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EVALUALUATION AND OPTIMIZATION OF BENDING MOMENT CAPACITY OF CORNER JOINTS WITH DIFFERENT BORING PLANS IN CABINET CONSTRUCTION

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ABSTRACT

In this study, the effects of end-distances and lengths of specimen (depths of cabinet) of ready-to-assemble (RTA) furniture on the bending moment resistance of corner joints were investigated and optimized by Artificial Neutral Networks (ANN). Melamine-coated particleboard (MCP) and melamine-coated fiberboard (MCP), cam fasteners, wooden dowels, and polyvinyl acetate (PVAc) adhesive were used for specimen construction as used in the furniture industry. For each of the specimens, five different lengths and four other illustrations which had diverse front and back end distances were prepared. Consequently, test results showed that the bending moment capacity went up when the distance is decreased and when the specimen length is increased. MCF moment values were 40 % higher than MCP moment values in the test results. According to ANOVA results for both MCP and MCF, significant differences were found in bending moment capacity with respect to the lengths of specimen and end distances. By ANN, the most appropriate boring plans for the end distance that belongs to 10 mm specimen lengths are introduced.

KEYWORDS: Ready-to-assemble furniture, corner joints, boring plans, melamine-coated boards, bending moment resistance, ANN.

INTRODUCTION

The designs of furniture construction have been carried out as results of trials and error methods. Joints are generally the weakest parts in the construction of furniture. Therefore, joint design is the most important step of furniture production (Eckelman 2003). In furniture manufacturing, over 10 thousand joint methods are available (Güntekin 2002). Some of them based on connectors with fasteners have been used in RTA since the middle of 20^{th} century. There are numerous types and sizes of RTA connectors such as mechanical cam locking, screws-in bolts, brackets, bolt-tightening, and hooks.

Panel type RTA furniture is usually attached with both cam fasteners and dowels which are placed as the cam fastener outer, and dowel inner position on a joint member. The various fasteners (cams, dowels etc.) are fixed 70-80 mm away from the member edge in workshops, and 50 mm away in mass production. Resistance values for all criteria of product groups need to be identified in order to set relevant standards related to optimal boring plans. Joint operations should be carried out according to boring plans in every type of furniture manufacturing. In this regard, for cabinet-type RTA furniture joints, time wasting should be minimized by using the optimal boring plan so that the number of processes, assembly and other stage operations can be reduced (Malkoçoğlu 2012).

ANN is a computer system which has been designed according to the assumed working principles of the human brain developed to establish skills for automatically producing new information and discovering through learning without any help. In the past, due to their ability to learn complex non-linear and multivariable relationships between process parameters, ANNs have been appropriate for modeling various manufacturing functions (Oztemel 2006; Ceylan 2008; Özşahin 2012).

There have not been many studies on cabinet-type ready-to-assemble furniture's optimal boring plans. In this study, the significant similarities among different strength experiments conducted with various materials and assembling methods were investigated. In similar studiescarried out with dowels, Bechmann and Hassler (Bechmann and Hassler 1975) studied joints constructed with 8 mm-diameter dowels. They found that for all practical purposes, the capacities of joints regularly increased when constructed with 1 to 4 dowels. They stated that spaces should not be closer than 100 mm.

Zhang and Eckelman (1993) found that the highest bending moment capacities at the spacing between dowels to be at least 75 mm. Likewise, Ho and Eckelman (1994) claimed that the most powerful approach to increasing strength was to place assembling tools very close to the front of the cabinet furniture. They found that maximum racking resistance was obtained with screw spacing of 75-90 mm. Rajak and Eckelman (1996) investigated the effects of specimen length, screw length, number and dimension on the bending moment capacity of joints. They found that bending moment capacity increased in direct proportion to the number of screws. Subsequent research by Liu and Eckelman (1998) determined that bending strength increased fast until the "zones of influence" of the fasteners overlap. They explained that no increase in strength was obtained beyond that point. The bending strength per fastener began to drop as the spacing between fasteners decreased below 57 mm.

