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WOOD SANDWICH PANEL CORE MATERIALS: RIGID POLYURETHANE (PU) COMPOSITES FILLED WITH ORGANIC AND INORGANIC PARTICLES

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ABSTRACT: In this study, polyurethane (PU) foam composite was produced by adding wheat flour (WF), satin surface finishing plaster (AL) and urea formaldehyde (UF) into polyurethane wood glue. In this study, it is aimed to produce water resistant, high screw holding force and light weight and rigid PU foam composite that can be used in the core layer of wooden sandwich panels. For this purpose, the fillers were added to the PU in certain proportions and the samples were foamed by mechanical mixing. The foaming time lasted approximately 30 minutes. The foam volume was brought to its initial level by mixing the foam in the first 15 minutes. Foaming continued in the next 15 minutes. Samples were kept in water for 2 hours and 24 hours and their thickness swelling (TS) and water absorption (WA) amounts were analyzed according to the relevant standards. In addition, the mechanical characterization of the samples was carried out by analyzing the screw withdrawal strength (SR) according to the relevant standard. According to the results obtained, it was determined that the addition of WF increased the densities, water absorption and swelling of the samples. This is a negative event. However, this increase did not exceed the particleboard standard limits. On the other hand, the addition of WF increased the SR forces of the samples. The addition of UF did not make a significant change in the SR strength when used with the addition of WF. However, UF significantly reduced the SR strength when used with AL. As a result, PU foams can be given a more rigid structure by using various fillers. In this way, the screw holding resistance can be increased and it can be used in the core layers of wooden sandwich panels. Thus, it indirectly contributes to the protection of forest resources.

Keywords: Wood sandwich panel, screw withdrawal, core layer, polyurethane, foams

AHŞAP SANDVİÇ PANEL ÇEKİRDEK MALZEMELERİ: ORGANİK VE İNORGANİK PARÇACIKLARLA DOLGULU RİJİD POLİÜRETAN (PU) KOMPOZİTLER

ÖZET: Bu çalışmada, poliüretan ahşap tutkalına buğday unu (WF), saten yüzey bitirme sıvası (AL) ve üre formaldehit (UF) ilave edilerek poliüretan (PU) köpük kompozit üretilmiştir. Ahşap sandviç panellerin çekirdek katmanında kullanılabilecek, suya dayanıklı, vida tutma kuvveti yüksek, hafif ve sert PU köpük kompozitin üretilmesi çalışmanın amacını oluşturmaktadır. Bu amaçla PU'ya belirli oranlarda dolgu maddeleri eklenmiş ve numuneler mekanik olarak karıştırılarak köpürtülmüştür. Köpürme süresi yaklaşık 30 dakika sürmüştür. İlk 15 dakikada köpüğün karıştırılmasıyla köpük hacmi başlangıç seviyesine getirilmiştir. Sonraki 15 dakika boyunca köpüklenme devam etmiştir. Numuneler 2 saat ve 24 saat suda bekletilerek ilgili standartlara göre şişme (TS) ve su emme (WA) miktarları analiz edilmiştir. Ayrıca ilgili standarda göre vida tutma kuvvetleri (SR) analiz edilerek numunelerin mekanik karakterizasyonu yapılmıştır. Elde edilen sonuçlara göre WF ilavesinin numunelerin yoğunluğunu, su emmesini ve şişmesini arttırdığı belirlenmiştir. Bu olumsuz bir olaydır. Ancak bu artış yonga levha standart sınırlarını aşmamıştır. Öte yandan WF ilavesi numunelerin SR kuvvetlerini arttırmıştır. UF ilavesi, WF ilavesiyle birlikte kullanıldığında SR mukavemetinde önemli bir değişiklik yaratmamış, ancak UF, AL ile birlikte kullanıldığında SR gücünü önemli ölçüde azaltmıştır. Sonuç olarak PU köpüklere çeşitli dolgu maddeleri ilave edilerek daha sert bir yapı kazandırılabilir. Bu sayede vida tutma direnci artırılarak ahşap sandviç panellerin çekirdek katmanlarında kullanılabilmektedir. Böylece orman kaynaklarının korunmasına dolaylı olarak katkı sağlanmaktadır.

