Celal Bayar University Journal of Science
Volume 18, Issue 1, 2022, p 9-16
Doi: 10.18466/cbayarfbe.958377


**Celal Bayar University Journal of Science**

# The Effect of Wood Species and Strip Width on Bending Strength and Modulus of Elasticity in End-Grain Core Blockboard

Yasemin Öztürk[1]*, Kıvanç Yılmaz[1, 2], Erol Burdurlu[1]

[1]Faculty of Technology, Gazi University, Dept. of Wood Products Industrial Engineering, Ankara, Turkey
[2]School of Vocational Technology, Hacettepe University, Dept. of Wood Products Industrial Engineering, Ankara, Turkey
* yozturk@gazi.edu.tr
* Orcid: 0000-0003-2292-2447

Received: 27 June 2021
Accepted: 8 March 2022
DOI: 10.18466/cbayarfbe.958377

## Abstract

It is aimed to compare the bending strength and modulus of elasticity of end-grain (vertical strip) core blockboard, unlike the usual (lengthwise strip core) blockboard construction, with that of the traditional blockboard with the face-grain or edge-grain core construction. Oriental beech and black poplar woods are provided by taking care to avoid the grain irregularities and visible defects are used in the study. These timbers are used to obtain the core, top and bottom layers of the blockboard. PVAc mounting glue is used for bonding the layers together. According to the test data: The bending strength and modulus of elasticity of oriental beech blockboard are 39% and 26% higher respectively than that of end-grain core black poplar blockboards. If we evaluated by neglecting wood species, strip width was an effective factor in the bending strength and ineffective modulus of elasticity. In addition, the bending strength of the end-grain core oriental beech blockboard is 79 MPa and that of the end-grain core black poplar blockboard is 57 MPa, regardless of the width of the core strip. When these values are compared with the values of other engineered wood, the result is considered open to improvement and satisfactory.

**Keywords:** Blockboard, Core Structure, Wooden Board, Bending Strength, Modulus of Elasticity

## 1. Introduction

Blockboard is defined as "A core layer made of strip bonded side by side and face layers formed by glueing at least one sheet perpendicular to the fiber direction on both sides of this layer under pressure". The blockboards are divided into two types, three-ply and five-ply, according to the number of layers, and the sheets forming the outer layers must be of the same wood species[1].

Blockboard is one of the alternative materials with better bending strength performance than plywood. The main prominent feature of the blockboard material is that it is produced from a core-containing frame formed by end-to-end additions from different types of wood materials, compressed with cross bands or face coverings on both sides and surrounded by solid wood borders, as can be seen in Figure 1 [2,3]. Blockboards produced by bonding under high pressure and temperature are considered as different types of plywood[4]. Blockboards are widely used in products such as furniture, cabinet backs and centre panels for framed doors, kitchen cabinets, cores for recessed doors, light and decorative doors[5,6].

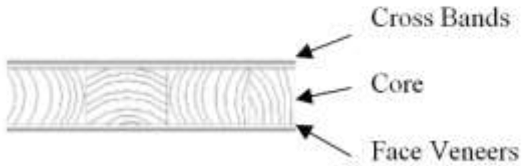


**Figure 1.** Cross-sectional view of a blockboard[7]

The wood species and quality of the layers, the type of glue used in bonding, fiber direction and angle affect the physical and mechanical properties of the wooden products[8–11].

Miter or notched joints are used instead of straight joints in the end-to-end joining of the bending strength of the blockboard [12]. The use of oiled wood dowel in the transverse direction and along the middle with the glue to bring the strips forming the mid-layer (core) side by side has positive effects on the bending strength, modulus of elasticity, and water resistance of the board [13]. In the cores of blockboards that can be used in different places such as flooring, formwork plate, floor coverings of railway wagons and caravans, barrel bottom and cover; using solid wood pieces combined side by side with dowels at an angle of up to 20 degrees increase the bending and tensile strength up to 20% [14]. By using different materials in the core, relatively lighter, environmentally friendly and lower cost blockboards can be produced [15,16]. By placing materials such as glass fiber, gauze, cotton fabric and jute between the core and both top and bottom face layer, an increase in the breaking and elastic modulus of the blockboard can be achieved from 35% to 245% [17].

