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THE END DISTANCE EFFECT OF KNOCK-DOWN FURNITURE FASTENERS ON BENDING MOMENT RESISTANCE OF CORNER JOINTS

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Abstract

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The goal of this paper is to investigate the effect of the end distance of cam lock fasteners on the bending moment resistance of knock-down corner joints. The preliminary study of knock-down furniture assembly plans was done in order to discover the manufacturers' fastener typical usage in case construction. Laminated particleboard, cam fasteners and wooden dowels were used for specimen construction. L-shaped joint specimens 760 mm in length were tested by pressing the joint members together – also called a compression test in the angle plane. The study results showed that cam fasteners with end distance of 60 mm from the member edges perform the best.

bending moment resistance, corner joint, end distance, cam fastener, wooden dowel

The joinery for knock-down furniture has been developed and used for almost half century. A large variety of connectors for knock-down furniture exists, including cam locking types, screw in types (e.g. confirmat, trapez), bolt tightening types (e.g. cross dowels), bracket types, hook types, and dowels used without glue. The mechanical strength of furniture depends mostly on the strength of the joints. Several investigations have been carried out on knock-down fastener joint strength. Among the most important ones are following studies.

Smardzewski and Prekrad (2002) studied the stress distribution in knock-down furniture joints by means of experimental testing along with numerical simulation. They tested three different joints (one cam type – VB36M/19 and two trapez types – TZ28 and TZ32S) in combination with two non-glued beech dowels (8x32mm). Their joint corner samples were made out of particleboard. The trapez joints performed the best in the tests. Results showed that the non-glued dowels played an important role in supporting the joint. Numerical simulations determined the distribution of stress in the joints and the bending moment carried by each fastener.

Joščák and Černok (2002) tested the load capacity of knock-down furniture joints made from laminated particleboard (18mm thick). Four types of corner joints (confirmat type, cam type Rafix, trapez type, and Stabilofix) were tested in angle plane by pressing the members of the joint together, Fig. 4, and by pulling them apart. The confirmat type joint performed the best when pressed together. Joints constructed with the Rafix cam type connector had the lowest moment in compression.

Burdurlu et al. (2006) determined the most suitable type of fitting for the assembly of knock down panel furniture. In his study he used six knock-down furniture fittings (two cam types, metal locking type, trapez type, bracket type and pipe type). The direct labor, direct material, direct energy cost, and stopwatch assembly work time in construction of the furniture were observed. Cam fasteners were determined to be the best for knock-down furniture assembly because of the shortest assembly time. Even though cam fasteners cost more, they save labor time in the assembly process, which is one of the costliest operations in furniture factories. For this reason, cam fasteners are the most used by knock-down furniture manufacturers. The advantage of cam fasteners for customers is easy assembly without the use of special tools. The low load capacity of cam fasteners is augmented by the use of non-glued dowels because unglued wooden dowels can greatly increase joint load capacity at a lower cost than the addition of cams.

OBJECTIVE

The objective of this study is to observe the effect of cam fastener end distance on bending moment resistance of corner joints.

PRELIMINARY STUDY

Before the experimental investigation began, a preliminary study of several knock-down furniture assembly plans was conducted in order to observe how cam fasteners and wooden dowels are used by manufacturers. These plans showed that:

- there are usually two cam fasteners used in the length of one corner furniture joint;
- cam fasteners are usually placed close to the end of the connected members;
- cam fasteners are combined with two or more non-glued wooden dowels but sometimes are used without dowels;
- geometric types of commonly used cam fasteners are very similar to the one used in this study.

MATERIALS AND JOINT DESIGNS

All joint specimens were constructed from 19 mm thick laminated particleboard, which is one of the materials most used in knock-down furniture. The panels were tested for specific gravity (SG), moisture content (MC), internal bond (IB), modulus of elasticity (MOE), and modulus of rupture (MOR) in accordance with ASTM D1037 (2002). From the large variety of cam fasteners, the Minifix (Catalog No. 262.26.620 + 262.27.921, Häfele Inc.) was chosen for this study (Fig. 1). Multi-groove beech dowels 8 mm in diameter and 35 mm in length were chosen to be used with the Minifix fasteners.