Anahtar kelimeler: Ahşap sandviç panel, vida çekme, çekirdek katman, poliüretan, köpükler

INTRODUCTION

The rapid increase in the global population has led to a corresponding rise in consumption patterns (Şahin, 2020). This heightened consumption has contributed to the rapid depletion of natural resources, disrupting ecological balance. Recognizing the imbalance, individuals have begun seeking ways to implement more environmentally friendly production methods. Research is being conducted, especially in the context of conserving forest resources, to utilize wood as a raw material more efficiently, preserve it, and incorporate it in composite form with other materials (Istek et al., 2017).

One of the most significant research areas in wood composite materials is wood sandwich panels (WSPs). WSPs are crucial as they employ wood material on the surface while the core layer can consist of thermoplastic or thermoset polymers with desired thickness and density. This approach can lead to a 60 % reduction in wood usage, thereby aiding in the substantial preservation of forest resources (Lakreb et al., 2015).

Depending on the application, the polymers used in the core layer of WSPs can vary widely in structure. Some WSPs prioritize insulation properties (Kawasaki & Kawai, 2006; Smardzewski, 2019), while others require high screw mechanical strength (Osei-Antwi et al., 2013; Lakreb et al., 2015). Particularly in furniture manufacturing, WSPs need to adhere to standardized SR strength requirements. Consequently, the core layer of WSPs should be rigid, possess low density, and exhibit high mechanical properties. Achieving these features is often accomplished by foamed thermoset polymers, with Polyurethane being one of the most important polymers used as a foamed material (Gama et al., 2018; Mohammadi et al., 2021). WSP, also known as foam core panels, can undergo manufacturing through either a batch process involving the assembly and adhesive bonding of pre-made layers or a method wherein a foaming liquid is injected between two pre-fabricated facings to create the core material. The integration of prefabricated layers and the associated high production expenses are pivotal challenges in advancing foam core panels within the furniture sector. In this context, the utilization of in-situ foaming, a one-step manufacturing process, emerges as a promising avenue for producing lightweight foam core panels with substantial potential (Karlsson & TomasAström, 1997; Shalbafan et al., 2013; Lou et al., 2015).

Foam-based sandwich composites find extensive applications in aerospace, automotive, and architectural industries due to their favorable attributes such as lightweight nature, ease of machining, and versatile multi- or hybrid structural designs. These composites often utilize core materials like honeycomb, metal foam, and polymer foam, while their functionality is heightened by incorporating metal plates and fabric as face sheets (Kang et al., 2008; Li et al., 2014; Xiong et al., 2014). These face sheets and core structures serve to reinforce overall integrity and augment load-buffering capabilities, respectively (Ghalami-Choobar & Sadighi, 2014; Ma et al., 2014). Schematic of a sandwich structure was given in Figure 1.

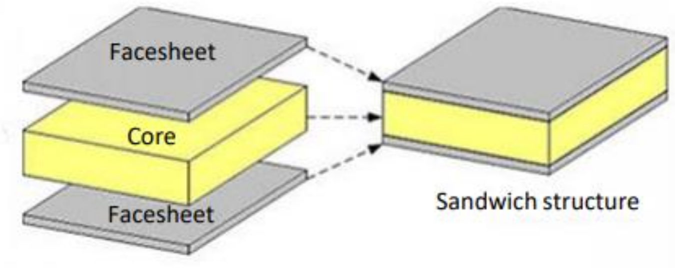

Figure 1. Schematic of a Sandwich Structure (Subramaniyan, 2019)

Foams, valued for their cost-effectiveness, ease of use, extensive coverage, and strong damping properties, are favored materials for thermal and sound insulation, as well as energy absorption; their suitability for heavy-duty applications is constrained by their inherent weakness and lack of stiffness (Ashby et al., 2001).

Figure 2 introduces a novel advancement in the realm of all-composite sandwich structures through the utilization of lattice truss core designs. Notably, both the lattice truss cores and the facesheets are fabricated within a singular manufacturing process, eliminating the need for subsequent bonding. This innovation addresses the inherent challenge of a fragile interface between the core and skins, a critical vulnerability in sandwich structures (Wadley, 2002).

Within the domain of the plastic industry, polyurethanes stand out as a highly sought-after class of polymers, primarily attributable to their exceptional versatility. The synthetic process of polyurethanes entails the chemical reaction between a constituent bearing isocyanate moiety and another constituent harboring hydroxyl groups, wherein both constituents possess functionalities of two or greater (Woods, 1990).