The impregnation of the solid wood material used in its core with boron compounds increases the resistance of the blockboard against fungi that cause rotting [18]. The veneers used in the blockboard were treated with either boric acid (BA), disodium octoborate tetrahydrate (DOT), alumina trihydrate (ATH), or a BA/DOT mixture. Treatments had a little negative effect on flexural strength; flexural stiffness was significantly lower for the highest treatment levels [19].

By comparing the flexural performance of unreinforced low-grade glulam and glulam which was reinforced with adhesively bonded recyclable Fibre-reinforced polymers (FRPs), Raftery and Harte[20] found that glass fibre reinforced polymer plates could be a good alternative to serve both as flexural reinforcement for low-grade glulam beams and a substitute for high-quality wood laminations.
The massive parts used in the production of the core in the usual blockboard production are horizontal and the fiber direction is parallel to the horizontal (face-grain structure)[21].

It has been observed that the direction of the forces applied on the glue line and the densities of the wood materials used are effective in the strength values in two different studies conducted to determine the flexural strength and elasticity modulus values of wood-based laminated materials obtained by using Eastern beech and Lombardy poplar. In both studies, the flexural strength and modulus of elasticity values of the test materials were observed to be high against the forces applied parallel to the glue line[22,23].

In the study, it was aimed to determine the bending strength and modulus of elasticity of the blockboard, which was constructed by directing vertically the fiber directions of the solid wood strips used as core with a different technique (end grain structure).

## 2. Materials and Methods
### 2.1. Materials

Oriental beech (Fagus Orientalis L.) and black poplar (Populus Nigra L.) woods provided from a supplier as timber in Ankara/Siteler region by taking care to avoid the grain irregularities and visible defects were used in the study as core and face materials.

APEL brand PVAc mounting glue was used for bonding the core strips and facings together. According to the values reported by the manufacturer, the minimum film-forming temperature of the glue is 7℃, and the curing time varies between 45 minutes and 2 hours.

### 2.2. Preparation of Test Samples

A sufficient number of core strips were cut from oriental beech and black poplar timbers in finished dimensions of 14 x 22 mm, 28 x 22 mm and 42 x 22 mm (width x thickness) and 500 mm length. In addition, oriental beech and black poplar sheets in 5 mm x 22 mm x 380 mm dimensions were manufactured to form the top and bottom layer of the blockboards. Panels with dimensions of 22 x 380 x 500 mm were manufactured by glueing 14 mm, 28 mm and 42 mm strips side by side with PVAc glue, separately in each size group. The glueing process was carried out by applying an equal amount of 250 grams per square meter, depending on the manufacturer's recommendation. Panels were machined to a finished thickness of 20 mm by passing through a calibrated sanding machine with 80-grade sandpaper at a speed of 10 m / sec. The pieces were cut so that the core thickness was 16 mm and the sheets were bonded with PVAc glue on top and bottom of these pieces. Subsequently, the pieces were machined to a finished size of 20x 26 x 360 mm. Completely solid wood control samples of 20x20x360 mm were prepared from oriental beech and black poplar (Figure 2).

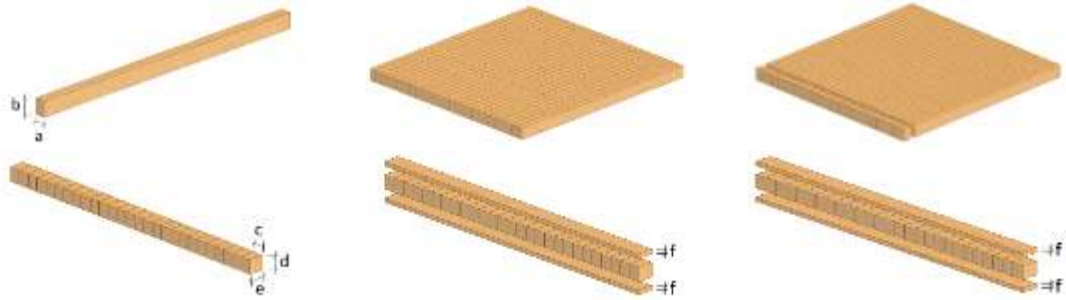


**Figure 2.** The process of preparing test samples (a: 14, 28 ve 42 mm; b: 22 mm e: 20 mm; d: 16 mm; c: 14, 28 ve 42 mm; f: 5 mm)