Norvydas et al. (2005) concluded that dowel centers and the dowel spacing and edge affected joint strength. They reported that edge components were the weakest part of cabinet-type ready-to-assemble furniture. Also, according to the same authors, when the space between the dowel and edge was smaller than 45 mm, then a decrease in the joint strength could be explicitly observed. Furthermore, the observations showed that the strength increases parallel to increases in the dowel spacing and the dowel distance to the edge.

In related works investigating types of fastener and material, Albin et al. (1987) conducted extensive tests on corner joints constructed both with adhesive-based and mechanical fasteners. Overall, they found that the capacity of the joints varied mostly depending on the type of fastener along with the quality of particle board in the specimens. According to Efe (1998) and Tankut (2005), bending moment capacity was improved by increasing specimen length. MCF corner joints yielded approximately 3 times better results than MCPs joints. Also, Tankut (2005) explained that the maximum moment is obtained in joints when the spacing between dowels is at least 96 mm.

Simek et al. (2010) investigated the effect of the end distance of cam-lock RTA fasteners and un-glued wooden dowels on the splitting and bending moment resistance and number of dowels of RTA corner joints, respectively. Laminated particleboard, cam fasteners, and wooden dowels were used for specimen construction. They determined that the cam joints with a 60 mm end distance had significantly higher moment capacity than the joints with 30 and 90 mm edge distances.

The main purpose of this study was to determine the moment strength resistance of RTA furniture corner joints in the multi-boring unit machine which is mostly used in mass production. The effects of the corner joint and different panel types on the different lengths of specimen and end distances according to previously determined boring plan on the moment resistance were investigated. In addition, the maximum strength value and optimization of the moment capacity of 10 mm specimen length were determined using ANN application.

MATERIAL AND METHODS

Material

All specimens were constructed from 18-mm-thick MCP and MCP because of their common utilization in the furniture sector. The panels were tested (Tab. 1) for moisture content (MC), density (D), and modulus of elasticity (MOE) in accordance with ASTM D 1037-06a (2006). Cam fasteners with 15 mm diameter were chosen for this study. Multi-grooved beech dowels with 8 mm in diameter and 34 mm length were used in combination with cam fasteners. Also, PVAc adhesive was used for the bonding of the dowels into the holes on the edge butt members.

Methods

Specimen preparation

The general configuration of the corner joint members is shown in Fig. 1. Each specimen consisted of a face and butt members with dowels that were assembled with two cam fasteners. The parts of the cam fastener are listed as; plug, bolt, and cam housing as shown in Fig. 2.

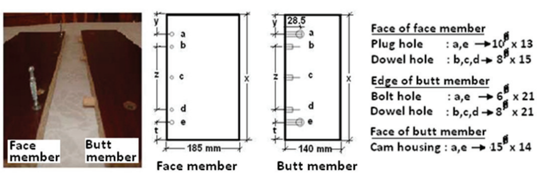

Fig. 1: Members with connectors and description of boring plans applied in the tests.

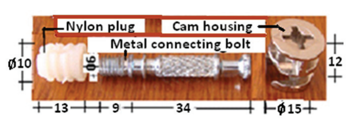

Fig. 2: Sizes and parts of cam fastener used in the tests (mm).

The boring plans of the members were prepared as shown in Fig. 1, and each of them is presented in Tab. 1.

By using two different types of panels (MCP and MCF), five lengths of test specimens (320, 390, 460, 530 and 600 mm), and four end distances (50, 60, 70, and 80 mm), a total of 400 specimens with ten replications for each boring plan parameter were prepared. In addition, twenty different boring plans were applied for five different lengths of specimens and four different end distances. Specimens were drilled according to the boring plans in the multi boring unit's machine with five units. Boring plans and descriptions of the specimens in the tests are given in Fig. 1 and Tab. 1.

Tab. 1: Boring plans and description of the specimens used in the tests (mm).

