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Deflection Performance of Particleboards and Their Potential as Built-in Materials

Noor Azrieda Abd. Rashid*, Hashim W Samsi, Nur Hanina Izzati Khairol Mokhtar, Yanti Abdul Kadir, Khairul Masseat, Siti Zaliha Ali and Muhammad Taufiq Tajuddin

Forest Product Division, Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia

ABSTRACT

Particleboard is a commonly used material in the construction of furniture. It is an engineered wood product made from wood particles, such as wood chips, sawmill shavings, or sawdust, combined with a resin binder and compressed into sheets. The advantages of using this material are its uniformity, stability, and affordable price. Some performance must be tested to ensure its quality and strength properties so that it can be used as a built-in material. This study evaluated deflection performance based on the different thicknesses and sizes. The objective of this study was to determine the deflection properties over time. The deflective capabilities of particleboard with 16, 18 and 25 mm thicknesses and sizes of 400 × 384, 560 × 350, 760 × 330, 800 × 380 and 910 × 390 mm were investigated in three weeks. Remarkably, the particleboard with a 25 mm thickness exhibited markedly diminished deflection two to three times lower than that of 18 mm and 16 mm thickness, thereby showcasing its superior strength when subjected to various loads. Conversely, utilizing longer spans resulted in noteworthy deflection increments, implying that extended spans tend to manifest increased deflection as time progresses. These observations indicate that a thicker and shorter particleboard is well-suited for use as a building material, given its lower deflection over time. In conclusion, this study elucidates the intricate relationship between particleboard characteristics and deflection behavior, providing valuable guidance for selecting suitable particleboards based on load requirements and structural considerations.

Keywords: Deflection, particleboard panels, size, strength, thickness, time

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E-mail addresses:
azrieda@frim.gov.my (Noor Azrieda Abd. Rashid)
hashimws@frim.gov.my (Hashim W Samsi)
nurhanina@frim.gov.my (Nur Hanina Izzati Khairol Mokhtar)
yanti@frim.gov.my (Yanti Abdul Kadir)
khairulm@frim.gov.my (Khairul Masseat)
sitizalehaali@frim.gov.my (Siti Zaliha Ali)
muhdtaufiq@frim.gov.my (Muhammad Taufiq Tajuddin)
* Corresponding author

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INTRODUCTION

Exploration of enhancing material strength has led to a growing demand for composite materials in the construction sector. Composite panels revolutionize construction materials by merging multiple substances into a high-performance unit. These panels outshine individual materials in physical and mechanical properties (Jim, 2015; Masuelli, 2013). Material selection is the cornerstone of their design, focusing on unique qualities such as strength, weight, durability, insulation, and resistance to moisture and fire. By layering these materials, composite panels are precision-engineered to fulfill specific performance demands across various applications (Papadopoulos, 2020; Patnaik et al., 2020).

Common materials in composite panels encompass aluminum, fiberglass, carbon fiber, foam, plywood, and plastics. Wood composites, which encompass materials like chipboard, plywood, particleboard, blockboard, high-pressure laminate (HPL), medium-density fiberboard (MDF), and high-density fiberboards (HDF), are typically produced using synthetic adhesives known for their excellent waterproof and strong bonding qualities (Aliu et al., 2019). These composite panels can be customized for traits like rigidity or flexibility, making them invaluable across construction, transportation, aerospace, marine, and manufacturing industries. For instance, composite panels such as particleboard, blockboard, HPL and MDF are nowadays common materials for furniture due to their strength and durability. Notably, particleboard is a versatile and cost-effective example, crafted from waste wood materials such as wood chips, sawmill shavings, offcuts, and sawdust. It eventually makes it an ideal raw material for mass-producing panel-based furniture (Grzegorzewska et al., 2020; Malaysian Panel-Products Manufacturers' Association, 2023; Wu & Vlosky, 2000).