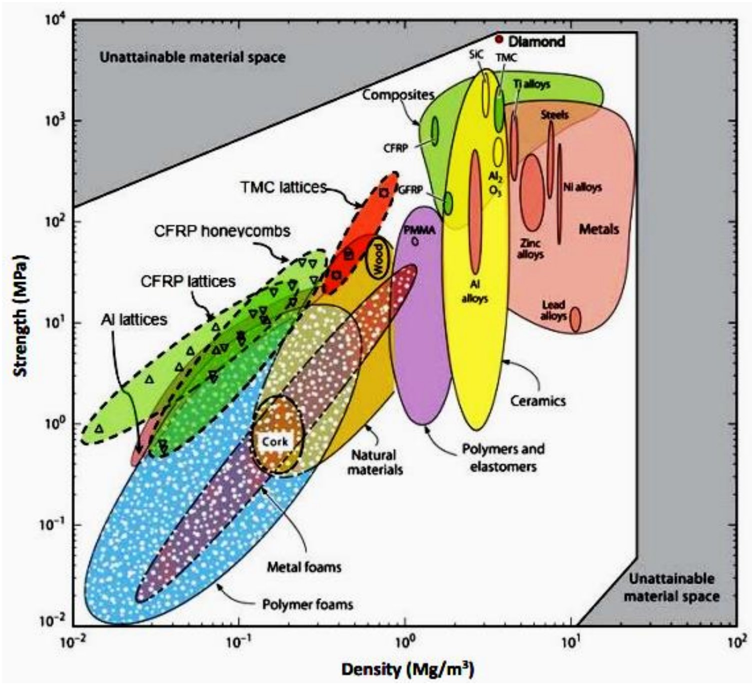

Figure 2. The Material Property Chart Illustrates a Comparison of Strength and Density Among Engineering Materials, Encompassing Foams, Honeycombs, and Lattices (Wadley, 2002)

The industrial-scale production of polyurethane predominantly relies on materials derived from the petroleum industry (Chian & Gan, 1998). However, in recent decades, a plethora of studies have emerged, substantiating the feasibility of incorporating vegetable oils into polyurethane formulations. This is achieved through the modification of these vegetable oils, wherein hydroxyl groups are introduced into their molecular structure, thereby rendering them suitable candidates for utilization as polyol components in polyurethane materials (Khot et al., 2001; Hu et al., 2002). Rigid polyurethane (PU) is one of the most widely employed polymers globally for insulation purposes. It is frequently utilized in the construction of electric home appliances such as refrigerators and freezers for insulation purposes (Hu et al., 2002).

Modern foam formulations for insulation primarily rely on polymeric methylene diphenyl diisocyanate (polymeric MDI) and either polyether or polyester polyols. These polyols can stem from various raw materials, with the incorporation of alkylene oxides like propylene oxide (PO) and/or ethylene oxide (EO). Common starting materials encompass natural substances like sucrose or sorbitol, as well as specialized organic compounds like ethylenediamine or industrial waste streams, such as toluene diamine (Hu et al., 2002).

The integration of economical natural fibers, sourced sustainably, within polymeric matrices extends material utility to diverse applications. Composite properties can undergo substantial transformations compared to unreinforced polymers, potentially reducing costs through natural fiber reinforcement. Generally, filler incorporation in polyurethanes yields heightened modulus and strength, contingent upon favorable fiber-matrix interfaces, yet may lead to diminished ultimate strain; recent research in nanoparticle reinforcement of rubbery polyurethanes has demonstrated increased modulus and strength while preserving considerable deformation capacity at the polymer matrix's breaking point (Mülhaupt et al., 1993; Wu et al., 2007). The production of polymer matrix can be carried out either continuously or discontinuously. The utilization of a one-step manufacturing process, commonly referred to as "in-situ foaming," exhibits significant promise in the realm of foam core panel production (Choupani Chaydarreh et al., 2017).

The shape of PU in the core layer also affects the mechanical properties. Mohamed et al.(2015) in a study they conducted that the core shear testing of sandwich panels highlighted the superior load-carrying capacity of trapezoidal PU core layer models in bending, attributed to their shear layers. A three-dimensional finite element model validated by experiments was developed for three sandwich structures, indicating the potential of prisma core sandwich panels for full-scale bridge decks. Future plans entail constructing composite bridge decks using prisma core and two-part thermoset polyurethane, with a focus on experimental stress verification in facings and reinforcing laminates.