Number of boring plan	Specimen length (mm)	End distances (y-t) (mm)	Distance between dowel hole centers (mm) (z)	Drill numbers in boring units				
				a	b	c	d	e
1	320	50-46	160	1	2	-	7	8
2		60-36	160	1	2	-	7	8
3		70-58	128	1	2	-	6	7
4		80-80	96	1	2	-	5	6
5	390	50-20	128-128	1	2	6	10	11
6		60-42	128-96	1	2	6	9	10
7		70-64	192	1	2	-	8	9
8		80-54	192	1	2	-	8	9
9	460	50-26	160-160	1	2	7	12	13
10		60-48	160- 128	1	2	7	11	12
11		70-70	128- 128	1	2	6	10	11
12		80-60	128- 128	1	2	6	10	11
13	530	50-32	192- 192	1	2	8	14	15
14		60-54	192- 160	1	2	8	13	14
15		70-44	192- 160	1	2	8	13	14
16		80-66	160- 160	1	2	7	12	13
17	600	50-38	160-160-128	1	2	7-12	16	17
18		60-60	160-128-128	1	2	7-11	15	16
19		70-50	160-128-128	1	2	7-11	15	16
20		80-72	192- 192	1	2	8	14	15

Preparation of boring plans

The boring plans were conducted according to the criteria of TS 4539 (1985) standard and furniture manufacturing applications. For each specimen, two cam fasteners with dowels were used in this study. Various numbers of dowels (i.e. 2, 3 or 4), which changed based on the length of specimens, and end distances were positioned between cam fasteners. After the first and before the last cam fasteners, dowels were applied with a 32 mm distance. When the space between these dowel holes centers (Fig.1b and d) exceeded 200 mm and its multiplies (which is based on applications in manufacturing, however; this the space was stated as 180 mm according to the above-mentioned standard), another one or two dowels were placed between them (Fig. 1c). If the dowel hole centers were not at the center of the dowel space, the closest place to the back edge of the members was chosen as the dowel hole center because forces are usually loaded at the back of the cabinet construction.

The dowels were bonded to butt members with polyvinyl acetate (PVAc) adhesive. Adhesive was applied to the dowel holes with about 150–200 g.m^{-2}. Dowels were nailed down to those adhesive holes with the help of a mold. All of the members were conditioned in the conditioning room at 20±2°C and 65±5 % relative humidity. Plugs were inserted into the holes on the face member surfaces, and then the bolts were tightened into the plugs. After the bolts were inserted in the cams, the cams were tightened.

Testing

All tests were carried out with a universal testing machine. A loading rate of 6 mm.min-1 was used in all tests. Specimens were fixed to the test machine by a mold (Fig. 3) and then the load was applied.

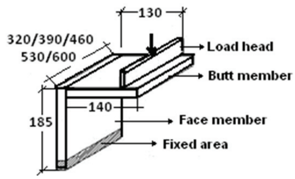

Fig. 3: Test specimen and loading type (mm).

The loading process was continued until a significant decrease was observed in the strength of joints. Once the loading process was ended, the amount of loading was measured with ± 0.1 N sensitivity. The strength of joints was characterized by the bending moment value when the joint was disabled.

Method of ANN

The development of the ANN models significantly depends on the experimental results. In the ANN modeling for the present work, the panel type, length of specimen (mm), first end distance mm (the space between the first hole center and front edge), back end distance mm (the space between the end hole center and back edge), number of dowels and distance between dowels (mm) were considered as the prime processing variables. The proposed ANN model was designed by software developed using the MATLAB Neural Network Toolbox. The data were obtained from the experimental study. To examine the effects of panel type, length of specimen, front end distance, back end distance, number of dowels and distance between the dowel hole center on moment capacity and the elasticity values of MCP and MCF, the experimental data were divided into training and testing data. Among these data, 26 samples were selected for the ANN training process, while the remaining 14 samples were used to verify the generalization capability of ANN. The data sets used in the prediction model are shown in Tab. 2 and Tab. 3.

The application of ANN

The ANN models, which have different network structures and parameters were constituted, and ANNs training processes were performed with MATLAB package software to determine weight and bias values and to minimize the mean square error (MSE). MSE was calculated using Eq. 2. In order to determine the performance of networks, the models were tested using a set of data (namely test data) containing input-output pairs which were not utilized for the training processes. Thus, the most sensitive (appropriate) ANN result was targeted.

The bending moments were calculated with Eq.1.

$$M = P \times l \qquad \text{(Nm)} \qquad (1)$$

where: M- joint bending moment (Nm),
P- applied load (N),
l- moment arm defined in Fig. 3.

