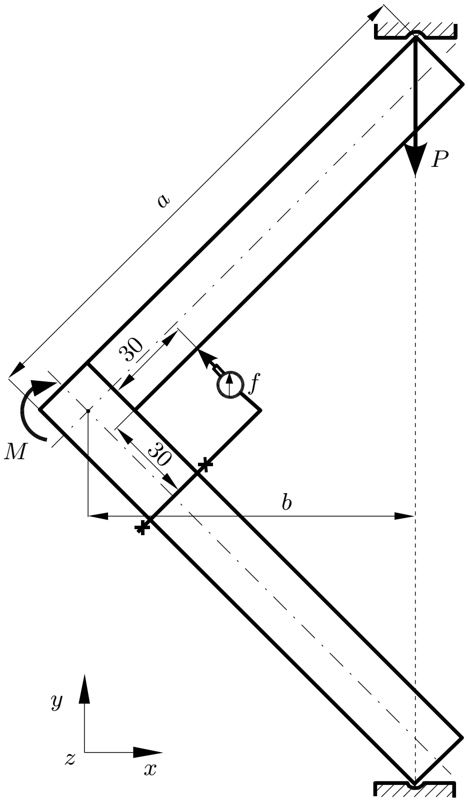

Fig. 2. Diagram of measuring of the angle of relative rotation of joint
Rys. 2. Schemat pomiaru kąta względnego obrotu ramion połączenia

RESULTS AND DISCUSSION

In Table 3 there were presented the mean results of the experimental examinations of the stiffness k and the load capacity M of a biscuit joint.

The stiffness coefficient k of a biscuit is significantly dependent on the type of biscuits used, with this coefficient increasing twice as much when the biscuit type is changed from '0' to '10' more than when it is changed from '10' to '20'. In the case of two-biscuit-joints, the increase of their dimension from '0' to '10' contributes to the growth of stiffness by 204 Nm/rad (52.2%), whereas the change from '10' to '20' – by 170 Nm/rad (28.6%).

With the three biscuits, the differences are not so large and amount to 192 and 128 Nm/rad (34.2 and 17.0%) respectively. The effect of the number of biscuits on the stiffness of the joint depends on their type and is greatest for the biscuits of the smallest dimensions. The increase in the number of the biscuits of the '0' type from 2 to 3 contributes to the growth of the stiffness coefficient by 171 Nm/rad (43.7%), whereas in the case of the biscuits of the '20' type, this growth amounts only to 117 Nm/rad (15.3%).

The load capacity of the joint also increases with the increment of the dimension of a biscuit, but contrary to the case of the joint stiffness, this increase is greater when the change of the biscuit type from '10' to '20' takes place. In the case of the joint with 2 biscuits, the increment of their dimension from '0' to '10' and from '10' to '20' causes the growth of load capacity by 5.2 and 8.8 Nm (17.4 and 25.1%) respectively, whereas with 3 biscuits in the joint the advantages due to the increment of their dimension are much smaller and amount to 3.5 and 5.4 Nm (8.3 and 11.8%) respectively. The effect of the number of biscuits on the load capacity of the joint is similar to their impact on its stiffness, with the growth of load capacity that results from using 3 biscuits amounting to 12.6, 10.9 and 7.5 Nm (42.3, 31.1 and 17.1%) for the biscuits of the '0', '10', and '20' types, respectively.

The thickness of the boards of which a joint was made has little influence on the mechanical properties of a biscuit joint. The joint made of 16 mm thick boards is – depending on the type and number of biscuits – characterised by stiffness

Table 3. The results of the examination of the stiffness k and the load capacity M of a biscuit joint
Tabela 3. Wyniki badania sztywności k i nośności M połączenia o złączu lamelkowym

Test combination Układ badawczy			Stiffness coefficient k Współczynnik sztywności k		Load capacity M Nośność M	
thickness of particleboard t grubość płyty t	number of biscuit n liczba lamelek n	type of biscuit typ lamelki	mean value wartość średnia	variation coefficient współczynnik zmienności	mean value wartość średnia	variation coefficient współczynnik zmienności
mm			Nm/rad	%	Nm	%
16	2	'0'	336	11.5	27.8	23.2
		'10'	521	8.0	30.3	17.4
		'20'	671	8.6	41.0	20.4
	3	'0'	489	13.5	35.6	19.0
		'10'	643	7.2	39.6	18.7
		'20'	761	8.8	48.1	14.0
18	2	'0'	391	9.6	29.8	15.6
		'10'	595	10.3	35.0	7.3
		'20'	765	8.1	43.8	15.9
	3	'0'	562	9.1	42.4	12.5
		'10'	754	7.8	45.9	8.8
		'20'	882	8.6	51.3	10.2

12.3 to 14.7% smaller, and by load capacity 6.2 to 16.0% smaller than that made of 18 mm thick boards.

