*Quest Journals*
*Journal of Architecture and Civil Engineering*
*Volume 10 ~ Issue 2 (2025) pp: 39-45*
*ISSN(Online) : 2321-8193*
www.questjournals.org

**Research Paper**

# Investigation of the Tensile Strength of Perpendicular to the Fibers of Wooden Materials Reinforced with FRP and Joined with Wooden Dowels

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***ABSTRACT:*** *Tensile strength is the resistance of the wood material to two forces applied in opposite directions and trying to break and separate the fibers. This study was carried out to determine the tensile strength perpendicular to the fibers of beech lumber reinforced with basalt fiber reinforced polymer (BFRP), glass fiber reinforced polymer and plaster mesh (PSM) and joined with beech dowel (BD), oak dowel (OD) and black pine dowel (BPD). Beech (Fagus orientalis Lipsky), Black pine (Pinus nigra Arnold) and oak (Quercus petraea Lieble) wooden were used as wooden dowels. Polyurethane (PUR-D4) wase used as the adhesive. The BFRP, GFRP, and PSM were added as one layer of reinforced materials. The experimental reinforced with BFRP, GFRP, and PSM were tested in the four different locations unreinforced, reinforced lumber with BFRP, GFRP, and PSM. Tests were performed on the experimental samples to investigate the tensile strength perpendicular to fiber (┴σt). The test results showed that the reinforcement process increased the (┴σ). The ┴σt value of samples reinforced with BFRP was 11%, 53%, and 66% higher than reinforced with GFRP, unreinforced, and reinforced PSM, respectively. The ┴σt value of samples joined with oak dowel was 7%, 14%, and 23% higher than those reinforced with beech, black pine, and control, respectively. Accordingly, the BFRP and oak dowel (OD) have been the potential to serve as options for reinforced wood structural.*
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***KEYWORDS:*** *Tensile strength; Wooden dowel; BFRP; PUR-D4; GFRP; PSM.*

***R**eceived 03 Feb., 2025; **R**evised 11 Feb., 2025; **A**ccepted 13 Feb., 2025 © The author(s) 2025.*
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## I. INTRODUCTION

Wood is one of the most widely used materials today. It is a sustainable material that exhibits high durability, is easy to recycle and is fully compatible with nature. It has the advantages of being lightweight but having sufficient mechanical properties, being easy to process, being renewable, being environmentally friendly, requiring less energy for processing and being aesthetic compared to other building materials [1]. For the sustainability of wooden structures, the selection of appropriate materials, protection of the material from moisture and the use of carrier materials with sufficient cross-sectional area are critical [2].

Fiber-reinforced polymers (FRP) offer many advantageous features such as high mechanical strength, non-conductive lightweight structure, corrosion resistance, and reduced recycling requirements FRP has been effectively used for decades to increase the structural integrity and strength of concrete structures. This material is preferred in areas such as restoration applications, I-beam production, bridge coatings, and wooden beams and columns in all kinds of reinforcement and support connections due to its strength properties. Structural composite timber can be reinforced with synthetic fibers to further increase the performance of structures. In addition, FRP reinforcement has the potential to increase the bending stiffness and ultimate bearing capacity of wooden beams [3]. The commonly utilized fiber reinforced-polymers (FRPs) as reinforcement for wood beams are carbon fiber reinforced polymer (CFRP), glass fiber-reinforced polymer (GFRP), basalt fiber-reinforced polymer (BFRP), and aramid fiber-reinforced polymer (AFRP) [4], [5], & [6].

Dowel-type timber joints made of wood are of particular interest for interventions on built heritage because such heritage buildings often involve timber structures. Wooden dowels offer a lower cost when compared with other connectors and conform to the tendency for using wood-based solutions to retrofit timber structures. Dowel connections can be divided into two principal groups: small and large dowel connections. The designation refers to the relative length of the fastener in the wood member to the diameter, similar to the slenderness ratio for columns. This differentiation of dowel connections can be made because small dowel connections tend to be governed by the yield strength of the dowel, and are usually considered to share the load equally. This is because as the individual fasteners yield, the load is redistributed to the other fasteners in the connection and all of the fasteners will yield and bend before the wood fails. On the other hand, large dowel connections tend to be increasingly governed by the crushing strength of the wood. Imperfections in the connection due to construction tolerances and variability of the wood material cause the load to be carried unequally between the individual fasteners in the connection. Dowel-type connections are widely employed in construction because they are easy to use and relatively cheap. In terms of design, it is essential to understand their mechanical properties and the factors that affect their behaviour. The mechanical properties are dependent on parameters such as the wood species, dimensions, diameter of the fastener and loading configuration, together with external factors like climatic conditions (temperature and humidity), moisture content, biological factors (insects, moulds), age of wood and state of the connections (if they have been affected by time, insect damage etc.) [7].

