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DETERMINATION OF AIR-DRY DENSITY AND COMPRESSION STRENGTH PARALLEL TO THE GRAINS OF BASALT FIBER-REINFORCED POLYMER (BFRP) WOVEN FABRICS AND PLASTER MESH (PSM) REINFORCED GLUED LAMINATED OAK LUMBER

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ABSTRACT: This study was carried out to determine the changes in air-dry density and fiber-parallel compressive strength of basalt fiber-reinforced polymer (BFRP) woven fabrics (WF) and plaster mesh (PSM) reinforced sessile oak laminated timber. One component polyurethane (PUR) glue was used as the adhesive. The BFRPWF abd PSM were added as a reinforcement layer between wood veneers to improve properties of laminated composite material. The BFRPWF and PSM were tested in three different locations non-reinforced laminated oak lumber (LOL), reinforced laminated oak lumber with the BFRPWF (LOL- BFRPWF), and reinforced laminated oak lumber with the PSM (LOL-PSM). Tests were performed on the LOL, LOL- BFRPWF, and LOL-PSM to investigate their air-dry density (δ_{12}), and compression strength (σ_b). The test results showed that the reinforcement process increased both δ_{12} and σ_b parallel to the grains. The LOL-BFRPWF samples give better results than PSM and control samples. Accordingly, the samples of LOL-BFRPWF and LOL-PSM samples have the potential to serve as viable options for both furniture and building materials.

Keywords: BFRP, compression strength, oak, PSM.

BAZALT KUMAŞ VE PLASTER NET İLE GÜÇLENDİRİLMİŞ LAMİNE MEŞE KERESTENİN HAVA KURUSU YOĞUNLUK VE LİFLERE PARALEL BASINÇ DİRENCİNİN BELİRLENMESİ

ÖZET: Bu çalışma, bazalt kumaş (BFRP) ve plaster mesh (PSM) güçlendirilmiş sapsız meşe lamine kerestenin hava kurusu yoğunluk ve liflere paralel basınç direncindeki değişimlerin belirlenmesi amacıyla yapılmıştır. Yapıştırıcı olarak tek komponentli poliüretan (PUR) tutkalı kullanılmıştır. BFRPWF ve PSM, lamine kompozit malzemenin mekanik özelliklerini geliştirmek için ahşap kaplamalar arasına takviye katmanı olarak eklenmiştir. BFRPWF ve PSM, takviyesiz lamine meşe kereste (LOL), BFRPWF (LOL-BFRPWF) ile güçlendirilmiş lamine meşe kereste ve PSM (LOL-PSM) ile güçlendirilmiş lamine meşe kereste üç farklı lokasyonda test yapılmıştır. Hava kuru yoğunluk (δ_{l2}) ve liflere paralel basınç direncini (σb) araştırmak için LOL, LOL-BFRPWF ve LOL-PSM üzerinde testler yapılmıştır. Test sonuçları, güçlendirme işleminin hem δ_{l2} hem de σ_b'yi arttırdığı göstermiştir. LOL-BFRPWF örnekleri PSM ve kontrol örneklerinden daha iyi sonuçlar elde edilmiştir. Buna göre LOL-BFRPWF ve LOL-PSM örneklerinin örnekleri, hem mobilya hem de yapı malzemeleri için uygun seçenekler olarak hizmet etme potansiyeline sahip olduğu söylenebilir.

Anahtar kelimeler: BFRPWF, basınç direnci, meşe, PSM.

INTRODUCTION

Use of advanced fibre reinforced polymers (FRPs) to increase the performance of timber structures has recently received much attention (Raftery et al., 2011). The FRPs are increasingly used in construction owing to their high corrosion resistance, good strength-to-weight ratio, and ease of cutting (Castelo et al., 2020; Liang and Hota, 2021). A significant application of FRP is the reinforcement of timber, engineered bamboo (Lv et al. 2019). Making full use of the advantages of FRP can not only advance the problems (Fang et al., 2019), corrosion (Fang et al., 2019), fire (Kandare et al., 2014), but also reinforces the existing components and improves their bearing capacity (Yang et al., 2021).

