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1st International Conference on Modern and Advanced Research

July 29-31, 2023 : Konya, Turkey

https://as-proceeding.com/index.php/icmar

The Effect of Reinforcement Number on Bending Properties of Chestnut Glulam Beams

Şemsettin KILINÇARSLAN*, Yasemin ŞİMŞEK TÜRKER [2]

[1]Department of Civil Engineering, University of Süleyman Demirel, Turkey

*(semsettinkilincarslan@sdu.edu.tr)

Abstract – Throughout history, wood has been recognized as one of the most ancient construction materials. Wood material is used in a wide variety of fields due to its many positive properties. Despite its extensive use and distinct characteristics, it does have certain weaknesses, particularly in terms of being relatively brittle, especially under bending forces. To enhance its performance and reinforce wooden structural components, a viable solution is to incorporate FRP (Fiber-Reinforced Polymer) components, which are commonly utilized in rehabilitation processes. The versatility and ease of application with various materials like concrete, wood, and steel have facilitated the enhancement of structural elements' strength and ductility. In recent years, fiber-reinforced polymers have been widely used to strengthen wooden structures. In this study, the effect of FRP reinforcement number on the bending properties of glulam beams obtained from chestnut tree species was investigated. Chestnut beams were reinforced with 1, 2 and 3 layers of FRP. The beams were subjected to the bending test. After the bending test, the maximum load carrying capacity, bending strength and modulus of elasticity values were examined. Obtained findings showed that flexural properties increased with strengthening. In addition, with the increase in the number of reinforcements, the maximum load carrying capacity, modulus of elasticity and flexural strength values increased.

Keywords – Wood Materials, Reinforcement, FRP, Glulam, Chestnut

I. INTRODUCTION

Wood has gained increasing popularity in structures due to its high tensile and compressive strength relative to its weight, its resilience against environmental impacts with proper precautions, and its sustainable nature when sourced from industrial forestry [1]. Moreover, wood's lightweight and remarkable resistance to dynamic effects, such as earthquakes, have contributed to its widespread use. This trend has led to the emergence of larger wooden structures, including multi-story buildings, industrial facilities, sports arenas, bridges, power transmission lines, and water towers [2]. Consequently, special wood structural elements supported by composite materials have been developed to replace solid wood elements. A prime example of these special wooden structural elements is laminated wooden beams, also known as glulam timber beams [3,4].

As the size and utilization of timber structures have expanded across various systems, there arises a need for glulam timber beams with larger openings and higher capacities. Additionally, timber structures might require reinforcement or retrofitting to accommodate increased traffic loads on highway or railway bridges and withstand dynamic earthquake effects [5-7].

Traditionally, steel or metal profiles were attached to timber elements using nails and screws or other materials to reinforce timber structures, often placed in the tension zone of the beams. Over time, certain drawbacks in such applications have been observed: increased structure weight, reduced installation height, lower durability due to corrosion, geometric limitations hindering adaptation to non-straight forms (e.g., arches, vaults, or domes), and high overall construction costs [8].

To address these issues, recent studies have explored the use of carbon or glass fiber-reinforced polymer fabrics as alternatives to steel elements for strengthening timber structural elements. Since 1965, Glulam beams have been reinforced with GFRP (Glass Fiber Reinforced Polymer) [9, 10]. In 1992, CFRP (Carbon Fiber Reinforced Polymer) was first utilized as a strengthening material [11]. Various studies have been conducted by researchers to analyze the strengthening of glulam beams using CFRP and GFRP for diverse purposes, employing analytical methods [12]. In their research, Kim et al. [13] presented the experimental findings of spruce wooden beams and substructures extracted from a 32-year-old university building. They strengthened these beams with pultruded CFRP laminate. As demonstrated in their model [14], the CFRP reinforcement significantly increased the bearing capacity of the timber beams, ranging from 33% to 184% compared to control specimens. The strain behavior showed a linear response without plastification. Numerous studies have explored the use of FRP pultruded rods for strengthening purposes. For instance, Borri et al. [15] investigated the effects of externally adhered CFRP pultruded laminates applied to the tension zone located at the corners of the drawer bottom of the wooden beams. They placed one or two rods into slits in the tension zone. The results showed improvements in ultimate strength of about 42% and 60% (for two or three strips, respectively) and 55% for corner strips. In this study, the effect of FRP reinforcement number on the bending properties of glulam beams obtained from chestnut tree species was investigated. Chestnut beams were reinforced with 1, 2 and 3 layers of FRP.

II. Materials and Method

Glulam beams were used, made from chestnut (Castenea sativa) wood, with the dimensions of 120 mm (width) x 120 mm (height) x 2500 mm (length) in a 3-layer configuration. Each layer had a thickness of 40 mm. The bonding between the lamellas was achieved using melamine formaldehyde glue, following the instructions provided by the glue manufacturer company. The glue was applied toonly one of the opposing lamella surfaces with a brush, at an approximate rate of ~180 gr/m^2.

