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# Experimental testing of cam fittings

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**Abstract:** The experimental testing of knock down fittings in furniture corner joints is the objective of this paper. Combination of cam fitting and non glued dowels has been used in a joint. Therefore this work deals with the effect of different joint type and different dowel spacing. A testing jig was developed for an experiment. The jig is useable for L type joint bending test in compression and tension. Bending strength of corner joints was tested on specimens 380 mm long which were manufactured out of laminated particle board. Tested fittings were Häfele Minifix and Rondorfix eccentric cams. These were combined with non-glued wooden dowels (always 2 pieces). As a result a comparison of influence of dowel spacing and joint type on corner joints strength is described.

*Keywords:* Cam fitting, knock down furniture, mechanical properties, bending strength, joints, testing

## INTRODUCTION

Dismountable joints are widely used in many furniture applications. Those insert fittings are commonly used in dismountable furniture, mainly for its quick assembly on site at the end customer. Even lot of joints tests were made, by many researchers and limited information from manufacturers is available problem of joint strength is still actual. (Barboutis et al. 2006) According to Eckelman (1993) and Joscak (1999), joint is the weakest point of a carcass construction. Except of an influence on construction strength and stiffness there is also economic reason. In a joint should be used sufficient amount of a fitting to make furniture reliable and safe. On the other hand, there is no reason to use more joints than necessary. Key to sufficient mechanical and economical properties is usually combination of expensive knock down fitting with cheap wooden dowels.

Important studies which gave overview about area of joint testing and possible testing methods were made by authors Eckelman, Smardzewski and Joscak. Related work by Eckelman was an experimental testing of a dowel joints spacing in a particle board. One of result of given paper is, that maximum bending moment is increasing with number of dowels in the joint. On the other hand with increasing number of dowels their failure zones become to overlap each other and moment per dowel is decreasing. He states, that maximum dowel joint strength is available, when spacing between dowels is at least 76.2 mm (3 inches). There is the lowest risk of failure zones overlapping. He also found a difference in material influence for compression and tension test. Compression has higher importance internal bonding strength of the board. For tension is more important surface tensile strength of the board (Eckelman, 1993). According to Joscak (1999) with increasing distance of dowels a joint strength increases. This dependence was tested up to a distance 96 mm. He also describes a failure area around the dowel similar to the Eckelman. He states, that failure zone width for 8 mm dowel 14 mm deep in the face member has width of the failure zone 57 mm. Smardzewski described joints by finite element analysis. He analyzed furniture joint combined of wooden dowel and eccentric fitting. He found out, that loads are transferred primarily by wooden dowel. In case of connector which use screw than has this one higher importance. (Smardzewski, 2002). Our study was focused only on fittings strength. According to Tankut 2009 edgebanding is incerasing joint strength. In this study edgebanding wasn't point of interest, even this construction element could rainforce the construction.

## RESEARCH OBJECTIVE

Objective of research was experimental testing of corner joints with focus on dependences of joints positioning and fitting type.

Dismountable joints are used for knock down furniture, usually in combination with non-glued dowels. The experiment was segmented in two main parts. Initial experiments were quite widespread. This approach allowed determination of a risk group of joints for second part of an experiment. Area of our interest was strength of joints with different spacing of dowels.

Initial hypotheses were confirmed: compression load is more dangerous than tension and that influence of fitting spacing is crucial.

## MATERIAL

In first part were tested more groups of joints, but in each group were only 3 specimens. Those reference groups were evaluated and following tests were focused on most important groups.

In the second part, main focus was on a compression load and specimens connected with cam and dowel.

For determination of specimen load is used terminology compression and tension. There is no standard for given test, so method of testing is made in way that is commonly used by other researchers. Our approach is inspired by Eckelman and Joscak. When furniture carcass is stressed by bending moment, either tension and/or compression occurs (Figure 4). General name for given loads is bending in angle plane.

### *Testing equipment*

For testing it has been developed a jig which is able to cope with both compression and tension loads. Main parts are: base plate with a groove, 2 pieces of carrier for specimen length 150 mm, 2 pieces of carrier for specimen length 380 mm, push beam with mortise - 380 mm long. All parts are made out of steel class 11600. In the middle of plates and beam is always a groove 1 mm deep with 120° inner angle.