All the examined samples of the joint, irrespective of the type and number of biscuits, suffered destruction in the same manner – through breaking off a biscuit with a fragment of the face member (Fig. 3). Therefore, one decided to make an analysis of stresses occurring in this part of the joint subjected to the forces closing its arms. The analysis was made on the basis of the finite element method, using the computer program ALGOR. To this end, a suitable numerical model was

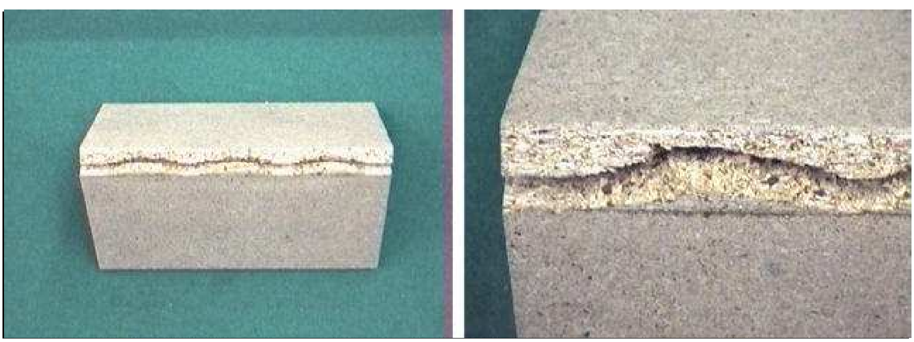

Fig. 3. The pictures of destruction of a biscuit joint
Rys. 3. Obrazy zniszczenia połączenia o złączu lamelkowym

prepared, that was described in a paper published earlier on the analysis of stresses in a corner biscuit joint (Kociszewski and Wilczyński 2001).

Estimated were normal and tangential stresses in the section most exposed to destruction and adjoining indirectly to the back walls of milled nests of the face element. The stresses in this section were recognised as the most important as being responsible for the delamination of the face member.

The distributions of normal stresses σ_x and tangential ones τ_{xy} in the AB section are presented in the Figures 4 a, b. Both components of the tensor of stress

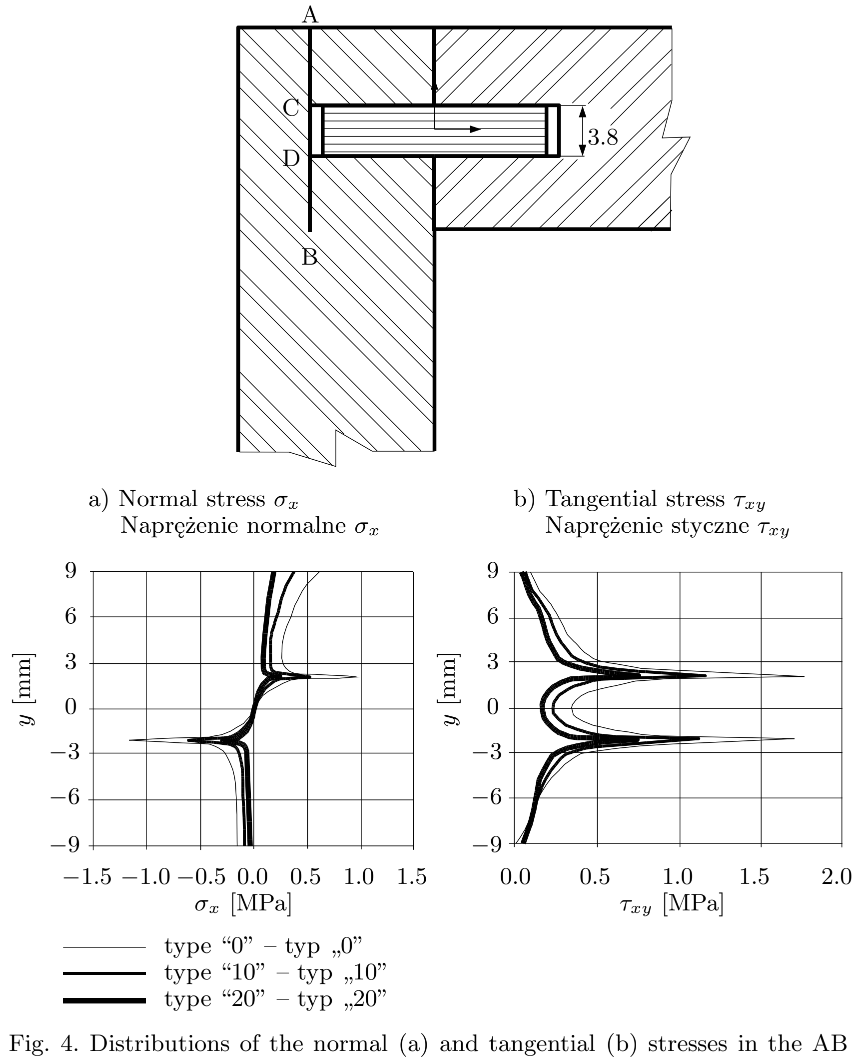

Fig. 4. Distributions of the normal (a) and tangential (b) stresses in the AB section of a biscuit joint with biscuits of various types (joints of 18 mm thick boards)