Celal Bayar University Journal of Science
Volume 18, Issue 1, 2022, p 9-16
Doi: 10.18466/cbayarfbe.958377


### 2.3. Methods

In the tests of bending strength perpendicular to the surface, the principles specified in the [24] standard were followed. In the tests, the samples were loaded right in the middle and the loading speed of the test device was set as 2 mm/min. The bending strength was calculated by:

$$F_m = (3 \times F_{max} \times L)/(2 \times b \times h^2) \qquad \textbf{(2.1)}$$

Where $F_m$ is bending strength (MPa), $F_{max}$ is the maximum load at break (N), $L$ is support clearance (mm), $b$ is sample width (mm) and $h$ is sample thickness (mm).

In bending tests, the modulus of elasticity was also calculated. For this purpose, the principles specified in the [25] standard were followed and the calculations were made according to:

$$E = (\Delta F \times L^3)/(4 \times b \times h^3 \times \Delta f) \qquad \textbf{(2.2)}$$

Where $E$ is the modulus of elasticity (MPa), $\Delta F$ is the difference in applied forces (N), $L$ is support clearance (mm), $b$ is sample width (mm), $h$ is sample thickness (mm) and $\Delta f$ is displacement amount (mm).

### 2.4. Statistical Analysis

In order to determine the statistical analysis method, whether the data obtained from the tests show a normal distribution or not was tested with IBM SPSS Statics Version 22 package program and it was seen that the data showed normal distribution according to the distribution criteria of kurtosis and skewness [26]. After this analysis, multiple variance analysis was performed in the MSTAT-C Version 5.4 package program to determine whether the independent variables of wood type and middle layer strip width affect the dependent variable of elasticity modulus in bending. Duncan's multiple range test was used to level the effect sizes of variables in case of interaction between variables.

## 3. Results and Discussion

### 3.1. The Effect of Wood Type and Strip Width on Bending Strength

The bending resistance values obtained as a result of the tests are given in Table 1 and shown in Figure 3 according to the wood type and strip width.

**Table 1.** Bending strength values of end-grain core blockboard according to wood type and strip width

| | **Bending Strength Values (MPa)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Oriental Beech** | | | | **Black Poplar** | | | |
| | **Control** | **14 mm** | **28 mm** | **42 mm** | **Control** | **14 mm** | **28 mm** | **42 mm** |
| **Minimum** | 84.67 | 65.62 | 54.35 | 65.52 | 91.16 | 37.01 | 31.90 | 32.04 |
| **Maximum** | 120.54 | 78.60 | 74.34 | 83.13 | 124.81 | 46.62 | 48.38 | 49.59 |
| **Average** | 108.27 | 71.78 | 66.13 | 73.50 | 105.73 | 42.07 | 39.59 | 41.53 |
| **Standard deviation** | 9.56 | 3.45 | 4.07 | 4.33 | 9.37 | 2.98 | 4.72 | 3.43 |
| **Coefficient of variation** | 8.83 | 4.81 | 6.15 | 5.89 | 8.86 | 7.09 | 11.93 | 8.26 |