Basalt fiber reinforced polymers (BFRP), as a new type of composite material, is another high-tech fiber composite material after carbon fibers (Subagia et al., 2014). The BFRP has an interesting relationship between quality and cost compared with the conventional FRPs (Ouyang et al., 2021). Manikandan et al. (2012) concluded that basalt fiber composites showed generally superior properties than those of the glass fiber reinforced polymer. The BFRP is much cheaper than carbon fiber reinforced polymers (CFRP) (Wu et al., 2020), and has higher mechanical properties than glass fiber reinforced polymers (GFRP) (Song et al., 2021). Furthermore, it has a wide range of raw materials, an environmentally friendly production process and meets the requirements of green sustainable requirements (Gao et al., 2020).

More recently, research on timber columns reinforced with FRPs has increased. Most of the research on fiber-reinforced timber columns has focused on the compressive strength of FRP-reinforced wood columns (Najm et al., 2007; Taheri et al., 2009; Ouyang et al., 2011; Zhang et al., 2012; Zhu et al., 2013; Dong et al., 2015a; Dong et al., 2015b; Xiong et al., 2015; Li et al., 2021; Rosa et al., 2021; Siha et al., 2021; Wang et al., 2021; O’Callaghan et al., 2022).

Najm et al. (2007) investigated the compressive performance improvement of CFRP reinforced short timber columns. Taheri et al. (2009) studied the effect of reinforcing glulam columns with carbon or glass fibers and found that fiber composites have a positive impact on the compressive strength of the columns. Li et al. (2021) studied the axial compression behavior of short columns confined with CFRP. Rosa et al. (2021) investigated the compression behavior of short wild pinewood columns constrained by BFRP and CFRP. Siha et al. (2021) presented new fber reinforcement methods for short timber columns. Wang et al. (2021) investigated the feasibility of reinforcing laminated bamboo columns by using AFRP. O'Callaghan et al. (2022) used GFRP wrapped square timber columns to effectively avoid unnecessary splitting and shear failure of the columns and improve their post-peak performance.

The aim of the current study was to comparatively investigate the air-dry density and compressin strength of control LOL, the LOL-BFRPWF, and LOL-PSN reinforced with the BFRPWF and the plaster mesh using PUR adhesive cured under room temperature conditions.

MATERIAL AND METHOD

Material

For the study, the oak wood (*Quercus petrea* L.), widely employed in the furniture sector, was chosen as the wooden material. The selection of it was conducted randomly from timber merchants located in Yenice-Karabuk, Turkey. As a test material, oak lumber pieces (5 × 80 × 1000 mm) was used. It is a material that full-dry density (δ_0) 0.650 g/cm^3, air-dry density (δ_{l2}) 0.690 g/cm^3. Also, its compression strength parallel to the fibers (σ_b) is 65 MPa (Bozkurt and Erdin, 2000).

The BFRPWF for 200 gr/m^2 plain materials used in the study was obtained by Dost Chemical Industry Raw Material Industry and Trading Company (Turkey, Istanbul) (Figure 1a). It demonstrated the following values: 2.8 g/cm^3 for density, 0.140 mm for thickness, 89 GPa for modulus of elasticity, 4.8 GPa for tensile strength, and 3.2 % for elongation to fracture (Fiore et al., 2011).

The plaster mesh (PSM) used had a weight of 160 g/m^2. It was alkali resistant and orange in color, with a 4 mm × 4 mm mesh pattern (Figure 1b).

The polyurethane adhesive (PUR) used in this the study was obtained by Apel Kimya Industrial Industry and Trade Company (Turkey, Istanbul) (Figure 1c), At a temperature of 20°C, the density of the material is measured to be 1.11 ± 0.02 g/cm^3, while at 25°C, the viscosity is determined to be 14.000 ± 3.000 mPas, When exposed to an environment with a temperature of 20°C ± 2 and a relative humidity of 65 ± 3, the material undergoes hardening within a time frame of 30 minutes.