Rys. 4. Rozkłady naprężeń normalnych (a) i stycznych (b) w przekroju AB złącza lamelkowego z lamelkami różnego typu (połączenia płyt o grubości 18 mm) undergo very strong peaks at the points C and D lying at the height of relevant glue lines. In the case of normal stresses σ_x maximum values are achieved by the stresses at the lower point D, whereas for tangential stresses – higher values are possessed by the stresses at the point C of the examined section. These stresses in a considerable degree depend on the dimension of a biscuit. The change of a biscuit from the '0' to the '20' type results in a decrease of the stresses σ_x in this section by 0.3 MPa (by 75%), and of the tangential stresses τ_{xy} from 1.75 to 0.75 MPa (by 57%).

The value of the load destroying the joint should depend indirectly on the level of stresses in the joint. Therefore, one decided to relate the values of the selected stress at the most tender place of the joint to the bending stress of the joint (Fig. 5). Due to the fact that the most frequent picture of the destruction of the joint was the delamination of the face element, one decided to compare the maximum normal stress σ_x being the cause of breaking the board in the direction perpendicular to its surface, to the limit moment in the joint, which was calculated for one biscuit. It was found that the greater the load capacity of the joint is the smaller these stresses are.

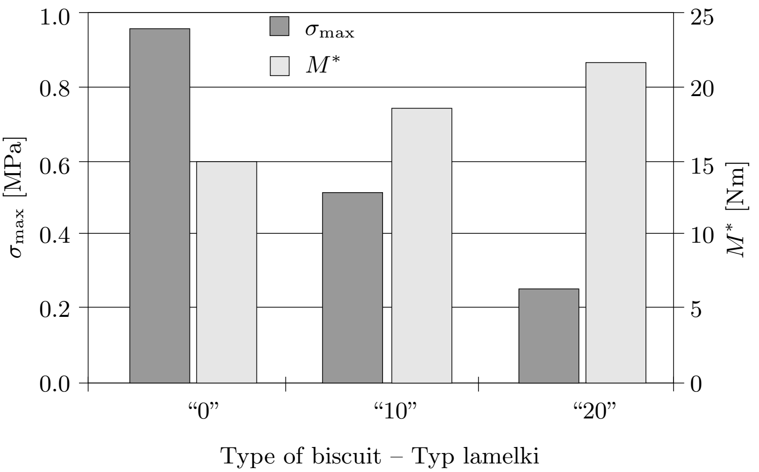

Fig. 5. Maximum tensile stresses $\sigma_{\max}$ in the face member and bending strength M^* of the joint reduced to one biscuit for the joint made of 18 mm thick boards

Rys. 5. Maksymalne naprężenia rozciągające $\sigma_{\max}$ w elemencie licowym i nośność M^* połączenia sprowadzona do jednego łącznika dla połączenia płyt o grubości 18 mm

The value of the moment destroying the joint depends not only on the maximum value of one stress in the joint, but also on other factors, among others, a destruction place, the location of stress peaks and the accumulation of the peaks of different components of the tensor of stress in the given section. Therefore, one should state that the presented relation of the stress stretching the face element to bending face cannot be applied indirectly to other dimensional systems of joints without a deeper analysis of their pictures of destruction.

CONCLUSIONS

1. The stiffness and load capacity of a biscuit joint considerably depend on the type and number of biscuits.
2. The using of a biscuit of greater dimensions has effect on the considerable growth of the stiffness and the moderate growth of the load capacity of the joint.
3. The increase of the number of biscuits causes the moderate growth of the stiffness and load capacity of the joint.
4. The joints of 16 mm thick boards are characterized by stiffness on average 13.4% smaller and load capacity 10.4% smaller than those of 18 mm thick boards.
5. The characteristic picture of destruction of biscuit joints is breaking off a biscuit with a fragment of the face element.
6. The increment of the dimensions of a biscuit causes a considerable decrease in the values of maximum stresses in the face element of the joint.

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SZTYWNOŚĆ I NOŚNOŚĆ POŁĄCZENIA O ZŁĄCZU LAMELKOWYM

Streszczenie

W pracy przedstawiono badania dotyczące wpływu wymiarów złącza lamelkowego na sztywność i nośność połączenia kątowego płyt wiórowych. Czynnikami zmiennymi były: grubość płyt, rozmiar lamelki oraz ich liczba w złączu. Wykazano, że analizowane czynniki istotnie wpływają na właściwości mechaniczne połączenia. Ponadto, nośność odniesiono do obliczonych za pomocą metody elementów skończonych naprężeń normalnych i stycznych w połączeniu. Stwierdzono, że nośność połączenia w znacznym stopniu zależy od poziomu naprężeń normalnych w jego elemencie licowym.

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