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ORIGINAL ARTICLE

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Screw withdrawal capacity used in the eccentric joints of cabinet furniture connectors in particleboard and MDF

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Abstract Eccentric joints are commonly used to join particleboard and medium-density fiberboard (MDF) in cabinet furniture construction. Screws and screws with plastic sockets are offered by many manufacturers for these kinds of joints, yet little information is available concerning their withdrawal capacity in these materials. Research reported here indicates that face withdrawal strengths of the screws differ slightly from manufacturer to manufacturer in particleboard and MDF, whereas withdrawal strengths of screws with plastic sockets differ greatly from one manufacturer to another. Furthermore, the withdrawal capacity of the screws was found to correlate with the density of both particleboard and MDF.

Key words Withdrawal capacity · Eccentric joint · Cabinet furniture · Particleboard · MDF

Introduction

Based on the literature, it can be stated that the durability of furniture depends primarily on the strength of the joints used in its construction.[1] Factors affecting joint strength have been studied by many researchers.[1–4] The resistance to withdrawal of different types of fasteners has been studied by Eckelman and Cassens[5] in five wood species, by Cassens and Eckelman[6] in particleboards, medium-density fiberboard (MDF), and oriented strandboard (OSB), by Erdel and Eckelman[7] in particleboards and OSB, by Örs et al.[8] in particleboards, MDF, werzalit, and beech wood, and by Rabiej et al.[3] in particleboards. Also, Smardzewski and Prekrad[1] have studied the stress distribution in disconnected furniture temporary joints.

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After proving that the mechanical properties and density of raw materials used in the construction of case furniture determined and limited the strength of joints, Eckelman[2] suggested formulations for the prediction of the withdrawal forces. The resistance to withdrawal of the specific fasteners used in eccentric joints of ready-to-assemble case furniture has not been studied. Today, insert fittings for eccentric joints of many manufacturers (patented or not) are sold in the European market and a study of their comparative screw withdrawal capacity is needed. A knowledge and understanding of the factors affecting the screw withdrawal strength of eccentric joints can be used for joint improvements in ready-to-assemble case furniture construction. Nowadays, as much as 90% (or more) of all furniture made in Europe is based on wood-based panels, especially on particleboards and MDFs.[9]

Materials and methods

The wood-based panels tested included particleboard and MDF, of 16-mm thickness. Specifically, particleboards uncoated (of four different mean densities Pd1, Pd2, Pd3, Pd4), coated with melamine (Pdm), and veneer (Pdv); and MDF uncoated (MDF), coated with melamine (MDFm), and veneer (MDFv) were tested. The specimens measured 5 cm square. The insert fittings [screws and screws with plastic sockets (screws wps)] of three manufacturers used in the study were commercially available standard items (Fig. 1).

Manufacturers' recommendations were followed with respect to pilot hole size and the insertion of screws and screw plastic sockets (Table 1). Pilot holes were drilled through the center of each specimen by means of a drill in a direction perpendicular to the face of a sample. Prior to the insertion of fasteners, all samples were conditioned to constant mass at a temperature of 20°C and a relative humidity of 65%. The rate of crosshead movement was adjusted so that the maximum load was reached within 60 ± 30 s throughout the test. All of the tests were carried out on a

Table 1. Description of the insert fittings of the three manufactures used in the study

Fitting parameter	Manufacturer A		Manufacturer B		Manufacturer C	
	Screw	Screw wps	Screw	Screw wps	Screw	Screw wps
Hole diameter (mm)	5.0	5.0	5.0	5.0	5.0	5.0
Hole length (mm)	13.0	13.0	13.0	13.0	13.0	13.0
Screw diameter (mm)	5.0	3.0	5.0	3.0	5.0	3.0
Screw length (mm)	11.0	11.0	11.0	11.0	11.0	11.0
Socket diameter (mm)	–	5.0	–	5.0	–	5.0
Socket length (mm)	–	13.0	–	9.0	–	12.0

wps, with plastic socket

Table 2. Withdrawal strength of screws of three screw manufacturers in particleboard and medium-density fiberboard (MDF)

