Effect of Edge Banding Thickness, Dowels, and Adhesive Types on Withdrawal Strength in Oriented Strand Board

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Composite materials, edge banding, and wooden dowels are being used in inner decorations and the construction of furniture frames. However, there is little information available concerning the withdrawal strength of various fasteners and in particular, dowels in these materials. The aim of this study was to determine the withdrawal strengths of PVC edge bandings with 0.8-, 1-, and 2-mm thicknesses, and dowels produced from six different wood species (ash, black pine, beech, chestnut, oak, and Uludağ fir) bonded parallel to the surfaces of oriented strand board with polyvinyl acetate (PVAc-D4) or polyurethane (PUR-D4). According to TS 4539 standard, the effect of wooden dowel species, thickness of edge banding, and the type of adhesives on the withdrawal strength were determined. Withdrawal strength values of the PUR-D4 adhesive was found to be 26% higher than the strength values of the PVAc-D4 adhesive. The highest withdrawal strength was obtained for beech dowel bonded using PUR-D4 in the samples with 0.8 mm PVC edge banding (4.782 N/mm^2), while the lowest withdrawal strength value was obtained for Uludağ fir dowel with the PVAc-D4 in the samples with 2 mm PVC edge banding (2.529 N/mm^2). These values are higher than the predictive statement that allows designers to estimate the withdrawal strengths of dowels.

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INTRODUCTION

As a widely utilized engineered wood-based panel product, oriented strand board (OSB) has gained significant prominence in structural applications within both residential and commercial sectors of the construction industry in recent years. Recognized for its versatility and performance, OSB has become a critical material in various construction applications, contributing substantially to its growing adoption in the field (Hiziroglu 2009). The OSB offers several advantages, including comparable mechanical properties and significantly reduced costs when compared to structural plywood (Gündüz *et al.* 2011). Research indicates that the OSB demonstrates superior performance over time, even though plywood initially exhibits higher strength (Sinha *et al.* 2011). When utilized in applications such as roof or wall sheathings, the OSB is subjected to various environmental factors that can lead to degradation. To address these challenges, the OSB panels are classified into four distinct categories based on their intended use: OSB-1, OSB-2, OSB-3, and OSB-4. The OSB-1 is designed for interior applications, such as partitions and furniture manufacturing, under dry conditions; OSB-2 is suitable for load-bearing applications in dry environments; OSB-3 is engineered to withstand load-bearing conditions in humid settings, while OSB-4 is intended for heavy load-bearing applications in humid environments (TS EN 300, 2008). This classification ensures that the appropriate type of OSB is selected based on specific performance requirements and environmental conditions. The boards are manufactured to meet precise specifications regarding thickness, density, dimensions, surface texture, and mechanical strength. These specialized products are extensively utilized in both indoor and outdoor structural applications, including furniture, reels, pallets, boxes, trailer liners, and flooring for recreational vehicles (Barbuta *et al.* 2011, 2012; Jin *et al.* 2016; Salem *et al.* 2018).

Dowel joints are commonly employed in the construction of furniture frames, serving both as load-bearing structural connections and as alignment mechanisms for component parts. Such joints may experience various forces, including withdrawal, bending, shear, and tension. However, the individual dowel pins within these joints are primarily subjected to withdrawal and shear forces (Eckelman and Erdil 1999). To effectively utilize dowel-type joints, it is essential to comprehend their mechanical behavior under load, including load-slip relationships, stress distribution patterns, ultimate strength, and failure modes. The mechanical performance of wooden joints is influenced by a range of factors, including geometric, material, and loading parameters. These factors encompass wood species, fastener diameter, end and edge distances, spacing between fasteners, the number of fasteners, fastener-to-hole clearance, friction, and loading configuration (Santos *et al.* 2010).

In the furniture industry, edge bands, which are generally used for aesthetic purposes, are available in three different types: PVC, melamine, and solid. Edge bands are preferred by the manufacturer depending on the furniture production and type. PVC edge bands are a hard plastic and are preferred especially in mass-produced cabinet type furniture due to their easy and practical application. Having a hard structure restricts the use of this type of edge bands in the case of furniture with tightly curved surfaces. They are available in the market in many widths, thicknesses, and patterns. Melamine edge bands, which have a flexible structure, can be damaged when exposed to impacts on the applied edge. For this reason, the thickness and width range of melamine edge bands is not as wide as PVC. There are glued and glueless varieties. Solid (wood) edge bands are edge bands used in solid construction furniture or in particle boards and fiber boards with solid surfaces to provide a color and pattern suitable for the type of wood. Since solid construction furniture is more expensive than other types of furniture, the solid appearance is usually obtained from boards with solid surfaces and edges. Solid edge bands can be obtained by peeling, cutting and sawing methods. Edge banding is widely regarded as a critical component in furniture manufacturing, serving both functional and aesthetic purposes. It is utilized to prevent the absorption of moisture and humidity while enhancing the visual appeal of decorative surfaces (Sözen 2008). Tankut and Tankut (2010) conducted a study to investigate the influence of edge banding material type specifically polyvinyl chloride (PVC), melamine, and wood veneer having the thickness of the edge banding material (0.4, 1, and 2 mm), and the type of wood composite panel on the diagonal compression and tensile strength.