Joint made with beech dowel has higher bending resistance than the Hornbeam which showed that dowel of higher tensile strength will contribute to better performance of joint [8]. The tensile strengths of beech dowels with straight and grooved bodies of different lengths and diameters on oak, beech, and Scots pine wood were investigated. As a result, it was reported that the highest tensile strength in longitudinal joints was obtained with dowels of 8 mm diameter and 36 mm length in oak [9]. Dowel tensile strength values of wooden joints prepared using dowels obtained from ash (Fraxinus excelsior Lipsky) and chestnut (Castanea sativa Mill.), and oak (Quercus petraea Lieble) were also investigated. According to the test results, the highest dowel tensile strength value was obtained in the test specimens prepared with ash dowel and polyvinyl acetate (PVAc-D4) glue,the lowest dowel tensile strength value was obtained in the test specimens prepared using polyurethane (PU-D4) glue with chestnut dowel [10].

This study aimed to determination of the effects of fiber-reinforced polymer types (BFRP, GFRP, and PSM) and wooden dowel species (Oak, Beech, and Black pine dowel) on the tensile strength perpendicular to the fibers of wooden materials.

## II. MATERIALS AND METHODS

### 2.1 Materials

The woods used in this study, Beech wood (*Fagus orientalis* L.), beech (*Fagus orientalis* Lipsky), Oak (*Quercus petraea* Lieble), and Black pine (*Pinus nigra* Arnold) were obtained from a local sawmill located in Yenice-Karabük, in Turkey (Figure 1a). Wooden dowels were prepared with a cylindrical shape in nominal dimensions of 8 mm × 50 mm (Figure 1b).

The polyurethane adhesive (Apel (D4): Beta Kimya, Turkey) was obtained from Beta Kimya Industry and Trade Inc., in Turkey (Figure 1c). The technical properties of the PUR-D4 were as follows: density of 1.110 g/cm$^3$, pH of 5.0 (25°C), viscosity of 5000-10000 mPas (20°C), and application amount of (200 gr/m$^2$).

The BFRP and GFRP for 200 gr/m$^2$ plain materials were obtained from Dost Chemical Industry Raw Material Industry and Trading Company in Turkey (Figure 1d,e respectively). The BFRP and GFRP were prepared by cutting them to a length of 1000 mm and a width of 52 mm. The density of BFRP and GFRP are 2.8 gr/cm$^3$ and 2.56 gr/cm$^3$, respectively.

The elasticity modulus, tensile strength, and elongation to fracture of BFRP and GFRP were 8900 and 76000 MPa, 2800 and 2500 MPa, and 3.15% and 3.2%, respectively [11]. The PSM used weighed 160 g/m$^2$. It was alkali-resistant and orange in color, with a 4 mm × 4 mm mesh pattern (Figure 1f).

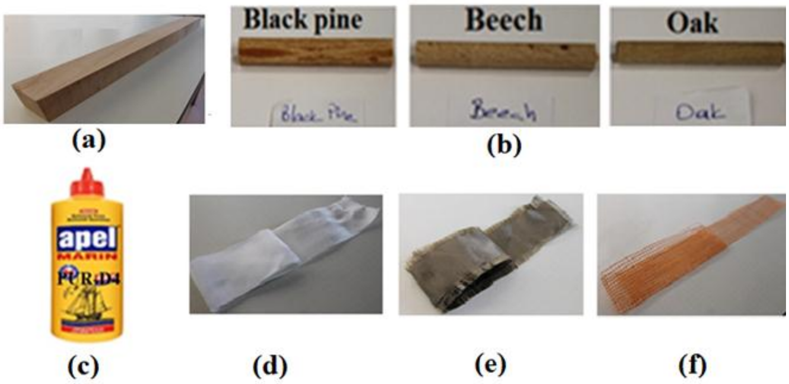


**Figure 1:** Materials used in experiments: a) Beech wood, b) Wooden dowels, c) PUR-D4 adhesive, d) GFRP, e) BFRP, and f) PSM