In the context of composite boards, two critical factors, "creep" and "deflection," are pivotal for assessing their strength and durability. Creep refers to the gradual deformation of a material over time under a sustained load or stress (Betten, 2008). In the context of particleboard, creep can result in permanent deformation, ultimately compromising the board's structural integrity. The extent of creep is influenced by a multitude of factors, including the magnitude of the applied load (Jeya & Bouzid, 2018), temperature conditions (Ayrilmis et al., 2009), and the intrinsic properties of the material (Georgiopoulos et al., 2015). Conversely, deflection is a critical parameter in understanding how a particleboard or any composite board behaves when subjected to external loads. It is the extent to which the board bends or flexes under the influence of applied forces. This property is instrumental in determining the board's structural integrity and suitability for specific applications (Rackham et al., 2009).

Particleboard deflection hinges on key factors. Firstly, load distribution is paramount, with uniformity reducing deflection, while uneven loads induce excess deflection and structural issues. The second factor is span length or the gap between supports, notably impacts deflection, with longer spans prone to more deflection due to reduced support. Material stiffness is also vital, as stiffer materials decrease deflection, bolstering structural integrity. The next key factor is adequate edge support, essential in shelving or cabinetry applications. Lastly, environmental factors, like moisture and temperature fluctuations, can influence deflection, potentially weakening adhesives and affecting dimensional stability (Rackham et al., 2009; Tankut, 2009).

Furthermore, deflection testing is a standard procedure used to assess a panel's ability to withstand mechanical stress and deformation, providing valuable data for engineering and design purposes in various industries. Generally, the composite panel is subjected to incremental loading during the test until the desired load level or failure occurs. Deflection measurements are collected at predetermined locations on the panel's surface. This data allows engineers to evaluate the panel's stiffness, strength, and overall structural performance. The setup and apparatus for deflection testing can vary based on standards, test methods, and available equipment (Hardiyatmo, 2011; Sharaf et al., 2020; Zhao et al., 2021).

Manufacturers must implement strategies to improve their performance and durability to make composite panels suitable for use as a built-in material or in furniture construction (Fan & Schodek, 2007). It involves carefully choosing materials stiff and resistant to deformation over time. They also need to design their products to minimize bending or sagging when bearing typical loads (Jivkov et al., 2010; Liu et al., 2016). Installing these panels correctly according to the manufacturer's guidelines is crucial to prevent excessive forces or stress that could weaken their structural integrity. Additionally, in a technical bulletin by the Composite Panel Association (2022), the most important factors in designing a shelf system are shelf thickness and the distance between supports. The thicker the shelf and the closer the supports, the stronger the shelf will be and the less it will exhibit deflection.

Therefore, this study aimed to determine the impact of various thicknesses and dimensions on the deflection performance of a specific composite panel, specifically particleboard, over three-week. All particleboards of different thicknesses and sizes were subjected to three levels of loading, categorized as light, medium, and heavy, to ensure consistent results. The deflection tests were conducted following established procedures and standards (BS 4875-7, 2006; BS EN 16122, 2012; BS EN 16121, 2013) to assess the overall performance of the tested particleboard.