Tab. 2: The training data set used in the prediction model and prediction model results.

Panel type	Length of specimen (mm)	End distances (mm)	Number of dowel	Distance between dowel hole centers (mm)	Moment (Nm)		
					Measured	Predicted	Error %
MCP	320	50-46	2	160	8.85	9.03	-1.99
		60-36	2	160	12.63	12.66	-0.22
		80-80	2	96	10.99	11.00	-0.08
	390	50-20	3	128-128	15.35	15.34	0.04
		70-64	2	192	8.76	8.73	0.40
	460	60-48	3	160-128	13.09	13.04	0.35
		70-70	3	128-128	13.54	13.20	2.49
		80-60	3	128-128	13.60	13.58	0.14
	530	50-32	3	192-192	12.33	12.29	0.33
		70-44	3	192-160	12.75	12.75	-0.02
	600	50-38	4	160-160-128	23.60	23.56	0.17
		60-60	4	160-128-128	19.70	19.77	-0.37
		80-72	3	192-192	12.98	12.98	0.01
MCF	320	50-46	2	160	12.43	14.94	20.22
		60-36	2	160	15.72	14.94	4.94
		70-58	2	128	16.13	14.95	7.29
	390	60-42	3	128-96	24.38	24.38	0.00
		70-64	2	192	15.30	14.94	2.36
		80-54	2	192	15.12	14.94	1.18
	460	50-26	3	160-160	18.80	18.76	0.19
		80-60	3	128-128	17.14	17.20	-0.38
	530	50-32	3	192-192	17.03	17.06	-0.15
		60-54	3	192-160	18.45	18.40	0.25
		70-44	3	192-160	18.23	18.31	-0.42
	600	60-60	4	160-128-128	30.23	30.19	0.12
		80-72	3	192-192	19.93	19.70	1.14
MAPE					**1.740**		
RMSE					**0.578**		

Tab. 3: The testing data set used in the prediction model and prediction model results.

Panel type	Length of specimen (mm)	End distances (mm)	Number of dowel	Distance between dowel hole centers (mm)	Moment (Nm)		
					Measured	Predicted	Error (%)
MCP	320	70-58	2	128	11.46	11.88	-3.70
	390	60-42	3	128-96	15.83	15.78	0.34
	390	80-54	2	192	7.67	8.40	-9.49
	460	50-26	3	160-160	13.62	13.52	0.75
	530	60-54	3	192-160	14.18	13.22	6.79
	530	80-66	3	160-160	15.35	12.58	18.04
	600	70-50	4	160-128-128	22.85	22.59	1.14
MCF	320	80-80	2	96	15.49	14.99	3.21
	390	50-20	3	128-128	20.55	19.74	3.96
	460	60-48	3	160-128	14.18	17.03	20.13
	460	70-70	3	128-128	16.94	17.11	-1.02
	530	80-66	3	160-160	22.45	18.20	18.93
	600	50-38	4	160-160-128	31.23	32.30	-3.41
	600	70-50	4	160-128-128	31.09	30.17	2.96
MAPE						**6.705**	
RMSE						**1.659**	

$$\mathrm{MSE} = \frac{1}{N}\sum_{i=1}^{N}(t_i - td_i)^2 \tag{2}$$

where: t_i - the actual output (targeted values),
td_i - the neural network output (predicted values),
N - the total number of measurements.

The obtained predicted values as a result of the testing process were compared with the real (measured) values. The model providing the best prediction values with respect to the root mean-square error (RMSE) ratio and the mean absolute percentage error (MAPE) ratio calculated with Eq. 3 and Eq. 4 respectively, was chosen as the prediction model (Eckelman 2003, Simek et al. 2010).

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(t_i - td_i)^2} \tag{3}$$

$$\mathrm{MAPE} = \frac{1}{N}\left(\sum_{i=1}^{N}\left[\left|\frac{t_i - td_i}{t_i}\right|\right]\right)\times 100 \tag{4}$$

In Tabs. 2 and 3, the values calculated by utilizing this prediction model for the training and test data, real values, percentage error ratio, and the RMSE and MAPE values are indicated. Fig. 4 shows the ANN model containing one input layer, two hidden layer, and one output layer. The selected ANN model represents the prediction model that produced the closest values to the measured values for the moment capacity value of MCP and MCF. The panel type, length of specimen, first end distance, back end distance, number of dowels and distance between dowels were used as the input variables, while the moment capacity values were used as the output variables in the ANN model. The processing element numbers (neurons) of the hidden layers were 2 and 6 for the model in Fig. 4. The numbers of hidden layers and neurons in the hidden layers were determined by trying various networks.