Each specimen consists of two main parts. Length of the inset arm is 132 mm, length of the onset arm is 150 mm. Total length of both sides is 150 mm. Specimens were tested in length 150 mm and 380 mm. Eight specimen types were used in the 1$^{st}$ part of the experiment. Those were used for confirmation of jig functionaliy. It was also necessary to determinate differences between joint legth, joint type and load type. Eight specimen types were used in 2$^{nd}$ part were 380 mm long and differences were in fitting type and dowel position.

### *Fittings*

Selected fittings are cam type. Häfele Minifix 15 (Figure 1) and Häfele Rondorfix (Figure 2). Those two types represent most common cam fittings for knock down furniture.

Häfele Minifix connector housing – new desingn for 18mm thickness type. Combined with thread in dowel Minifix connecting bolt – bolt head 7 mm, screw length 11 mm.

Häfele Rondorfix – universal for board thickness from 16 mm.

Combined with Rondorfix connecting bold – for pre-drilled hole ø 5 mm.

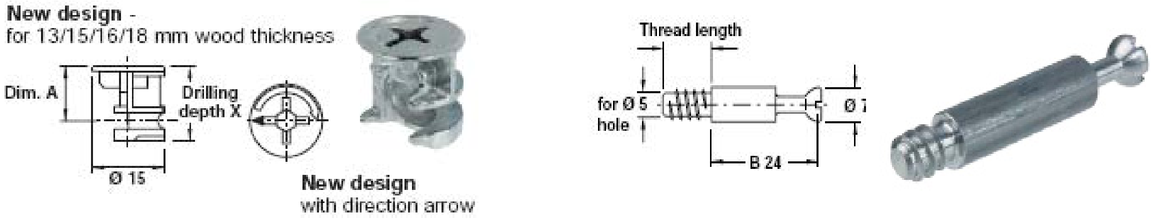


Figure 1. Minifix cam fitting and dowel

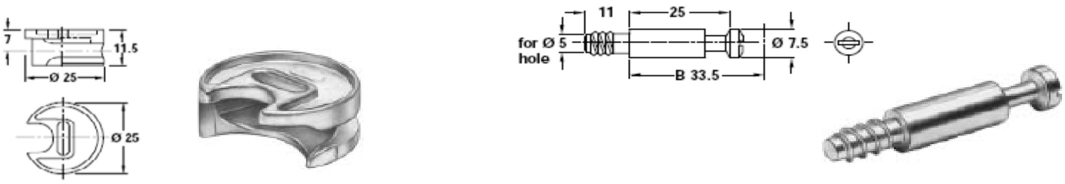


Figure 2. Rondorfix cam fitting and dowel

As an aditional connector to both cam fittings was used beech dowel ø 8 x 35 mm with straight roughing.

*Specimen types and construction*

In the major part of the experiment were used 380 mm long specimens (figure 3) of 8 different types, loaded only in compression . Each type of specimen was manufactured in 22 pieces. All of the pieces were manufactured on CNC machine. All parts were formated on its outline and than drilled. For tightening of cam fitting was used torsion moment of 6 Nm for Minifix and 5 Nm for Rondorfix. Tightening for screw-in bolt was set on 4 Nm for booth. Specimen types are specified in the table I.

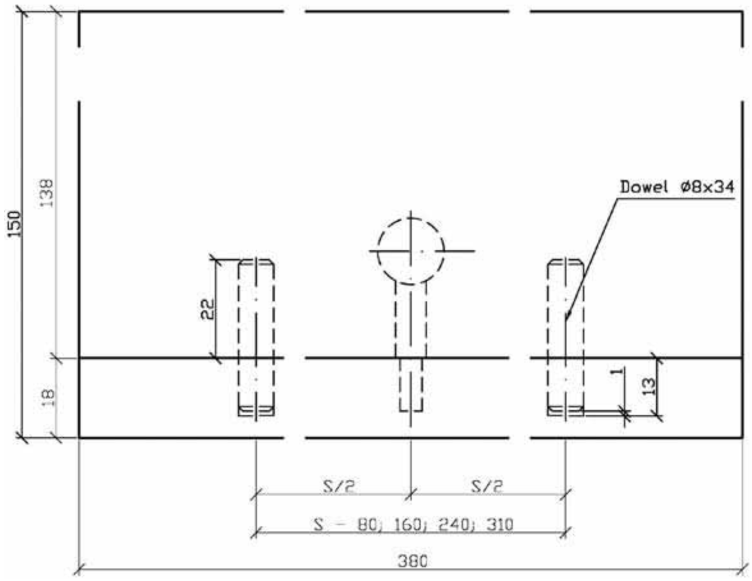


Figure 3. Specimen construction and dowel spacing. S – dowel spacing [mm]

