Contents lists available at Science-Gate

International Journal of Advanced and Applied Sciences

Journal homepage: http://www.science-gate.com/IJAAS.html

Effects of screw insertion on screw withdrawal strength

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ARTICLE INFO

Article history:
Received 27 December 2015
Received in revised form
17 January 2016
Accepted 17 January 2016

Keywords:
Particleboard
Chipboard screw
Screw withdrawal strength
Screw insertion technique

ABSTRACT

The effect of chipboard screw sizes on screw withdrawal strength was investigated using different screw insertion technique. Large diameter chipboard screw has a thicker screw thread depth than small size chipboard screw. If large chipboard screw tested on screw withdrawal test, then it will have significantly higher screw withdrawal strength than smaller chipboard screw because it will have better particle grip during screw insertion. The objective of this study is to determine screw withdrawal strength of three difference sizes chipboard screw using different types of screw insertion technique; self-drilling, pilot-hole and P+CSK insertion technique. Screw withdrawal strength of different sizes of chipboard screw was measured through its resistance after insertion to the particleboard panel using different style of screw insertion technique. Results obtained shows that the best practice for screw selection was based on screw insertion technique. Samples from three different screw sizes with self-drilling screw insertion technique have met the minimum requirement of screw withdrawal strength. Smaller chipboard screw which is 3.5M CS has the highest screw withdrawal strength when applied with self-drilling screw insertion technique. However, this small diameter of chipboard screw did not meet minimum standard requirement when applied with both screw insertion technique which used pilot-hole pre-drilling; pilot-hole and P+CSK screw insertion technique. The result shows only large chipboard screw applied with pilot-hole insertion technique has better screw withdrawal strength compared to small chipboard screw. There is no significant different of screw withdrawal strength for self-drilling screw insertion technique. This suggests that chipboard screw sizes or screw thread depth did not affect the screw withdrawal strength unless it was applied with pilot-hole pre-drilling.

1. Introduction

The fields of furniture products especially built-in kitchen cabinet panel deal with the issue of damages on particleboard panel surface and weak in carcass jointing. Jointing of this bio-resource product especially made from particle/wood fiber tends to damage the face surface especially during the joints construction. Abu and Ahmad, (2011a) claimed that 43% of screw installed damages during jointing process. The durability of the particleboard carcass depends on the strength of the joints. Many problems in joints durability are often related to the interaction of screw withdrawal strength and damages on panel surface. Chip-off or damages on particleboard surface will reduced the screw holding strength of the joints. Many studies on screw withdrawal strength by enhancing physical and mechanical properties of particleboard were done. According to Abu and Ahmad (2011b), the damage was not because of the mechanical and physical properties of the board. It has been tested and met the minimum requirements under the test procedures define by European Union (EN) standard BS EN 312:2003 (The European Standard, 2003).

Selection of chipboard screw is vital to the installer. An additional features on screw head and self-drilling features did not have significant different result in reducing number of damages compared to the common chipboard screw head (Abu and Ahmad, 2013). However, selecting different chipboard screw sizes and screw insertion technique manages to reduce the number of damages (Abu and Ahmad, 2014a; Abu and Ahmad, 2014b).

Chipboard screw size affect the screw withdrawal strength on screw withdrawal test. A large chipboard screw size has more screw thread depth. Depth of the screw thread is one of the factors affecting joint

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strength (Anderson, 2007). The depth of the threads will determine the holding strength. A screw with a parallel-threaded thread is recommended for a greater holding strength. In Malaysia, there is three size of chipboard screw available in the market; 3.5M, 4M and 5M chipboard screw. The common used is 4M chipboard screw with 1.5mm thread depth. Based on previous research, screw with large thread depth will result in greater holding strength. Therefore, we assumed that the 5M chipboard screw with 1.8mm thread depth resulted in better joint strength compared to the others.

Selecting on methods of screw insertion technique and the sizes of chipboard screw affected the presence of number of damages. According to Abu and Ahmad (2014a), there are three types of screw insertion technique applied by the industry or installer during screw jointing; self-drilling screw insertion technique, pilot-hole screw insertion technique and P+CSK screw insertion technique. Most damages were appeared during carcass / panel jointing in six types of failure modes (Abu and Ahmad, 2012). Application the correct screw insertion method with screw sizes has a potential to reduce number of damages. Even though application of 5M chipboard screw resulted in high number of damages presence, it is hopefully get better in holding strength results.