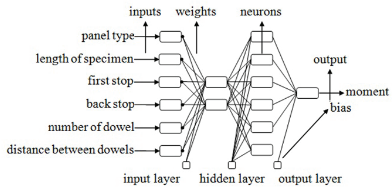

Fig. 4: ANN architecture selected as the prediction model for moment.

A feed forward and back propagation multilayer ANN was used for solving problems, and the network training and testing was carried out using the MATLAB software package. In this study, the hyperbolic tangent sigmoid function (tansig) and the linear transfer function (purelin) were used as the activation transfer functions, the Levenberg Marquardt algorithm (trainlm) was used as the training algorithm, the gradient descent with a momentum back propagation algorithm (traingdm) was used as the learning rule and MSE was used as the performance function.

The data in the training and test sets must be normalized in order to increase the efficiency of the neural network. Inputs and outputs were min-max normalized within the range of -11 for ANN modeling by the operation given in Eq. 5 in MATLAP.

$$X_{norm} = 2 \times \frac{X - X_{min}}{X_{max} - X_{min}} - 1 \qquad (5)$$

where: X_{norm} - the normalized value of variable X (real value of the variable),
X_{max} and X_{min} - the maximum and minimum values of X, respectively.

RESULTS AND DISCUSSION

Properties of materials

The average physical and mechanical properties of the MCP and MCF are shown in Tab. 4. acquired moment values as results of the experiments are shown in Tab. 5.

Analysis of variance (ANOVA) was carried out on the data at the 0.001 significance level as shown in Tab. 6.

Tab. 4: Average MC and mechanical properties of the MCP and MCF.

Material	MC (%)	Density ($g.cm^{-3}$)	MOR ($N.mm^{-2}$)	MOE
MCP*	8.34(0.28)	0.65 (0.01)	15.55 (1.5)	2826 (274)
MCF*	7.56(0.18)	0.75 (0.01)	27.67 (2.22)	3522 (263)

*Values in the parentheses are standard deviations.

Tab. 5: Average moment values for the length of specimens and end distances.

Number of boring plan	Length of specimen (x) (mm)	End distances (y-t) (mm)	Distance between dowel hole centers (mm)	Moment values (Nm)	
				MCP*	MCF*
1	320	50-46	160	8.85 (1.38)	12.43 (0.96)
2		60-36	160	12.63 (0.81)	15.72 (1.71)
3		70-58	128	11.46 (1.12)	16.13 (1.59)
4		80-80	96	10.99 (1.40)	15.49 (2.12)
5	390	50-20	128-128	15.35 (0.82)	20.55 (1.59)
6		60-42	128-96	15.83 (1.40)	24.38 (1.40)
7		70-64	192	8.76 (1.01)	15.30 (1.67)
8		80-54	192	7.67 (0.90)	15.12 (1.50)
9	460	50-26	160-160	13.62 (1.39)	18.80 (1.42)
10		60-48	160-128	13.09 (1.32)	14.18 (1.44)
11		70-70	128-128	13.54 (1.13)	16.94 (1.13)
12		80-60	128-128	13.60 (1.08)	17.14 (1.47)
13	530	50-32	192-192	12.33 (1.10)	17.03 (1.76)
14		60-54	192-160	14.18 (1.39)	18.45 (1.98)
15		70-44	192-160	12.75 (1.28)	18.23 (1.71)
16		80-66	160-160	15.35 (0.99)	22.45 (1.89)
17	600	50-38	160-160-128	23.60 (1.00)	31.23 (1.62)
18		60-60	160-128-128	19.70 (1.72)	30.23 (1.60)
19		70-50	160-128-128	22.85 (0.52)	31.09 (1.38)
20		80-72	192-192	12.98 (1.36)	19.93 (1.27)

*Values in the parentheses are standard deviations.