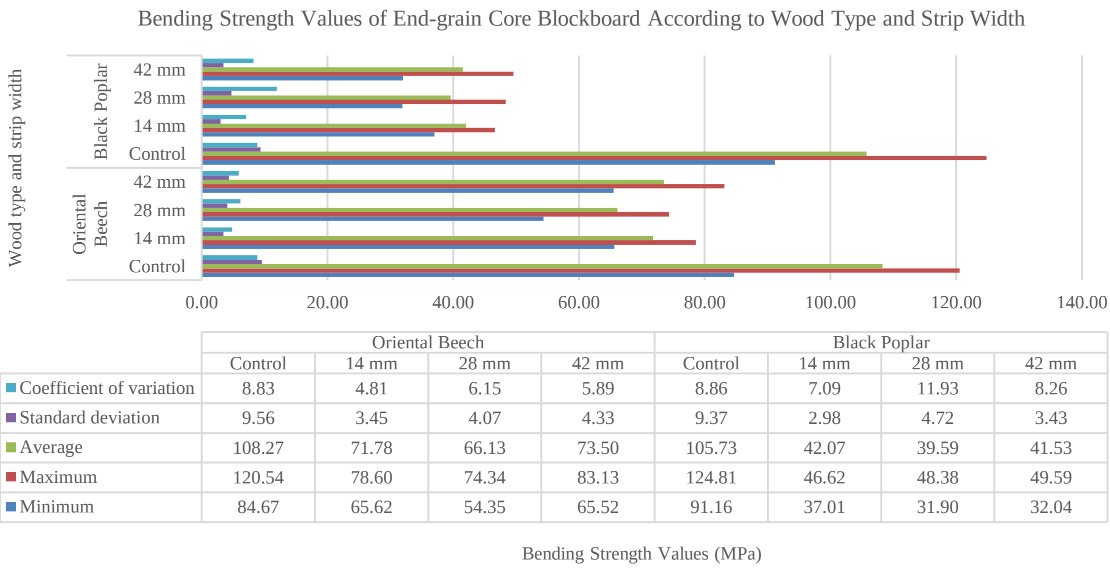


**Figure 3.** Bending strength values of end-grain core blockboard according to wood type and strip width

According to the bending strength values given in Table 1, the analysis of variance was given in Table 2 to determine whether the wood species and width of the strip used in the core affected the bending strength.

As seen from Table 2, the wood species of strip used in the core, strip width and the dual interaction of these two variables were effective on the bending strength ($p < 0.05$).

**Table 2.** Multiple variance analysis for the effect of wood type and strip width on bending strength

| Variance Sources | Degree of Freedom | Sum of Squares | Average of Squares | F Value | Probability of Error (p < 0.05) |
|---|---|---|---|---|---|
| **Strip width (A)** | 3 | 79,261.22 | 26,420.41 | 745.79 | 0.00* |
| **Wood species (B)** | 1 | 20,595.87 | 20,595.87 | 581.38 | 0.00* |
| **AB** | 3 | 5,563.37 | 1,854.46 | 52.35 | 0.00* |
| **Error** | 152 | 5,384.73 | 35.43 | | |
| **Total** | 159 | 110,805.19 | | | |

*p<0.05

The levelling made depending on the importance of the differences between the bending strength values obtained depending on the width of each strip is given in Table 3.

**Table 3.** Levelling of bending strength values depending on strip widths

| Strip Width | Bending Strength (MPa) | Homogeneity Group |
|---|---|---|
| **Control Group** | 107.00 | A |
| **14 mm** | 56.93 | B |
| **28 mm** | 52.86 | C |
| **42 mm** | 57.52 | B |

Least Significant Difference (LSD) = 2.63

According to the strip widths, the highest bending strength was obtained with 107 MPa from the control samples, while the difference between them was insignificant, followed by the samples with 14 mm and 42 mm strip widths, and the lowest bending strength was obtained in the samples with 28 mm strip width.

The levelling made depending on the importance of the difference between the bending strength values depending on the wood species is given in Table 4.

**Table 4.** Levelling bending strength values depending on the wood species

| Wood Species | Bending Strength (MPa) | Homogeneity Group |
|---|---|---|
| **Oriental Beech** | 79.92 | A |
| **Black Poplar** | 57.23 | B |

Least Significant Difference (LSD) = 1.859

With the value of 79.92 MPa, the bending strength values of the blockboards with oriental beech core were higher than the blockboards with black poplar core (57.23 MPa).

The levelling made depending on the importance of the differences between the bending strength values due to the binary interaction of strip width and wood species is given in Table 5.

**Table 5.** Levelling bending strength values based on binary interaction of strip width and wood species

| Interaction Type | Bending Strength (MPa) | Homogeneity Group |
|---|---|---|
| **Control x Oriental Beech** | 108.30 | A |
| **Control x Black Poplar** | 105.70 | A |
| **42 mm x Oriental Beech** | 73.50 | B |
| **14mm x Oriental Beech** | 71.79 | B |
| **28 mm x Oriental Beech** | 66.13 | C |
| **14 mm x Black Poplar** | 42.07 | D |
| **42 mm x Black Poplar** | 41.53 | D |
| **28 mm x Black Poplar** | 39.59 | D |

Least Significant Difference (LSD) = 3.72

Depending on the dual interaction of strip width and wood species, the highest bending strength was achieved in the oriental beech end-grain core blockboards with 42 mm and 14 mm strip width, followed by oriental beech end-grain core blockboards with 28 mm strip width. Strip width was not found to be effective on bending strength in black poplar end-grain core blockboards.