Research on polyurethane (PUR) reinforced with synthetic and natural fillers has surged recently because of their degradability, lightweight nature, cost-effectiveness, and favorable mechanical traits (Atiqah et al., 2017). Natural fillers like agricultural residues (e.g., oil palm empty fruit bunch, rice husk, and wood flour) offer advantages over synthetics due to their abundance, cost-effectiveness, renewability, and biodegradability. However, they come with processing challenges such as property variations, limited operational temperatures related to biological components, and high moisture content (Sae-Ueng, 2021).
One exciting aspect of this field is the diverse range of studies exploring how to optimize sandwich panels for specific needs. Gazzola et al. (2022) introduced the groundbreaking single-phase sandwich panel with a self-contained lattice structure. Not only did this panel block out unwanted noise, it looked like a masterpiece of engineering done with sophistication and elegance.

The sandwich panels were fabricated by bonding all components, including flat layers and corrugated cores, together using a polyurethane adhesive (LOCTITE HB X452 PURBOND, from Henkel) at room temperature. Specifically for roof and floor applications, single-layered core sandwich panels, were created by bonding wood-strand flat panels to both sides of a corrugated layer (Mohammadabadi et al., 2021).

In this study, PU composites were produced using wheat flour (WF), urea formaldehyde (UF) and gypsum (AL), and their physical and mechanical characterization was conducted. WF, UF and AL were chosen as filler materials due to their abundant availability, low cost, and easy purchased. UF was added the blending because it can be supplied extra rigidity. This approach aims to create polymer composites that can be utilized in the core layer of WSPs, possessing high mechanical properties, being lightweight, and being less affected by water and moisture compared to solid wood.

MATERIAL AND METHOD

Materials

In the study, WF, UF and AL were used as filling materials in polyurethane (PU) wood glue. PU one of the most used wood glues in furniture sector. The PU glue is moisture-curing, light brown with a density of 1,1 g/cm^3. It has a viscosity of 5000-15000 cp, could withstand temperatures ranging from -30 to 100 °C, and dried within 25 to 50 minutes. PU wood glue was used to create foam matrix by mixing WF, UF and AL.

Satin surface finishing plaster (AL) is an inorganic substance frequently used in the construction industry. The AL used in the study was purchased from the local market. Some of its characteristics are provided in Table 1.

Table 1. Satin Surface Finishing Plaster Some Technical Properties (Alçıbay, 2023)

Trade Name	Light mixed plaster for building (spraying)
STANDART	TS EN 13279-1
Types of gypsum	C6
Physical Form	White Powder
Content	$CaSO_4$+1/2H_2O (hemihydrate gips), Calcite, water absorber,
Dry Density	710 gr/lt
PH	7,5-8
Surface Hardness	40 SHORE D
Flexural Resistance	min. 1 N/mm^2
Compressive resistance	min. 2 N/mm^2
Fire Resistance	A1 (non flammable product)

The urea formaldehyde (UF) resin used in the study was sourced from the Yıldız Entegre Particle Board Factory. The UF resin have a solid concentration of 65 %, a density of 1,284 g/cm^3, a viscosity of 300 centistokes (mm^2/s), and a gelation time of 45 seconds when exposed to a temperature of 100 °C.

Wheat flour (WF) was purchased from the local market. WF is commonly used in the food sector and is easily obtainable. Some technical properties of the WF were that fat (1%), carbohydrate (27 %), sugar (3 %), protein (20 %), fiber (14 %), salt (0,1 %), other (35 %). WF flour fraction was 125 µ < WF < 212 µ according to standard (TS 4500, 2010). Easily available and cost-effective filling materials were preferred in this study. Additionally, a comparison of the behavior of organic and inorganic filling materials within the Polyurethane (PU) is performed. The usage ratios of AL, UF and WF were given in Table 2.