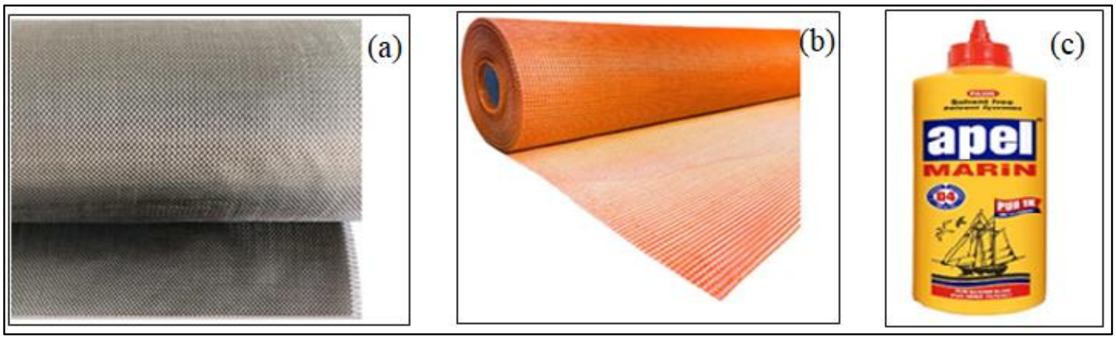

Figure 1. Materials Used in Experiments. (a) BFRPWF. (b) PSM and (c) PUR Adhesive.

Preparation of experimental samples

Slats with dimensions of 5 mm thickness, 80 mm width, and 1000 mm length (T × W × L) were obtained from oak timber through the utilization of a circular saw machine employing the mowing technique. Once stacked, the slats were stored in a temperature-controlled room with a consistent temperature of 20 ± 2°C and relative humidity conditions of 65 ± 5%. The slats remained in the specified environment until they attained a moisture content of 12%. The test samples were prepared following the guidelines outlined in the TS 5497 EN 408 (2006) standard. The PUR was utilized in the preparation of the samples. The technical properties of the glue are as follows: density 1.1± 0.02 g / cm3, viscosity (25°C) 4500±500 cp, pH value 3, gluing time 20°C, 30 minutes in 65% relative humidity conditions, recommended by the manufacturer

As shown in Figure 2, reinforced laminated elements were produced by placing the BFRPWF or PSM between each layer with the objective of inreasing the resistance. For interlayer samples, 3 layers of reinforced materials were used for intermediate support between solid layers. Approximately 200 g/m^2 of adhesive was used for surface. The samples, which consisted of four layers, were placed into 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 a duration of 180 minute. As a result, desired laminated veneer lumbers were produced in the cold pressure at 20 ± 2°C and 65 ± 5% relative humidity. The pressing of test samples are shown as in Figure 3.

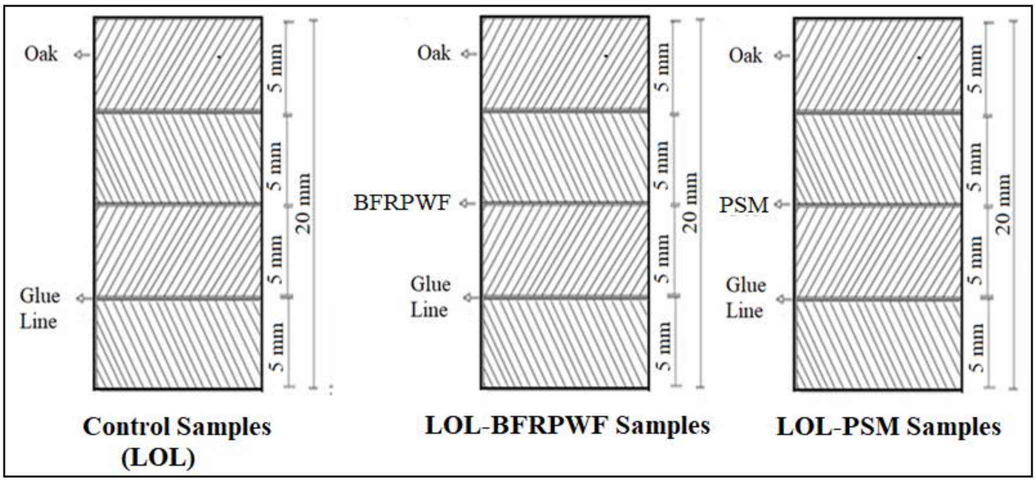

Figure 2. All of The Experimental Samples.

Figure 3. Pressing of Test Samples.

