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Investigation of the effect of pilot hole diameter, pilot hole depth and thickness on screw direct withdrawal resistance in OSB

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ABSTRACT **Research Article**

Background and aims OSBs are an engineered wood-based composite material and is widely used especially in the construction and furniture sectors. Screw connections are one of the critical elements that determine the mechanical strength of OSB. The aim of this study is to investigate the effects of pilot hole diameter, pilot hole depth and board thickness on the screw direct withdrawal resistance in OSB. In the study, screw direct withdrawal resistance was tested by using 11mm and 18mm thick OSBs, taking into account different pilot hole diameters (60% and 85%), pilot hole depths (50% and 80%) and screwing directions (edge and face).
Methods Uncoated 11mm and 18mm thick OSBs were used in the experiments. Zinc-plated sheet steel screws 3.5×30mm were used.
Results The results showed that pilot hole diameter, depth, and screwing direction significantly affected screw withdrawal resistance. A 60% pilot hole diameter and 50% depth provided higher resistance than 85% and 80%, respectively. Face screwing yielded greater strength than edge screwing. While OSB thickness had no significant effect, 18 mm boards showed slightly higher resistance on average.
Conclusions The factors should be selected correctly in order to use OSBs more safely and efficiently in engineering and construction applications. In particular, it is recommended to prefer face screwing and to use a pilot hole diameter of 60% and a depth of 50% in proportion to the screw diameter. These findings will contribute to the creation of more reliable and durable connections in the areas where OSBs are used.

Key Words: OSB, screw direct withdrawal resistance, pilot hole diameter, pilot hole depth, screwing direction, building materials, mechanical connections

OSB'lerde pilot delik çapı, pilot delik derinliği ve levha kalınlığının vida çekme direnci üzerine etkisinin incelenmesi

ÖZ

Giriş ve Hedefler OSB'ler levhalar, mühendislik ürünü ahşap esaslı kompozit malzemeler olup, özellikle yapı ve mobilya sektörlerinde yaygın olarak kullanılmaktadır. Vida bağlantıları, OSB levhaların mekanik dayanımını belirleyen kritik unsurlardan biridir. Bu çalışmanın amacı, OSB levhalarda pilot delik çapı, pilot delik derinliği ve levha kalınlığının vida çekme direnci üzerindeki etkilerini incelemektir. Çalışmada, 11mm ve 18mm kalınlığındaki OSB levhalar kullanılarak farklı pilot delik çapları (%60 ve %85), pilot delik derinlikleri (%50 ve %80) ve vidalama yönleri (kenar ve yüzey) dikkate alınarak vida çekme dirençleri test edilmiştir.
Yöntemler Deneylerde yüzeyi kaplanmamış 11mm ve 18mm kalınlığındaki OSB levhalar kullanılmıştır. Çalışmada 3,5×30 mm boyutlarında sunta vidalar kullanılmıştır.
Bulgular Elde edilen sonuçlara göre, vida çekme direnci üzerinde pilot delik çapı, derinliği ve vidalama yönünün önemli bir etkisi olduğu tespit edilmiştir. Pilot delik çapının vida çapına oranı %60 olduğunda, %85 oranına kıyasla daha yüksek vida çekme direnci sağlanmıştır. Benzer şekilde, %50 pilot delik derinliği, %80 derinliğe göre daha yüksek mukavemet göstermiştir. Vida bağlantılarında yüzey vidalamanın kenar vidalamaya kıyasla daha yüksek çekme direnci sağladığı belirlenmiştir. OSB levha kalınlığının ise vida çekme direnci üzerinde anlamlı bir etkisi olmadığı, ancak 18 mm kalınlığındaki levhaların ortalama olarak daha yüksek çekme direncine sahip olduğu görülmüştür.
Sonuçlar OSB levhaların mühendislik ve yapı uygulamalarında daha güvenli ve verimli kullanılabilmesi için pilot delik çapı ve derinliği gibi faktörlerin doğru seçilmesi gerektiğini göstermektedir. Özellikle, yüzey vidalamanın tercih edilmesi ve vida çapına oranla %60 pilot delik çapı ile %50 derinliğin kullanılması önerilmektedir. Bu bulgular, OSB levhaların kullanım alanlarında daha güvenilir ve dayanıklı bağlantılar oluşturulmasına katkı sağlayacaktır.