Table 2. Material Ratios

Sample code	Description	PU (g)	WF (g)	AL (g)	UF (g)
PU-CTRL	Control sample	100	-	-	-
PU-WF	Wheat flour added	100	50	-	-
PU-WF-UF	Wheat flour and urea formaldehyde added	100	50		20
PU-AL	Satin surface finishing plaster added	100	-	50	-
PU-AL-UF	Satin surface finishing plaster and urea formaldehyde added	100	-	50	20

Preparation of samples

Totally five samples group were prepared. In accordance with the ratios given in Table 2, PU and filler (WF, UF and AL) materials were poured into a tin container. No water was added to the mixture. The mixture was mechanically stirred for 30 seconds. Subsequently, the mixture was poured into paper cups (20 g). The volume of the mixture inside the cup began to increase (Figure 3). After 10 minutes, the mixture was mechanically stirred again to restore it to its initial level. The volume increase of the mixture within the cups stopped after 20 minutes. After 120 minutes, the cups were cut, and the solidified samples were removed. The samples were then cut again to prepare analysis specimens.

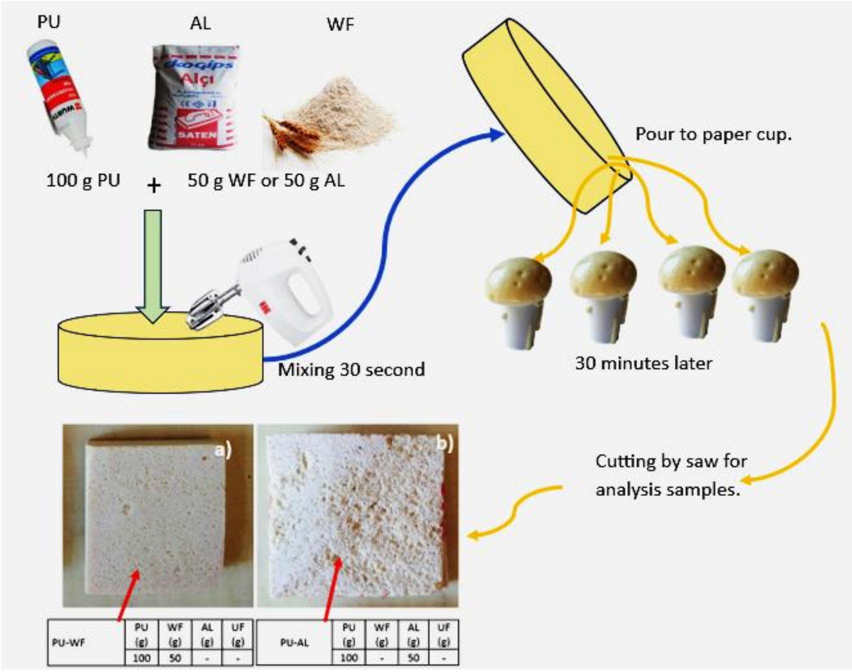

Figure 3. Preparation of Analysis Samples a) PU-WF, b) PU-AL

Methods

The preparation of the samples carried out by mechanically mixing and molding without pressure. The samples, which increased in volume and solidified, were cut into dimensions of 50 x 50 x 20 mm to create analysis specimens. The physical characterization of the samples was conducted through thickness swelling (TS), water absorption (WA), and density (DN) analyses. TS and WA analyses were performed on samples immersed in water for 2 and 24 hours. The mechanical characterization of the samples was carried out using screw withdrawal strength (SR) analysis. A screw with a length of 38 mm and a diameter of 4,2 mm was employed for the SR analysis (Figure 4). The TS, WA, DN, and SR analyses were conducted in accordance with TS EN 317, TS EN 322, TS EN 323, and TS EN 320, respectively. The obtained analysis results were statistically analyzed using the SPSS statistical software program. Homogeneity analysis of variances, One-way ANOVA, and Duncan's post hoc tests were employed to determine if there were significant differences between the results (P<0,05).

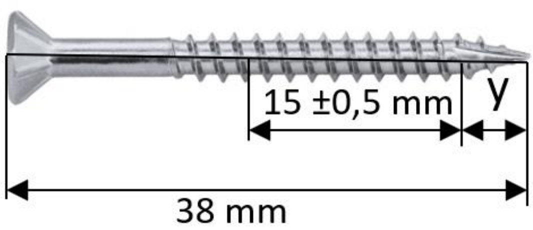

Figure 4. Screw for SR Analysis

RESULTS AND DISCUSSION

Physical and mechanical properties

The addition of filler materials (AL and WF) into the PU resulted in an increase in the densities of the samples (Table 3). The incorporation of WF led to a higher increase in density compared to AL. While the density of the PU control sample was 188 kg/m³, the addition of WF resulted in a 240 % increase, reaching 649 kg/m³, and the addition of AL led to a 200 % increase, reaching 630 kg/m³.