Table I. Specimens by drilling type

| Length 380, Compression | Minifix [pcs] | Rondorfix [pcs] |
|---|---|---|
| Dowel spacing 310 mm (155 mm from specimen center) | 22 | 22 |
| Dowel spacing 240 mm (120 mm from specimen centre) | 22 | 22 |
| Dowel spacing 160 mm (80 mm from specimen centre) | 22 | 22 |
| Dowel spacing 80 mm (40 mm from specimen centre) | 22 | 22 |

## METHODS

*Principle of experiment*

Determination of maximum joint bending strength which cause its failure in angular plane. This type of load could be classified as a compression or tension. For testing was used universal testing machine Zwick.

*Setup of testing machine*

Preload 10 N; preload speed 10 mm/min; pressure speed 10 mm/min; data sampling: 0,1s (approximately 400 – 500 samples per specimen)

Compression speed has been set to time of filure 90 s ± 30 s. Tension in the specimen is not able to balance, but it is possible to determinate deformation smoothly. Testing has started by 10N force for preload of the specimen. Due to this we are able to figure out position of measurement tools. After preload and measuring setup test is started. After maximum load is test finished.

Raw data from testing machine were recalculated to the from of bending moment. :

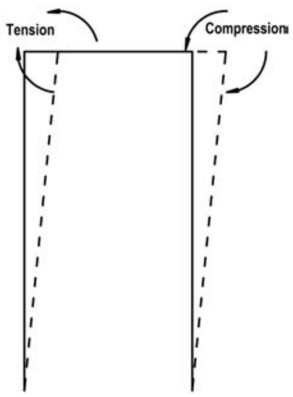


Figure 4. Compression and tension in carcass construction

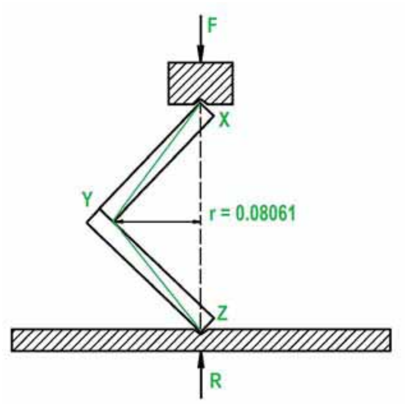


Figure 5. Calculation schema

Bending moment was calculated according to this expression:

$$M = R \times \sqrt{|XY|^2 - |YZ|^2} \quad (1)$$

Where M – bending moment [N·m], r – arm of loading force [m], R – reaction force [N]

## RESEARCH RESULTS

In the figures 6 – 11 are available test results of all specimen types which we are focusing on. Graphs in figures 6 and 7 were created by regress analysis with function “High precision polynomical order 20“ and shows values of displacement (X axis) on moment (Y axis). Moment was calculated from force multiplied by arm distance (Formula 1). Calculation has been done with dynamic change of arm length during sample displacement by the schema in figure 5.

Best results by regression analysis for Minifix are reached by the spacing 160 mm and 240 mm. Dowel which are too close or too far don’t give enough support to the cam fitting. Minifix specimens with dowel spacing 320 mm, 240 mm and 160 mm are very close up to the value of 8 N·m. In figures 6 and 7 only small difference is visible and order of regression curves is 320 mm, 240 mm and 160 mm. On the edge of 8 N·m occurs influence of dowel spacing and best results at the end of a test are given by distances 240 mm and 160 mm. Worst result in connection with booth fittings have got spacing of 80 mm. Dowels were to close and failure zones were overlapped. Main failure was visible in a face member joint, where board failed in the middle layer. This crack was visible around all connector positions. Worse result of 320 mm spacing is probably caused by too high distance of members which are than acting as separate dowels which is decreasing final stiffness.

At Rondorfix fitting are results similar to the Minifix. Differences between different spacing aren't so crucial as for Minifix, but also here has spacing 80 mm worst result. Important is an influence of a fitting on a joint stiffness which reaches better values in comparison with Minifix. In a box plots we can see that Rondorfix fitting (Figure 9) cause more equalized values for all types of specimens, even dispersion of specimens values is higher than in case of Minifix (Figure 8).