**2.2 Preparation and Construction of Specimens**

In the preparation of the test samples, the wooden materials were sawn using a high-speed circular saw machine to 30 mm thickness, 50 mm width, and 1000 mm length, with annual rings perpendicular to the adhesion surface (Figure 2a). Once stacked, the lumbers were stored in a temperature-controlled room at a constant temperature of 20 ± 2 °C and a relative humidity of 65 ± 5%. The lumber remained in the specified environment until they reached a moisture content of 12%. Test samples were prepared following the guidelines outlined in the TS 5497 EN 408 standard [12].

After the edges and surfaces of the wooden materials were smoothed in the planer machine (Figure 2b), they were brought to the appropriate thickness (2.5 ± 0.1 mm) in the high-speed thicknessing machine, and the pressing process was started (Figure 2c). For interlayer samples, one layer of reinforced materials (GFRP, BFRP, and PSM) was used as an intermediate support between the solid layers. Approximately 200 g/m$^2$ of adhesive was used for surface (Fig. 2d). The samples, which consisted of two layers, were placed in a hydraulic press (Hydraulic Veneer SSP-80; ASMETAL Wood Working Machinery Industry Inc., Ikitelli, Istanbul, Turkey) at room temperature. The press exerted a pressure of approximately 1.5 N/mm$^2$ on the samples for 3 h. The test samples were produced at cold pressures of 20 ± 2 °C and 65 ± 5% relative humidity. The pressing of the test samples is shown in Figure 2e.

After the pressing process, one of the edges was smoothed on the planar machine, and test samples were prepared on a high-speed circular saw machine in accordance with the TS ISO 13061-7 standards [13] (Figure 3a,c). On the Vertical Drill machine, appropriate settings were made, and two holes of Ø25 mm and 50 ± 1 mm depth were opened symmetrically in the direction of the part thickness in the middle of the test samples. The test samples were obtained by grading on a horizontal circular machine with a plotter (Figure 3b). In the dowel hole drilling machine, appropriate settings were made for the dowel hole and a dowel hole of Ø8 mm and 50±1 mm depth was drilled on the surfaces of the test samples from the exact center point of the section. Dowels made of beech, oak and black pine wooden materials of Ø8 mm and 50 mm length were placed in the drilled holes without glue (Figure 3c). The specimens under tensile testing were fabricated as illustrated in Figure 4. Accordingly, three fiber-reinforced polymers (BFRP, GFRP, PSM, and Unreinforced), three wooden dowel species (Beech, Oak, Black pine, and Control) 10 samples of each material (4 × 4 × 10 =160) were used as variables. A total of 160 specimens were constructed in this study. Before testing, all samples were conditioned in a humidity chamber controlled at 20 ± 2 °C and 65% relative humidity (RH) for two weeks.