Table 3. Physical and Mechanical Analysis Results

Samples	TS 2h (%)	WA 2h (%)	TS 24h (%)	WA 24h (%)	SR (N)	Density (kg/m^3)
PU-CTRL	2,7 (1,3)* b	12 (±3,6) b	0,7 (±1,1)	20 (±7,6) b	104 (±28) b	188 (±36) a
PU-WF	1,7 (±0,3) b**	6 (±0,6) a	4,4 (±0,6)	25 (±2,9) c	386 (±126) d	649 (±52) b
PU-WF-UF	2,4 (±1,4) b	12 (±1,5) b	3,7 (±0,7)	32 (±3,1) c	363 (±12) d	704 (±11) c
PU-AL	0,3 (±0,7) b	12 (±2,2) b	3,0 (±0,7)	24 (±1,9) c	184 (±59) c	643 (±29) b
PU-AL-UF	-3,2(±4,6) a	19 (±4,3) c	-3,7 (±0,5)	38 (±4,7) a	32 (±42) a	609 (±17) b

*: Standard deviation, **: Duncan analysis group

The addition of WF increased the WA of the PU, whereas the addition of AL reduced it. Despite enhancing the water uptake of the samples, the incorporation of AL decreased their thickness. Also, the addition of UF worsened the physical properties of PU composites.

When Figure 5 is examined, it is seen that the PU-CTRL sample left in water for 2 hours swells more than 24 hours. Normally, PU glue is cured by reacting with moisture in the air. Staying of PU in more water may have increased its conductivity and changed the course of the chemical reaction in the matrix. For this reason, the volume of PU may be reduced after remaining in more water. After adding WF and AL this situation was reversed. That is, the samples that remained in water for more time (24 h) increased in thickness more than those that remained less (Figure 5).

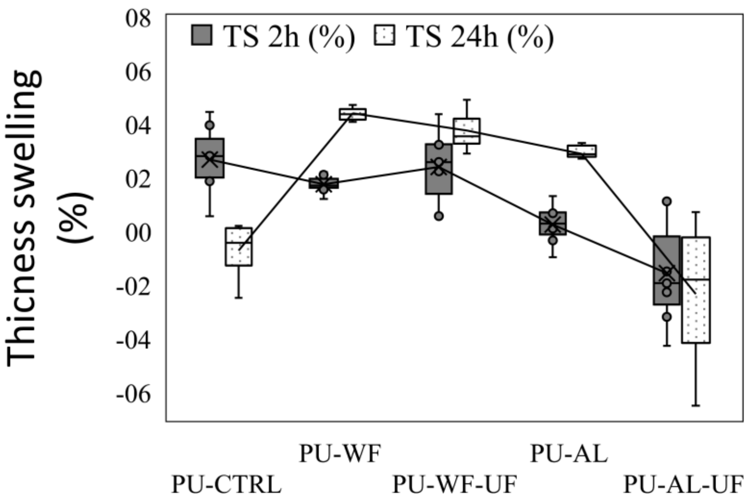

Figure 5. Samples 2 h and 24 h Thickness Swelling (TS)

The addition of WF gave more positive results than the addition of AL. It is expected that the thickness of wood composites remaining in water for 2 hours will increase by a maximum of 8 % according to the standards (TSE EN 317, 1999). The thickness increases of all samples after being kept in water for 2 hours or even 24 hours is less than 8 %. Thus, it is considered that PU foams reinforced with WF, UF and AL can be used in the core layers of wood sandwich panels. It was determined that the addition of UF did not create a significant change with WF. However, the addition of UF with AL caused less swelling of the PU matrix. The addition of UF also reduced the SR force. When evaluated in this respect, the addition of UF did not create the desired stiffness in the PU matrix.

The addition of WF gave more positive results than the addition of AL. It is expected that the thickness of wood composites remaining in water for 2 hours will increase by a maximum of 18 % according to the standards. The thickness increases of all samples prepared in the study after being kept in water for 2 hours or even 24 hours is less than 18 %. Thus, it is considered that PU foams reinforced with WF, UF and AL can be used in the core layers of wood sandwich panels. In their study, Ulay and Güler (2010) reported that wooden sandwich panels using PU in the core layer have mechanical strength close to particle board.