Test Method

The air-dry density was measured following the guidelines specified in TS 2474 (1976). Test samples were prepared with dimensions of 20x20x30 mm for the purpose of conducting the density determination. The samples were subjected to conditioning in an environment with a relative humidity of 65±5% and a temperature of 20±2°C. Conditioning was continued until the samples reached an equilibrium moisture content of 12%. Subsequently, the samples were weighed using a digital precision scale, and their dimensions were determined using a digital precision compass. Next, the equations provided were utilized to compute the density values of the samples after air drying:

$$\delta_{12} = \frac{M_{12}}{\vartheta_{12}} \quad (1)$$

where, δ_{12} is the samples of density (g/cm^3), M_{12} is the weight, and ϑ_{12} is the volume (cm^3).

Compression strength parallel to grain

In accordance with the TS 2595 (1976) standard, compression strength tests were conducted on both fiber and glue lines. For this purpose, test samples were prepared dimensions 20x20x30 mm and numbers 60 test samples (Figure 4). Compression strength (σ_b) to grain test was conducted an electromechanical universal testing machine (UTM) with a capacity of 10 kN. The following equations calculated compression strength (σ_b) parallel to grain values.

$$\sigma_b = \frac{F_{max}}{a \times b} \quad (2)$$

In the given context, the variables are defined as follows: σ_b (N/mm^2) Fmax represents the maximum load applied during testing, measured in N. The variable a denotes the width of the samples, measured in mm. The variable represents the thickness of the samples, also measured in mm.

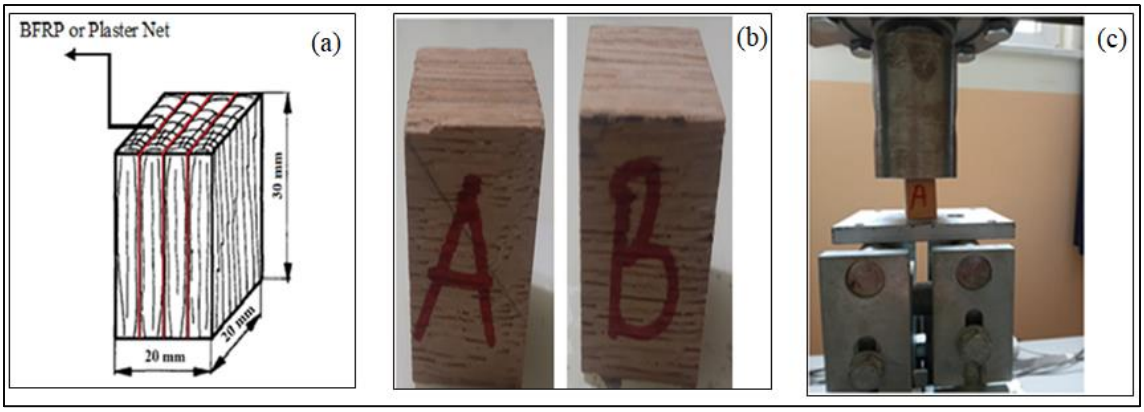

Figure 4. Compression strength test. (a) Static System. (B) Test Samples. (C) Testing.

Statistical analyses

The statistical analysis of the experimental data involved calculating the arithmetic mean and standard deviation. Multiple analysis of variance (ANOVA) was employed to assess the impact of various factors on the values obtained for all sample groups. To determine the significance level of the interaction between the factors, Duncan's test was utilized, with a significance level set at 5% ($p < 0.05$). This allowed for determining the degree of significance if the mutual strength of the factors exhibited a significant effect.

RESULTS

Table 1 presents a summary of the test results for the air-dry density (g/cm^3), and the compression strength (N/mm^2) properties of the samples. Descriptive statistics, including the maximum, minimum, mean, and standard deviation, were used to summarize the data. These statistical values provide an overview of the observed variability and central tendencies in the tested properties of the samples.