The configuration of the corner joint specimens is shown in Fig. 2. Every L-shaped specimen consisted of two structural members, a face member and an edge member, which were joined together by specified connectors. Based on the findings from assembly plans, the Minifix fasteners were placed close to the edge of the joint members. Specimens with three Minifix end distances (30, 60 and 90 mm from the end of members, Fig. 3) were tested first (18 replications per distance). Then reference specimens with glued and non-glued dowels in the best Minifix performed position as determined by these tests were tested (12 replications for each kind). A polyvinyl acetate emulsion adhesive with 48% solid content was used for the reference specimens with glued dowels. Holes 15 mm in diameter and 14.5 mm in depth were drilled into the edge members for the Minifix cam housings. Connecting holes for the metal bolts 8 mm in diameter were drilled into the edge members. Holes 8 mm in diameter and 22 mm in depth were drilled into the edge members for the dowels. Corresponding holes 8 mm in diameter and 14 mm in depth were drilled into the face members for dowels. Holes 5 mm in diameter and 12 mm in depth were drilled into the face members for the threaded part of the metal bolts. Glued dowel reference specimens were assembled using an excessive amount of glue, i.e., both dowels and holes were coated with glue. A square piece of thin plastic with hole in the center was slipped over the dowels to prevent the face from adhering to the edge member owing to excess glue.

All corner joint members were manufactured on the CNC router Thermwood C40. Reason for use of this machine was to obtain as high specimen production precision as obtained in industry. Assembly of the joints was done with basic tools including a rubber mallet, screwdriver and cordless drill. Metal bolts were tightened up to 3 N.m and all Minifix cam housings were tightened to 4 N.m by torque wrench. Glued dowel specimens were pressed together by metal clamps. Only dowels that provided a tight fit in the hole were used. Twenty-four dowels and drilled holes were randomly selected and their diameters measured by means of a digital caliper. Maximum and the minimum diameters were averaged. Differences between holes and dowel diameters averaged 0.1 mm.

METHOD OF TESTING

All joints were loaded in compression as shown in Figure 4 in a universal testing machine MTS 338.25. A loading rate of 8 mm.min^{-1} was used for all specimens. Joint strength was characterized as ultimate bending moment. Maximal load values were converted to bending moments by means of the expression M_{max} = 0.0792 R (N.m), where 0.0792 is the moment arm length in meters and R is the applied force, in Newtons. All specimen failures occurred within 90 seconds ± 30 seconds.

Before testing, all specimens were conditioned at a temperature of 22 °C and 35 % relative humidity for at least 48 hours. Analyses of variance (ANOVA, α = 0.05) were carried out to determine the significance of the differences between results for joint variations. Means were compared by employing the Tukey test to identify which groups were significantly different. Regression analyses of all bending moment-displacement graph plots were carried out as well.

RESULTS AND DISCUSSION

Table I shows the average physical and mechanical properties of the laminated particleboard. As expected, the MOE and the MOR values of the material were high in comparison to non-finished particleboard standards (Wood Handbook, 1999). This result agrees with the findings of Nemli (2005), who found that lamination significantly improves the MOR and MOE of particleboard, but has no effect on the IB.

An ANOVA test of joint maximum bending moments showed that there are significant differences between joint variations at the 0.05 level. The Tukey procedure (Tab. II) determined that the Minifix joints with 60 mm end distance from the edges and glued wooden dowel joints had significantly higher moment resistance than two other Minifix joints tested in the first study. Thus, the 60 mm end distance for the Minifix fasteners provides the greatest moment resistance of the three end distances. Even though the joints with 60 mm end distance proved to perform better than the 30 and 90 mm end distances, the difference of about 2 N.m is not great. Glued dowel joints had more than twice the bending moment capacity of all the mechanical joints tested in the first study (Fig. 5). Non-glued wooden dowel joints had a bending moment capacity almost as high as Minifix joints with 30 and 90 mm end distance. The significant differences between non-glued dowel joint and Minifix joints (which are in the same Tukey group) are in displacement, where non-glued dowel joints had over four times the displacement of Minifix joints (Fig. 5). In general, all types of failures occurred in the face members (where the Minifix fasteners were attached, Fig. 6). The laminated particleboard split on the edge; the lengths of the fissures varied from 15 to 70 mm.