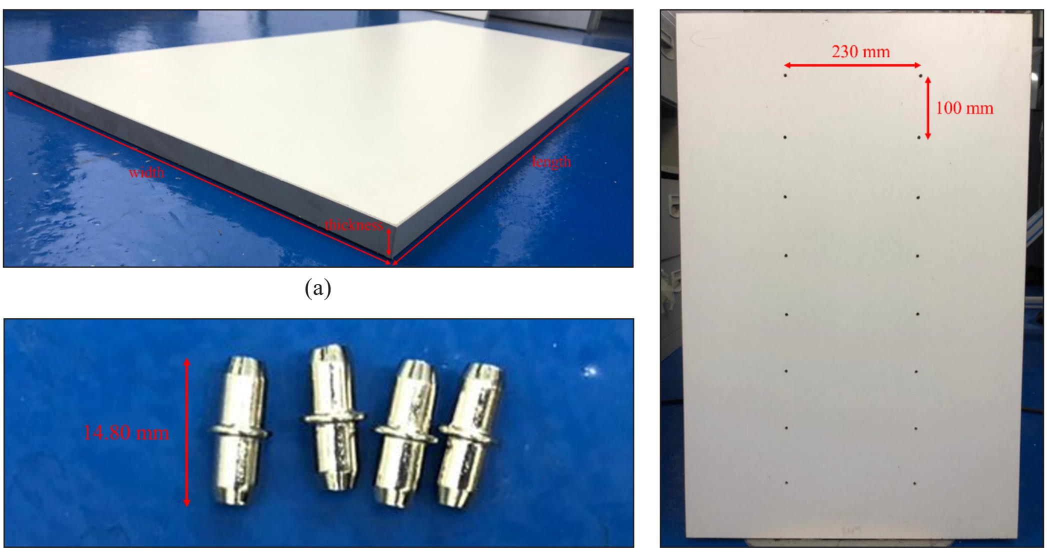
MATERIALS AND METHODS

Materials

Particleboard with 16 mm, 18 mm, and 25 mm thicknesses was manufactured and supplied by the composite panels industries in Peninsular Malaysia. A digital dial gauge and digital caliper were purchased from Mitutoyo (Kanagawa, Japan), shelf support pin nails were obtained from common Malaysia's supplier and measuring tape was purchased from Stanley (Maryland, USA).

Specimen Preparation and Setup

A total of 18 particleboard samples were categorically distributed into three groups based on thickness: 16 mm, 18 mm, and 25 mm. Each sample's length and width were meticulously measured and labeled (Figure 1a), resulting in six replicates per thickness category. The classification of each particleboard is shown in Table 1. Subsequently, all specimens were methodically supported by four shelf support pin nails, each with a width of 14.80 mm (Figure 1b). These pins were precisely centered on two parallel edges, maintaining a consistent spacing of 230 mm between them (Figure 1c). This meticulous setup and labeling procedure ensured uniformity and accuracy in the experimental process.



(a) (b) (c)

Figure 1. (a) Measurement of length, width and thickness of a particleboard; (b) shelf support pin nails; and (c) spacing between shelf supports on two parallel edges of the support board

Table 1
Classification of particleboard tested based on different sizes and thicknesses

Label	Size (length × width), mm	Thickness, mm		
A	400 × 384	16	18	25
B	560 × 350	16	18	25
C	760 × 330	16	18	25
D	800 × 380	16	18	25
E	910 × 390	16	18	25

Load Determination

The load applied to the samples was calculated using a specific formula: the product of the sample's area and a loading factor. This calculation was determined based on the standards, BS EN 16121 (2013), level 1–2 and BS 4875-7 (2006), level 5, where each loading factor was duplicated. For example, replicates 1 and 2 were subjected to a loading factor of 1.5, while replicates 3 and 4 had a loading factor of 2 applied. Replicates 5 and 6 were tested with a loading factor of 2.5. A summary of the load determination is shown in Table 2. Figure 2 shows the types of loads applied to the sample, which were 100 g, 500 g, 1 kg, 2 kg, 5 kg and 10 kg, respectively. This approach ensured a systematic and controlled variation in the applied loads across the experimental replicates.

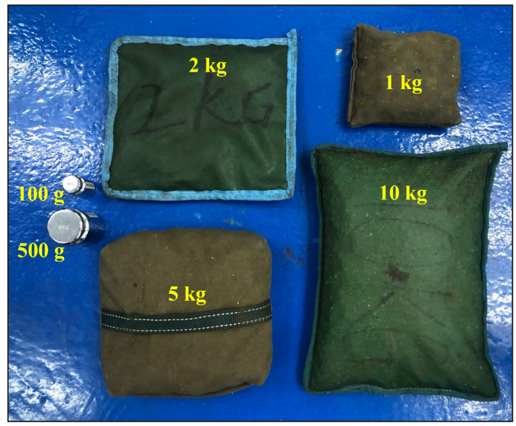


Figure 2. Types of loads applied for deflection test of a particleboard

Table 2
Summary of load determination according to loading factor for each particleboard

Label	Size (length × width), mm	Thickness, mm	Loading Factor/ Replicates						Total number of particleboards tested for each size
			1.5		2.0		2.5		
A	400 × 384	16	1	2	3	4	5	6	18
B	560 × 350	18	1	2	3	4	5	6	18
C	760 × 330	25	1	2	3	4	5	6	18
D	800 × 380		1	2	3	4	5	6	18
E	910 × 390		1	2	3	4	5	6	18
Overall									90

