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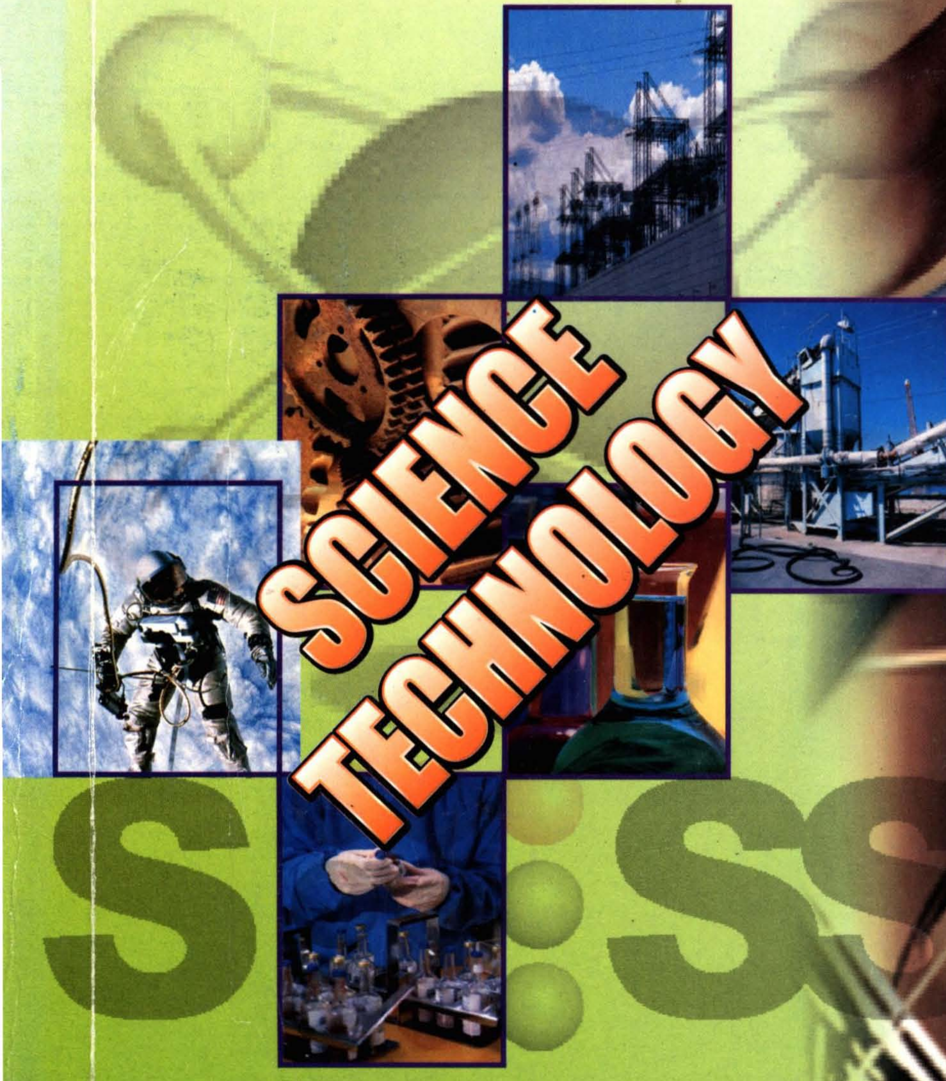

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Withdrawal Holding Strength Analysis of Tapered Threaded Metal Inserts in Medium Density Fibreboard (MDF)

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ABSTRACT

The withdrawal holding strength of two sizes of tapered threaded metal insert fastener i.e. 4mm diameter by 10mm length (4 X10) and 6mm diameter by 13mm length (6 X 13) embedded in the face of a commercially manufactured medium density fiberboard (MDF) of 16mm and 19 mm thickness from Malaysia was carried out in this study. The results generally indicated that longer metal inserts with greater depth of embedment produced significantly higher withdrawal holding strengths while diameter of the metal inserts have no significant effect on the holding strength. Further test carried out to determine the effect of pilot holes size on the holding strength indicated that to some extent, the use of optimum pilot holes apparently increases the withdrawal holding strength of threaded metal inserts fastener. However, it should be cautioned that the optimum pilot hole sizes recommended in this study should only be used as first estimates and adjustments should be made as needed for the specific board properties in question.

Keywords: *withdrawal holding strength, threaded metal inserts, medium density fiberboard, optimum pilot hole size*

Introduction

Composite wood products have gained an appreciable market share in wood related industry and shall continue to grow as smaller trees are used to support the demand for wood products. Some examples of wood composite products that are commonly used in the industry are oriented strand board (OSB), particleboard, medium density fiberboard (MDF), composite I-joist, and composite lumber. From the above listings, particleboard and MDF had enjoyed success in the furniture industry for many years.