When Figure 6 is examined, it is seen that the amount of WA of the PU control sample increased at the end of 24 hours in contrast to the TS. It is thought that this is caused by the increased surface area due to the gaps formed between the foam matrix formed. Although the addition of WF decreased the amount of WA after 2 hours, it increased it after 24 hours. The addition of UF together with WF further increased the WA amount of the PU composite. It is thought that the addition of UF may cause more voids in the PU matrix. Polyurethane composites (PUCs) demonstrate exceptional characteristics including high impact resistance, low density, superior strength-to-weight ratio, remarkable elasticity, and resistance to corrosion and abrasion, contingent upon the specific reinforcement employed (Vaithylingam et al., 2017).

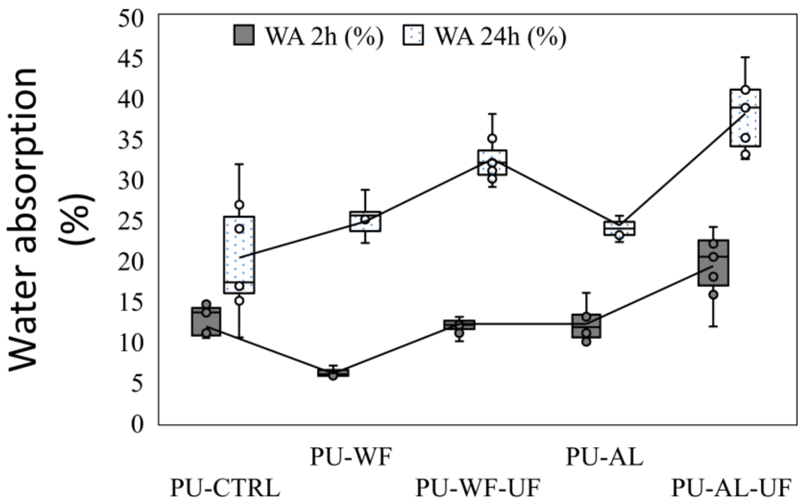

Figure 6. Samples 2 h and 24 h Water Absorption (WA)

Normally, it is expected that the SR will increase as the density increases in wooden sandwich panels (Eckelman, 1975). When Figure 7 is examined, it has been determined that the SR force does not increase at the same rate as the density increases. Especially the addition of UF caused a decrease in the SR strength with the addition of AL. The addition of WF significantly increased the SR strength. The addition of WF and UF did not cause a significant change in the SR strength according to PU-WF sample. The addition of AL slightly increased the SR strength of the PU matrix (from 108 N to 184 N), while it decreased it with the addition of UF (From 104 N to 33 N).

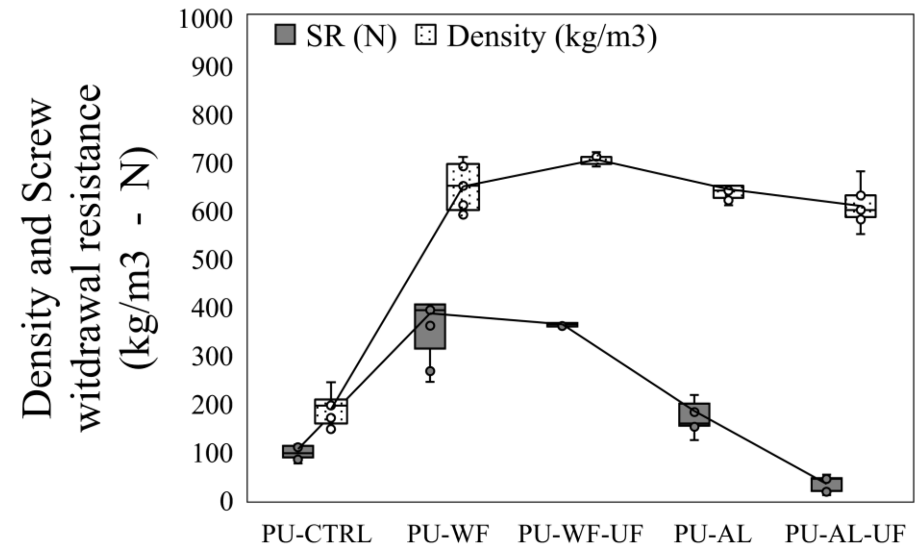

Figure 7. SR Analysis Results

In a similar study, Shalbafan et al. (2021) produced a sandwich panel using particleboard surfaces and rigid polyurethane (PU) foam core through a one-step in situ foaming process, finding that the variation in blowing agent concentration did not significantly affect screw withdrawal resistance from the face and thickness swelling. The obtained data were analyzed statistically. According to the Test of Homogeneity of Variances, there are significant differences in variance between samples (Table 4). According to the One-way Anova analysis (Table 5), there were significant differences between samples for all analyzes (P<0,05).

