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SIZE AND CHARACTER OF THE LOADS IN CORNER JOINTS WITHIN STORAGE FURNITURE

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ABSTRACT

The variations in number and method of applied joints within storage furniture gave idea for this investigation. Importance of joint selection and its geometrical characteristic is clear if we bear in mind that the joints are critical points in the structure, and the rigidity and durability of storage furniture are in direct correlation with the type of the applied joint. Results presented in scientific papers provide little useful information to the engineer for the safe selection of the optimal joint. Number of joints along the connecting line (depth of the box type element) engineers determined empirically. In order to define stress state in the storage furniture, data on size of the load, that the box element has to with stand during its use, should be determined. The aim of this study was to determine the size and character of the loads in corner joints in storage furniture. Based on this data, as well as on the basis of information about the strength of the corner joints it is possible to calculate the required number of appropriate joining elements for each separate case.

KEY WORDS: Storage furniture, joints, bending moment, loads.

INTRODUCTION

The idea for this research was based on the overview of testing results of case furniture within the Institute for Furniture Quality Control at Faculty of Forestry, University of Belgrade. The analysis of the test results of durability of case furniture, according to EN 16122: 2012, revealed the large variation within the applied constructive solutions. These variations are concerning the method of application of the joints, and the number of joining elements by depth of the product. During the process of systematization of the products by its dimensions and type and number of used joints, application pattern was not recognized. Incompatibility of number of applied joints was noticed even on products of similar size and construction, where the same type of joint was used.

The importance of the optimal joint selection and application is obvious if we have in mind that joints presents critical points in the construction, and that the rigidity and durability of case-type furniture are directly affected by the strength of applied corner joints (Yerlikaya 2014, Aktas 2012). A literature review reviled a large number of factors that have effect on the strength of the corner joints within case furniture: panel type (Atar et al. 2009, Barboutis and Vassiliou 2009, Maleki et al. 2012, Malkoçoğlu et al. 2014, Tankut and Tankut 2010, Yerlikaya 2014, Yuksel et al., 2015, Yuksel et al. 2014, Maleki et al. 2012), panel thickness (Yuksel et al. 2014), panel length (Malkoçoğlu et al. 2014, Malkoçoğlu et al. 2013); insert fittings type (Barboutis and Vassiliou 2009, Nurdan et al 2012, Kořený and Simek 2011, Maleki et al. 2012, Simek et al. 2008, Yuksel et al. 2015), the number of joints along the connecting line (Malkoçoğlu 2014, Malkoçoğlu et al. 2013), joint geometric characteristics (Derikvand and Ghanbar 2014, Kasal et al. 2016), joints position along the connecting line (Kořený and Simek 2011, Malkoçoğlu et al. 2013, Simek and Eckelman 2008, Yerlikaya 2014, Yhang and Eckelman 1993); edge banding type (Tankut and Tankut 2010), adhesive type Atar et al. 2009) and joining orientation type: miter or butt (Atar et al. 2009, Maleki et al. 2012).

On the other hand, there is lack of data regarding the stress values in critical parts of case furniture during exploitation, which is related to the size of load that the case furniture has to withstand during its use. Despite the undoubtable contribution of research results presented in scientific papers in this field there is not enough information that could ensure confident selection of the optimal joint in practical use. The engineers most often determine the number of joints along the connecting line (depth of the case furniture) based on empirical experience.

During their use joints are affected by bending moment M, that develops under the external forces of action. In order to simplify the analysis, static force is applied at a distance of 50mm from the cabinet front edge, at a height of not more than 1600 mm from the floor (according to EN 16122: 2012), as shown in Fig. 1.

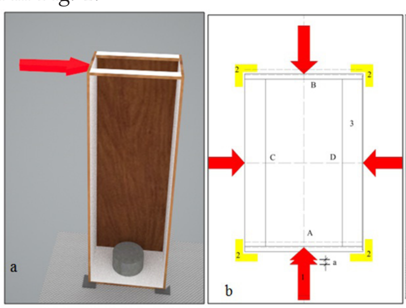

Fig. 1: Loading of case furniture: a) Test method; b) Force application points.

Moment of force action (torque) M which seeks to disrupt the rigidity of the case furniture consists of external force of action, weight of furniture, and shelf loads in accordance with applied standard. Reactive moments that resists to moment M depend on the type of joints (fixed or inserted), as well as the factors that affect the strength of the joints. In order to achieve adequate rigidity of the case furniture fallowing condition must be satisfied:

$$M \leq \sum_{i=1}^{n} M_i [Nm] \quad (1)$$

where: M - moment of force (Nm),
M_i- raective moments,
N - number of raective moments.