In this study, stable front distances in the boring plans for every single specimen length, and differences in the numbers of the dowels and back distances affected the moment values of the specimens.

Tab. 6: ANOVA results.

Panel type	Source of variation	Sum of squares	df	Mean square	F_{ratio}	Level of significance
MCP	A	891.30	4	472.83	335.68	***
	B	263.98	3	87.99	62.47	***
	AxB	1121.69	12	93.48	66.36	***
	Error	253.54	180	1.41	--	--
	Total	3530.51	199	--	--	--
MCF	A	4129.72	4	1032.43	412.60	***
	B	180.64	3	60.21	24.06	***
	AxB	1682.92	2	140.24	56.07	***
	Error	450.41	180	2.50	--	--
	Total	6443.67	199	--	--	--

*** Highly significant with probability<0.001,

A: Length of specimen,

B: Distances between dowel hole center and front edge of member.

Results of these analysis show that there were significant differences in bending strength in terms of the length of sample, space between the front hole center and front edge and corresponding interactions of those. Average moment values based on length of samples are shown in Fig. 5. In addition, Duncan's test results for determining the homogeneity of groups are given in Tab. 7.

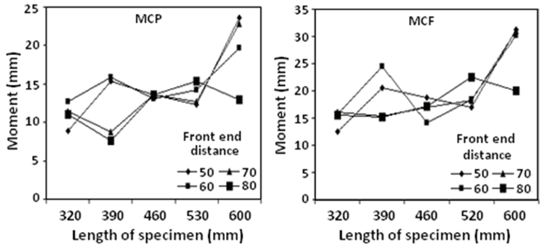

Fig. 5: Moment values based on the length of specimens.

Tab. 7: Homogeneity groups of moment values based on the length of specimens.

Length of specimens (mm)	MCP		MCF	
	Moment (Nm)	HG*	Moment (Nm)	HG*
320	10.98	D	14.94	D
390	11.90	C	18.84	B
460	13.46	B	16.77	C
530	13.65	B	19.04	B
600	19.78	A	28.12	A

* Homogeneity groups

As shown in Fig. 5 and Tab. 7, increasing the specimen lengths improved the strength values. This may be due to increasing the number of dowels and decreasing the distances between the hole center of the dowels.

In the studies related with fastener numbers, increasing the number of fasteners improves the strength of the joints (Bechmann and Hassler 1975; Rajak and Eckelman 1996; Lui and Eckelman 1998; Simek et al. 2010). When the distances between joint members were considered, lower strength values were obtained by using the lowest and greatest values in optimal numbers for distances. The strength values were lower for the distances 57 mm (Liu and Eckelman 1998), 32 and 64 mm (Norvydas et al. 2005), 32 and 128 mm (Tankut 2005) and less than 160 mm (Norvydas et al. 2005), while they were greater for the distances 75 mm (Zhang and Eckelman 1993; Ho and Eckelman 1994) and less than 100, 96 and 128 mm (Tankut 2005). Likewise, increasing member length improved the strength values (Tankut 2005). Accordingly, increasing the specimen lengths and the number of dowels improved the strength values. The results in this study illustrated similar findings to previous studies (Zhang and Eckelman 1993; Rajak and Eckelman 1996; Simek et al. 2010).

The average moment values based on the end distances are shown in Fig. 6. Furthermore, Duncan's test results which were made to determine the homogeneity of groups are given in Tab. 8.

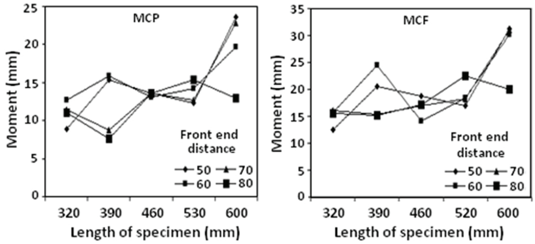

Fig. 6: Moment values based on end distances.

Tab. 8: Homogeneity groups of moment values based on front end distance.