Panel type	Density (g/cm^3)	Manufacturer A		Manufacturer B		Manufacturer C	
		Screw	Screw wps	Screw	Screw wps	Screw	Screw wps
Pd1	0.64	590 (30)	687 (43)	568 (24)	541 (40)	622 (54)	545 (32)
Pd2	0.66	687 (61)	734 (47)	719 (30)	642 (56)	724 (29)	475 (35)
Pd3	0.69	872 (43)	918 (35)	851 (65)	740 (41)	897 (21)	559 (72)
Pd4	0.73	962 (37)	1076 (53)	1031 (23)	796 (31)	1040 (27)	565 (28)
Pdm	0.65	681 (35)	804 (41)	733 (34)	594 (14)	718 (60)	598 (25)
Pdv	0.62	793 (33)	880 (39)	830 (71)	704 (45)	767 (30)	567 (21)
MDF	0.72	995 (40)	987 (41)	1067 (69)	880 (43)	906 (29)	780 (55)
MDFm	0.76	1000 (50)	1070 (30)	1084 (42)	789 (50)	1077 (47)	680 (68)
MDFv	0.74	962 (58)	1067 (46)	1151 (50)	794 (44)	1025 (59)	597 (74)

Withdrawal strength results given in Newtons are the means of 20 samples. Values in parentheses are standard deviations
Pd1, Pd2, Pd3, Pd4 are uncoated particleboards. Pdm, melamined particleboard; Pdv, veneer particleboards; MDF, uncoated MDF; MDFm, melamined MDF; MDFv, veneer MDF

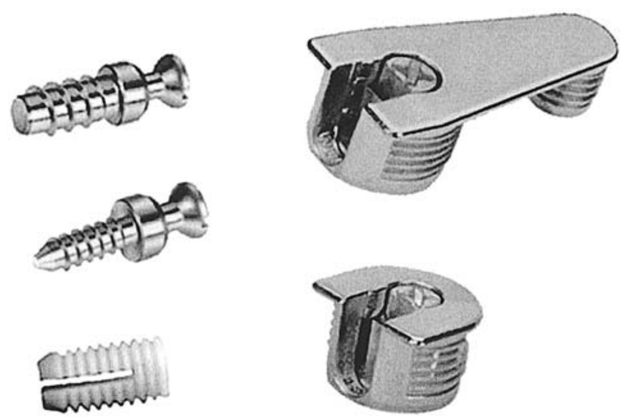

Fig. 1. Eccentric joint fittings used in the study

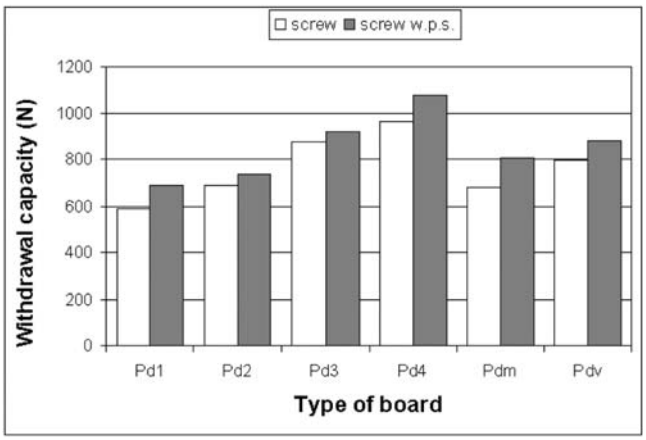

Fig. 2. Withdrawal capacity of manufacturer A screws in particleboards. *Pd1–Pd4*, uncoated particleboards; *Pdm*, melamine particleboard; *Pdv*, veneer particleboard; *wps*, with plastic sockets

Shimadzu testing machine according to the standard EN 13446:2002. The withdrawal capacity was expressed in Newtons (N) in order to show the absolute values of the maximum load applied for the different insert fittings (screws inserted by screwing, plastic and metal fittings inserted by knocking).

Results and discussion

Results of the tests of all manufacturers' insert fittings and of all board types are given in Table 2. In general, the resistance to withdrawal of the screws of all manufacturers were about the same for the same type of board. The resistance to withdrawal of the screws wps, however, varied greatly from manufacturer to manufacturer for the same type of board. Detailed results of the tests for each manufacturer's screws are given in Figs. 2–7.