The values of reactive moments, on the right side of the Eq. 1, have been defined a number of times. The value of the load to which the joints are exposed during explatation (left side of the equation) is missing. The aim of this study is to determine the size and character of the loads in corner joints of case furniture (L type joints), with special emphasis on the convergence of scientific experiments to the real requirements of practical application. Maleki. et al. (2012) gave a recommendation that stress analysis can be used in addition to results of bending moment resistance to determine the strength of corner joints in case furniture. Having in mind the impact of other factors on construction, the next logical step is the stress analysis of the entire product, as well as determination of the size of loads that joints will be exposed during use. Determining the stresses state in case type furniture during its use opens the way towards rationalization in terms of the required number and types of joints. Based on the result of stress analysis of corner joints and the information of the corner joints strength, it will be possible to estimate the required number of appropriate joining elements in each single case.

MATERIAL AND METHODS

The analysis of case furniture stress state was made by static analysis. The conventional static analysis is complemented by the results of the analysis of the case furniture using finite element method (hereinafter FEM). The analytic results are compared with experimental results obtain on real samples of case furniture.

Both analysis have been conducted on the samples dimensions: 600 x 400 x 1600 mm (width x depth x height), Fig. 2. Dimensions of the sample for this study were determined on the basis of the case furniture which were tested in the last five years at the Institute for Furniture Quality Control, Faculty of Forestry in Belgrade. Stress state of samples was analyzed by calculating the value of the torque and induced displacement in main four points of the construction (node 8 - top left corner, node 9 - top right corner, node 6 - bottom left corner and node 10 - bottom right corner) and at the point force application by the piston (node 7 - 50 mm from the upper front edge of the box, at a height of 1600 mm from the floor).

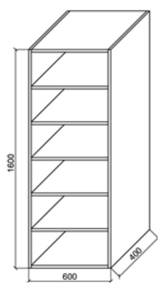

Fig. 2: Testing sample.

For the purposes of this research, 18 mm thick three-layer melamine faced particleboard was used. Particleboard is one of the mostly used materials in the production of cabinet furniture. According to the technical specification of the manufacturer, average density of the board was 710 $kg\cdot m^{-3}$, while average value of modulus of elasticity (MOE) was 1950 $N\cdot mm^{-2}$.

Based on the results obtained by Atar et al. (2008), it is evident that the backboard as well as the way it is attached to construction contributes to the compression strength of case furniture. In addition, previous studies (Denizli-Tankut et al. 2003, Smardzewski and Dziegielewski 1993) have shown that the type and thickness of the material that is used for backboard, as well as the method of fastening, have a significant impact on the rigidity of case furniture.

In accordance with that, in order to avoid the impact of the backboard and socle (Smardzewski (2015) on the rigidity of the case furniture, these two elements were omitted from the structure. This approach allowed us to analyze the stress state in the corner joints free from impact of other structural elements that reduces the stress in the joints.

The model for static stress analysis was conducted in accordance with the recommendations given by Nicholls and Crisan (2002), who offered a new approach in modeling of the joints for cabinet furniture. Joints are defined as elastic elements that can accept and transmit torsion load. Cai et al. (1993, 1995), analyze the strength of the corner joints in cabinet furniture and gave the recommendation for the linear structural analysis of case furniture with the use of the FEM. In their work, joints are defined as semi rigid based on their reduced elastic properties.) Determination of the number of shelves and the load on them, was carried out in accordance with EN16122: 2012, section 6.1.1. The values of the loads and the force of action, were given in accordance with this norm.

For the purpose of verification of the results obtained by analytic method, samples of case furniture were made. Testing of the rigidity was carried out according to EN 16122: 2012, section 6.4. In accordiance with the aim of working real models also did not have backboard or socle. In accordance with the recommendations of Nicholls and Crisan (2002), test models were fastener within sert cam fittings Minifix (produced by HAFELE) and reinforced with dry dowels. Application of glued joints, for the fixed connecting, can lead to the formation of compressed zone of altered material properties, which was confirmed by highest stain in the glue line of joint (Derikvand and Ebrahimi (2014)).The choice of insert fittings enables the properties of particle boards in the zone of joints to remain unchanged.

RESULTS AND DISCUSSION

The results of static analysis are presented on diagram of bending moments, Fig. 3, and on diagram of displacements, Fig. 4. The static analysis of a model was done in accordance with the recommendations given by other authors, where model is freely standing on the surface. The virtual model of case furniture for static analysis is designed in such manner that model have contact with surface that allows twisting but prevents movement on the surface.