During the gluing process, the lamellas were compressed with a pressure of around 1-2 N/mm² at 3 different points using a clamp. After compression, the assembled beams were kept at room temperature for 24 hours to ensure proper hardening of the glue.

Chestnut wood, known for its widespread use in the production of wood composites and particularly for structural purposes, was the focus of this investigation. The beams used in the study were provided by Nasreddin Forest Products (Naswood) in Antalya Organized Industry. Before subjecting the glulam beams to the bending test, they were conditioned in an air conditioning cabinet at 65% relative humidity and 25°C until the equilibrium humidity reached 12%.

In this study, chestnut beams were reinforced with carbon fiber reinforced polymer fabrics in 1, 2 and 3 layers. In accordance with the standard GB/T 26899-2011, a static four-point load bending test (Method A) was performed at a loading speed of 8 mm/min. To monitor the deformation, an LVDT (Linear Variable Differential Transformer) sensor was placed at the center of each specimen.

In order to calculate the modulus of elasticity (MOE) for bending and modulus of rupture (MOR), Gao et al. (2015) [16] employed the following equation:

$$MOE=\frac{\Delta P\ (l-s)(2l^2+2ls-s^2)}{8\Delta y b h^3} \quad (1)$$

$$MOR=\frac{3P_{max}(l-s)}{2bh^2} \quad (2)$$

In the formula below, the variables represent the following parameters:

Δy: Midspan deflection corresponding to ΔP
b: Width of the specimen
h: Depth of the specimen
P_{max}: Maximum load applied
l: Span between supports of the specimen
s: Span between loading sites of the specimen
ΔP: Difference between the upper and lower loads at the proportional limit.

III. Results and Discussion

The flexural strength and modulus of elasticity values of 1, 2 and 3 layers reinforced chestnut glulam beams are given in Fig. 1 and Fig. 2.

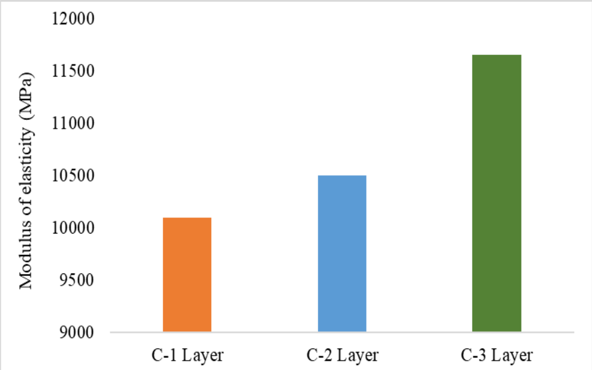

Fig. 1. Experimental results of modulus of elasticity

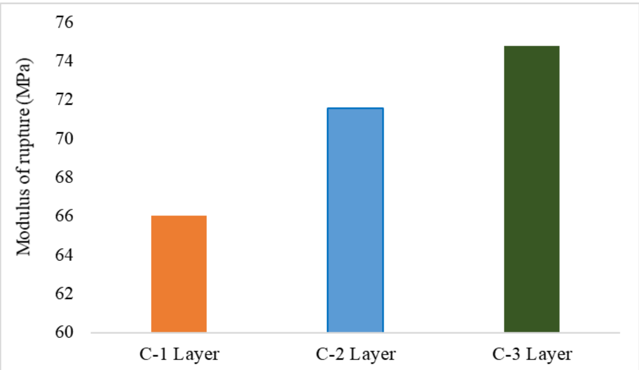

Fig. 2. Experimental results of modulus of rupture

As a result of this study, it was determined that the modulus of rupture value was 13% higher in the 3-layer reinforced beam than in the 1-layer reinforced beam. It was determined that the modulus of rupture value of 2-layer reinforced beams is higher than 1-layer reinforced beam. When the modulus of elasticity values was examined, it was determined that the modulus of elasticity of the 3-fold reinforced beam was 15% higher than that of the 1-layer reinforced beam.

IV. Conclusion

The effect of FRP reinforcement number on the bending properties of glulam beams obtained from chestnut tree species was investigated. Chestnut beams were reinforced with 1, 2 and 3 layers of FRP. The findings of this investigation revealed that the 3-layer reinforced beam exhibited increase in the modulus of rupture compared to the singly reinforced beam. Moreover, the 2-layer reinforced beams displayed a higher modulus of rupture compared to the 1-layer reinforced beam. In terms of the modulus of elasticity, the 3-layer reinforced beam demonstrated a substantial enhancement in comparison to the 1-layer reinforced beam. It is seen that the properties of the beams produced from wood materials with low mechanical properties are improved with the reinforcement. Therefore, it is important to apply FRP to beams produced from various wood materials.

Acknowledgment

This study has been prepared within the scope of the thematic area of "Sustainable Building Materials and Technologies" with SDÜ BAP project with FDK-2019-6950 project code and YÖK 100/2000 doctoral program. The authors thank the SDU BAP unit, YÖK and YÖK100/2000 program staff.

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