Table 1. Descriptive Statistical Values of δ_{12} (g/cm^3), and $//\sigma_b$ (N/mm^2)

Physical and mechanical properties	Values	LOL	LOL-PSM	LOL-BFRPWF
	X	714	738	788
	SD	21.18	11.26	22.58
δ_{12}	COV (%)	0.45	0.13	0.51
	Min,	680	718	758
	Max,	753	755	831
	N	20	20	20
	X	71.72	80.30	85.34
$//\sigma_b$	SD	2.867	2.519	2.471
	COV (%)	8.222	6.343	6.108
	Min,	68.36	76.88	80.24
	Max,	77.87	84.22	88.35
	N	20	20	20

δ_{12}: Air-Dry-Density, $//\sigma_b$ =Compression Strength, X: Mean values, SD: Standart deviation, COV (%): Coefficient of variation, N: Number of samples, $\perp$: LOL : (Non-reinforced laminated oak lumber), LOL-PSN (Laminated oak lumber with reinforced PSN), LOL-BFRPWF (Laminated oak lumber with reinforced BFRPWF).

The comparison between LOL, LOL-PSM, and LOL-BFRPWF samples was dependent on the ANOVA analysis (Table 2). According to analysis, the δ_{12}, and parallel to the glue line σ_b was were statistically significant at the level of 0.05.

Table 2. The result of ANOVA.

Physical and Mechanical Properties	Source	SO	DF	MS	F Value	Sig.
δ_{12}	Between Groups	0.03205	2	0.016027	44.29	0.000
	Within Groups	0.01086	30	0.000362		
	Total	0.04291	32			
$//\sigma_b$	Between Groups	59505749	2	29752874	115.14	0.000
	Within Groups	7752263	30	111731		
	Total	67258012	32			

In cases where the observed differences between groups were deemed statistically significant, the Duncan test was employed to determine the specific differences between means. This analysis was conducted at a predetermined significance level of α=0.05. The results of the Duncan test, indicating the significant differences between means, can be found in Table 3.

Table 3. The result of Duncan Test.

Physical and Mechanical Properties	Process					
	LOL		LOL-PSM		LOL-BFRPWF	
	X	HG	X	HG	X	HG
δ_{12}	0.714	C	0.738	B	0.788	A
$//\sigma_b$	71.72	C	80.90	B	85.34	A

In cases where the observed differences between groups were deemed statistically significant, the Duncan test was employed to determine the specific differences between means. This analysis was conducted at a predetermined significance level of α=0.05. The results of the Duncan test, indicating the significant differences between means, can be found in Table 3.

Table 3 shows that the some physical and mechanical of the LOL showed was the lowest, and the some physical and mechanical properties of the LOL-BFRPWF was the highest, the δ_{12} of the LOL-BFRPWF samples were determined 0.788 g/cm^3, and σB values is 90.44 N/mm^2. Upon through examination of the overall results, it was observed that the LOL-BFRPWF samples exhibited the most favorable properties. However, it is worth noting that the LOL samples demonstrated the lowest value among all the tested. The some and mechanical properties of the LOL-BFRPWF were higher than that of the LOL samples δ_{12} 10.36 %, and σB 20.00 %.

Similarly, some physical and mechanical of properties the LOL-PSM samples were higher than that of the LOL samples (δ_{12} 3.36 %, and σB 12.80 %. Based on results, laminated wood materials, higher values (14.08 % in LOL-PSM, 20.00 % in LOL-BFRPWF) than the LOL samples which were representing their kinds.

Air-dry density, and compression strength of the LOL, LOL-PSM, and LOL-BFRPWF samples concerning diagrams were given on the Figure 4.