Common materials used for edge banding include laminates, wood, PVC, acrylonitrile butadiene styrene (ABS), acrylic, melamine, and wood veneer. In the contemporary furniture industry, PVC and wood veneer edge bands with thicknesses of 0.4, 0.8, 1, and 2 mm are predominantly employed. Numerous studies have been conducted to explore various aspects of edge banding, including its application and performance (Yerlikaya 2019). Özcan *et al.* (2013) investigated the withdrawal strength of dowels manufactured from ten distinct wood species, which were bonded using either polyvinyl acetate (PVAc) or D-VTKA (Desmodur VTKA, a type of polyurethane (PUR) adhesive) adhesives on both the edges and surfaces of medium-density fiberboard (MDF) and particleboard (PB).

Extensive research has also been undertaken to investigate the influence of solid wood edge banding thickness, adhesive varieties, and dowel diameters on the withdrawal strengths of wooden dowels in engineered wood products such as PB, MDF, and plywood. Uysal and Kurt (2007) examined the withdrawal strength of beech dowels in PB specimens with 5, 8, and 12 mm beech edge banding strips, bonded with PVAc adhesive. They found that the highest withdrawal strength occurred in MDF with 5 mm solid-edged strips, while the lowest strength was observed in non-edged particleboard. Sözen (2008) similarly found that 2 mm wood edge bands outperformed 1.0 mm bands in flat corner joints for case-type furniture, with tension tests showing higher performance than compression tests.

Karaman (2021) evaluated the withdrawal strengths of PVC edge bandings with thicknesses of 0.8, 1, and 2 mm, as well as dowels fabricated from six distinct wood species, when bonded parallel to the surfaces of melamine-coated MDF using two adhesive types: PVAc-D4, and PUR-D4. Abdoli *et al.* (2022) examined the withdrawal performance of 3-ply CLTs made from poplar as a fast-growing species with various fasteners (seven types of screws and two types of nails) in three withdrawal loading directions (parallel to grain and perpendicular to the grain, both radial and tangential) in two-layer arrangements of 0-90-0° and 0-45-0°. Karaman (2022) studied that the withdrawal strengths of PVC edge bandings with thicknesses of 0.8, 1, and 2 mm, as well as dowels fabricated from six distinct wood species, when bonded parallel to the surfaces of melamine-coated particleboards using two adhesive types: PVAc-D4, and PUR-D4. Abdoli *et al.* (2023) investigated the impacts of different types of fasteners (nails and screws) with the end distances of one, two, and three centimeters, panel strength directions, and layer arrangements on the lateral performance of the single shear plane lap joints of CLT manufactured by poplar wood (*Populus alba*) *via* experimental tests and analytical approaches.

This study was performed (1) to evaluate the thickness of edge bandings (control, 0.8, 1, and 2 mm) on the withdrawal strength, (2) to determine the effects of wooden dowel species, namely, Ash, Black pine, Beech, Chestnut, Oak, and Uludağ fir on the withdrawal strength, (3) to evaluate adhesive types, namely, the PVAc-D4 and the PUR-D4 on the withdrawal strength.

EXPERIMENTAL

Material

In this study, 18-mm thickness OSB-2 class boards produced by Sumaş company Edremit-Balıkesir/Turkey were used. All specimens for this study have been made from 18 mm OSB produced by Sumaş-Turkey. The specimens' sizes were 244 mm in length, 122 mm in width, and 18 mm in thickness (Fig.1a). Some of the characteristics of the OSB-2 are given in Table 1.

Table 1. Physical and Mechanical Properties of the OSB-2 Panels Used in this Study

Density (g/cm^3)	0.650	Modulus of Elasticity (N/mm^2) (//)	3500
Bending Strength (N/mm^2) (//)	18	Modulus of Elasticity (N/mm^2) (┴)	1400
Bending Strength (N/mm^2) ┴	9	Tensile Strength (N/mm^2)	0.30

The wood species utilized in this study, namely beech (*Fagus orientalis Lipsky*), ash (*Fraxinus excelsior* L.), oak (*Quercus petraea* Liebl.), Uludag fir (*Abies bornmülleriana* Mattf.), black pine (*Pinus nigra* Arnold), and chestnut (*Castanea sativa* Mill), are extensively employed in the wood construction industry and were selected as the dowel material for the experimental investigations. The wood specimens were randomly sourced from timber four suppliers in Ankara, Turkey. Care was taken to ensure that the selected wood materials were free from defects, exhibiting no knots, zone lines, reaction wood, decay, or damage caused by insects or fungi, and were representative of normally grown timber. The air-dry density properties of the wood materials, determined in accordance with the TS 2472 (1976) standard, are presented in Table 2. The wooden dowels were fabricated in a cylindrical form with nominal dimensions of 8 mm in diameter and 70 mm in length (Fig. 2b).