Anahtar Kelimeler: OSB, vida çekme direnci, pilot delik çapı, pilot delik derinliği, vidalama yönü, yapı malzemeleri, mekanik bağlantılar

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1. Introduction

Oriented Strand Board (OSB) is an engineered wood material produced by orienting wood strands in a specific order, gluing them and pressing them under high temperature and pressure. These boards have a wide range of uses, especially in the construction sector, furniture production and decorative applications. According to the EN 300 standard, OSBs are divided into four classes according to their load-bearing capacity and moisture resistance. Each class is intended for different application areas (EN 300, 2006).

OSB-I, General purpose use in dry environments: This class is used in elements that do not carry mechanical loads. It is generally preferred in furniture manufacturing, packaging boxes and temporary internal partitions. Its moisture resistance is low and is only suitable for dry internal environments (Kurt and Altınok, 2015). It is generally used in furniture back plates, packaging cases and interior decoration surfaces. OSB-II, Structural use in dry environments (non-bearing structures): This class is suitable for non-bearing applications in low humidity environments within the structure. For example, it is used in interior wall cladding or decorative applications. It is generally used as interior partition walls, shelf systems, dry environment floor coverings. OSB-III, Structural use in humid environments (bearing elements): OSB-III boards, which have structural bearing capacity, can also be used in humid environments. It is widely used as exterior cladding in timber-framed structures and as water-resistant coating on roofs. It also plays an important role in carrier floor systems and prefabricated wall panels (Dündar et al. 2008; Özdemir, 2012; Ferhatoğlu and Sarı, 2017). It is generally used in wooden construction exterior walls, roof soffits, and exterior panels. OSB-IV, High bearing capacity, structural use for humid environments: This class of boards is used in applications requiring high mechanical strength. It is suitable for use in industrial structures, load-bearing wall systems and modular building elements. It has both higher strength and is resistant to longer-term exposure to humidity compared to other classes (Kollmann and Côté, 1968; USDA Wood Handbook, 2010). It is generally used in industrial building panels, modular containers and heavily loaded flooring systems.

The mechanical strength of OSB and its interaction with fasteners are of critical importance in ensuring the efficient and safe use of these materials (Zhang and Lee, 2005). The strength of the screw connections is one of the basic elements that determine the structural integrity of the board, and the screw direct withdrawal resistance is considered an important parameter in this context (Ayrılmış and Özkan, 2015).

Screw direct withdraweal resistance (SDWR) is one of the basic parameters that determine screw holding capacity (Kollmann and Gering, 1965; Kurt and Kılıç, 2010). In a study conducted by Akbulut and Ayrılmış (2002), it was determined that the SDWR value of OSBs was lower than plywood, but the screw withdrawal strength in certain directions was sufficient. However, in a study conducted by İstek et al. (2016), it was emphasized that some mechanical properties of OSBs could be improved and SDWR capacity could be increased with the addition of silane. In particular, it has been observed that the SDWR perpendicular to the face varies depending on the direction of the fibers in the board.

OSBs offer some advantages and disadvantages when compared to other wood-based materials in terms of screw withdrawal capacity (Moses and Prion, 2002). In a study conducted by Kasal and Diler (2013), it was determined that the screw withdrawal capacity of OSBs were lower than materials such as MDF and plywood, but they exhibited sufficient performance in certain areas of use (Guan and Rodd, 2008). In addition, a study conducted by Efe and İmirzi (2007) stated that SDWR of OSBs was lower than plywoods but showed better performance compared to MDF.

In a study conducted by Korkmaz et al. (2017), it was determined that production conditions have a significant effect on the SDWR of OSBs. It has been emphasized that factors such as the type of wood used, resin ratio and pressing temperature directly affect the SDWR of the board. Another study conducted by Esen and Yapici (2013) revealed that the screw withdrawal performance of OSBs obtained from different wood species varies. It has been stated that the screw withdrawal capacity of birch wood based OSBs is lower, but this capacity can be improved when the resin ratio is increased.

In this study, four basic variables affecting the SDWR of OSBs, such as OSB thickness (11 mm and 18 mm), screw direction (edge and face), pilot hole diameter (60% and 85%) and pilot hole depth (50% and 80%), were investigated. Pilot hole diameter and depth in screw connections are one of the important factors that determine the stability of the connection, and incorrectly selected hole sizes can cause the screw connection to fail and reduce the mechanical properties of the board (Yiğittap, 2016). In this context, the effects of different pilot hole ratios on SDWR of OSBs were analyzed experimentally.