### 3.2. The Effect of Wood Type and Strip Width on Elasticity Modulus in Bending

The test values of modulus of elasticity in bending obtained from the tests according to the wood species and strip width are given in Table 6 and shown in Figure 4.

**Table 6.** Modulus of Elasticity values of end-grain core blockboard according to wood species and strip width

| | Modulus of Elasticity (MPa) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Oriental Beech | | | | Black Poplar | | | |
| | Control | 14 mm | 28 mm | 42 mm | Control | 14 mm | 28 mm | 42 mm |
| **Minimum** | 7,183.21 | 6,683.75 | 5,057.79 | 6,440.85 | 8,404.97 | 3,979.49 | 3,609.12 | 3,097.60 |
| **Maximum** | 10,320.84 | 8,449.78 | 7,760.02 | 8,653.74 | 12,046.47 | 5,728.67 | 5,701.49 | 5,320.68 |
| **Average** | 9,307.02 | 7,531.54 | 6,975.45 | 7,205.49 | 10,466.59 | 4,726.28 | 4,864.54 | 4,623.77 |
| **Standard deviation** | 783.29 | 422.21 | 524.40 | 543.92 | 920.06 | 494.88 | 552,18 | 524,47 |
| **Coefficient of variation** | 8.42 | 5.61 | 7.52 | 7.55 | 8.79 | 10.47 | 11,35 | 11,34 |

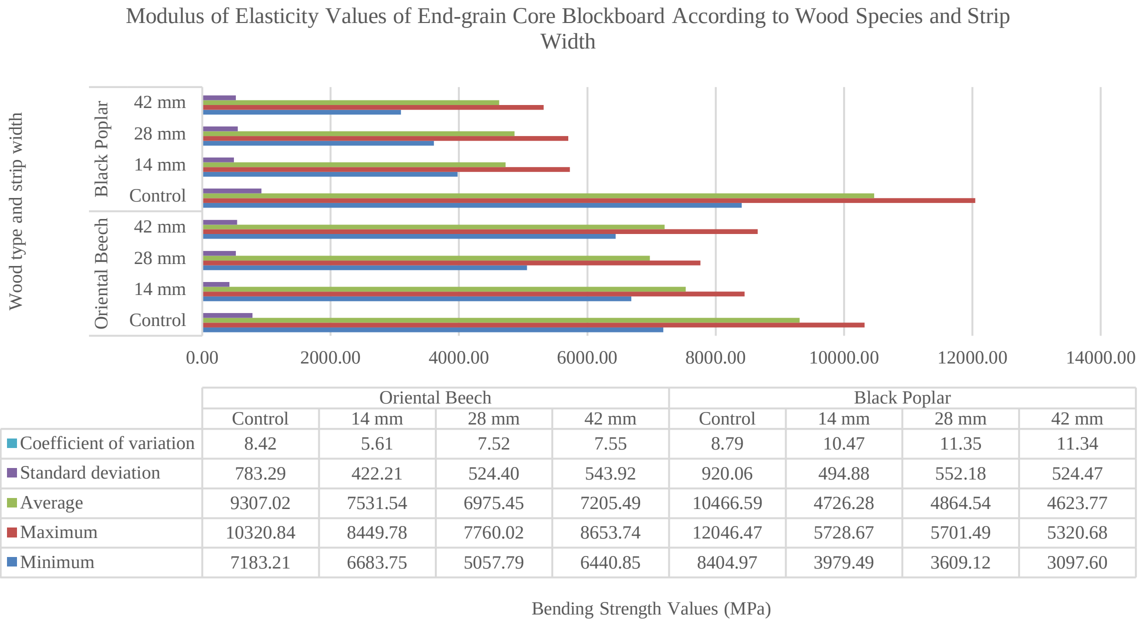


**Figure 4.** Modulus of Elasticity values of end-grain core blockboard according to wood species and strip width

According to the bending strength values given in Table 6, an analysis of variance is given in Table 7 to determine whether the wood species and width of strip used in the core affect the bending strength. As can be seen from Table 7, strip width, wood species and mutual interaction of these two variables were effective on elastic modulus in bending.