Table 2. Density of Wood Materials (Çetin and Gündüz 2016)

Wood Material and Wood Composite Material	**D_{12} (g/cm^3)**
Beech (*Fagus orientalis* Lipsky)	0.66
Ash (*Fraxinus excelsior* Lipsky)	0.69
Oak (Quercus petraea Liebl.*)*	0.68
Uludağ fir (*Abies bornmülleriana* Mattf.)	0.43
Black pine (*Pinus nigra* Arnold)	0.56
Chestnut (*Castanea sativa* Mill)	0.63

D_{12}= Air dry density at 20 °C and 65% relative humidity.

The PVC edge banding employed in this study was manufactured using premium-grade resins and high-impact modifiers, resulting in a product characterized by superior machinability, impact resistance, durability, and aesthetic quality. In the furniture industry, PVC edge bands with a thickness of 0.8 mm are commonly utilized. For the purposes of this research, PVC edge bands with thicknesses of 0.8 mm, 1 mm, and 2 mm were employed (Fig. 1c).

In this study, the PVAc-D4 and the PUR-D4 adhesives, which are extensively used in the woodworking and box-type furniture manufacturing sectors, were selected for evaluation (Fig. 1d). The PVAc-D4 was obtained from Kronen Furniture Glue Accessory Industrial Products Industry and Trade Limited Company, located in Turkey. The PUR-D4 was supplied by Apel Kimya Industry and Trade Inc., also based in Turkey (Fig. 1d). Technical properties of the adhesives used in the study are given in Table 3.

Furthermore, a hot-melt thermoplastic synthetic resin adhesive, widely employed for edge bonding of PVC materials in the furniture industry, was also examined (Fig. 1d). This adhesive is specifically recommended for use in environments with a relative humidity level of 8% to 10%. The optimal application temperature for this adhesive fall within the range of 200 to 230 °C, and the processing is typically carried out at a speed of 8 to 80 m/min.

Table 3. Technical Properties of Adhesives

Technical Properties	PVAc-D4	PUR-D4
Density (g/cm³)	1.08	1.10
Viscosity (25 °C)	14000 -15000 mPa/s	5000-10000 mPa/s
pH (25 °C)	3.5	5
Curing time	20 min for cold press and 2 min at 80 °C are recommended at 6% to 15% humidity	20 °C and 65% relative humidity, solidified in 30 min.
Amount of adhesive applied to the surface (g/m²)	170-180	170-180