Therefore, this research paper studies on determination of screw withdrawal strength on three different types of chipboard screw. The priority was to choose the best chipboard screw sizes with suitable screw insertion technique which resulted in high screw withdrawal strength. This work will provide ideal selection of screw fixing for the installer and related industry involved.

2. Materials

2.1. Particleboard

A built-in kitchen cabinet is categorized as the static structures. Kitchen compartment were separated into two parts; wall unit and base unit. Carcass, door, shelve, cornice, box-up, pelmet and fly over panel (FOP) is made from particleboard. Only back-ply and table top supporting panel use medium density fiberboard (MDF). Particleboard is well suited for the construction of furniture because of its uniformity, moderate density, ease of cutting, and low cost. Even though it is lower in dimensional stability and strength properties, customer objection on high cost of MDF and plywood promotes it to be used as the raw material (Nemli et al., 2007). Jointing compartment especially made from bio-based resource usually resulted in damages. Even though sometimes, there are requirement of moving to a new house, unfasten or disengagement of the kitchen cabinet at least on any gross scale usually considered a failure to the structure (Messler, 2004).

Particleboard production is based on the standard requirement of the country in demand (The European Standard, 2003; 1993; 1994). Particleboard used in this study is P2 type particleboard. It is 16 mm in thickness and 700±2 kg/m^3 in density. P2 type particleboard use urea formaldehyde (UF) grade of adhesive where its requirements are for interior fitments (including furniture) use in dry conditions. P2 type particleboard requires moisture content range from 5% to 13%. The bending strength and modulus of elasticity in bending is 13.0 N/mm^2 and 1600 N/mm^2 respectively. Meanwhile the internal bond is 0.35 N/mm^2.

2.2. Chipboard screw

Eckelman (1975) suggested that the manufacturer of kitchen should carry out their own test in determining the screw that best suited for its purposes. According to Eckelman (1975), the screw withdrawal strength can be predicted either the insertion at the face or edge. He has formulated an equation that express withdrawal strength as a function of screw diameter, depth of embedment, and specific gravity (SG) of the particleboard. In 2009, Gates (2009) suggested that it is difficult to apply any screw withdrawal equation because of the different specifications of particleboard. The linear or polynomial equations incorporating board density, screw dimensions and depth of penetration can be derived to predict panel screw withdrawal strength. However, the setback was that the particleboard properties were varied between boards and especially between panel manufacturers.

Table 1 shows type and screw specification used in this study. All screw specification is elaborated based on the European standard in BS ISO 1891:2009 (The European Standard, 2009). The 4M chipboard screw (4M CS) is a common chipboard screw used by the installer. The other two was 3.5 M chipboard screw (3.5M CS) and 5 M chipboard screw (5M CS). 3.5M CS is the smallest chipboard screw with small thread depth; 1.0 mm. While 5M CS is the largest chipboard screw with 0.8 mm more depth in thread compared with 3.5M CS.

Table 1: Chipboard screw diameter, root diameter, and thread depth

Screw Type	Screw Diameter (mm)	Root Diameter (mm)	Thread Depth (mm)
3.5 M chipboard screw	3.2	2.2	1.0
4 M chipboard screw	3.7	2.2	1.5
5 M chipboard screw	4.6	2.8	1.8

Fig. 1 shows the screw dimensions. Label C is the root diameter meanwhile label D is the screw diameter. The root diameter is the thickness of the screw excluding screw thread. Screw thickness goes by numbers. A same screw number might have similar thickness but different in lengths. For example, 4M chipboard screw were available in ½ inch (12.7 mm) and1¼ inch (31.75 mm). Chipboard

screw is classified with number while wood screw is classified by gauge sizes. The higher the number/gauge means the larger the screw. In terms of strength, thicker screw diameter is reliable in strength. However, according to Özçifçi (2009), smaller diameter is much better. The insertion of the screw into the particleboard would not split the wood. Hence, it will give higher withdrawal strength. According to Park et al. (2006), avoiding thicker screws for the butt-pointed shelve applications using particleboard is the best option.