Front distance (mm)	MCP		MCF	
	Moment (Nm)	HG*	Moment (Nm)	HG*
50	14.75	A	20.01	A
60	15.09	A	20.59	A
70	13.87	B	19.54	B
80	12.12	C	18.03	C

* Homogeneity groups

As shown in Fig. 6 and Tab. 8, increasing the end distances decreased the strength values. Increasing the end distances which causes a decrease in the distances between dowels and the number of dowels could be reasons for the decrease in the strength values.

There are limited findings on the length or diameter of fasteners for end distances studies. In one study, end distances increased from 20 to 45 mm with an increment of 5 mm (Norvydas et al. 2005); however, the best strength values were obtained at 50, 55, and 60 mm end distance values (Norvydas et al. 2005). Likewise, another study showed that the strength values were lower for end distances for 30 and 90 mm than the one of end distance for 60 mm (Simek et al. 2010). In our study, it was observed that the strength was increased by decreasing end distances. This observation shows similarity to the previous studies (Ho and Eckelman 1994; Norvydas et al. 2005; Albin et al. 1987).

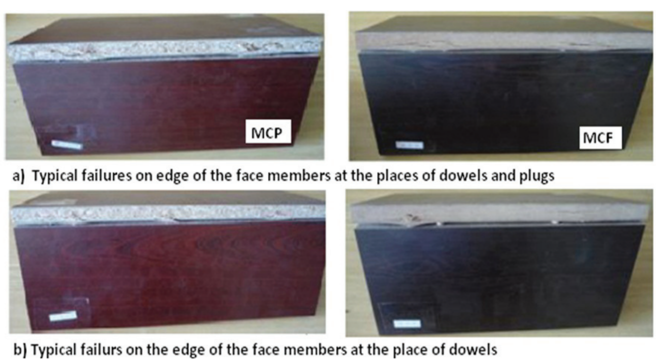

Fig. 7: Typical failures on the edges of face members.

Failures of materials occurred mostly in the holes of the blugs and dowels on the edges of the face members, and some in the cam holes of butt members as seen in Fig. 7. As it would be expected, these joint failures could be due to the location of face member in construction that is very close to the end of the edge.

Artificial neural network

It was decided that the 0.005 targeted MSE values would be sufficient for the training of the artificial neural networks. When the MSE of the ANN training process reached 0.005, the training was terminated, and the change of flow and stability were modeled with the obtained network parameters. The amounts of error variation depending on the iteration of the selected ANNs are shown in Fig. 8 for moment. The number of epochs after which the training model was stopped was 100. Fig. 9 shows the relationship between the real values and calculated values obtained using the prediction model. The comparative plot of these values is given in Fig. 10.

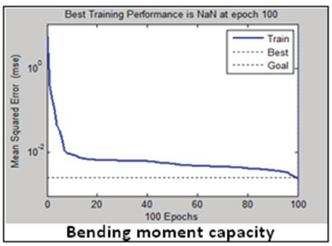

Fig. 8: A plot of error variation depending on the iteration of the ANN.

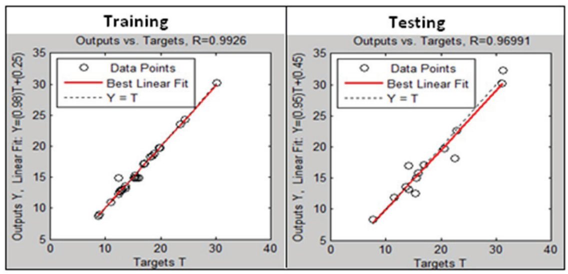

Fig. 9: The relationship between experimental results and ANN predicted results for bending moment capacity.

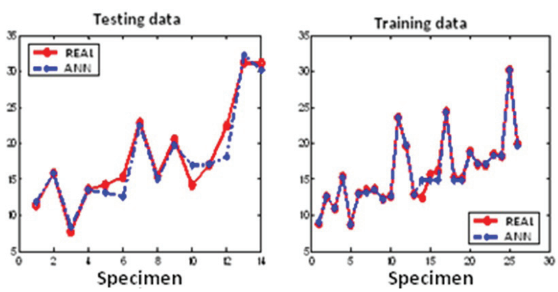

Fig. 10: The comparison of the real and calculated values for bending moment capacity.