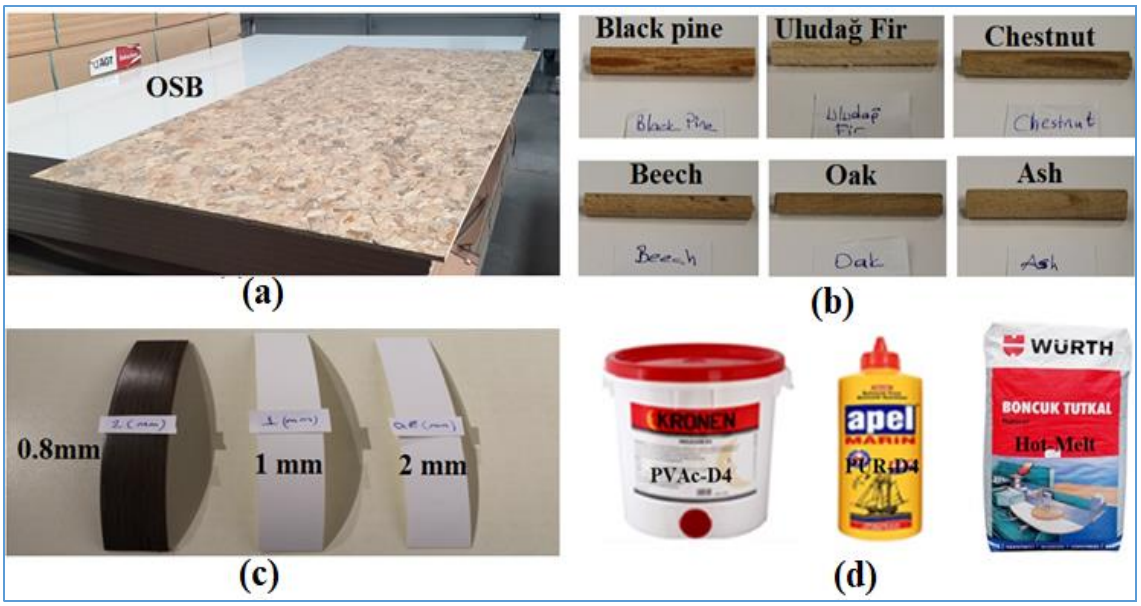

Fig. 1. Materials used in experiments: a) OSB, b) Wooden dowels, c) PVC edge banding, d) Adhesives

Preparation and Construction of Specimens

The wood materials were conditioned in a controlled environment maintained at 20 ± 2 °C and 65 ± 3% relative humidity until they reached equilibrium moisture content, ensuring consistent weight stability. Dowels were then manufactured from the sapwood of several species, including ash, black pine, beech, chestnut, oak, and Uludağ fir. Utilizing a dowel machine, 1000 × 11 × 11 mm pieces were transformed into grooved dowels with an 8 mm diameter. The OSB manufacturer was used isocyanates (polymeric diphenyl methane diisocyanate (pMDI)) and phenolic resins (phenol-formaldehyde (PF)) adhesives in the production of OSB panels. A total of 480 specimens were prepared for this study, incorporating OSB-2 panels, two types of adhesives (PVAc-D4 and PUR-D4), six different wood dowel species, and three thicknesses of PVC edge banding (0.8, 1, and 2 mm), alongside control samples, each replicated ten times. The OSB-2 panels were precisely cut into 31 pieces per panel, each measuring 18 × 75 × 1220 ± 1 mm, using a CNC machine (Fig. 2a). For edge banding, PVC edge bands with thicknesses of 0.8, 1, and 2 mm were bonded to the edges of the OSB panels using hot melt adhesive on the edge banding machine (Fig. 2b).