Table 4. Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
TS2h	3,415	4	30	,020
WA2h	4,513	4	30	,006
TS24h	8,987	4	30	,000
WA24h	5,605	4	30	,002
SR	3,231	4	30	,026
DN	3,644	4	30	,016

Table 5. One-way Anova Analysis

		Sum of Squares	df	Mean Square	F	Sig.
TS2h	Between Groups	160,0	4	40,000	7,589	,000
	Within Groups	158,1	30	5,271		
	Total	318,1	34			
WA2h	Between Groups	607,6	4	151,900	19,263	,000
	Within Groups	236,5	30	7,886		
	Total	844,1	34			
	Between Groups	336,7	4	84,180	18,756	,000

TS24h	Within Groups	134,6	30	4,488		
	Total	471,3	34			
WA24h	Between Groups	1427,0	4	356,757	17,183	,000
	Within Groups	622,8	30	20,762		
	Total	2049,8	34			
SR	Between Groups	762,7	4	190,698	41,294	,000
	Within Groups	138,5	30	4,618		
	Total	901,3	34			
DN	Between Groups	1236042	4	309010,6	226,562	,000
	Within Groups	40917	30	1363,914		
	Total	1276960	34			

Screw withdrawal strength is one of the most important mechanical resistance properties of sandwich panels. For this reason, it is frequently investigated by researchers. In their study, Köksal and Kelleci (2023) foamed polyurethane by adding MDF powder and egg white and used it in the core layer of the wooden sandwich panel. When they compared the screw retention resistance of the panels they produced, they reported that MDF powder had better screw retention resistance than egg white filling. Uysal and Gultekin (2024) found that sandwich panels composed of plywood and medium-density fiberboard exhibited the highest screw withdrawal strength at 12,51 MPa. The difference between predicted and experimental screw withdrawal resistance varied from 0.20 % to 24.86 %. There was no notable distinction in screw withdrawal strength between the top and bottom face-laminated panels. Both face-laminated panels (sandwich panels) displayed superior screw withdrawal strength, density, and predicted resistance compared to single face-laminated panels.

CONCLUSIONS

In this study, PU foam was produced by adding WF, AL and UF to PU wood glue. In this study, it is aimed to produce a water-resistant composite with high screw holding force that can be used in the core layer of wooden sandwich panels. After the fillers were added to the PU, it was mixed mechanically and foamed. After the prepared samples were kept in water for 2 hours and 24 hours, thickness swelling (TS) and water absorption (WA) were analyzed. In addition, the mechanical characterization of the samples was determined by analyzing the screw withdrawal strength (SR).

According to the results, it was determined that with the addition of WF, the amount of WA and TS of the PU composites increased after 2 hours and 24 hours compared to the control sample. The addition of UF together with WF did not cause any significant changes in the PU composite. While AL addition increased the water absorption of the samples, it either did not change or decreased the thickness swelling amount. AL has absorbed plenty of water into its body. This is a negative feature. UF addition decreased the swelling amount in AL added PU samples while increasing the water uptake amount.

When the SR strength was examined, it was determined that the SR force increased depending on the increase in density. However, the same increase was not observed in the SR strength, although the density increased with the addition of AL. Especially with the addition of UF, the addition of AL significantly reduced the SR strength of the PU composite. In this regard, we do not recommend a mixture of PU and UF in the production of wooden sandwich panels. Addition of WF and AL both significantly increased the densities of the samples and became more rigid. In this respect, especially with the addition of WF, the PU foam composite is provided to be more rigid, and the SR strength is increased. As a result, it has been understood that PU foam can be made more rigid by using different fillers, and it has been concluded that it can be used in the core layers of wooden sandwich panels.

AUTHOR CONTRIBUTIONS

Süheyla Esin Köksal: Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft. **Orhan Kelleci:** Conceptualization, Methodology, Data curation, Formal analysis, Writing - original draft.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS COMMITTEE APPROVAL

This study does not require any ethics committee approval.

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