By ANOVA analysis is statistically significant only difference between dowel spacing 80 mm and 160 mm with Minifix (Figure 10). For Rondorfix, there are no statistically important differences (Figure 11). This could be caused by sturdy construction of fitting and larger diameter of the eccentric part. T-test also showed, that important is difference between 80 mm spacing with use of Minifix and Rondorfix. This could confirm that Rondorfix construction has higher influence on the joint than Minifix.

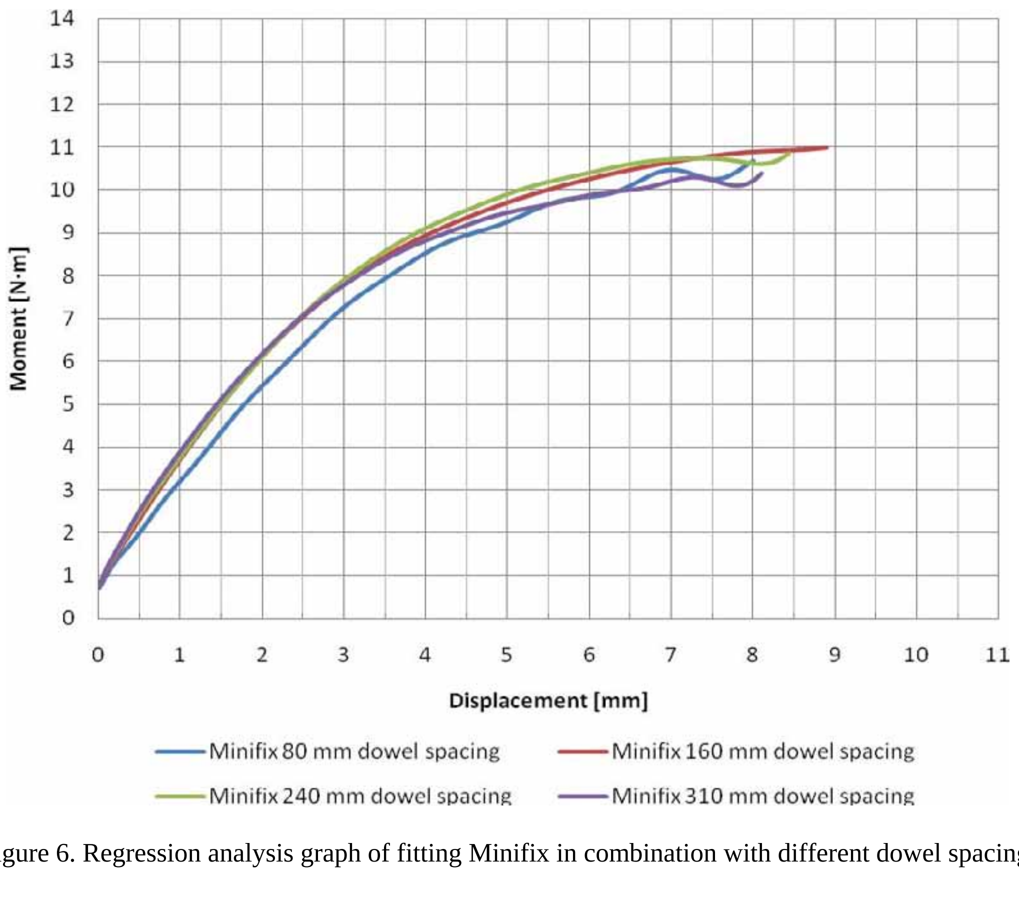


Figure 6. Regression analysis graph of fitting Minifix in combination with different dowel spacing