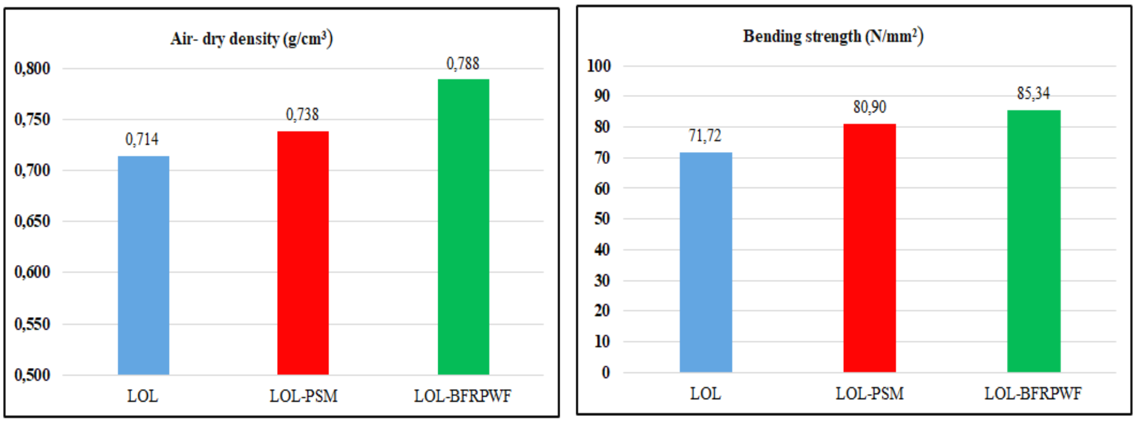

Figure 4. Air-dry density and compressive strength of the test samples.

According to Figure 4, the air-dry density (δ_{12}) increase varied between 3.36% and 10.36% in the LOL-PSM -LOL (0.738 g/cm^3) and LOL-BFRPWF (0.788 g/cm^3) , respectively (Figure 4a). In the parallel to the glue line (Figure 4b), the compression strength increase varied between 12.80% and 19.00%, in the LOL-PSM (80.90 N/mm^2) and LOL-BFRPWF (85.34 N/mm^2), respectively (Figure 4).

DISCUSSION AND CONCLUSIONS

The air-dry density and compression strength of the control samples (LOL), and the LOL samples reinforced with the BFRP and plaster net (PSN) using PUR adhesive.

The Some physical and mechanical properties of LOL samples were determined the δ_{12} is 0.714 g/cm^3, and σB is 71.72 N/mm^2. The PSN-LOL samples were found the δ_{12} is 714 g/cm^3, and the σB is 80.90 N/mm^2. The BFRP-LOL samples were determined t the δ_{12} is 0.788 g/cm^3, and the σB is 85.34 N/mm^2.

According to the overall results, the BFRP-LOL samples demonstrated the best properties among all the tested samples. However, it is important to note that the LOL samples exhibited the lowest value among all of the samples.

Ouyang et al. (2011) studied the nonlinear stability of FRP reinforced simply supported timber columns, and the results showed that the FRP reinforcement layer enhanced the ultimate bearing capacity of the columns. Zhang et al. (2012) investigated the compressive bearing capacity improvement of long timber columns. Zhu et al. (2013) used different FRP materials to strengthen short wood columns. Dong et al. (2015a) compared the reinforcement impacts of Aramid fber reinforced polymers (AFRP), CFRP, and BFRP considering the efect of knots on the bearing capacity of short timber columns. Dong et al. (2015b) investigated the compressive damage mode, bearing capacity, load– strain curve of FRP reinforced short timber columns. Xiong et al. (2015) investigated the efect of fiber reinforcement on the compressive capacity of short timber columns. Liu et al. (2023) explained that a bearing capacity of the the BFRP reinforced LBL columns was about 8.75% higher than the unreinforced LBL. Dong et al. (2015a) investigated the compressive performance of camphor Pine columns reinforced

BFRP, CFRP, AFRP and reported that wood columns reinforced with two layers of BFRP were the highest load bearing capacity.

On the empirical findings regarding the technical characteristics of BFRP and PSN as support materials, the strength of the laminated wood material was observed to be enhanced. Given the substantial enhancements in the resistance properties of the intermediate filling material utilized in laminated wood materials, it is advisable to prioritize high-strength properties in furniture and construction materials

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ETHICS COMMITTEE APPROVAL

This study does not require any ethics committee approval

REFERENCES

Bozkurt, A.Y., & Erdin, N. (2000). *Wood Anatomy*. Istanbul University publication number: 4263, Faculty of forestry publication number: 466, Istanbul, Turkey.

Castelo, A., Correia, J. R., Cabral-Fonseca, S., & de Brito, J. (2020). Inspection, diagnosis and rehabilitation system for all-fibre-reinforced polymer constructions. *Construction and Building Materials*, 253, 119160. https://doi.org/10.1016/j.conbuildmat.2020.119160

de la Rosa, P., González, M. D. L. N., Prieto, M. I., & Gómez, E. (2021). Compressive behavior of pieces of wood reinforced with fabrics composed of carbon fiber and basalt fiber. *Applied Sciences*, 11(6), 2460. https://doi.org/10.3390/app11062460