Deflection Testing

Deflection testing of the particleboard was performed at the FRIM Furniture Testing Laboratory (FTL) according to BS EN 16122 (2012), clause 6.1.4. The arrangement of all panels utilized a set of supporting boards (Figure 3a). Prior to subjecting the samples to load, an initial reading was taken using a dial gauge (Figure 3b) with an accuracy of ±0.01 mm to establish a baseline measurement. The deflection of the particleboard was measured at a point 10 mm from the front edge where the deflection is greatest. The loads were uniformly distributed onto the samples after determining the loading conditions. Subsequently, deflection readings were recorded immediately after the load was applied. This deflection testing protocol was systematically conducted over three weeks, with readings documented at regular intervals of 24 hours.

(a)

(b)

Figure 3. (a) Arrangement of panels on a set of supporting boards; and (b) a digital dial gauge used for deflection measurement

Statistical Analysis

Statistical analyses were performed using GraphPad Prism version 8.0.2. All data are presented as mean ± SD. The means were compared using two-way analysis of variance (ANOVA) followed by Tukey's post-hoc test. Differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Deflection of Particleboard

The effects of three different particleboard thicknesses, 16 mm, 18 mm and 25 mm, on the deflection (δ) of the particleboards at varying sizes were investigated. Determination of the deflection performance over three weeks was carried out under constant load conditions. The sizes (length × width) in mm tested were 400 × 384 (A), 560 × 350 (B), 760 × 330 (C), 800 × 380 (D), and 910 × 390 (E).

Particleboard of 16 mm in Thickness

Overall, low deflection performances ($\delta < 0.9$ mm) were observed for A and B compared to other sizes (Figure 4). This indicates that the loads applied to A and B had a lesser impact on the bending characteristics of the particleboard than on the other sizes. This phenomenon can be attributed to using a shorter span, leading to the lowest achievable maximum deflection, as indicated in prior research (D'Antino & Pisani, 2021). Conversely, the highest deflection value was recorded at the longest span, E, with a mean deflection measurement of $\delta = 11.45$ mm. The deflection exhibited a peak on day 2 following the application of the loads, with a continuous increment observed until it reached a plateau after approximately one week.

During the testing of span C, the total deflection at the end of the week increased approximately 7 to 9 times in comparison to that of spans A and B. Similarly, span D also exhibited a notable increase in total deflection, ranging from approximately 4 to 8 times

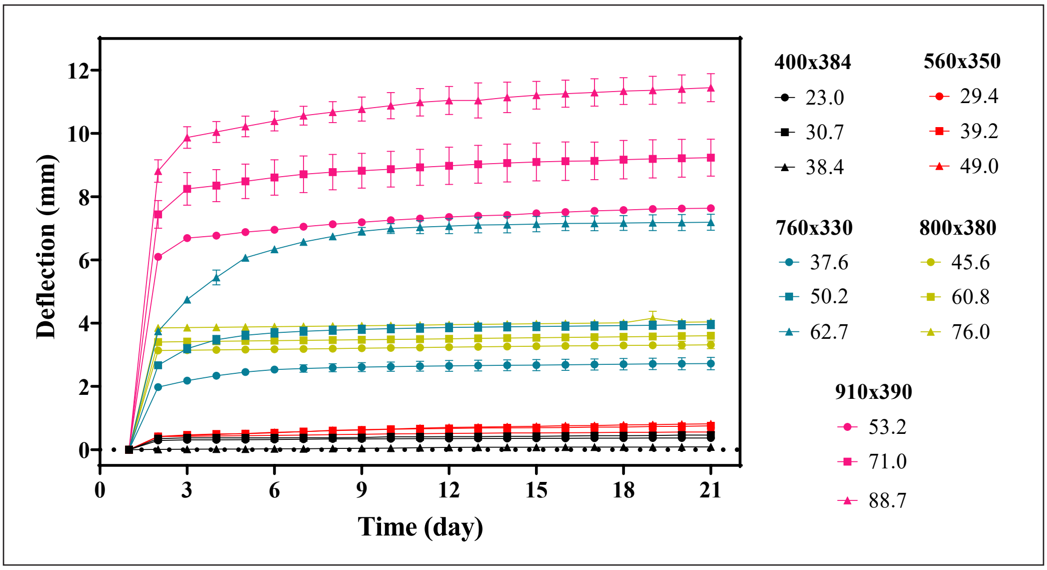


Figure 4. Performance of 16 mm-particleboard under loading with a factor of 1.5, 2 and 2.5 as denoted by "●", "■" and "▲" shape

to that of spans A and B. This result revealed that spans C and D have similar deflective capabilities, especially in bearing loads weighing 45.6 kg to 60.8 kg.