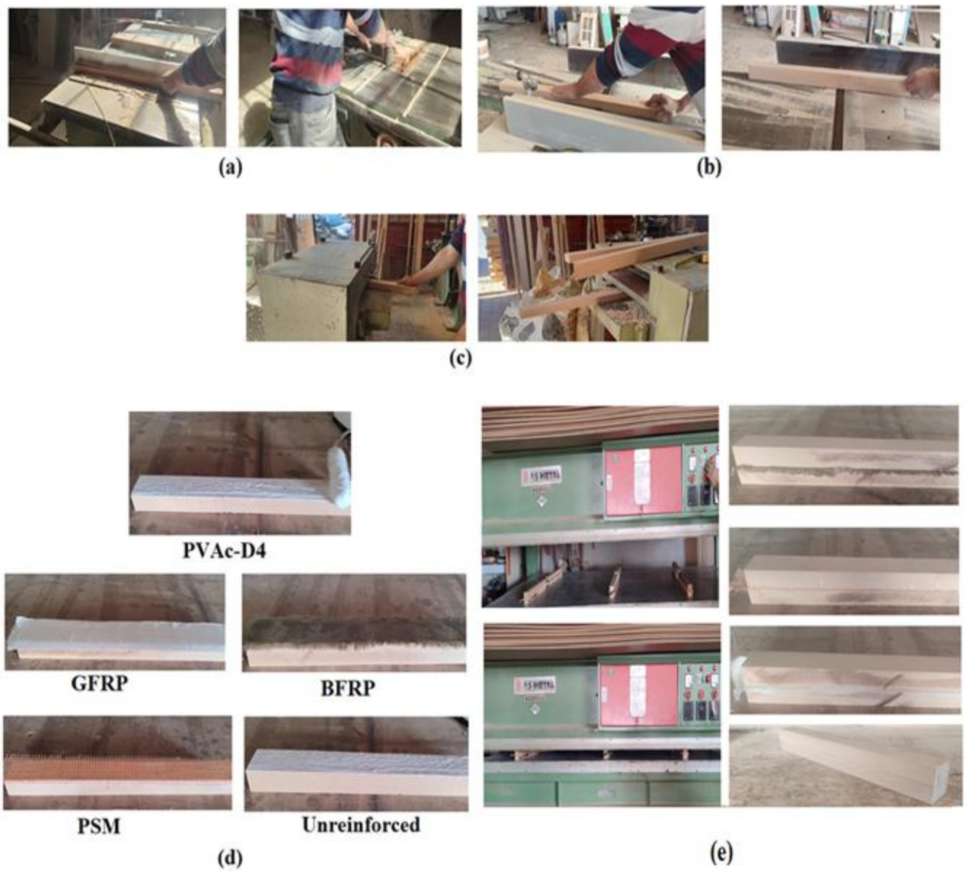


**Figure 2:** Production stages of test samples.

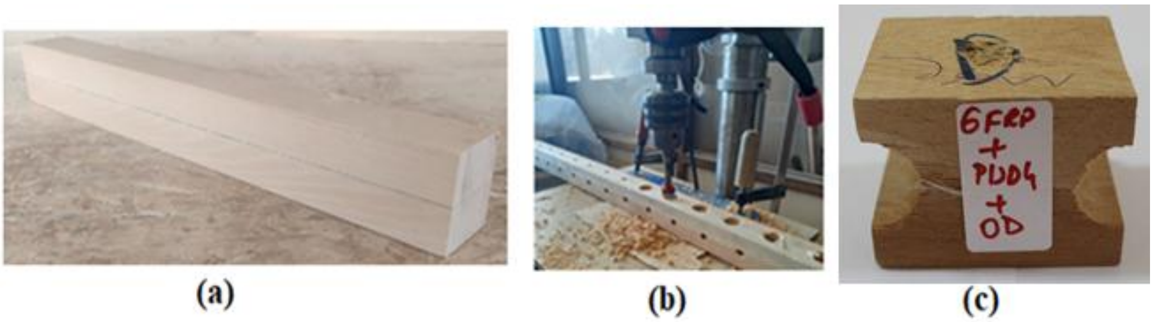


**Figure 3:** Manufacturing process for experimental samples: a) Slats, b) Hole drilling process, c) Test samples

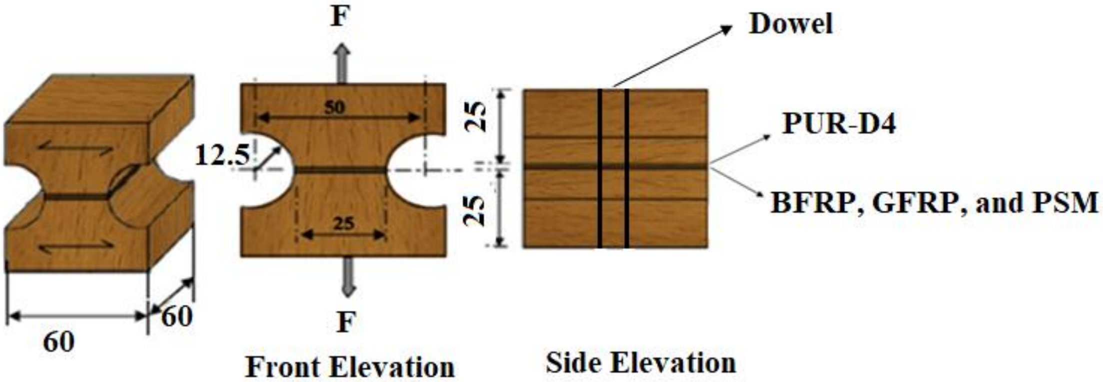


**Figure 4:** Geometry of specimens in the test (Unreinforced test samples, reinforced with BFRP, GFRP, and PSM test samples (dimensions in mm).