In most cases, these materials that were utilized for furniture construction used jointing system to assemble one part to another. There are many jointing systems available in the market, the most popular being the commonly used nails and screws. The rational design of furniture cases constructed with the used of fasteners requires that strength information be available concerning the holding strength of these fasteners. The trend in the industry has been towards the used of inserted screws. There are many types and sizes of inserted screw that is available to choose from in order to achieve the efficient design with desired strength. Such inserted screw is aptly to be used in the construction of corner joints in frameless cabinet as well as in other types of case furniture (Qinglin & Vlosky 2000).

Currently, the use of threaded metal inserts has become common in furniture construction usually with the intent of increasing fastener-holding strength especially in MDF. However, information concerning their holding strength is either non-existent or not readily available. More importantly, expression have not been developed and published which can be used to estimate the holding strength of these fasteners as a function of the MDF board properties manufactured locally.

Bachmann & Hassler (1975) for example evaluated the holding strength of treaded fasteners of several diameters and lengths in particleboard. They concluded that the withdrawal strength of fasteners in particleboard is strongly correlated with the length of the fasteners, but is little influenced by diameter. Although this information is helpful in estimating the holding strength of a particular fastener, it does not in general present sufficient data to allow for generalization of the results. Furthermore, studies on the holding strength of threaded metal insert screws in locally made MDF are very few in publication. The study reported herein therefore, attempt to provide a more detailed information on the withdrawal holding strength of tapered threaded metal insert embedded in the face of a commercially manufactured medium density fiberboard (MDF) from Malaysia. The effect of pilot holes size on the holding strength was also discussed.

Materials and Methods

Materials

The boards used in this study were obtained from a local commercial medium density fiberboard (MDF) manufacturer. The MDF boards in two thickness i.e. 16*mm* and 19*mm* conform to BS 1142 (British Standards 1989). Prior to testing, all material was conditioned to about 10-12 percent moisture content. The physical and mechanical properties of the boards as supplied by the manufacturer are given in Table 1. The threaded metal inserts used in this study were purchased from a local hardware store. Two sizes of tapered threaded metal insert were used i.e. 4mm diameter by 10mm length (4 X10) and 6mm diameter by 13mm length (6 X 13). Figure 1 shows the two different sizes of threaded metal insert fastener.

Table 1: Physical and mechanical properties of the test boards.

Board type	Thickness (*mm*)	Density (kg/m^3)	Internal bond (N/mm^2)	Modulus of rupture (N/mm^2)	Modulus of elasticity (N/mm^2)
MDF	13 - 19	730 -735	0.60	30	2200

Preparation of samples

Full size 1.22 by 2.44m (4 by 8 foot) sheets of the boards to be tested were first cut lengthwise into two halves. The board was then cut into test samples that measured approximately 10cm (4 inches) square. In all cases, each specimen group consisted of 10 replications. Since the recommended pilot hole size was not made available by the supplier, three pilot hole sizes were selected for each type of insert being tested based on the diameter of the tapered threaded metal inserts. The three pilot hole sizes used were 5.0mm, 5.5mm, and 6.0mm respectively for 4 X10 metal inserts, whilst for the 6 X 13 inserts, the pilot hole sizes used were 8.0mm, 8.5mm, and 9.0mm.

Pilot holes of the selected size were drilled through the center of each specimen perpendicular to the face. The threaded metal inserts were screwed into the holes with an allen key. Once the inserts were installed to the proper depth, the allen key was removed from the inserts.

Testing methods

All of the tests were carried out on a Universal testing machine. The jigs and fixtures that were used to hold the specimens in place and loaded were comparable to that used and proven in previous screw withdrawal tests carried out by Eckelman (1978). In general, the jigs and fixtures consists of a specimen holding fixture, which is attached to the lower crosshead of the testing machine, and a length of threaded rod that has one end attached to the upper crosshead. The purpose of the specimen holding fixture is to hold the face of the specimen perpendicular to the line of action of the withdrawal force while the threaded bolt provides a means for applying the force needed to withdraw the inserts.

Prior to testing, a specimen is placed in the holding fixture with the threaded insert face up and the insert is then centered within the diameter of the hole in the top face of the fixture. The screw is then screwed into the inserts and load was applied at a rate of 10mm/min to withdraw the insert.