The vertical sides are connected with semi rigid joints to the floor and the ceiling of model (upper and lower horizontal). Inside of the box five shelves were set at the same distance between each other. The shelves are freely supported so that their installation does not affect the rigidity of the case.

The weight of the horizontal elements was observed as the uniformly distributed load, while the weight of the vertical sides was considerate as concentrated force acting in the center of gravity of the side board. The shelves were loaded with concentrated force acting on the middle shelf, while the external load on the vertical sides was asymmetric. The value of the load was given in compliance with the EN 16122: 2012.

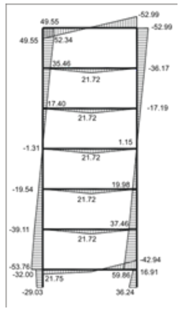

Fig. 3: Diagram of the moments.

Fig. 4: Diagram of the displacement.

The review of measured values of the moments and the induced displacements in corner joints in the observed nodes (Fig. 3) is shown in Tab. 1.

Tab. 1: Values of the moments and the displacements in observed nodes.

	Analytical results			Experimental results
Position of the joint	Node	Moment (Nm)	Displacement (mm)	Displaicements (mm)
Top left	8	52.9	62.0	-
Top right	9	52.9	62.0	-
Bottom left	6	53.7	1.4	-
Bottom right	10	36.3	1.4	-
Position of force application	7	-	62.0	65.0

The displacement was measured only at the position where force/piston was acting. Comparison between the values of displacement in the nodes, obtained by the static model analysis and the real experimental model, showed relatively small deviations (below 5%).

Smardzewski et al. (2014) examined the possibilities for calculating stiffness of the case furniture based on the modulus of elasticity of its joints. They presented experimentally obtained values of displacement at the top-right node of case-type furniture under the load from 0 to 500 N. When the value of force was 150 N displacement reached 8 mm, which is significantly lower value compared to the results presented in this study (62 mm). This disagreement is probably caused by additional reinforcement of structure with backboard, but also can be related to the differences in the testing method. Fastening of the model in the lower right corner probably contributed to the increase in stiffness or limited movement of the upper board of the model, and thus smaller displacement.

The values of bending strength of corner eccentric joints for case furniture found in literature are shown in Tab. 2. This overview includes only results obtain from experimental tests of the corner joints of sample with depth of 400 ± 20 mm.

Tab. 2: The bending strength of eccentric corner joint in case-type furniture.

Type of insert fitting	Reference	Bending moment (Nm)
Häfele, type „Minifix“ + 5 dry dowels	Džinčić, I. and Palija, T. (2016)	25.01
Häfele, type „Minifix“ + 4 dry dowels	Malkoçoğlu et al. (2013)	22.04
Häfele, type „Rondofix“ + 2 dry dowels	Koreny, A. and Šimek, M. (2011)	11.65

The corner joint strength, expressed by the values of measured bending moment that was found in literature (Tab. 2) is approximately two times lower than the values obtained by the static analysis (36 to 53 Nm) in observed nodes of this experiment (Tab. 1). This deviation of the experimental results from the results of the static analysis may be related to the construction differences between these two models, primarily the absence of the backboard and socle for static analysis model, which undoubtedly contribute to higher stiffness of the case type furniture.

The differences in the moments obtained by experimental work and those obtained by static analysis indicate that although the joint strength is usually estimated by calculation of the bending and/or tensile moments, this result cannot be taken as sufficient for assessing the stiffness of case type furniture, due to the necessity of inclusion of other constructive elements in the calculation.

CONCLUSIONS

This paper presents the static analysis of the case-type furniture with the aim of determination of the stress state in the corner joints. Despite the great number of data regarding the joint strength, literature review has not shown the information on the stress state in joints during exploitation use. The lack of information puts engineers in an unenviable position where the number of joining elements by depth of case furniture is determined on the basis of their experience. The knowledge about stress state in joints during exploitation combined with the information about joints strength allows engineers to choose the optimal type and number of the joining elements by depth of case furniture.

The analytic test model for this paper was defined on the basis on the recommendations and conclusions reached by other researchers. In order to avoid the impact of the backboard and socle on the rigidity of the case furniture, these two elements were omitted from the model construction. This exclusion of these elements gave us the possibility to perceive the stress state in the corner joints without impact of the other structural elements.

Based on the conducted static analysis and validation of the results using FEM and experimental work the bending moment in corner joints was determined. The value of the bending moments in four corner nodes ranged from 36 to 53 Nm.

The placement of the backboard and socle decreases the stress in corner joints. The impacts of these two elements on the rigidity and strength of case type furniture are not fully investigated, which leaves space for further researches.

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