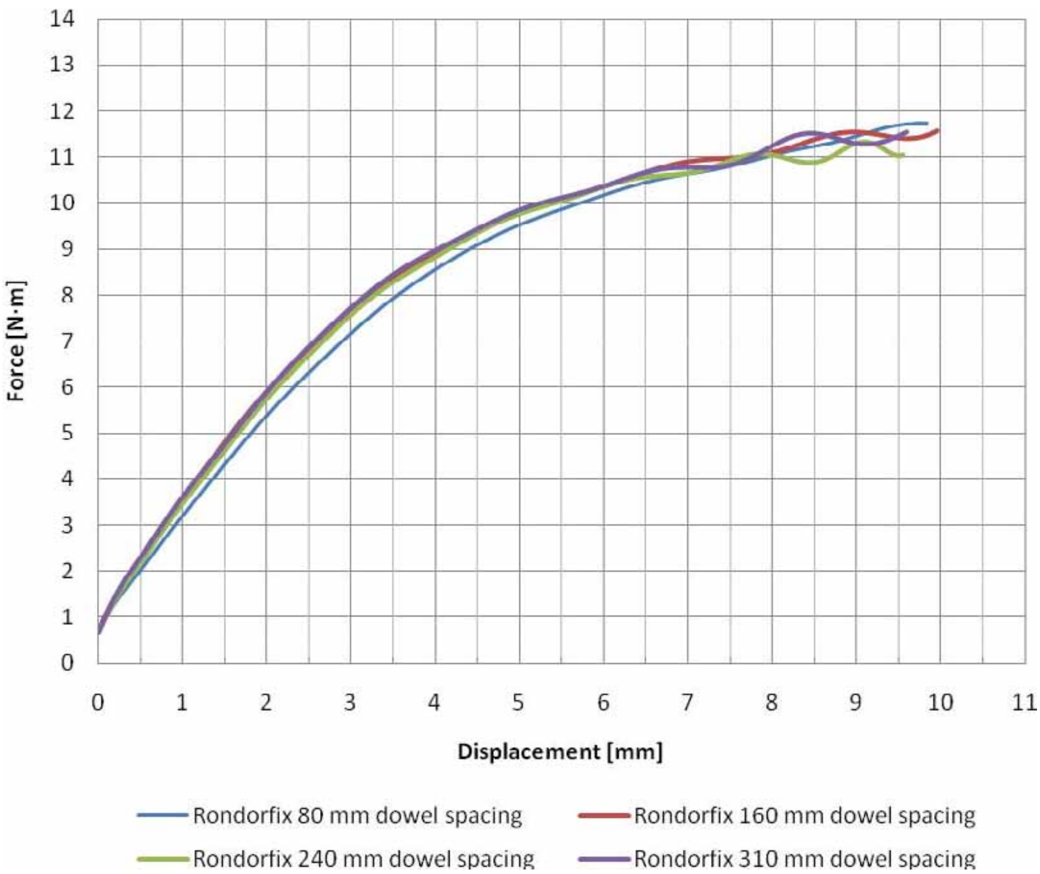


Figure 7. Regression analysis graph of fitting Rondorfix in combination with different dowel spacing