The regression curves of the output variables for the experiment and ANN data sets are shown in Figs. 4 and 5. The values of R^2 in the testing set are 0.94 for moment, which indicates that the network obtained explains at least 0.94 % of the observed data. This value supports the applicability of using ANNs in the present study.

MAPE and RMSE were used to evaluate the performance of the proposed ANN. The MAPE was 1.74 % for moment in training, and 6.71 % for moment in testing. MAPE and RMSE results are shown in Tabs. 2 and 3. The comparative plot of outcomes of the ANN modeling and the experimental results for the moment are shown in Figs. 7 and 8. Close examination reveals that the fits were quite reasonable.

The results are satisfactory for the moment, and meet the integrity of the ANN learning and testing stages. As seen from the results, the ANN approach has a sufficient accuracy rate for the prediction of moment values of MCP and MCF. ANN modeling can be used for the modeling (the optimization) of moment values of MCP and MCF without needing the experimental study requiring much time and high testing costs.

Tab. 9: Optimization of moment values according to different lengths of specimens and end distances of the MCP and MCF.

Length of specimen (mm)	MCP		MCF	
	End distances (mm)	Moment (Nm)	End distances (mm)	Moment (Nm)
320	60-36	12.66	80-80	14.99
330	80-58	12.58	80-58	14.96
340	70-46	9.76	80-68	14.96
350	60-44	8.41	80-78	14.96
360	50-22	16.49	50-22	17.22
370	50-32	15.50	50-32	18.46
380	60-32	15.44	60-32	21.22
390	60-42	15.78	60-42	24.38
400	60-52	16.56	70-42	27.91
410	70-52	16.96	70-52	30.30
420	80-52	17.77	80-52	32.07
430	80-62	15.36	80-62	32.91
440	70-50	13.52	80-72	33.28
450	80-50	14.08	50-48	17.05
460	80-80	13.58	50-26	18.76
470	80-70	14.40	50-36	19.21
480	60-36	12.70	80-80	20.73
490	60-46	11.59	80-58	23.77
500	70-46	11.40	80-68	26.94
510	50-44	12.44	80-78	29.58
520	50-22	13.04	60-44	18.99
530	60-54	13.22	60-54	18.40
540	60-32	12.24	70-54	17.66
550	50-20	29.71	50-20	31.37
560	50-30	27.78	50-30	31.09
570	60-30	27.43	50-40	30.83
580	60-40	25.19	50-50	30.60
590	50-28	26.77	50-28	32.63
600	50-38	23.56	50-38	32.30

The ANN can be used for optimization. For example, the optimization of the boring plans for MCP and MCF can be carried out through an analysis of the evaluated network response. The intermediate values not obtained from the experimental study were predicted by the designed ANN modeling. The highest moment values of MCP and MCF predicted by the ANN model for different length of specimen (mm) and end distances (mm) are given in Tab. 9.

Maximum values were obtained when the lower front end distances for MCP, and both the lowest and highest front end distances for MCF were determined. This could be a result of using both end distances and moment values for each specimen length together.

CONCLUSIONS

Generally, in both MCP and MCF, the biggest moment values based on length of specimen were obtained with the same end distance. In this regard, providing adequate resistance for the two types of boards in furniture construction can be suggested for the implementation of the same boring plans. The MCF corner joints obtained stronger values than the MCP corner joints. Accordingly, using MCF can be considered as appropriate in furniture manufacturing which has sensitivity to resistance. If higher resistance on furniture is not needed, MCP can be used.

According to the evaluation of the moment values of the lengths of specimens, these moment values were improved by increasing the length of the specimen. Thus, the effect of specimen size dimensions can be named as an important factor. The test results showed that bending moment capacity was decreased by increasing the end distance. The proposed ANN model yielded adequately sensitive results with 6.71 % MAPE for testing set of moment values. Depending on all this, the results obtained with ANN can be suggested for use in this type of furniture application.

For future studies, to determine and analyze joint moment capacity, the standard distances of dowels (first and last) between cam fasteners on different furniture member lengths might be considered as 64 and 96 mm instead of 32 mm. Some studies are needed to determine the interaction among furniture member size, fasteners, front and back end distances and boring machines.

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