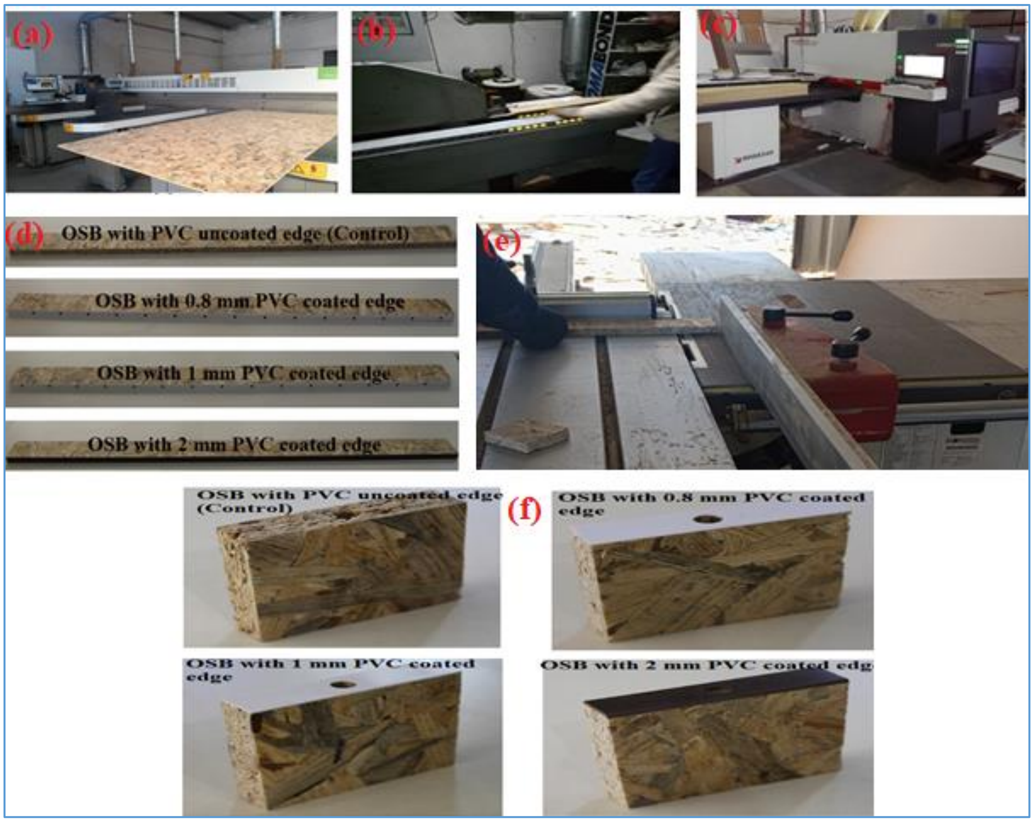

Fig. 2. Production stages of test samples

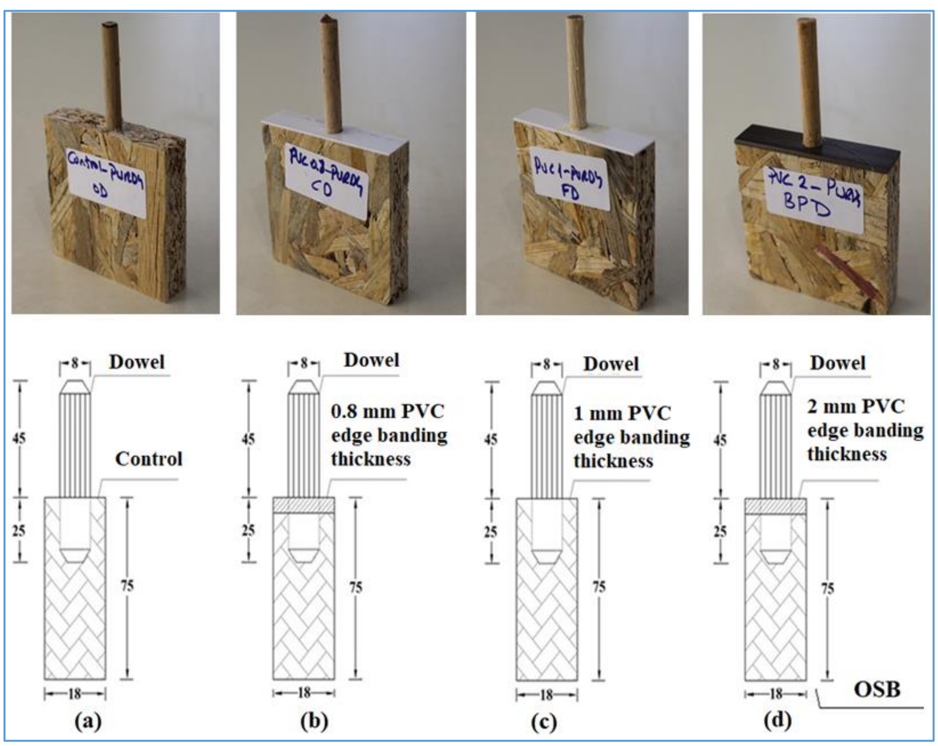

Fig. 3. The configuration of test samples; a) Control (non-edge banding), b) 0.8 mm edge banding, c) 1 mm edge banding, d) 2 mm edge banding

Following the TS 4539 (1985) standard, 25-mm deep holes with an 8-mm diameter were drilled into the samples using a CNC machine to facilitate dowel insertion for tensile testing (Fig. 2c). The test specimens, featuring PVC-coated edges and CNC-drilled holes, are shown in Fig. 2d. These specimens were further processed on a circular saw machine and trimmed to final dimensions of 18 × 75 × 75 ± 1 mm (Fig. 2e, 2f). Additionally, 50 pieces were retained as untreated controls. Before inserting the dowels, adhesives were evenly applied at a rate of 180 g/m² to both the dowel surfaces and the interior of the holes. The experimental configuration of the test samples is illustrated in Fig. 3. Prior to conducting withdrawal tests, all samples were reconditioned at 20 ± 2 °C and 65 ± 3% relative humidity until a moisture content of 12% was achieved.

Test Method

All experiments were conducted using an electromechanical universal testing machine (UTM) located in the laboratory of Kütahya Dumlupınar University, Simav Technical Education Faculty. The UTM, with a load capacity of 10 kN, was equipped with specialized fixtures designed to securely hold the test specimens, as illustrated in Fig. 4. In accordance with ASTM 1037 (1988) standards, a constant loading rate of 5 mm/min was maintained throughout all tests. The withdrawal strength was calculated using the formula provided in Eq. 1,

$$\sigma_k = \frac{F_{max}}{A} = \frac{Fmax}{h(2\pi r)} \tag{1}$$

where σ_k is withdrawal strength (N/mm^2), $F_{\max}$ is the maximum load (N), r is radius of dowel (mm), and h is depth of dowel (mm).