Dong, J.F., Yuan, S.C., Wang, Q.Y., & Liang, W. (2015a). Infuence of fractured wood texture on structural behaviour of timber columns with fibre reinforced polymer reinforcement. *Materials Research Innovations*, 19, 546–550. https://doi.org/10. 1179/1432891714z.0000000001149

Dong, J. F., Jia, P., Yuan, S. C., & Wang, Q. Y. (2015b). Compressive behaviours of square timber columns reinforced by partial wrapping of FRP sheets. *Materials Research Innovations*, 19(1), 465-468. https://doi.org/10.1179/1432891715Z.0000000001593

Fang, H., Bai, Y., Liu, W., Qi, Y., & Wang, J. (2019). Connections and structural applications of fibre reinforced polymer composites for civil infrastructure in aggressive environments. *Composites Part B: Engineering*, 164, 129-143. https://doi.org/10.1016/j.compositesb.2018.11.047

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

Gao, Y., Zhou, Y., Zhou, J., Kong, X., Zhang, B., Liu, S., & Jin, F. (2020). Blast responses of one-way sea-sand seawater concrete slabs reinforced with BFRP bars. *Construction and Building Materials*, 232, 117254. https://doi.org/10.1016/j.conbuildmat.2019.117254

Gattas, J. M., O'Dwyer, M. L., Heitzmann, M. T., Fernando, D., & Teng, J. G. (2018). Folded hybrid FRP-timber sections: concept, geometric design and experimental behaviour. *Thin-Walled Structures*, 122, 182-192. https://doi.org/10.1016/j.tws.2017.10.007

Kandare, E., Luangtriratana, P., & Kandola, B. K. (2014). Fire reaction properties of flax/epoxy laminates and their balsa-core sandwich composites with or without fire protection. *Composites Part B: Engineering*, 56, 602-610. https://doi.org/10.1016/j.compositesb.2013.08.090

Liang, R., & Hota, G. (2021). Development and evaluation of load-bearing fiber reinforced polymer composite panel systems with tongue and groove joints. *Sustainable structures*, 1(2),1-22. https://doi.org/10.54113/j.sust.2021.000008

Li, H., Li, H., Hong, C., Xiong, Z., Lorenzo, R., Corbi, I., & Corbi, O. (2021). Experimental investigation on axial compression behavior of laminated bamboo lumber short columns confined with CFRP. *Composites Part A: Applied Science and Manufacturing*, 150, 106605. https://doi.org/10.1016/j.compositesa.2021.106605

Lv, Q., Ding, Y., & Liu, Y. (2019). Study of the bond behaviour between basalt fibre-reinforced polymer bar/sheet and bamboo engineering materials. *Advances in Structural Engineering*, 22(14), 3121-3133. https://doi.org/10.1177/1369433219858725

Liu, J., Peng, Q., Li, W., & Wang, J. (2023). Mechanical properties of BFRP-reinforced glued laminated wood hollow round column under eccentric pressure. *In Structures*, 51, 1140-1152. https://doi.org/10.1016/j.istruc.2023.03.095

Manikandan, V., Jappes, J. W., Kumar, S. S., & Amuthakkannan, P. J. C. P. B. E. (2012). Investigation of the effect of surface modifications on the mechanical properties of basalt fibre reinforced polymer composites. *Composites Part B: Engineering*, 43(2), 812-818. https://doi.org/10.1016/j.compositesb.2011.11.009

Najm, H., Secaras, J., & Balaguru, P. (2007). Compression tests of circular timber column confined with carbon fibers using inorganic matrix. *Journal of Materials in Civil Engineering*, 19(2), 198-204. https://doi.org/10.1061/(ASCE)0899-1561(2007)19:2(198)

O'Callaghan, R. B., Lacroix, D., & Kim, K. E. (2022). Experimental investigation of the compressive behaviour of GFRP wrapped spruce-pine-fir square timber columns. *Engineering Structures*, 252, 113618. https://doi.org/10.1016/j.engstruct.2021.113618

Ouyang, L. J., Chai, M. X., Song, J., Hu, L. L., & Gao, W. Y. (2021). Repair of thermally damaged concrete cylinders with basalt fiber-reinforced polymer jackets. *Journal of Building Engineering*, 44, 102673. https://doi.org/10.1016/j.jobe.2021.102673