In the case of manufacturer A, the screws gave withdrawal strengths that ranged from 590 N to 962 N in particleboard (Fig. 2), and from 962 N to 1000 N in MDF (Fig. 3). The screws wps gave values of 687 N to 1076 N in

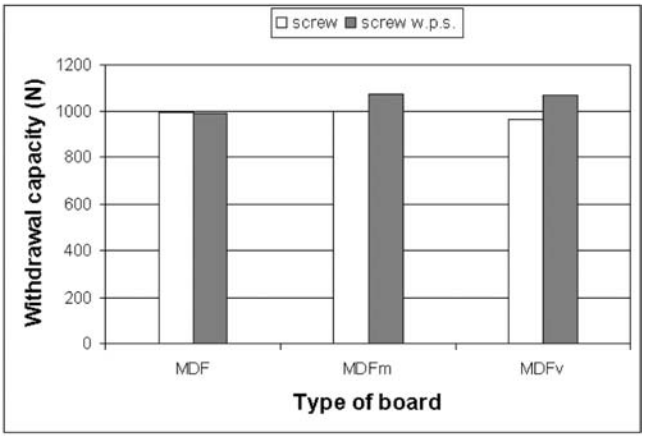

Fig. 3. Withdrawal capacity of manufacturer A screws in medium-density fiberboard (MDF). *MDFm*, melamine MDF; *MDFv*, veneer MDF