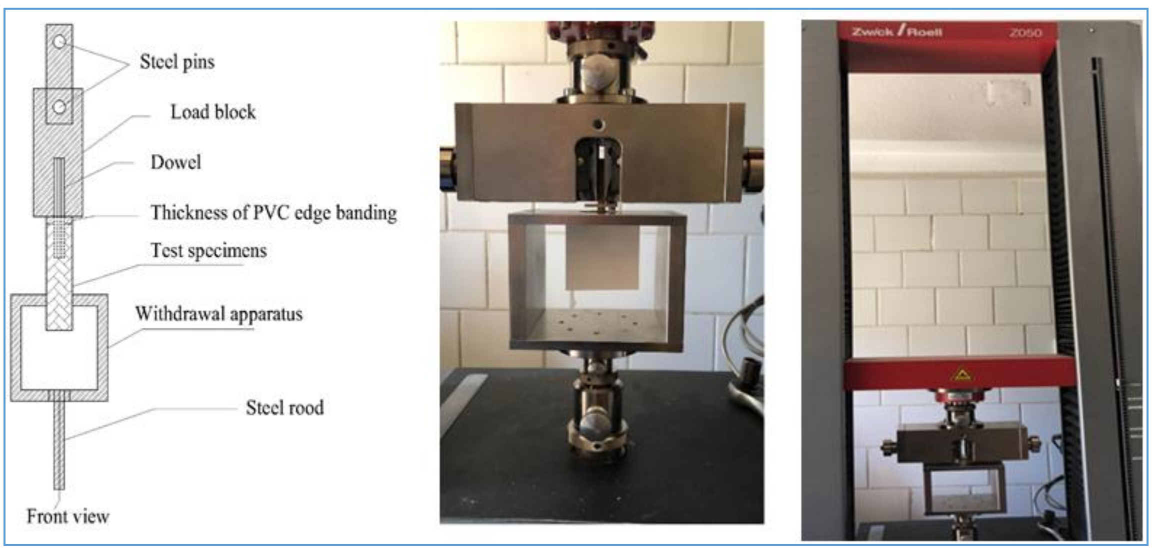

Fig. 4. Apparatus used to hold specimens for withdrawal strength tests

Statistical Analysis

Statistical analysis was performed to examine the data according to the analysis of variance (ANOVA) with the Duncan test ($p < 0.05$).

RESULTS AND DISCUSSION

The average withdrawal strength values derived from the test samples are provided in Table 4, while the average values of the interactions between the factors are presented in Table 5. Additionally, the results of the multiple variance analyses associated with these values are detailed in Table 6.

Table 4. The Average Values of Withdrawal Strength (N/mm^2)

Factor Source		x̄	SD
Adhesive type	PVAc-D4	2.999 (7.00)	0.21
	PUR-D4	3.805 (6.04)	0.23
The thickness of PVC edge banding	Control	3.480 (8.33)	0.29
	0.8 mm	3.818 (6.55)	0.25
	1 mm	3.279 (8.23)	0.27
	2 mm	3.030 (6.27)	0.19
Wooden dowel species	Ash	3.488 (5.44)	0.19
	Black pine	3.312 (4.83)	0.16
	Beech	4.177 (4.79)	0.20
	Chestnut	3.056 (3.60)	0.11
	Oak	3.698 (4.33)	0.16
	Uludağ fir	2.679 (6.72)	0.18

Note: Values in the parentheses are coefficients of variation, SD = Standard deviation.

According to the data presented in Table 4, the maximum withdrawal strength was achieved when beech was utilized as the wooden dowel species, the PUR-D4 was employed as the adhesive, and the thickness of the PVC edge banding was set at 0.8 mm.

Table 5 reveals that in control samples without PVC edge banding, the maximum dowel withdrawal strength was achieved using beech dowels with PUR-D4 adhesive (4.78 N/mm^2), while the minimum strength was noted for Uludağ fir dowels with PVAc-D4 adhesive (2.53 N/mm^2). For samples featuring 0.8 mm PVC edge banding, the highest withdrawal strength was again observed in beech dowels bonded with PUR-D4 adhesive, whereas the lowest values were associated with Uludağ fir dowels and PVAc-D4 adhesive. In the case of 1.0 mm PVC edge banding, beech dowels bonded with PVAc-D4 adhesive exhibited the highest withdrawal strength (4.38 N/mm^2), while Uludağ fir dowels with the same adhesive showed the lowest strength (2.67 N/mm^2). For samples with 2 mm PVC edge banding, ash dowels bonded with PUR-D4 adhesive demonstrated the highest withdrawal strength, whereas Uludağ fir dowels with PVAc-D4 adhesive recorded the lowest strength.

Table 6 presents the outcomes of a multiple variance analysis, which assessed the influence of adhesive type, PVC edge banding thickness, and wooden dowel species on dowel withdrawal strength.

The primary factors, namely adhesive types (A), PVC edge banding thickness (B), and wooden dowel species (C), were determined to have statistically significant effects at a significance level of 0.05. Additionally, all two-and three-way interactions among these factors were found to be statistically significant ($p \leq 0.05$). To identify the specific differences, Tukey's test was conducted, and the results are presented in Table 7.