**2.3. Mechanical Tensile Tests**

For the tensile strength tests, the specimens were tested using an electromechanical universal testing machine (UTM), in the laboratory of Kütahya Dumlupınar University Simav Technical Education Faculty having a capacity of 10 kN, in which they were subjected to a tensile force perpendicular to the substrate wood fibers (Fig. 5). According to the TS ISO 13061-7 standard [13], the applied load increased monotonically, due to the crossbar displacement at a rate of 2 mm/min, until the joint rupture. The loading was continued until separation occurred on the surface of the test samples and from the observed load ($F_{max}$), and the bonding area of the sample ($A$), the tensile strength perpendicular to fibers ($^{\perp}\sigma t$) was calculated using Eq. 1,

$$^{\perp}\sigma t = \frac{F_{max}}{A} \quad (1)$$

where $^{\perp}\sigma t$ is the tensile strength perpendicular to fibers (N/mm$^2$), $F_{max}$ is the ultimate applied force (N), and $A$ is the bonding area of the sample (mm$^2$).

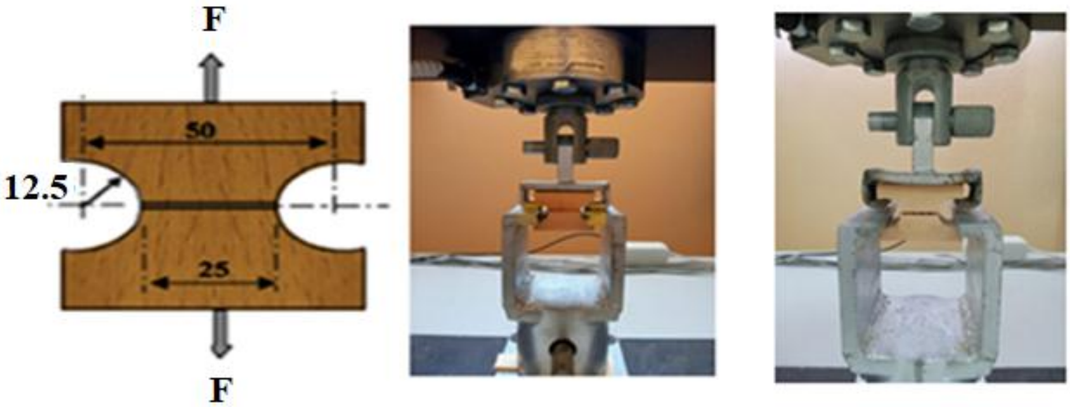


**Figure 5:** Apparatus used to hold specimens for the tensile strength perpendicular to fibers tests.

### 2.4. Statistical Analysis

Statistical analysis (Statistical Software, a computer-based statistical package, Minitab, Minitab®18, State College, PA, USA) was performed to examine the data according to the analysis of variance (ANOVA) with the Duncan test ($p < 0.05$).

## III. RESULTS

The mean values ┴σt under tension of the experimental samples with their standard deviation and coefficients of variation are presented in Table 1.