In addition, internal bonding strength tests were carried out to determine the internal structural strength of OSBs and the obtained data were compared with the SDWR. Internal bond strength is a parameter that represents the adhesive strength between the inner layers of the board and can directly affect the integrity of the board and its interaction with the fasteners (Özlüsoylu, 2016). In the studies, it was observed that the boards with high internal bonding resistance exhibited higher SDWR in screw connections (Efe, 2004). Therefore, in this study, the relationship between the SDWR values and the internal bonding strength values was tried to be determined.

This research is important in understanding how OSB exhibits SDWR under different screw connection conditions. Such studies, which are carried out to determine the optimum screwing conditions of OSBs, allow the fasteners to be used more efficiently and safely (Kasal and Diler, 2013). In addition, determining the factors affecting SDWR will contribute to the creation of reliable connections, especially in the construction and furniture sectors. In conclusion, this study comprehensively analyzes the factors affecting the SDWR of OSBs and reveals the relationship between this resistance and internal bonding resistance. The findings presented in this study will guide future engineering applications for more efficient use of OSBs and will contribute to the optimization process in mechanical connections of wood-based composite materials.

2. Material and Method

In this study, 11 mm and 18 mm thick uncoated OSB-II produced by Kronospan / Türkiye company were used. Samples with dimensions of 50x50 mm^2 were prepared according to EN 13446 standard (Figure 1). Prepared samples were conditioned in the climate chamber at 65% relative humidity and 20±2 °C temperature according to EN 320 for two weeks. The densities of OSBs were determined according to the TS EN 323 standard. Within the scope of the study, flat-headed 3.5 mm diameter × 30 mm long sheet metal screws made of zinc-plated steel were used.

Figure 1. Prepared test samples

Density, water absorption and thickness swelling (24, 48 and 72 hours) tests of OSB were carried out according to TS EN 317 (1999) standard. In order to determine the internal bonding quality of OSB, the principles specified in the TS EN 319 (1999) standard were used. Samples with dimensions of 50mm x 50mm were prepared according to the relevant standard. The prepared samples were bonded between metal plates as seen in Figure 2. Hot silicone was used for the bonding process.

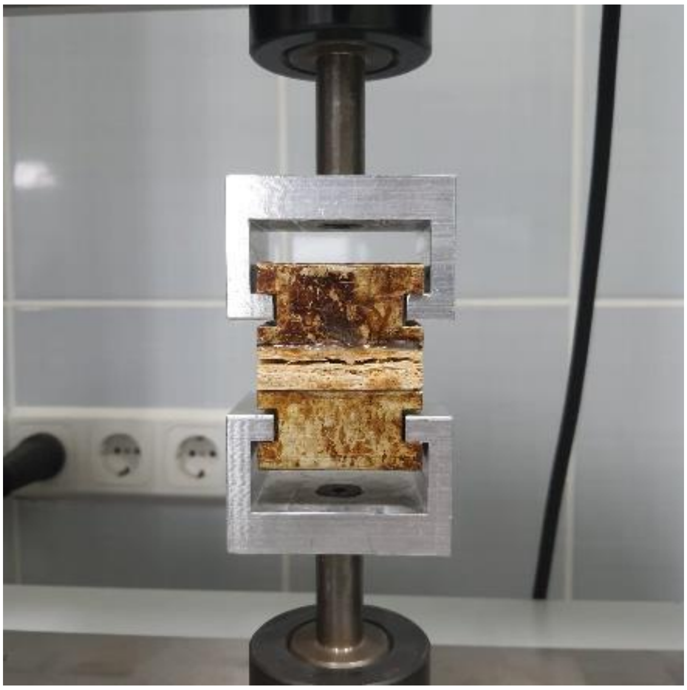

Figure 2. Internal bond tests

SDWR test variables were determined as OSB thickness, screw direction, pilot hole diameter and pilot hole depth. A total of 360 test samples were prepared, 20 for each group. The variables are shown in Table 1.

Table 1. Experiment parameters

OSB Thickness	Screw Orientation	Pilot Hole Diameter	Pilot Hole Depth
11 mm	Face	60%	50%
18 mm	Edge	85%	80%

The pilot hole diameter was drilled to be 60% and 80% of the screw diameter to be applied to the face and edge of the test blocks. Pilot hole depths were drilled to be 50% and 80% of the penetration depth. The screwing process was carried out at the same torque level with a 90° angle between the screw direction and the sample face. SDWR tests were carried out on the Shimadzu AGIC/20/50KN testing machine according to EN 320 and TS EN 13446 standards.