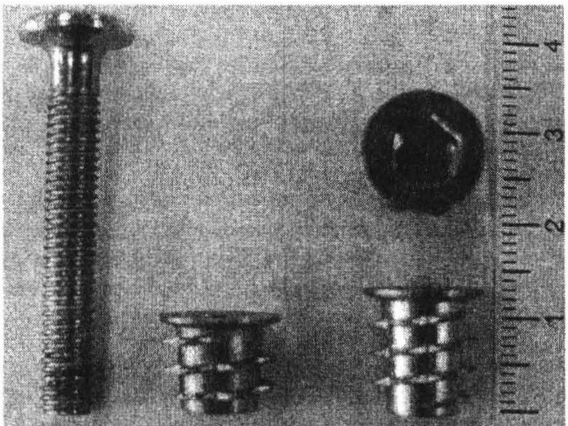

Fig. 1: Tapered threaded metal insert fastener used in the study.

Results and Discussion

Between different fastener size

Results of the withdrawal holding strength tests on two threaded metal inserts with size i.e. 4mm diameter by 10mm length (4 X10) and 6mm diameter by 13mm length (6 X 13) embedded in MDF board of 16mm and 19 mm thickness are given in Table 2. These results evidently indicate that diameter and depth of embedment of the inserts could have strong effect on the withdrawal holding strengths. The holding strength of 4 X 10 metal inserts was found to be much lower than the 6 X 13 metal insert fasteners in both 16mm and 19mm board thickness respectively. The mean holding strength of the 4 X 10 metal inserts in 16mm board, for example amounted to only 536.4*N* as compared to 1305.1*N* from the 6 X 13 metal inserts. Holding strength of the 4 X 10 metal inserts, therefore, was about 59 percent inferior than the 6 X 13 metal inserts. Similar tests with 19mm board gave a holding strength of 871.4*N*, which amounted to about 49 percent of the holding strength of the 6 X 13 metal inserts.

Table 2: Mean withdrawal holding strength values for 4 X 10 and 6 X 13 metal inserts embedded in 16*mm* and 19*mm* thickness MDF board.

Inserts diameter by length (*mm*)	No. of samples for each board thickness	Board thickness (*mm*)	
		16	19
		Withdrawal holding strength (*N*)	
4 X 10	30	536.4[a] (236.1)	871.4[a] (103.8)
6 X 13	30	1305.1[b] (375.2)	1788.1[b] (406.5)

Note: Values in parentheses denote standard deviations.
Means not followed by the same letter in the column are significantly different

Optimum pilot hole size

Results of withdrawal holding strength against pilot hole size tests are given in Table 3. A number of trends could be detected from analysis of means of the test results for the tapered threaded metal inserts. An examination of the holding strength for both size of metal inserts embedded in MDF of 16mm and 19 mm thickness, does not indicate a clearly discernible relationship between holding strength and pilot hole size.

The results for metal insert with 4mm diameter by 10mm length embedded in 16mm board thickness generally indicate that the holding strength increases as pilot hole size is increased, until the pilot hole size nears the top diameter of the threaded metal insert wherein the holding strength decreases. It was found that the mean withdrawal holding strengths were about 50 percent higher when pilot hole size is increased by 0.5mm. Further increase in pilot hole size by another 0.5mm on the other hand saw reduction of about 50 percent in withdrawal holding strength.

Results for metal inserts of the same size that were embedded in 19mm thickness board conversely showed a reversed trend. The holding strength decreases as pilot hole size is increased, until the pilot hole size is in close proximity to the top diameter of the threaded metal insert wherein the holding strength increases. The mean withdrawal holding strengths were reduced slightly from 904.9*N* to 831.6*N*, a drop of about 9 percent when pilot hole size is increased by 0.5mm. Additional increase in pilot hole size by another 0.5mm alternatively saw trivial increase of about 5 percent in withdrawal holding strength.

Table 3: Mean withdrawal holding strength values for 4 X 10 and 6 X 13 metal inserts embedded in 16*mm* and 19*mm* thickness MDF board through different pilot hole sizes.

Inserts diameter by length (*mm*)	Board thickness (*mm*)	Pilot hole diameter (*mm*)					
		5.0	5.5	6.0	8.0	8.5	9.0
		Withdrawal holding strength (*N*)					
4 X 10	16	456.3^{b} (222.5)	688.7^{a} (216.1)	464.0^{b} (211.6)	-	-	-
	19	904.9^{ns} (154.1)	831.6^{ns} (54.7)	877.9^{ns} (70.2)	-	-	-
6 X 13	16	-	-	-	1572.5^{a} (217.8)	1496.5^{a} (135.4)	846.2^{b} (183.5)
	19	-	-	-	2227.3^{a} (311.7)	1742.8^{b} (112.2)	1394.3^{c} (183.8)

Note: Values in parentheses denotes standard deviations.
Means not followed by the same letter in the row are significantly different
^{ns} - not significant

Another interesting finding in these tests was that holding strength of metal insert with 6mm diameter by 13mm length decreases as pilot hole size is increased nears the top diameter of the threaded metal insert. This trend was completely unrelated to circumstances previously discussed and was observed in both 16mm and 19mm board thickness respectively. The results for threaded metal insert embedded in 16mm board thickness show a decrease in mean withdrawal holding strengths of approximately 5 percent (from 1572.5*N* to 1496.5*N*) when pilot hole size is increased by 0.5*mm*. Further increase in pilot hole size by another 0.5*mm* markedly reduced the mean withdrawal holding strengths to 846.2*N*, a drop of about 40 percent in withdrawal holding strength. The decrease in mean withdrawal holding strengths for inserts embedded in 19mm board thickness on the other hand was relatively equal (around 20 percent) for every increase of the pilot hole size by 0.5*mm*.