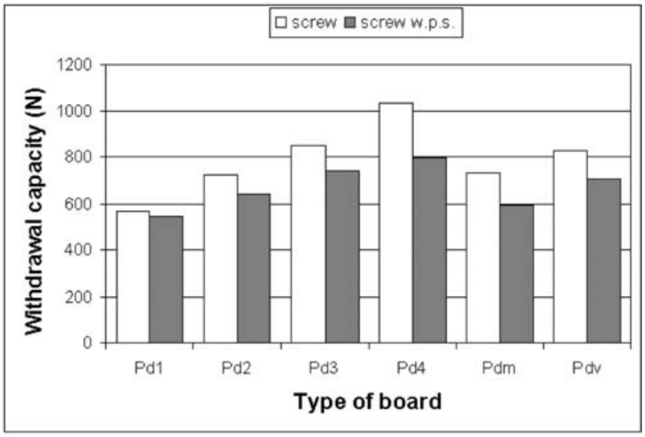

Fig. 4. Withdrawal capacity of manufacturer B screws in particleboards

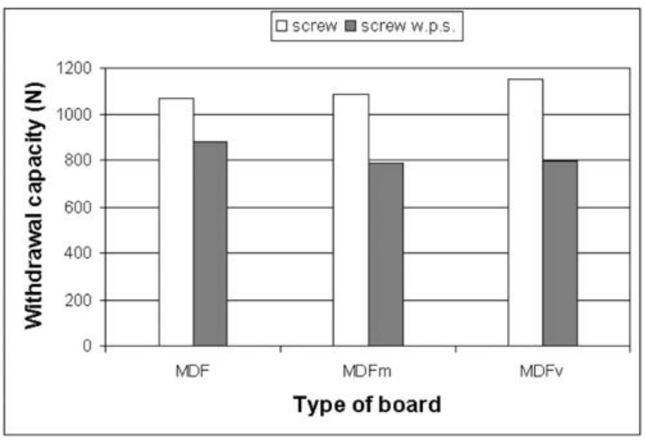

Fig. 5. Withdrawal capacity of manufacturer B screws in MDF

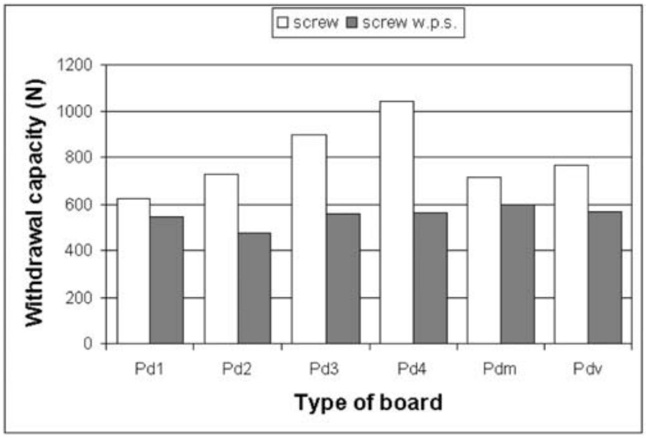

Fig. 6. Withdrawal capacity of manufacturer C screws in particleboards

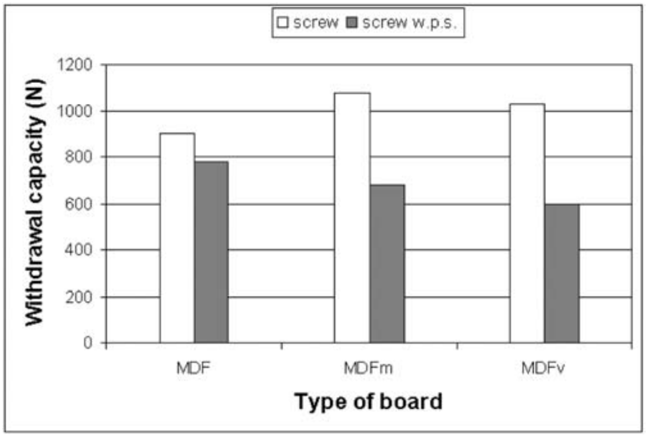

Fig. 7. Withdrawal capacity of manufacturer C screws in MDF

particleboards and 987 N to 1070 N in MDF. Obviously, the screws wps gave better strengths than the screws, with the mean withdrawal strength of the screws wps being 11.6% greater in particleboards and 5.7% greater in MDF. In the case of manufacturer B, the screws gave resistance to withdrawal that ranged from 568 to 1031 N in particleboards (Fig. 4) and from 1067 to 1151 N in MDF (Fig. 5). In comparison with manufacturer A's results there is a mean increase of 3.0% in withdrawal strength in particleboard and of 11.7% in MDF. On the other hand, the screws wps gave values ranging from 546 to 796 N in particleboards and from 789 to 880 N in MDF. When compared with the withdrawal strength of the screws this corresponds to a mean decrease in strength of 14.3% in particleboard and 25.2% in MDF. The corresponding decreases in comparison with manufacturer A's results are 24.3% in particleboard and 16.1% in MDF. In the case of manufacturer C, the screws gave a slight increase in mean withdrawal strength in both particleboard (by 4.0%) and MDF (by 1.8%) when compared with manufacturer A's results. Also, when screws wps were used,

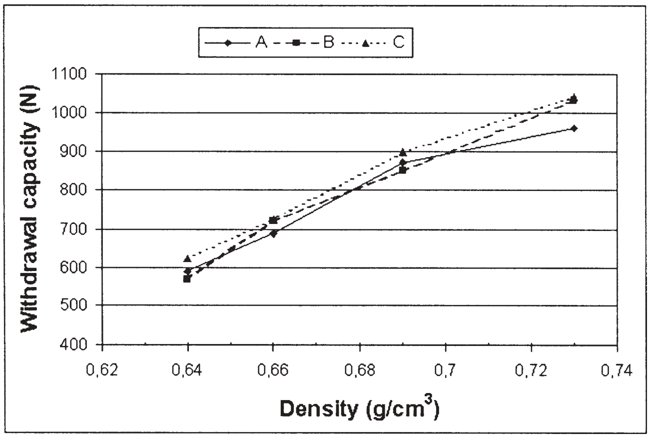

Fig. 8. Effect of uncoated particleboard density on screw withdrawal capacity for all manufacturers