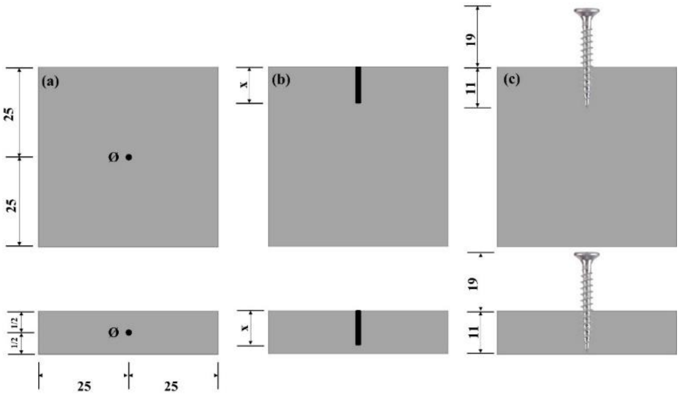

Figure 3. OSB test specimens (a. pilot hole position; b. pilot hole depth; c. screwing deph; Ø: 60% or 85% of screw diameter; x: 50% or 80% of screw penetration depth; mm)

IBM SPSS 23.0 package program was used for statistical evaluation of the obtained data. Variance analysis was applied to determine the differences between the results.

3. Results and Discussion

In this section, the experimental data obtained regarding the SDWR of OSBs are analyzed in detail and the results are discussed by comparing them with the studies in the literature. The physical properties of OSBs are given in Table 2.

Table 2. Physical properties of OSBs

Physical Properties	11 mm thick OSB	18 mm thick OSB
Moisture content (%)	7.59 ± 0.15	7.28 ± 0.27
Air dry density (g/cm^3)	0.59 ± 0.04	0.60 ± 0.03
Oven dry density (g/cm^3)	0.53 ± 0.04	0.57 ± 0.04
Wet density (g/cm^3)	0.77 ± 0.04	0.80 ± 0.03
Volumetric shrinkage rate (%)	2.88 ± 0.72	2.66 ± 0.42
Volumetric swelling rate (%)	21.81 ± 0.55	24.88 ± 0.71

According to Table 2, it is understood that the physical properties of 11 mm thick OSBs are generally similar to those of 18 mm thick. The water absorption and thickness swelling test results of OSBs at 24, 48 and 72 hours are given in Figure 4.

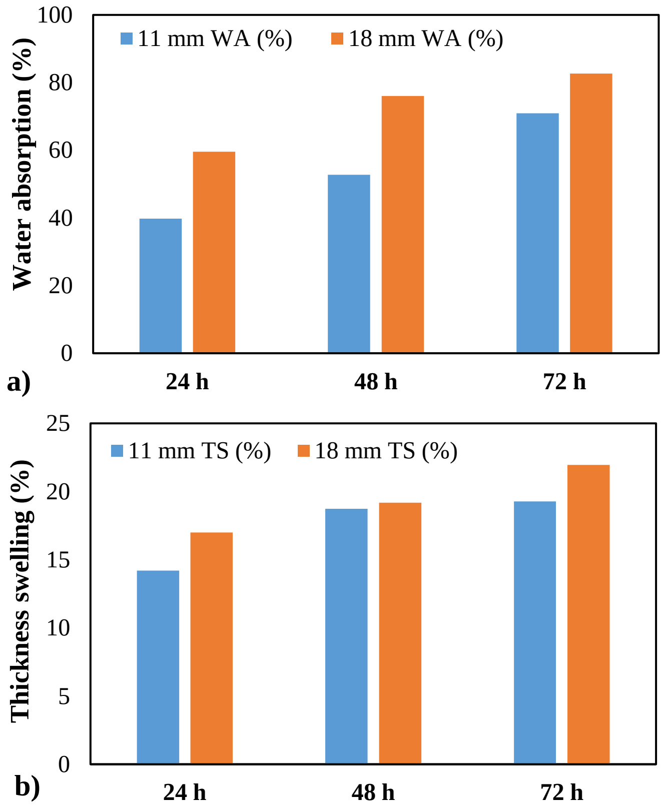

Figure 4. 24, 48 and 72 hours water absorption (a) and thickness swelling (b) test results of OSBs