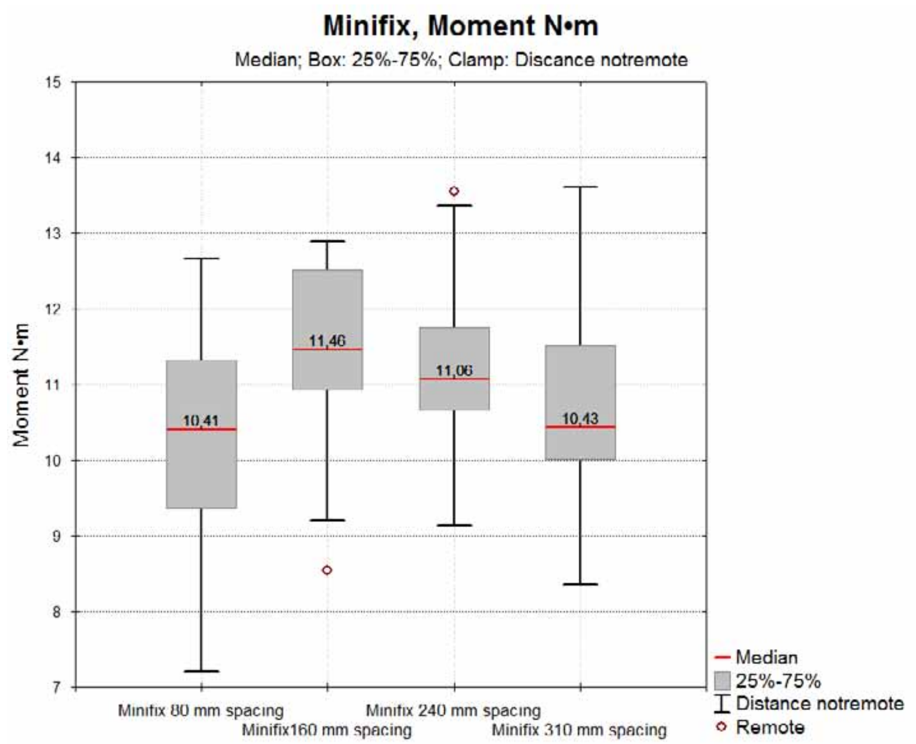


Figure 8. Boxplot graph of fitting Minifix with different dowel spacing

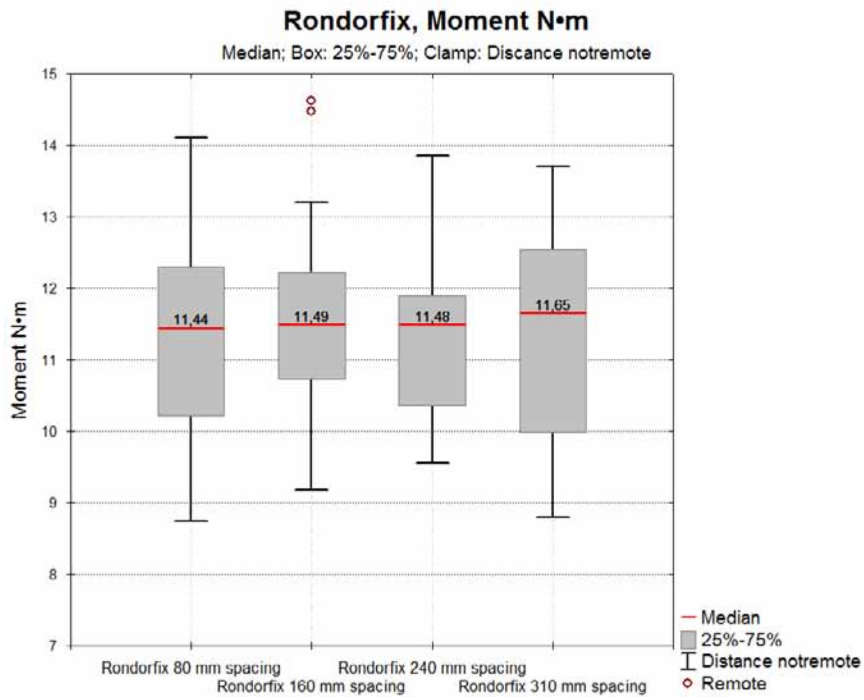


Figure 9. Boxplot graph of fitting Rondorfix with different dowel spacing

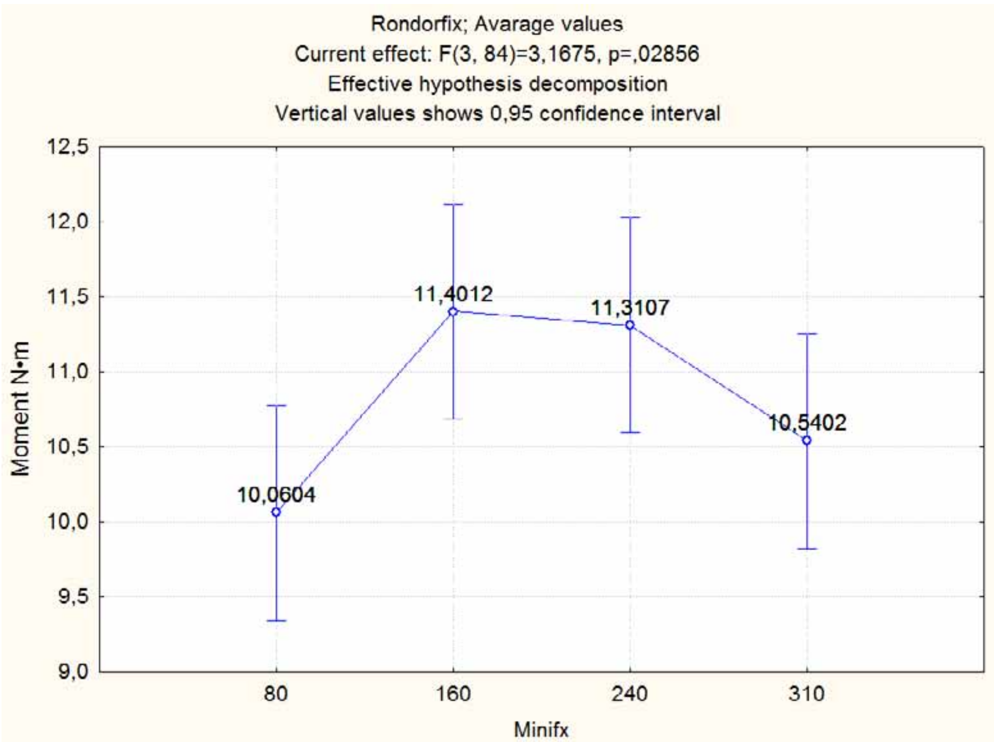


Figure 10. ANOVA graph of fitting Minifix with different dowel spacing

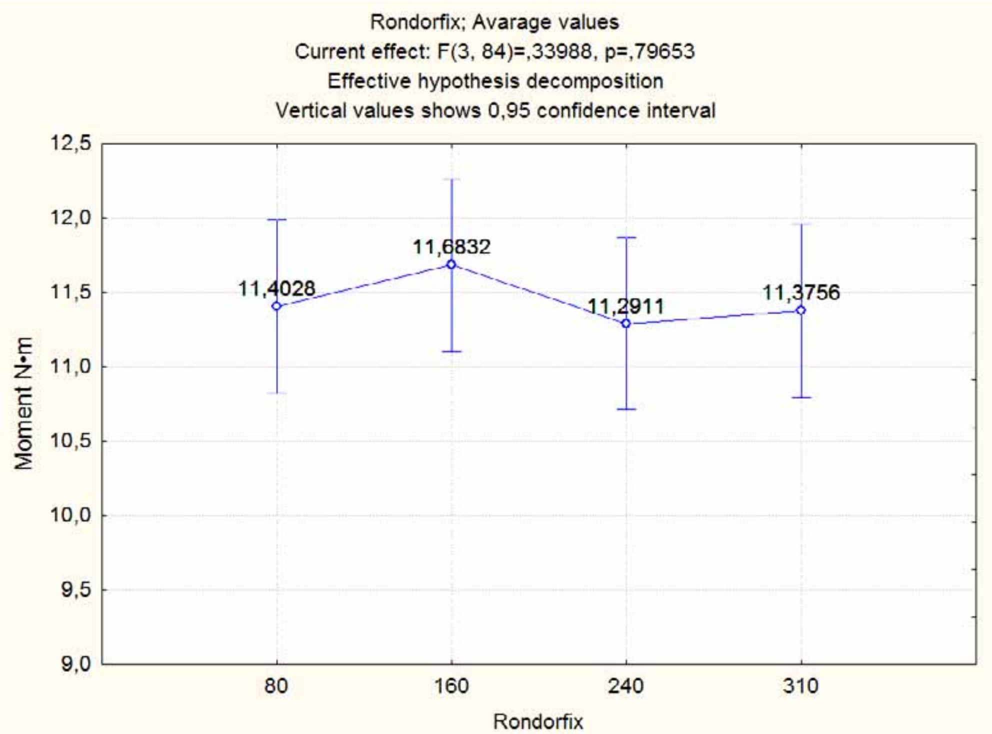

Figure 11. ANOVA graph of fitting Rondorfix with different dowel spacing

CONCLUSIONS

Lower load compression capacity of tested joints was confirmed in the first part of the study. Tested specimens were ordered as follows – glued dowels, non-glued dowels with cam fitting, non-glued dowels. Given ordering confirmed initial hypothesis which deals with basic order of joint stiffnes. From initial study was clear, that testing in the compression will be more important.

Major part of experiment was focused on Minifix and Rondorfix fitting combined with different dowel spacing. Main results of a study are:

- statistically tight difference is only between spacing 80 mm and 160 mm;
- Minifix joint combination demontrates slightly lower stiffness than Rondorfix;
- between specimens with use of Rondorfix are no statistically important differences;
- dowels that are placed too close to the conector cause lower stiffness of the joint;
- optimal dowel spacing is 160 mm – 240 mm;

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**Streszczenie:** *Badania eksperymentalne złączy mimośrodowych.* Celem pracy były badania eksperymentalne połączeń kątowych ściennych o złączach mimośrodowych. Rozpatrywano wpływ typu łącznika oraz odległości kołków ustalających na wytrzymałość na zginanie połączenia. Wykazano, że zbyt bliskie położenie kołka ustalającego w stosunku do głównego łącznika powoduje niską sztywność połączenia.

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