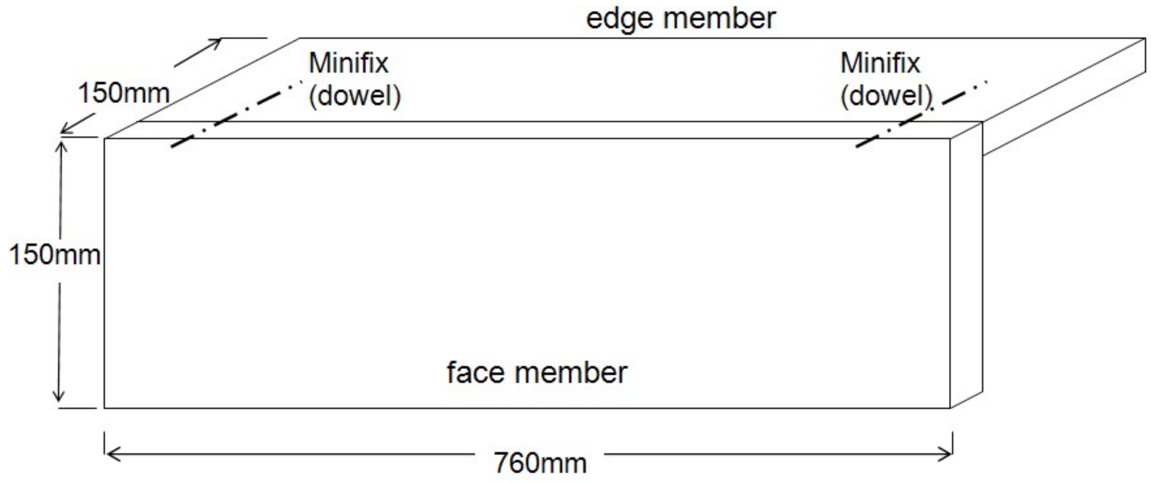
This study showed that the maximum bending moment in compression tests depends on the internal bond value of the particleboard. The core layer of the particleboard is the weakest because of larger particles. This was also the area where the splits usually started to form. The five-millimeter diameter hole (in the face member) for the metal dowel acted as a stress concentrator, i.e., a splitting point. Therefore, the length of the split depended on the particle dimensions which are present in the fixing area of the metal dowel threading. The non-glued dowel reference joints did not show any type of failure. The ultimate bending moment capacity of non-glued dowel joints was limited by the friction between dowel hole surface and multi-grooved dowel surface.

CONCLUSION

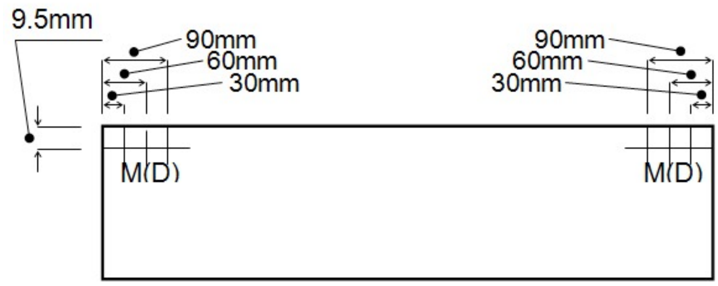
In general, the end distance of the Minifix cam fastener has a significant effect on the bending moment resistance of corner joints loaded in compression. In particular, the tests showed that:

- Minifix connectors located 60 mm from the edge of the joint had the highest moment capacity of the three end distances tested;
- non-glued dowel joints had about the same bending moment capacity as Minifix joints with 30 and 90 mm end distance;
- the bending moment resistance of all the joints tested is limited by the internal bond value of particleboard used for joint members.

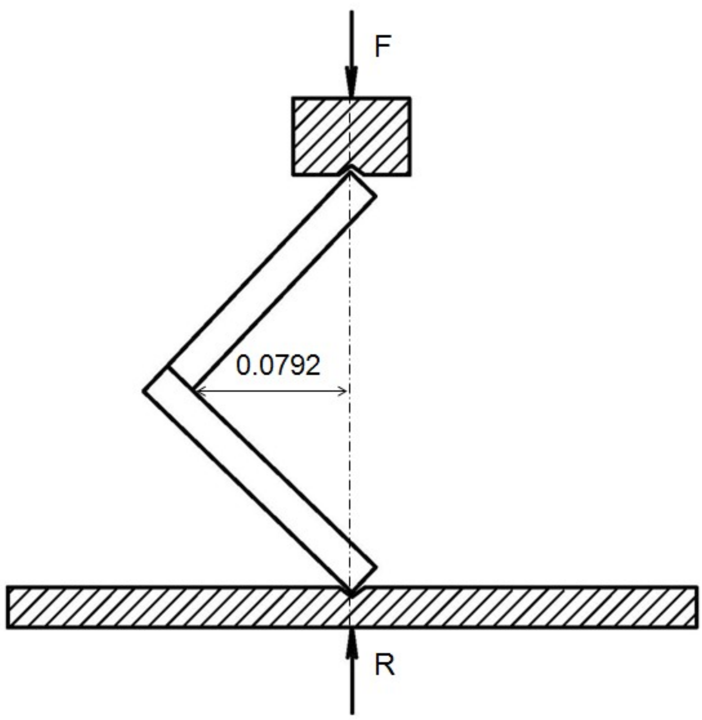
1: *Fasteners used: Minifix fasteners (metal connecting bolts, cam housings) and multi-grooved wooden dowels*