Furthermore, the increase in the extent of this deflection corresponded directly to the loading factor employed for load determination. Specifically, the greatest deflection was observed when a loading factor 2.5 was applied across all span sizes, followed by loading factors of 2 and 1.5, in decreasing order of deflection magnitude. These findings underscore the significant influence of load weight on the overall performance of the particleboard and highlight the distinct effects of different particleboard sizes on deflection behavior.

Particleboard of 18 mm in Thickness

When particleboards with a thickness of 18 mm were used, the same deflection pattern was observed (Figure 5). The highest deflection was consistently noted at the longest span, E, followed by D, C, B and A, for all load applied. In direct comparison to the 16 mm particleboard, it is noteworthy that the total deflection value for 18 mm thickness exhibited a reduction of 27%, with a recorded mean value of $\delta = 9.04$ mm at span E. This reduction in the deflection strongly indicates that the increased thickness of the particleboard confers greater structural strength, thereby diminishing its susceptibility to deflection under load.

Additionally, the disparity in the overall deflection performance of span C was narrower for the 18 mm particleboard compared to the 16 mm variant, exhibiting a 29% to 59% reduction across all applied loads. Conversely, span D displayed heightened deflection with 18 mm thickness compared to the 16 mm thickness. Increasing board thickness should

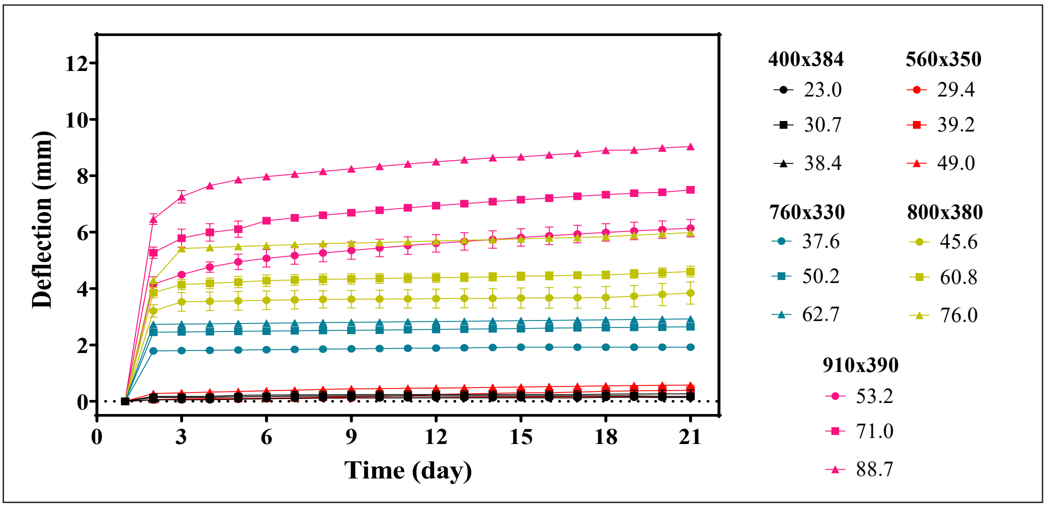


Figure 5. Performance of 18 mm-particleboard under loading with a factor of 1.5, 2 and 2.5 as denoted by "●", "■" and "▲" shape

theoretically lead to decreased deflection due to the additional layers or plies, thereby enhancing its structural integrity (Composite Panel Association, 2022). Nevertheless, the results for span D deviate from this expectation, potentially due to imbalances in the panel structure, including aspects such as panel density or internal bond. Despite these observations, it remains evident that longer spans manifest greater deflection compared to shorter spans.