Table 5. The Average Values of Interaction for Withdrawal Strength (N/mm²)

Thickness of PVC Edge Bandings	Wooden Dowel Species	Adhesives	x̄	SD
Control	Ash	PVAc-D4	2.942	0.48
		PUR-D4	4.325	0.17
	Black pine	PVAc-D4	3.137	0.25
		PUR-D4	3.522	0.22
	Beech	PVAc-D4	3.923	0.28
		PUR-D4	4.782	0.49
	Chestnut	PVAc-D4	2.763	0.25
		PUR-D4	3.297	0.15
	Oak	PVAc-D4	3.356	0.25
		PUR-D4	3.807	0.27
	Uludağ fir	PVAc-D4	2.529	0.27
		PUR-D4	3.337	0.36
0.8 mm	Ash	PVAc-D4	3.166	0.34
		PUR-D4	4.617	0.24
	Black pine	PVAc-D4	3.284	0.24
		PUR-D4	4.120	0.17
	Beech	PVAc-D4	4.114	0.36
		PUR-D4	5.280	0.24
	Chestnut	PVAc-D4	2.927	0.11
		PUR-D4	3.820	0.16
	Oak	PVAc-D4	3.966	0.32
		PUR-D4	4.789	0.26
	Uludağ fir	PVAc-D4	2.544	0.23
		PUR-D4	3.184	0.29
1.0 mm	Ash	PVAc-D4	2.409	0.35
		PUR-D4	4.129	0.15
	Black pine	PVAc-D4	2.847	0.30
		PUR-D4	3.594	0.28
	Beech	PVAc-D4	3.813	0.31
		PUR-D4	4.375	0.38
	Chestnut	PVAc-D4	2.718	0.18
		PUR-D4	3.369	0.23
	Oak	PVAc-D4	2.977	0.22
		PUR-D4	3.994	0.24
	Uludağ fir	PVAc-D4	2.447	0.30
		PUR-D4	2.674	0.26
2.0 mm	Ash	PVAc-D4	2.510	0.32
		PUR-D4	3.807	0.24
	Black pine	PVAc-D4	2.556	0.26
		PUR-D4	3.438	0.16
	Beech	PVAc-D4	3.386	0.17
		PUR-D4	3.741	0.21
	Chestnut	PVAc-D4	2.376	0.13
		PUR-D4	3.179	0.12
	Oak	PVAc-D4	2.949	0.22
		PUR-D4	3.743	0.10
	Uludağ fir	PVAc-D4	2.325	0.29
		PUR-D4	2.350	0.11

Table 6. Summary of the ANOVA Results for the Dowel Withdrawal Strength

Source	df	Sum of Square	Mean Square	F	Sig.
Adhesive types (A)[a]	1	77.987	77.987	1123.680	0.000
The thickness of PVC edge banding (B)[b]	3	39.851	13.284	191.401	0.000
Wooden dowel species (C)[c]	5	107.628	21.526	310.154	0.000
A × B	3	1.297	0.432	6.228	0.000
A × C	5	11.828	2.366	34.086	0.000
B × C	15	7.086	0.472	6.807	0.000
A × B × C	15	5.171	0.345	4.968	0.000
Error	432	29.982	0.069		
Total	480	5835.347			
Corrected Total	479	280.831			
R-Squared = 0.893 (Adjusted R Squared = 0.882)					

df: Degrees of freedom, [a] Adhesive types (PVAc-D4, PUR-D4), [b] Thickness of PVC edge banding (0.8, 1, and 2 mm), [c] Wooden dowel species (Ash, Black pine, Beech, Chestnut, Oak, and Uludağ fir)

The average dowel withdrawal strength values, calculated from the test samples based on material types, are also detailed in Table 7.

Table 7. Average Withdrawal Strength Due to Adhesive Types, Thickness of PVC Edge Banding, and Wooden Dowel Species (N/mm^2)

Types of Material	Statistical Value	
Adhesive types	**x̄**	**HG***
Polyurethane (PUR-D4)	3.805	A
Polyvinyl acetate (PVAc-D4)	2.999	B
Thickness of PVC edge banding	x̄	HG**
0.8 mm	3.818	A
1.0 mm	3.480	B
Control	3.279	C
2.0 mm	3.030	D
Wooden dowel species	**x̄**	**HG*** **
Beech	4.177	A
Oak	3.698	B
Ash	3.488	C
Black pine	3.312	D
Chestnut	3.056	E
Uludağ fir	2.679	F