2: *General configuration of corner joint specimen used to evaluate effect of the end position of cam fasteners + reference specimens with glued and non-glued dowels*



3: *Face member with distances where the connectors (M – Minifix, D – dowel) were placed in the first study*



4: *Loading form of specimens in compression test with a measurement of bending arm in meters*

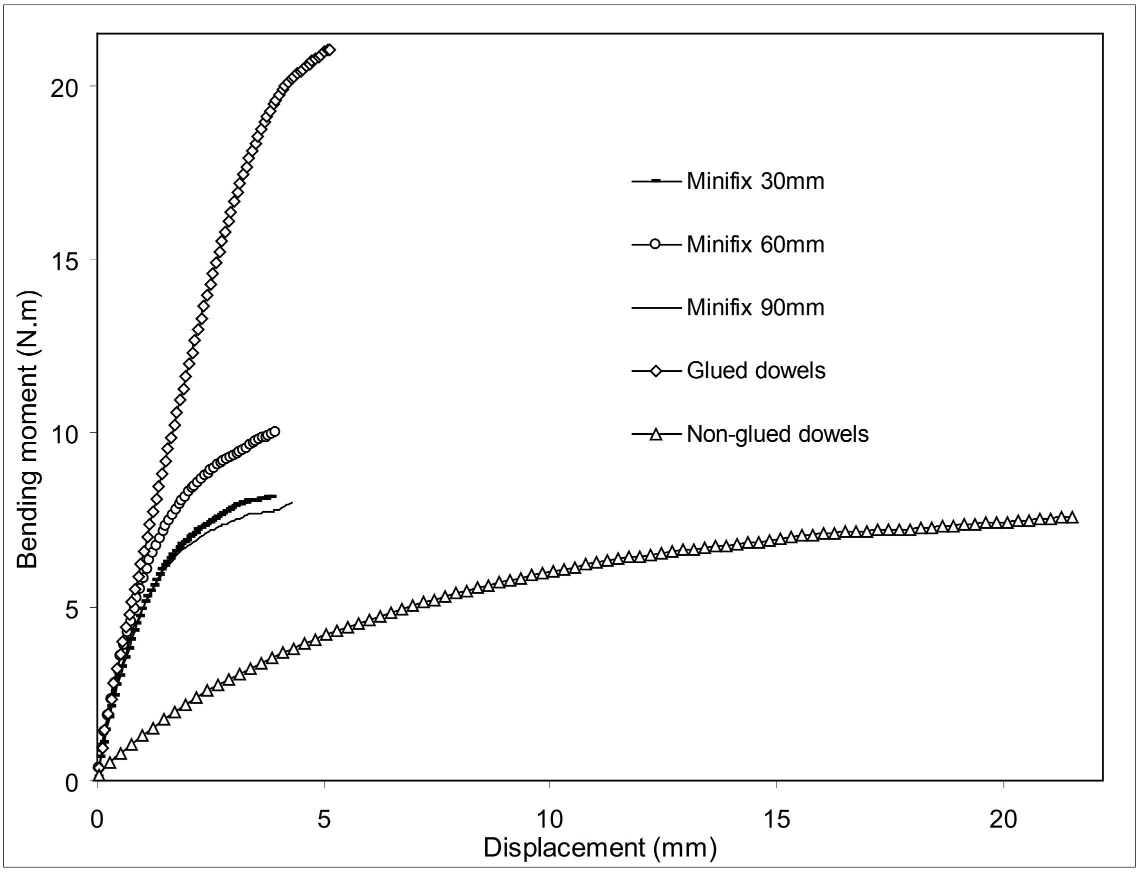
I: *Physical and mechanical properties of used laminated particleboard*

SG [kg.m^{-3}]	MC [%]	MOR [MPa]	MOE [MPa]	IB [MPa]
703.7 (2.4)*	6.7 (2.0)	25.4 (13.0)	2598 (12.1)	0.48 (19.5)