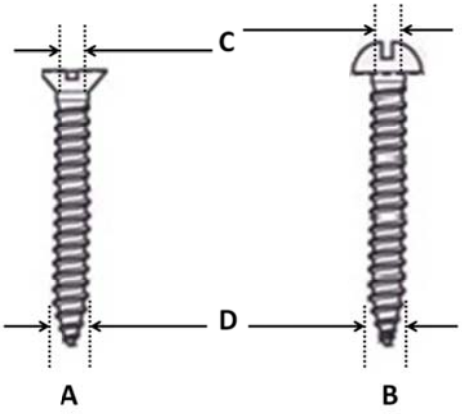

Fig. 1: Screw thickness

3. Methods

There are three different insertion technique and chipboard screw. Each screw insertion technique and chipboard screw type consists of twenty-five samples. Each sample was inserted with one screw to the panel wide surface. 225 numbers of samples were conditioned. The particleboards were collected during the site observation. All prepared samples were conditioned at 20oC temperature and 65% relative humidity. Screw insertion was done using self-drilling technique, pilot-hole technique and pilot-hole with countersunk (P+CSK) technique. Determination of screw withdrawal strength of the particleboard was done according to EN 320 (The European Standard, 1993). A spacer was used in order to have a constant depth. One-way ANOVA test was run to compare the mean of screw withdrawal strength.

4. Results and discussion

Table 2 shows ANOVA test for the screw withdrawal strength of three types chipboard screw. There is evidence to conclude that at 5% level of significance that the mean of screw withdrawal strength is similar for self-drilling insertion technique (p-value = 0.056 > 0.05). However, the mean of screw withdrawal strength is different for pilot-hole and P+CSK insertion technique. Both insertion p-value was below 0.05which is 0.000 and 0.001 respectively.

The highest screw withdrawal strength for each screw insertion technique was different. Self-drilling screw insertion technique was suitable to be applied by all three types chipboard screw. Pilot-hole screw insertion technique was not suitable to be applied by small sizes chipboard screw; 3.5M CS. While, P+CSK insertion technique was only suitable to be applied by common used chipboard screw; 4M CS.

Table 2: ANOVA of screw withdrawal strength in three-difference chipboard screw

	Analysis of Various Screw					
	Self-Drilling		Pilot-Hole		P+CSK	
Highest	3.5M CS		5M CS		4M CS	
Meet Standard	All		4M CS / 5M CS		4M CS	
Below Standard	None		3.5M CS		3.5M CS / 5M CS	
ANOVA	SIMILAR		Sig. Diff		Sig. Diff	
Good	All		5M CS		4M CS / 5M CS	
	4M CS	A	3.5M CS	A	3.5M CS	A
ANOVA	5M CS	AB	4M CS	B	5M CS	B
	3.5M CS	B	5M CS	C	4M CS	B

Table 3 shows the screw withdrawal strength of three difference chipboard screw. The result shows each screw insertion technique has highest screw withdrawal strength when applied with different sizes of chipboard screw. 3.5M CS has the highest screw withdrawal strength when applied with self-drilling insertion technique. 5M CS has the highest screw withdrawal strength when applied with pilot-hole insertion technique while 4M CS have the highest withdrawal strength when applied with P+CSK insertion technique. 3.5M CS withdrawal strength is 1521 N/mm^2, 5M CS screw withdrawal strength is 1463 N/mm^2 and 4M CS screw withdrawal strength is 1081 N/mm^2 respectively.

Screw withdrawal strength performances are difference in each type of insertion technique. The screw withdrawal strength increase as the screw sizes increase when applied with pilot-hole screw insertion technique. The result shows that the depth of the screw thread is one of the factors affecting joint strength similar with previous research made by Anderson (2007). However it was contrast when applied with self-drilling insertion technique. Smaller chipboard screw which has lesser screw thread depth resulted in higher screw withdrawal strength. It was also resulted in highest screw withdrawal strength compared to the others screw insertion technique.

Table 3: One sample test of screw withdrawal strengthTesting

		Self-drilling (N/mm^2)	Pilot-hole (N/mm^2)	P+CSK (N/mm^2)
3.5M CS	Mean	1521	820	726
	Std Deviation	312	352	217
4M CS	Mean	1283	1191	1081
	Std Deviation	251	289	306
5M CS	Mean	1469	1463	945
	Std Deviation	482	341	384

Fig. 2 shows graph of screw withdrawal strength with minimum a line of standard requirement. Self-drilling screw insertion technique is suitable for all types of chipboard screw. The result shows that any sizes of chipboard have a reliable screw withdrawal strength which is over 1000 N/mm^2 (standard requirement).