**Table 1:** Mean values of the ┴σt of joints and their coefficients of variation (N/mm$^2$)

| FRP Types | Wooden Dowel Species | Mean | SD | COV (%) |
|---|---|---|---|---|
| Unreinforced | Control | 2.92 | 0.20 | 6.85 |
| | Black pine (BPD) | 3.16 | 0.21 | 6.65 |
| | Beech (BD) | 3.34 | 0.22 | 6.59 |
| | Oak (OD) | 3.60 | 0.25 | 6.94 |
| PSM | Control | 2.71 | 0.12 | 4.43 |
| | Black pine (BPD) | 2.90 | 0.13 | 4.48 |
| | Beech (BD) | 3.10 | 0.14 | 4.52 |
| | Oak (OD) | 3.27 | 0.15 | 4.59 |
| GFRP | Control | 3.98 | 0.26 | 6.53 |
| | Black pine (BPD) | 4.31 | 0.31 | 7.19 |
| | Beech (BD) | 4.60 | 0.30 | 6.52 |
| | Oak (OD) | 4.93 | 0.34 | 6.70 |
| BFRP | Control | 4.42 | 0.11 | 2.49 |
| | Black pine (BPD) | 4.84 | 0.20 | 4.13 |
| | Beech (BD) | 5.12 | 0.13 | 2.54 |
| | Oak (OD) | 5.46 | 0.15 | 2.75 |

SD: Standard deviation, COV: Coefficient of variation, No-SMT: Unreinforced samples, ┴σt: tensile strength perpendicular to fibers.

According to Table 1, when interactions of the FRP types, and wooden dowel species were compared, the highest ┴σt value was obtained for reinforced BFRP in the oak dowel samples (5.46 N/mm$^2$). The lowest ┴σt value was obtained for reinforced PSM in the control samples (2.71 N/mm$^2$).

The results of the two-way ANOVA analysis of the FRP types and wooden dowel species on the tension strength perpendicular to the fibers of the experimental samples under the tension load are listed in Table 2.

According to the analysis of variance, as presented in Table 2, the effects of the main factors, including FRP types (A), wooden dowel species (B), and two-way interactions of FRP types × wooden dowel species (A×B)were found to be statistically significant at the level of 0.05. The Tukey's test was performed to determine these differences. The ┴σt mean according to the independent effects of test variables are given in Table 3.

**Table 2:** Summary of the ANOVA Results for ┴σt

| Source | Sum of Square | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 122.013[a] | 15 | 8.134 | 178.529 | .000 |
| Intercept | 2451.18 | 1 | 2451.18 | 53798.14 | .000 |
| FRP Types (A) | 106.857 | 3 | 35.619 | 781.757 | .000 |
| Wooden dowel species (B) | 14.322 | 3 | 4.774 | 104.778 | .000 |
| A×B | 0.835 | 9 | 0.093 | 2.036 | .004 |
| Error | 6.561 | 144 | 0.046 | | |
| Total | 2579.76 | 160 | | | |
| Corrected Total | 128.574 | 159 | | | |
| R Squared = ,949 (Adjusted R Squared = ,944) | | | | | |

df: Degrees of freedom, [a]FRP types (BFRP, GFRP, PSM, and Unreinforced), and [b] Wooden dowel species (Oak, Beech, Black pine, and Control)

**Table 3:** Independent Effects of Test Variables on Mean Values of ┴σt of Joints (N/mm$^2$)

| Source | | ┴σt | SD | HG |
|---|---|---|---|---|
| FRP types | BFRP | 4.96 | 0.14 | A |
| | GFRP | 4.45 | 0.29 | B |
| | Unreinforced | 3.25 | 0.21 | C |
| | PSM | 2.99 | 0.13 | D |
| Wooden dowel species | Oak (OD) | 4.32 | 0.21 | A |

| | | | | |
|---|---|---|---|---|
| | Beech (BD) | 4.04 | 0.19 | B |
| | Black pine (BPD) | 3.80 | 0.20 | C |
| | Control | 3.50 | 0.17 | D |

⊥σt: tensile strength perpendicular to fibers, HG: Homogeneity groups

For the FRP types, the highest ⊥σt value was obtained in BFRP (4.96 $N/mm^2$), and the lowest was in the PSM (2.99 $N/mm^2$). The ⊥σt value according to reinforced FRP declined in the order to BFRP, GFRP, unreinforced, and PSM. The ⊥σt value of samples reinforced with BFRP was 11%, 53%, and 66% higher than those reinforced with GFRP, unreinforced, and reinforced PSM, respectively. In the literature, some studies reported that BFRP has higher tensile strength and modulus of elasticity than GFRP [14], [15],[16],[17], [18] [19].