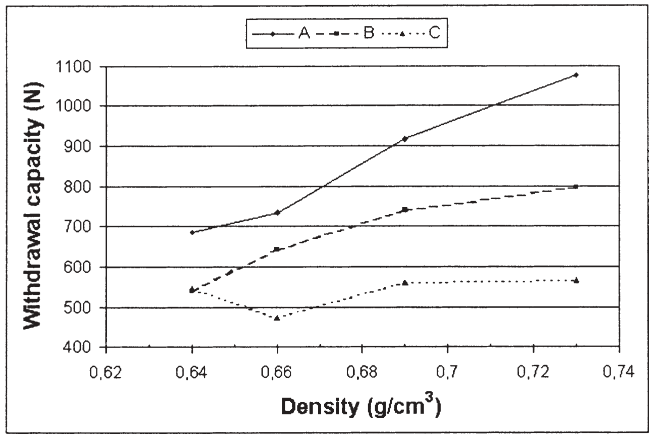

Fig. 10. Effect of particleboard density on withdrawal capacity of screws with plastic sockets, all manufacturers

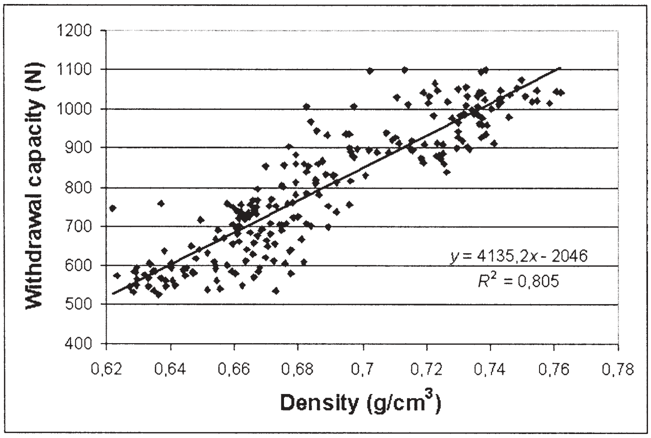

Fig. 9. Relationship between withdrawal strength of all manufacturers' screws and particleboard density

the mean strength values decreased by 34.0% in particleboard and by 34.1% in MDF, in comparison with manufacturer A's results.

In all cases, the differences in withdrawal capacities of the screws measured in the different panel types can easily be explained by the effect of panel density. Furthermore, the use of melamine and veneer coatings did not seem to affect the withdrawal strength of the screws. In the particleboard tests, in which enough panels of different densities were measured, the following conclusion could be drawn (Fig. 8). Apart from slight differences in withdrawal resistance of the screws between the three manufacturers, there is a strong relationship between the holding strength of the screws of all manufacturers and particleboard density. The results indicated that there is a near-linear increase in face withdrawal strength as the density of the particleboard increases (Fig. 9). The correlation between withdrawal strength and the particleboard density can be expressed by the following equation:

$$F = 4135.2D - 2046.0 \qquad (R^2 = 0.805)$$

where F is the withdrawal strength and D is the board density.

The results also showed that the same relationship exists between the holding strength of the screws of all manufacturers and MDF density. In contrast, the results showed that the same relationship between the withdrawal strength of screws wps and particleboard density does not hold for all manufacturers' fittings. The screws wps of manufacturer A had slightly better withdrawal strengths than the screws alone, and that could be predicted by the previous equation, whereas the screws wps of manufacturers B and C failed to obtain better results (Fig. 10). This can be attributed mainly to the socket lengths (9mm for manufacturer B and 12mm for manufacturer C) and the low quality of the plastic socket material. The results of this research demonstrate that better withdrawal strengths of insert fittings could be achieved by selecting the correct panel density and the right shape and material quality of the insert fittings. Plastic sockets made of good quality material and with lengths equal to screw lengths gave higher strength values than plastic sockets of shorter lengths.

Conclusions

Results of the study indicated that the withdrawal capacities of screws used in eccentric joints differ slightly from manufacturer to manufacturer in particleboard and MDF. In contrast, the withdrawal capacities of the screws with plastic sockets differ significantly from manufacturer to manufacturer in particleboard and MDF. This implies that cabinet furniture manufacturers should be careful when choosing insert fittings.

Results of the tests also indicated that there is a near-linear increase in face withdrawal capacity of the screws of all manufacturers as the density of the uncoated particleboard increases. In general, the withdrawal capacity of the screws can be expressed by the equation: $F = 4135.2D - 2046$. The same linear correlation appears to exist in uncoated MDF and all coated particleboards and MDF panels.

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