Analysis of variance (ANOVA) test conducted on the mean withdrawal holding strength values of the metal inserts between different pilot hole sizes employed revealed that significant different exists between them for nearly all tests, with the exception of 4 X10 metal inserts embedded in 19mm board. In the case of 4 X 10 metal inserts embedded in 16mm board thickness, the analysis indicated that maximum withdrawal holding strength would presumably be achieved with pilot hole sizes that were smaller than the top diameter, but slightly bigger than the base diameter of the tapered threaded metal insert. Such optimum pilot hole size would prevent undue crushing of the metal insert against the fibers that makeup the MDF while simultaneously avoiding too much gap at the base of the pilot hole. As such, for 4 X 10 metal inserts to be embedded in MDF of 16mm thickness, it may be said that the use of pilot hole size of 5.5mm would give the maximum withdrawal holding strength values.

In the case of 4 X 10 metal inserts embedded in 19mm board thickness, the analysis indicated that use of pilot hole with just a slight different in size would not significantly affected the withdrawal holding strength. The maximum withdrawal holding strength was obtained when pilot hole size of 5.0mm was used. This was followed by pilot hole size of 6.0mm and 5.5mm respectively, but the difference in terms holding strength produced was found not significant according to ANOVA test. Thus, based on the least deviations of withdrawal holding strength values, it may perhaps be assumed that pilot hole size of 5.5mm would provide somewhat maximum withdrawal holding strength values for 4 X 10 metal inserts to be embedded in MDF of 19mm thickness.

For 6 X 13 metal inserts embedded in 16mm board thickness, the ANOVA test indicated that the maximum withdrawal holding strength was obtained through pilot hole size of 8.0mm, followed by 8.5mm pilot hole size. Nevertheless, the difference in holding strength that was achieved through both pilot hole sizes was statistically not significant. Pilot hole size of 9.0mm gave the lowest holding strength and was significantly different from 8.0mm and 8.5mm pilot hole sizes respectively. Since the least deviations of holding strength values was found when 8.5mm pilot hole was used, it may be realistic to believe that pilot hole size of 8.5mm would comparatively provide utmost holding strength for 6 X 13 metal inserts to be embedded in MDF of 16mm thickness.

Finally, in the case of 6 X 13 metal inserts embedded in 19mm board thickness, the analysis indicated that maximum holding strength would apparently be achieved with 8.0mm pilot hole size, followed by 8.5mm and 9.0mm pilot hole size respectively. It was found that the holding strength obtained from the use of these three slightly different pilot hole sizes were significantly different from one another. As such, for 6 X 13 metal inserts to be embedded in MDF of 19mm thickness, it may be said that the use of pilot hole size of 8.0mm certainly would provide the highest holding strength values. However, in view of the fact that 8.5mm pilot hole size has the least deviations in holding strength values obtained, perhaps it may be possible to deem it as the optimum pilot hole also.

Based on the results obtained and discussions made in several preceding paragraphs, the optimum pilot hole size for the boards used in this study that would presumably give somewhat maximum holding strength values is given in Table 4. Nevertheless, outside this study, these recommended optimum pilot hole sizes should only be used as first estimates and adjustments should be made as needed for the specific board in question.

Table 4: Recommended optimum pilot hole sizes for 4 X 10 and 6 X 13 threaded metal inserts embedded in MDF of 16*mm* and 19*mm* thickness.

Inserts diameter by length (*mm*)	Board Thickness (*mm*)	Optimum pilot hole size (*mm*)
4 X 10	16 / 19	5.5
6 X 13	16 / 19	8.0, 8.5

Conclusion

Longer metal inserts with greater depth of embedment generally produced significantly higher withdrawal holding strengths while diameter of the metal inserts have no significant effect on the holding strength. The use of pilot holes does not only help to position the threaded metal inserts correctly but also facilitate their insertion in a desired direction. Additionally, the use of pilot holes of proper size apparently increases the withdrawal holding strength of the tapered threaded metal inserts fastener in MDF. In general, pilot holes size presumably should be slightly smaller than the top diameter, but somewhat bigger than the base diameter of the tapered threaded metal insert shank.

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