Particleboard of 25 mm in Thickness

When examining particleboard with a thickness of 25 mm, a consistent deflection performance pattern was observed with that of the 16 mm and 18 mm variants, with the longest span, E, exhibiting the highest deflection (E > D > C > B > A). However, a notable distinction for this particular thickness was the mean total deflection value, recorded at δ = 3.93 mm, occurring at span E under a loading factor 2.5 (Figure 6). It is worth emphasizing that this value represented a significant reduction, approximately two to three times lower when compared to the respective values observed for 18 mm and 16 mm thicknesses. This outcome again highlights the substantial influence that particleboard thickness exerts on the deflection performance of the panel.

Furthermore, in contrast to spans A and B, both spans C and D demonstrated an enhancement in deflection performance ranging from approximately 4 to 11 times, corroborating previous findings that longer spans tend to exhibit amplified deflection. It is worth noting that all tests were conducted in accordance with the prescribed standards (BS 4875-7, 2006; BS EN 16122, 2012; BS EN 16121, 2013), ensuring the reliability of the results and their potential for replication in future studies.

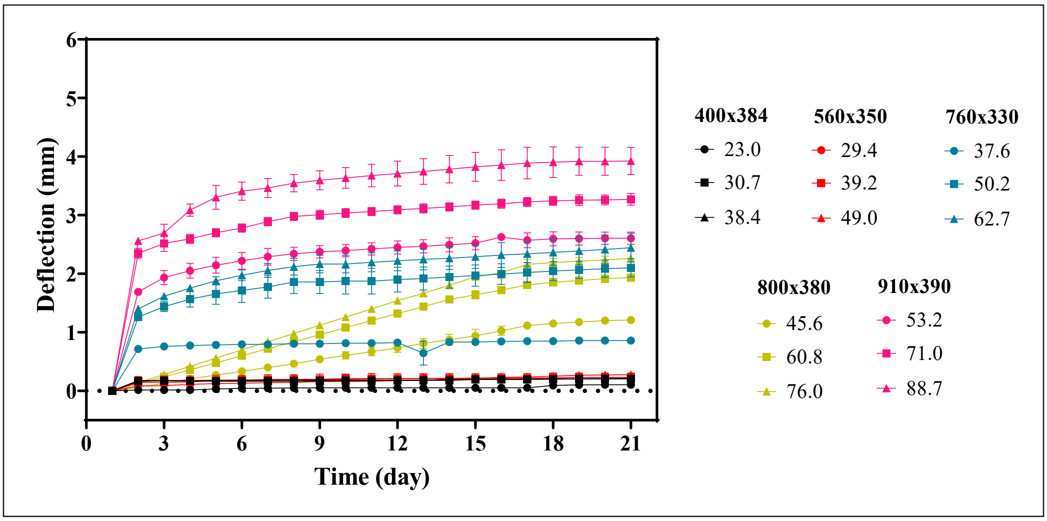


Figure 6. Performance of 25 mm-particleboard under loading with a factor of 1.5, 2 and 2.5 as denoted by "●", "■" and "▲" shape

Comparison Between All Thicknesses Tested

A comprehensive statistical analysis was performed to assess the significance of particleboard thickness and size and derive meaningful conclusions differences. The graphical representation of our findings exhibited a general trend of increasing deflection readings across all spans. Notably, a deviation from this trend was observed when thicker particleboard was employed (Figure 7). Upon closer examination, the analysis indicated no statistically significant differences in deflection performance among all thicknesses for spans A and B. It suggests that, at these specific spans, particleboard thickness had a relatively minor impact on deflection behavior. Furthermore, it is worth noting that loads ranging from 23 to 49 kg could be applied to both spans over three weeks without causing substantial deflection. It indicates that spans A and B, measuring 400 × 384 and 560 × 350, respectively, demonstrated an equivalent strength and load capacity of up to 49 kg. Consequently, there is potential for material reduction in the furniture design at these specific sizes.