The pilot-hole and P+CSK screw insertion technique required pilot-hole pre-drilling. The result shows that 3.5M CS is weak in withdrawal strength if the insertion technique required pilot-hole pre-drilling. The screw withdrawal strength was below the minimum requirement for pilot-hole and P+CSK insertion technique. It is probably due to diameter of the pilot-hole that is too big for the 3.5M chipboard screw. Bigger clearance hole will reduce the screw thread grip with the board particles. Common 4M CS and 5M CS have better withdrawal strength when using pilot-hole pre-drilling. It shows that the pilot-hole diameter only match well for 4M CS and 5M CS. Indeed, both chipboard screw has continuously proven its ability in matching with pilot-hole pre-drilling by maintaining withdrawal strength over 1200 N/mm^2 for 4M CS and 1400 N/mm^2 for 5M CS.

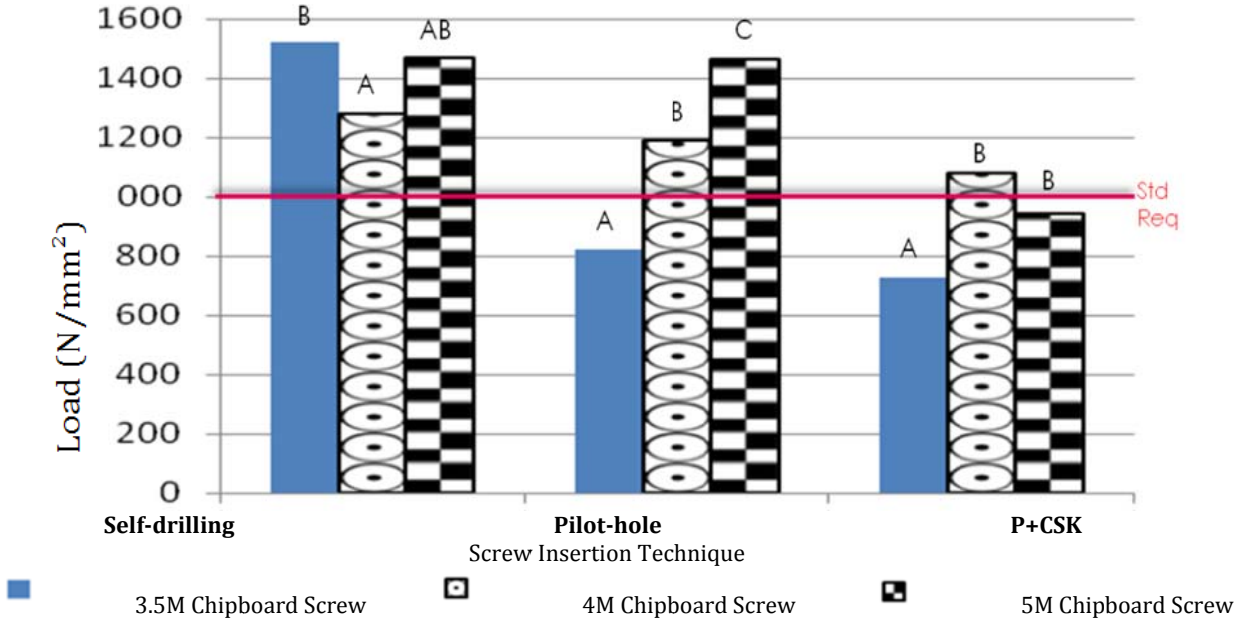

Fig. 2: Screw withdrawal strength in three-difference chipboard screw

Overall, the depth of screw thread affected the screw withdrawal strength only if it was applied with pilot-hole pre-drilling. The screw thread depth did not affect the screw withdrawal strength if it was used with the self-drilling screw insertion technique. It will result on better screw withdrawal strength for smaller diameter screw compared to the larger diameter. This result was similar to Gates (2009) and Özçifçi (2009) findings. A small diameter screw result in better withdrawal strength.

5. Conclusion

The purpose of this study is to analyze the effect of chipboard screw sizes on screw withdrawal strength by applying different screw insertion technique. In conclusion, small chipboard screw which is 3.5M CS cannot be used if it was applied with pilot-hole pre-drilling. It is suitable only for self-drilling screw insertion technique which is preferable screw insertion technique by the installer. The largest chipboard screw with pilot-hole screw insertion technique has better screw withdrawal strength compared with others. There is no significant different of screw withdrawal strength for self-drilling and P+CSK screw insertion technique. This suggests that chipboard screw sizes did not affected the screw withdrawal strength.

Acknowledgement

The authors would like to thanks Universiti Teknologi MARA (UiTM) Shah Alam and Research Management Institute (RMI) for sponsoring and

funding the project under Research Acculturation Grant Scheme (RAGS).

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