HG: Homogeneity Group

The data presented in Table 7 reveal that the PUR-D4 exhibited the highest dowel withdrawal strength among the adhesives evaluated. Specifically, PUR-D4 demonstrated a 27% greater withdrawal strength compared to PVAc-D4. This superior performance can be attributed to the expansion characteristics of PUR-D4 after application, which enhances mechanical bonding within the wood substrate. Uysal and Kurt (2007) similarly reported that dowels bonded with D-VTKA adhesive achieved higher withdrawal strength than those bonded with PVAc and hot-melt adhesives. Furthermore, studies by Sterley *et al.* (2004) and Bomba *et al.* (2014) corroborated that PUR adhesives generally exhibit stronger bonding properties than PVAc adhesives. The maximum withdrawal strength of 6.37 N/mm² was achieved using beech dowels in combination with 5 mm thick solid wood edge banding made from Uludag fir, bonded with D-VTKA adhesive (Kurt *et al.* 2009). Özcan *et al.* (2013) also found that the withdrawal strength values of D-VTKA were 37% higher than those of PVAc when comparing adhesive types. Karaman (2021, 2022) further emphasized that PUR-D4 demonstrated superior embedded strength compared to PVAc, owing to its gap-filling capabilities and enhanced mechanical adhesion.

Regarding the influence of PVC edge banding thickness, dowels with 0.8 mm PVC edge banding exhibited approximately 10%, 16%, and 26% higher withdrawal strength compared to those with 1.0 mm PVC edge banding, the control group (no edge banding), and 2 mm PVC edge banding, respectively. In terms of the contribution of the edge banding material to the strength of the dowel, the relative flexibility of the 0.8 mm thick PVC edge banding can probably be explained by the fact that it allows relative movement of the dowel, so that the internal stresses resulting from the applied load are more evenly distributed between the contact points between the dowel surfaces and the OSB panels. The mechanical interlocking between the dowel surface and the OSB can probably be said to contribute more than others to the strength of the dowels installed with 0.8 mm thick edge banding material.

Tankut and Tankut (2010) reported that 0.4 mm melamine edge banding yielded the highest compression strength, while 1.0 mm PVC edge banding resulted in the lowest strength. Yapıcı *et al.* (2011) observed that the highest withdrawal strength was achieved in beech dowels with 5 mm thick solid wood edge banding bonded with D-VTKA adhesive. Bal and Akkok (2018) indicated that indicated that the use of edge bands on the hidden edge increased the mechanical performance of the points at which the pieces of the furniture were joined. Additionally, Karaman (2021, 2022) reported that 0.8 mm PVC edge banding provided better adhesion and mechanical strength compared to 1 mm and 2 mm thicknesses.

Dowels fabricated from beech exhibited the highest withdrawal strength, while those made from chestnut and Uludağ fir displayed the lowest values (Table 5). These variations can be attributed to differences in wood density, structural characteristics, mechanical properties, and bonding performance. Özcan *et al.* (2013) observed the highest tensile strength values in wooden dowel samples produced from beech, oak, and mulberry wood species. Karaman (2021, 2022) reported that beech dowels exhibited the highest embedded strength due to their density and structural properties, whereas Scots pine dowels demonstrated lower strength. Collectively, these findings underscore the significant impact of material properties, adhesive types, and manufacturing processes on the performance of dowels in wood-based composites.

The plastic nature of the PVC edgebands prevented the delamination occurring in dowel joints from the edges of the board. In the 0.8 mm PVC edge bands, bending and stretching occurred, but due to its more flexible structure, fractures did not occur, and it was observed that the structural integrity of the joint was preserved. It can be said that fractures generally occurred in wooden dowels.

CONCLUSIONS

1. The joints assembled with the PUR-D4 adhesive demonstrated a 27% higher withdrawal strength compared to those glued with the PVAc-D4 adhesive. This enhanced strength is attributed to the curing process of the PUR-D4, which causes it to swell and fill the gaps in the dowel holes, resulting in improved mechanical adhesion. The results indicate that smoother surfaces on both the dowel and the hole wall yield better mechanical adhesion with the dowels.
2. Among the six wood species studied, beech, oak, and ash dowels exhibited the highest withdrawal strength values, with significant differences observed among them. These variations may be influenced by the density of the different wooden materials.
3. In terms of withdrawal strength of dowels from the edges of oriented strand board (OSB), the 0.8 mm thick PVC edge banding showed a 26% higher performance compared to the 2 mm PVC banding, 10% higher than the 1 mm PVC banding, and 16% higher than the control (without edge banding).
4. The optimal withdrawal strength values were achieved using beech dowels, the PUR-D4 adhesive, and 0.8 mm PVC edge banding. The findings suggest that smoother surfaces on the dowel and hole wall enhance mechanical adhesion with dowels and OSB. Additionally, for applications requiring resistance to withdrawal strength, it is recommended to use oak, and ash dowels with the PUR-D4 adhesive when working with OSB in case-type furniture.

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