Physical properties of OSB such as density, moisture content and water absorption capacity are the determining factors on SDWR. Since the densities of the OSBs used in the experiments were at similar levels (0.59-0.60 g/cm³, Table 2), the examination of the effect of this parameter on SDWR was limited. However, it was observed that the SDWR capacity of the boards with high internal adhesion resistance was higher. Similarly, in the study conducted by Efe (2004), it was stated that OSBs with high internal bonding strength exhibited better performance in screw connections. Internal bonding resistance test results of OSBs are given in Table 3, and SDWR test results are given in Table 4.

Table 3. Internal bonding strength test results of OSBs

OSB Thickness	Internal Bond Strength (N/mm²)
11 mm	936.25 ± 134.33
18 mm	1061.16 ± 116.74

OSB thickness has a significant effect on SDWR. As a result of the comparison of 11 mm and 18 mm thick OSBs used in the study, it was determined that the average SDWR values of 18 mm boards were higher than 11 mm boards (Table 5). However, statistical analysis showed that this difference was not significant ($p>0.05$). This suggests that the internal bond strength properties and densities of OSBs affect the screw withdrawal performance regardless of the thickness.

Similar results have been reported in previous studies. For example, Efe and İmirzi (2007) stated that OSBs have lower SDWR values compared to plywoods but perform better compared to MDF. Korkmaz et al. (2017) revealed that OSB production processes (e.g. pressing temperature, resin ratio) can directly affect SDWR. Esen and Yapici (2013) stated that the screw withdrawal capacity of OSBs varies depending on the type of wood used, but in general, as the thickness increases, the screw withdrawal capacity improves somewhat.

The surface on which the screw is applied to the OSB significantly affects the SDWR. The experimental results show that screwing to the face (404.52 N) provides statistically significant higher SDWR than screwing to the edge (259.62 N) ($p<0.05$, Table 6). When screwing is done in the edge direction, the screw withdrawal capacity decreases because the fibers do not support the connection. Ayrılmış and Özkan (2015) stated that fiber orientation in OSBs is a determining factor in screw withdrawal capacity and that screw loosening occurs earlier, especially in edge screwing.

Table 4. Screw direct withdrawal resistance results in OSBs

OSB Thickness	Screw Orientation	Pilot Hole Diameter	Pilot Hole Depth	SDWR (N)
11 mm	Face	60%	50%	388.95 ± 52.28
			80%	437.98 ± 41.88
		85%	50%	400.73 ± 38.78
			80%	309.40 ± 66.59
	Edge	60%	50%	292.02 ± 56.74
			80%	365.71 ± 66.59
		85%	50%	240.83 ± 32.90
			80%	176.07 ± 31.11
18 mm	Face	60%	50%	472.10 ± 53.21
			80%	463.39 ± 30.43
		85%	50%	451.25 ± 44.56
			80%	312.33 ± 52.02
	Edge	60%	50%	331.53 ± 46.00
			80%	279.05 ± 25.65
		85%	50%	239.00 ± 26.95
			80%	152.77 ± 30.99

Table 5. OSB thickness effect

Screw Thickness	Mean SDWR (N)	Minimum SDWR (N)	Maximum SDWR (N)
11 mm	$326.46^{A} \pm 96.09$	144.59	486.94
18 mm	$337.68^{A} \pm 116.07$	122.13	549.00

Mean is arithmetic means. Superscript letters of A is a homogeneous subset of post hoc test results $p>0.05$.

In a study conducted by Kasal and Diler (2013), it was reported that the edge screwing performance of OSBs was lower than materials such as MDF and plywood but provided sufficient strength in screwing in the face direction. For this reason, it can be said that surface screwing should be preferred in the structural connections of OSBs.

Table 6. Screw orientation effect

Screw Orinetation	Mean SDWR (N)	Minimum SDWR (N)	Maximum SDWR (N)
Face	$404.52^{B} \pm 76.41$	232.77	549.00
Edge	$259.62^{A} \pm 79.37$	122.13	475.59

Mean is arithmetic means. Superscript letters of A, is a homogeneous subset of post hoc test results $p<0.05$.