**Table 7.** Multiple variance analysis of the effect of wood species and strip width on elastic modulus in bending

| Variance Sources | Degree of Freedom | Sum of Squares | Average of Squares | F Value | Probability of Error ($p < 0.05$) |
|---|---|---|---|---|---|
| **Strip width (A)** | 3 | 457,762,038.72 | 152,587,346.24 | 381.68 | 0.00* |
| **Wood species (B)** | 1 | 100,592,063.80 | 100,592,063.80 | 251.62 | 0.00* |
| **AB** | 3 | 102,681,051.93 | 34,227,017.31 | 85.61 | 0.00* |
| **Error** | 152 | 60,766,458.67 | 399,779.33 | | |
| **Total** | 159 | 721,801,613.12 | | | |

*p<0.05

The levelling made depending on the importance of the differences between the elasticity modulus values in bending obtained depending on the width of each strip is given in Table 8.

The elastic modulus (9,889 MPa) of the control group samples was higher than the elastic modulus values of the end-grain core blockboards. Since the difference between elastic modulus values was insignificant, strip width did not affect the elastic modulus in bending.

**Table 8.** Levelling of elastic modulus values in bending depending on strip widths

| Strip Width | Modulus of Elasticity (MPa) | Homogeneity Group |
|---|---|---|
| **Control Group** | 9,889 | A |
| **14 mm** | 6,129 | B |
| **28 mm** | 5,920 | B |
| **42 mm** | 5,915 | B |

Least Significant Difference (LSD) = 279.2

**Table 9.** Levelling the elastic modulus values in bending depending on the tree type

| Wood Species | Modulus of Elasticity (MPa) | Homogeneity Group |
|---|---|---|
| **Oriental Beech Core** | 7,756 | A |
| **Black Poplar Core** | 6,170 | B |

Least Significant Difference (LSD) = 197.40

The levelling made depending on the importance of the differences between the elasticity modulus values in bending according to the wood type is given in Table 9.

As seen from Table 9, the modulus of elasticity in bending (7,756 MPa) of the blockboard with oriental beech core was higher than that of the blockboard with black poplar core (6,170 MPa).

The levelling made depending on the importance of the difference between the modulus of elasticity values due to the dual interaction of strip width and wood species is given in Table 10.

**Table 10.** Levelling of the modulus of elasticity values based on binary interaction of strip width and wood species

| Interaction Type | Modulus of Elasticity (MPa) | Homogeneity Group |
|---|---|---|
| **Control x Black Poplar** | 10,470 | A |
| **Control x Oriental Beech** | 9,312 | B |
| **14mm x Oriental Beech** | 7,532 | C |
| **42 mm x Oriental Beech** | 7,205 | CD |
| **28 mm x Oriental Beech** | 6,975 | D |
| **28 mm x Black Poplar** | 4,865 | E |
| **14 mm x Black Poplar** | 4,726 | E |
| **42 mm x Black Poplar** | 4,624 | E |

Least Significant Difference (LSD) = 394.90

As seen from Table 10, the highest modulus of elasticity was obtained in the blockboard from black poplar with the value of 10,470 MPa, followed by the blockboard from oriental beech with the value of 9,312 MPa. While the width of the strip was found effective on the modulus of elasticity in the oriental beech core blockboards, it was not found effective on the black poplar ones.

## 4. Conclusions

This study, it is aimed to determine the effect of strip width and wood species on the modulus of elasticity in bending and bending strength in end-grain core blockboards. In the usual blockboards, the direction of the strips forming the core is parallel to the horizontal and in the direction of the length. In this study, the strips forming the core were perpendicular to the horizontal and in the direction of the thickness of the blockboard to ensure more effective use of waste and non-standard wooden parts and this study is a pioneering work in this respect.

The bending strength and modulus of elasticity of oriental beech end-grain core blockboards were 39% and 26% higher, respectively, compared to black poplar ones. It is thought that the higher the density of the oriental beech and the lower the void ratio affected this result. In oriental beech end-grain core blockboards, higher bending strength and modulus of elasticity values were obtained in the blockboards with core from the strips 14 mm and 42 mm in width compared to 28 mm strip width without any noticeable difference between them. And also, the strip width was not an effective factor in bending strength and modulus of elasticity in black poplar end-grain core blockboards. As another result, regardless of the wood type, strip width was an ineffective factor on the modulus of elasticity, but effective on bending strength.