In contrast, it is important to highlight that the disparities in thickness exhibited statistically significant effects for spans C, D, and E. To illustrate, span C displayed marked differences in deflection performance when comparing the 16 mm thickness with 18 mm and 25 mm thicknesses across all applied loads. Similarly, span D revealed a statistically significant divergence in deflection when comparing the 25 mm thickness with the 16 mm and 18 mm variants, particularly under a load of 45.6 kg. Furthermore, it is noteworthy that, in the case of spans other than C and D, statistically significant differences emerged across all thicknesses for all loads applied to the specimens. This finding implies that thicker

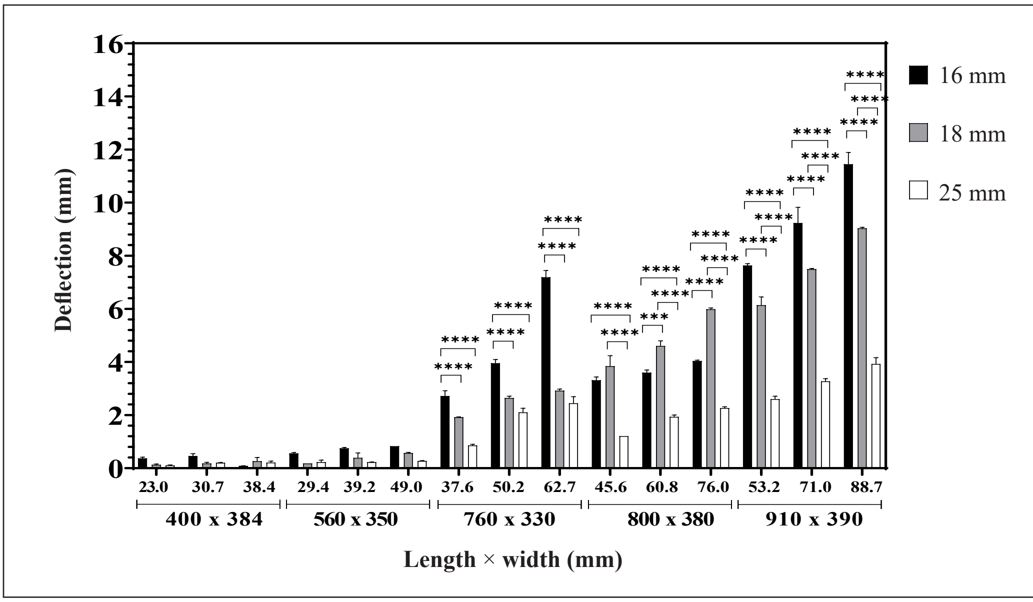


Figure 7. Comparison between particleboard thickness and sizes

particleboard demonstrates reduced deflection readings, while extended spans contribute to an increase in deflection readings over time.

According to Mirski et al. (2019), the thickness of particleboard predominantly correlates with two critical material properties: the modulus of rigidity and the tensile strength perpendicular to the board plane. Generally, when thickness increases, the modulus of rigidity tends to decrease, while the modulus of elasticity tends to increase. In the study of panel deflection, a uniform load was applied across the entire surface to simulate balanced stress, mimicking domestic use. Uneven loading on a shelf can result in exaggerated moments, potentially leading to rupture. The Composite Panel Association (1998) stated that the load, shelf span, and panel thickness influence the extent of shelf deflection. Moreover, the structural design of the panel's shelf is directly related to its maximum load-bearing capacity. This relationship underscores the importance of considering not only board thickness but also the geometric aspects of the material when assessing its mechanical properties and structural behavior.

CONCLUSION

This study provides a practical exploration of how different particleboard thicknesses and sizes perform in terms of deflection over three weeks. Notably, the 25 mm-thick particleboards substantially reduced deflection, showcasing its superior strength under various applied loads. Conversely, longer spans revealed a notable increase in deflection performance, suggesting that particleboards spanning extended distances tend to exhibit greater deflection over time. However, amidst this lies an opportunity for material optimization in furniture design at dimensions of 400 × 384 and 560 × 350, as both sizes demonstrated comparable strength and a common load capacity. This research sheds light on the intricate relationship between particleboard thickness, span size, and deflection behavior over an extended duration. These findings offer valuable insights for the judicious selection of particleboard, especially in domestic storage applications, considering the requisite load-bearing capacities and structural considerations.

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