The ratio of pilot hole diameter to screw diameter is a critical parameter for the stability of screw connections. Experimental results show that 60% pilot hole diameter has a more positive effect on SDWR. While the average SDWR at 60% pilot hole diameter was 378.84 N, this value decreased to 285.30 N at 85% diameter ($p<0.05$, Table 7). Larger pilot holes are thought to reduce friction between the screw and the OSB and therefore lower the SDWR.

These findings align with those of Yiğittap (2016), who reported that large-diameter pilot holes in screw connections decrease adhesion strength and compromise the internal integrity of the material. Özlüsoylu (2016) reported that the optimum pilot hole diameter in OSB should be between 50-70% of the screw diameter. The 60% rate obtained in this study is among the optimum values recommended in literature.

Table 7. Pilot hole diameter effect

Pilot Hole Diameter	Mean SDWR (N)	Minimum SDWR (N)	Maximum SDWR (N)
60%	$378.84^{B} \pm 84.31$	227.52	549.00
85%	$285.30^{A} \pm 105.97$	122.13	528.59

Mean is arithmetic means. Superscript letters of A, is a homogeneous subset of post hoc test results $p<0.05$.

Pilot hole depth is an important factor that determines how far the screw penetrates into the material. According to the experimental results, SDWR at 50% depth (352.05 N) is significantly higher than at 80% depth (312.09 N) ($p<0.05$, Table 8). Deeper pilot holes weaken the mechanical bond between the screw and OSB, thus reducing the SDWR.

Baltacı (2010), in his study examining screw connection performances in different wood-based materials, found that deep pilot holes reduce the compressive strength in the material and cause screw connections to loosen more quickly. İstek et al. (2016) stated that the optimum hole depth should be between 40-60% of the screw length to increase the SDWR capacity of OSBs. The 50% ratio obtained in this study is consistent with the values recommended in the literature.

Table 8. Pilot hole diameter depth effect.

Pilot Hole Depth	Mean SDWR (N)	Minimum SDWR (N)	Maximum SDWR (N)
50%	$352.05^{B} \pm 95.29$	196.00	549.00
80%	$312.09^{A} \pm 113.49$	122.13	498.38

Mean is arithmetic means. Superscript letters of A, is a homogeneous subset of post hoc test results $p<0.05$.

The findings obtained in this study are largely consistent with previous studies in literature. Akbulut and Ayrılmış (2002) stated that the SDWR capacity of OSBs is lower compared to plywood, but successful results can be achieved with correct pilot hole ratios and optimum screw connection strategies. Kasal and Diler (2013) stated that OSBs exhibit different strength values compared to MDF and plywood but can provide sufficient stability with appropriate connection strategies from an engineering perspective.

4. Conclusions

In this study, the main factors affecting the SDWR of OSBs were investigated and evaluated according to the experimental data. According to the results, it was observed that the OSB thickness did not have a significant effect on the SDWR, but the 18 mm thick boards generally exhibited higher SDWR. However, statistical analysis shows that this difference is not significant.

In the experiments, it was determined that the screwing direction has a significant effect on SDWR. Screwing in the face direction provided statistically significant higher SDWR values compared to screwing in the edge direction. In edge screwing, it was observed that the SDWR capacity decreased due to the fibers not being able to support the screw connection sufficiently. Therefore, it is recommended to prefer face screwing in the structural connections of OSBs.

It was found that the pilot hole diameter significantly affects SDWR. Pilot hole diameter of 60% provided higher SDWR compared to pilot hole diameter of 85%. It was observed that large diameter pilot holes reduce the friction between the screw and OSB and thus reduce SDWR capacity. These findings are consistent with the optimum pilot hole diameter range suggested in the literature.

In terms of pilot hole depth, it was determined that 50% hole depth provided higher SDWR than 80% hole depth. It was observed that deeper pilot holes weakened the mechanical bond between the screw and the material and therefore reduced the SDWR capacity. This finding is consistent with previous studies indicating that the optimum hole depth should be between 40-60% of the screw length to increase the stability of screw connections.

In conclusion, this study has comprehensively analyzed the main factors affecting the SDWR of OSBs and contributed to the determination of the optimum values of these factors. The obtained data will guide engineering practices aimed at increasing the safe and efficient use of OSBs. Determining the optimum conditions in screw connections of OSBs in structural and furniture applications will contribute to the creation of more durable and secure connections in the long term. Future studies can further expand the knowledge in this area by detailing the effects of different OSB production processes on SDWR.

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