According to the wooden dowel species, the best results were obtained for test samples with oak dowels. The ⊥σt value of samples with oak dowel was 7%, 14%, and 23% higher than beech, black pine, and control, respectively. The reasons for this are the density differences of the wood materials, structural properties, mechanical properties, and improved bonding strength. The density of oak wood was higher than that of other wood samples used in the experiments.

Özcan et al. (2013) investigated the effect of dowel species, the direction of withdrawal, board type and the type of adhesive on the withdrawal strength. The results showed that the highest values were obtained from dowels made from oak, beech, and apple wood materials. The lowest values were determined from dowels made fir wood materials [20]. Podlena et al. (2020) investigated the withdrawal strength of plain dowels was compared with the spiral dowels manufactured from beech (*Fagus sylvatica* L.) and oak wood (*Quercus robur* L.). The results showed that the highest values were obtained from spiral dowels made from oak [21]. In a study conducted to determine the performance of dowel fasteners with plywood and particleboard materials, oak dowels showed high values in plywood joining [22]. When the studies conducted in the literature are examined, it is seen that the dowel tensile resistance of high-density wood materials is high [23-25].

## IV. CONCLUSION

This study investigated the tensile strength perpendicular to fibers of timber joined with a wooden dowel and reinforced with basalt BFRP, GFRP, and PSM using PUR-D4.

According to the overall results, the experimental samples reinforced with BFRP and joined with an oak dowel demonstrated the best properties among all the tested samples. The highest tensile strength perpendicular to fibers value was obtained from oak dowels and reinforced with BFRP. At the same time, the lowest tensile strength perpendicular to the fibers value was obtained from control samples and reinforced PSM.

On the empirical findings regarding the technical characteristics of BFRP as support materials and oak as wooden dowel, the tensile strength perpendicular to fibers of the wood material was observed to be improved. Given the substantial enhancements in the resistance properties of the intermediate filling material utilized in reinforced wood materials, it is advisable to prioritize high-strength properties in wood furniture and structural timber materials. In wooden structures where the tensile strength value perpendicular to the fibers is important, the use of BFRP and an oak dowel as the wooden dowel type can be recommended.

## REFERENCES

[1]. Aydın-Yılmaz, A. (2017). Türkiye'de Yetişen Önemli Ağaç Türlerinin Ortotropik Mekanik Davranış Özellikleri. Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Orman Mühendisliği Anabilm Dalı, Doktora Tezi, Isparta Turkiye.

[2]. Bozkurt, Ö. (2011). Geleneksel Tekirdağ evlerinde kullanılmış meşe ahşabının mekanik özellikleri ve kimyasalla koruma uygulamalarının mekanik özellikler üzerine etkisi. Politeknik Dergisi, 14 (2): 115- 119. doi: https://doi.org/10.2339/2011.14.2.

[3]. Jian, B. Cheng, K. Li, H. Ashraf, M. Zheng, X. & Dauletbek, A. (2022). A review on the strengthening of timber beams using fiber reinforced polymers. Journal of Renewable Materials, 10 (8): 2073-2098. doi: https://doi.org/10.32604/jrm.2022.021983

[4]. Tingley, D.A. (1996). The Stress-Strain Relationships in Wood and Fiber-Reinforced Plastic Laminae of Reinforced Glued-Laminated Wood Beams. Ph.D. Thesis, Oregon State University, Corvallis, OR, USA.

[5]. Borri, A. Corradi, & M. Grazini, A. (2003). FRP reinforcement of wood elements under bending loads. In Proceedings of the 10th International Conference on Structural Faults and Repair, London, UK, 1–3 July 2003.

[6]. Yan, L.B. Chouw, N. & Jayaraman, (2014). K. Flax fibre and its composites—A review. Composites Part B: Engineering, 56:296–317.

[7]. Teodorescu, I. Pereira, B. Aquino, C. D. & Branco, J. M. (2020). Experimental evaluation of dowel-type timber joints with wooden dowels. Proceedings of the Institution of Civil Engineers-Structures and Buildings, 173 (12): 927-938. doi; https://doi.org/10.1680/jstbu.20.00021

[8]. Dalvand, M., Ebrahimi, G., Tajvidi, M., & Layeghi, M. (2014). Bending moment resistance of dowel corner joints in case-type furniture under diagonal compression load. Journal of Forestry Research, 25: 981-984.