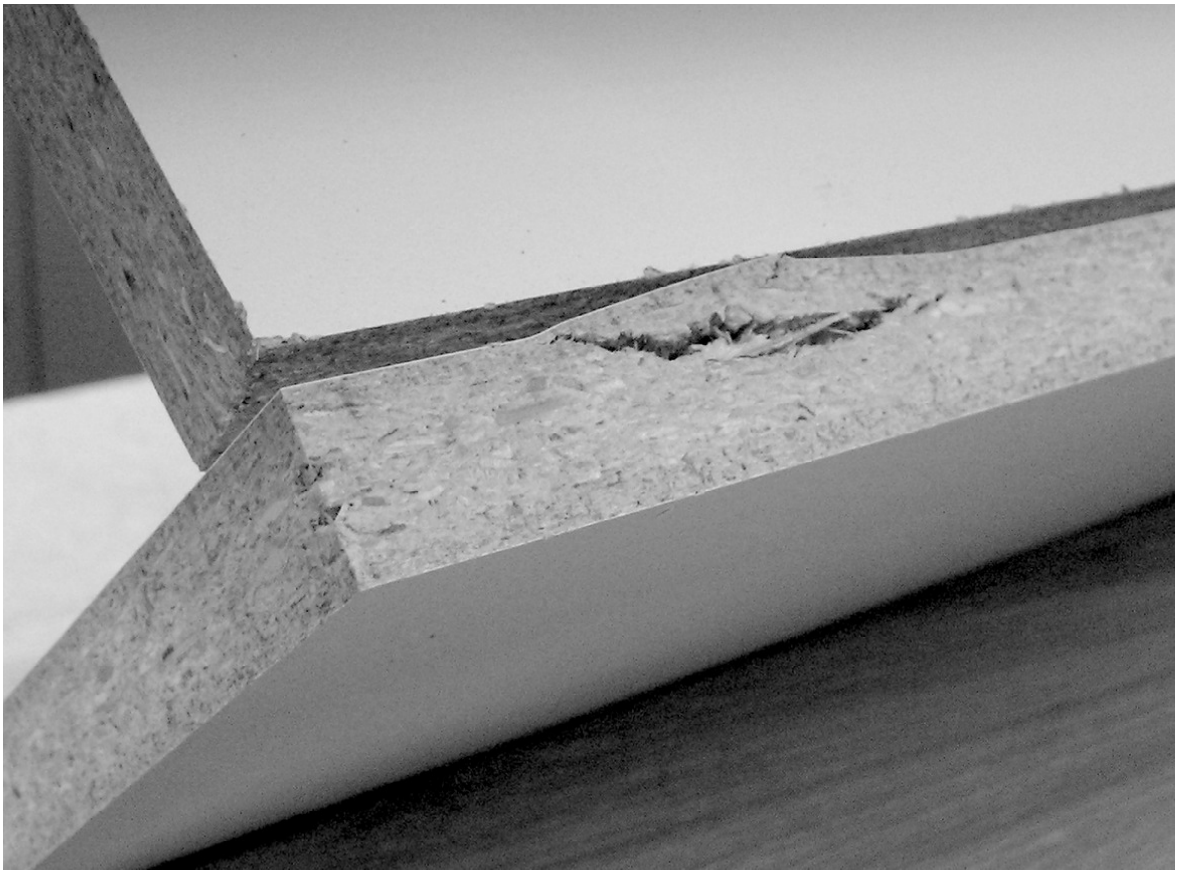
* COV (coefficient of variation in %)

II: *Average bending moment resistance, Tukey results and r^2 values of predicted plots*

Bending moment resistence study					
Joint specimen	n	M_{max} (N.m)	Tukey group	COV* (%)	r^2
Minifix 30mm	18	8.11	x	19.63	0.80
Minifix 60mm	18	9.91	y	16.75	0.81
Minifix 90mm	18	7.89	x	15.53	0.80
Glued dowels	12	20.94	z	8.53	0.95
Non-glued dowels	12	7.60	x	9.18	0.92



5: *Regression analyses results of the study*



6: *Typical mode of failure in the face member*

SOUHRN

Vliv koncové polohy demontovatelného nábytkového kování na odolnost vůči ohybovému momentu u korpusového nábytku

Cílem této práce je výzkum vlivu koncové polohy excentrického spojovacího kování při namáhání rohových demontovatelných nábytkových spojů. Přípravná studie montážních plánů demontovatelného nábytku byla provedena s cílem zjistit typické uplatnění spojovacího kování výrobci v korpusovém nábytku. Vzorky jsou konstruovány z laminované dřevotřískové desky, excentrického kování a bukových kolíků. Testování vzorků ve tvaru písmene L, o délce 760 mm, probíhalo stlačováním dílců vzorku k sobě – taktéž nazýváno jako tlaková zkouška v úhlové rovině. Výsledky zkoušek ukázaly, že excentrické spoje umístěné 60 mm od konce styčného dílce mají nejlepší odolnost vůči ohybovému momentu.

odolnost vůči ohybovému momentu, rohový spoj, koncová vzdálenost, excentrické spojovací kování, dřevěný kolík

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