Raftery, G. M., & Harte, A. M. (2011). Low-grade glued laminated timber reinforced with FRP plate. *Composites Part B: Engineering*, 42(4), 724-735. https://doi.org/10.1016/j.compositesb.2011.01.029

Siha, A., Zhou, C., & Yang, L. (2021). Experimental study on axial compression behavior on circular timber columns strengthened with CFRP strips and near-surface mounted steel bars. *Journal of Structural Engineering*, 147(3). https://ascelibrary.org/doi/10.1061/%28ASCE%29ST.1943-541X.0002931#:~:text=https%3A//doi.org/10.1061/(ASCE)ST.1943%2D541X.0002931

Song, J., Gao, W. Y., Ouyang, L. J., Zeng, J. J., Yang, J., & Liu, W. D. (2021). Compressive behavior of heat-damaged square concrete prisms confined with basalt fiber-reinforced polymer jackets. *Engineering Structures*, 242, 112504. https://doi.org/10.1016/j.engstruct.2021.112504

Subagia, I. A., Kim, Y., Tijing, L. D., Kim, C. S., & Shon, H. K. (2014). Effect of stacking sequence on the flexural properties of hybrid composites reinforced with carbon and basalt fibers. *Composites Part B: Engineering*, 58, 251-258. https://doi.org/10.1016/j.compositesb.2013.10.027

Taheri, F., Nagaraj, M., & Khosravi, P. (2009). Buckling response of gluelaminated columns reinforced with fber-reinforced plastic sheets. *Composite Structure*, 88,481–490. https://doi.org/10.1016/j.compstruct.2008.05. 013

TS 5497 EN 408, 2006: *Timber structures-structural and glued laminated timber-determination of some physical and mechanical properties*, Institute of Turkish Standards, Ankara, Turkey.

TS 2472, 1976: *Wood* – determination of density for physical and mechanical tests. Institute of Turkish Standards, Ankara, Turkey.

TS 2595, 1976: *Wood-determination of ultimate stress in compression parallel to grai*n, Institute of Turkish Standards, Ankara, Turkey.

Wang, X., Zhou, A., Zhao, L., & Chui, Y. H. (2019). Mechanical properties of wood columns with rectangular hollow cross section. *Construction and Building Materials*, 214, 133-142. https://doi.org/10.1016/j.conbuildmat.2019.04.119

Wang, Z., Li, H., Fei, B., Ashraf, M., Xiong, Z., Lorenzo, R., & Fang, C. (2021). Axial compressive performance of laminated bamboo column with aramid fiber reinforced polymer. *Composite Structures*, 258, 113398. https://doi.org/10.1016/j.compstruct.2020.113398

Wu, X. (2020). Research progress on application of basalt fiber in civil engineering. *Bulletion of The Chinese Ceramic Society*, 39, 1043-1056.

Xiong, X. Y., & Su, Z. Y. (2015). Experimental study and theoretical analysis of carbon fibre-reinforced polymer strengthening timber pier column. *Materials Research Innovations*, 19(5), 1246-125 https://doi.org/10.1179/1432891714Z.0000000001288

Yang, L., Li, X., Fang, H., Liu, W., Hong, J., Hui, D., & Gaff, M. (2021). Compressive behaviour of wood-filled GFRP square columns with lattice-web reinforcements. *Construction and Building Materials*, 310, 125129. https://doi.org/10.1016/j.conbuildmat.2021.125129

Zhang, W., Song, X., Gu, X., & Tang, H. (2012). Compressive behavior of longitudinally cracked timber columns retrofitted using FRP sheets. *Journal of Structural Engineering*, 138(1), 90-98. https://doi.org/10.1061/(ASCE)ST.1943-541X.0000423

Zhang, Y., Wang, J., Lin, J., Zhang, F., & Yan, X. (2021). Crushing mechanical responses of natural wood columns and wood-filled composite columns. *Engineering Failure Analysis*, 124, 105358. https://doi.org/10.1016/j.engfailanal.2021.105358

Zhu, Y. M., Long, T., Hou, M., & Wang, Q. (2013). FRP reinforced short wood columns under axial compressive load. *Advanced Materials Research*, 671, 484-487. https://doi.org/10.4028/www.scientific.net/AMR.671-674.484