[9]. Efe, H. (1998). Çerçeve konstrüksiyonlu mobilya boy birleştirmelerinde farklı kavela türlerinin mekanik davranış özellikleri. Gazi Üniversitesi Politeknik Dergisi, 1(1/2): 65-74.

[10]. Karaman, A., Yildirim, M.N., & Uslu, E. (2019). Effect of dowel wood species on dowel tensile strength in wooden length jointsbonded with different adhesives. Turkish Journal of Forestry, 20 (4): 427-432. doi: https://doi.org/10.18182/tjf.591404

[11]. Fiore, V., Di Bella, G., & Valenza, A. (2011). Glass–basalt/epoxy hybrid composites for marine applications. Materials & Design, 32(4): 2091-2099. doi: https://doi.org/10.1016/j.matdes.2010.11.043

[12]. TS 5497 EN 408 (2006). Timber structures-structural timber and glue laminated timber-determination of some physical and mechanical properties. Turkish Standards Institution, Ankara, Turkey.
[13]. TS ISO 13061-7 (2021). Wood-determination of ultimate tensile stress perpendicular to the grain. Turkish Standards Institution, Ankara, Turkey.
[14]. Speranzini, E.& Tralascia, S. (2010). Engineered lumber: LVL and solid wood reinforced with natural fibres. In Proceedings of the WCTE, 20-24 June 2010, Trentino, Italy.
[15]. Wei, B., Cao, H., & Song, S. (2010). Tensile behavior contrast of basalt and glass fibers after chemical treatment. Materials & Design, 31(9): 4244-4250. doi: https://doi.org/10.1016/j.matdes.2010.04.009
[16]. Carmisciano, S., De Ros, I. M., Sarasini, F., Tamburrano, A., & Valente, M. (2011). Basalt woven fiber reinforced vinyl ester composites: Flexural and electrical proprieties. Materials & Design, 32: 337-342. doi: https://doi.org/10.1016/j.matdes.2010.06.042
[17]. Lopresto, V., Leone, C., & De Iorio, I. (2011). Mechanical characterization of basalt fiber reinforced plastic. Composites Part B: Engineering, 42(4): 717-723. doi: https://doi.org/10.1016/j.compositesb.2011.01.030
[18]. Dorigato, A., & Pegoretti, A. (2012). Fatigue resistance of basalt fibers-reinforced laminates. Journal of Composite Materials, 46(15): 1773-1785. doi: https://doi.org/10.1177/0021998311425620
[19]. Monaldo, E. Nerilli, F. & Vairo, G. (2019). Basalt-based fiber-reinforced materials and structural applications in civil engineering. Composite Structures, 214, 246-263. https://doi.org/10.1016/j.compstruct.2019.02.002
[20]. Özcan, C. Uysal, B. Kurt, Ş. Esen, R. ( 2013). Effect of Dowels and Adhesive Types on Withdrawal Strength in Particleboard and MDF. Journal of Adhesion Science and Technology, 27(8): 843–854. https://doi.org/10.1080/01694243.2012.727157
[21]. Podlena, M., Böhm, M., Hýsek, Š., Procházka, J., & Černý, R. (2020). Evaluation of parameters influencing the withdrawal strength of oak and beech dowels. *BioResources*. 15 (1): 1665-1677.
[22]. Zhang, J.L., Quin, F., & Tackett, B. (2001). Bending strength and stiffness of two-pin dowel joints constructed of wood and wood composites. Forest Products Journal, 51(2): 29-35.
[23]. Kasal, A. (2007). Determination of the dowel holding performance of some solid wood and wood composite materials. Gazi University Faculty of Engineering and Architecture Journal, 22(3): 387-397.
[24]. Kasal, A. (2008). Bending moment and shear force capacities of the T-type doweled furniture joints reinforced with different sizes of corner blocks. Gazi University Faculty of Engineering and Architecture Journal, 23(2): 273-282
[25]. Çağatay, K., Efe, H., & Kesik, H.İ. (2013). Determination of the effects of the tensile direction and glue type on dowel holding strength on different wood materials. Kastamonu University, Journal of Forestry Faculty, 13(2): 182-191.