Efe and Kasal[27], determined bending strengths as 129 MPa in oriental beech, 73 MPa in Scots pine, 65 MPa in Okume blockboard, 32 MPa in MDF (Medium-Density Fiberboard) and OSB (Oriented Strand Board) in their studies. In the same study, the modulus of elasticity was found as 12,250 MPa, 11,760 MPa, 7,730 MPa, 5,498 MPa, 6,530 MPa, respectively. Altınok and Kılıç found the bending strength of particleboard as 12 MPa and the bending strength of particleboard faced with laminate (CPL) as 24 MPa [28].

According to the data obtained from this research, the bending strength of the end-grain core oriental beech blockboard is 79 MPa and that of the end-grain core black poplar blockboard is 57 MPa, regardless of the width of the core strip. When these values are compared with the values of other engineered wood, the result is considered open to improvement and satisfactory.

By using the wood species, strip width and adhesive type variables, it is possible to manufacture different end-grain (vertical strip) core blockboard and strength values can be further improved.

## Author's Contributions

**Yasemin Öztürk:** Made literature search, prepared the samples used in the experimental work, wrote the manuscript, and performed the experiment and result in analysis.
**Kıvanç Yılmaz:** Made literature search, prepared the samples used in the experimental work, wrote the manuscript, and performed the experiment and result in analysis.
**Erol Burdurlu:** Supervised the experiment's progress, result in interpretation and helped in manuscript preparation.

## Ethics

There are no ethical issues after the publication of this manuscript.

## References

**[1].** TSE, *TS 1047 - Blockboards for general purposes-with rotary cut veneer*. Turkey: Turkish Standardization Institute (TSE), 1982.

**[2].** Eterno Teixeira, D., & Penna Firme de Melo, M. 2017. Effect of battens edge bonding in the properties of blockboards produced with pinus sp. recycled from construction sites. *Asian Journal of Advances in Agricultural Research;* 4(2), 1-11. https://doi.org/10.9734/AJAAR/2017/38389.

**[3].** Nazerian, M.., Moazami, V., Farokhpayam, S., Gargari, R. M. 2018. Production of blockboard from small athel slats end-glued by different type of joint. *Maderas, Cienc. tecnol;* 20(2): 277-286. ISSN 0718-221X. http://dx.doi.org/10.4067/S0718-221X2018005021101.

**[4].** Zanuttini, R., Cremonini, C. 2002. Optimization of the test method for determining the bonding quality of core plywood (Blockboard). *Mater Struct*; 35(246):126–132.

**[5].** Laufenberg, T., Ayrilmis, N. and White, R. 2006. Fire and bending properties of blockboard with fire retardant treated veneers. *Holz Roh Werkst*; 64: 137–143, https://doi.org/10.1007/s00107-005-0041-4.

**[6].** Kartal, S. N., Ayrilmis, N. 2005. Blockboard with boron-treated veneers: laboratory decay and termite resistance tests, *International Biodeterioration & Biodegradation*; 55(2): 93-98, ISSN 0964-8305, https://doi.org/10.1016/j.ibiod.2004.08.001.

**[7].** Kiran, M. C., Dhanapal, S., Uday, D., Vijay Kumar, P. 2020. Block Board from Melia dubia. *International Journal of Forestry and Wood Science*, 7(2): 096-100.

**[8].** Hearmon, R. F. S. 1948. Elasticity of Wood and Plywood. *Nature*; 162(4125): 826–826, doi: 10.1038/162826a0.

**[9].** Dzięgielewski, A., Wilczyński, St. 1990. Elasticity of furniture elements glued by layers. *Zesz. Probl. Postępów Nauk Rol.;* 379: 89–107.

**[10].** Prekrat, S. and Smardzewski, J. 2008. Effect of wood species and glue type on contact stresses in a mortise and tenon joint. *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.*; 222(12); 2293–2299, doi: 10.1243/09544062JMES1084.

**[11].** Fakoor, M. and Rafiee, R. 2013. Transition angle, a novel concept for predicting the failure mode in orthotropic materials. *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.;* 227(10); 2157–2164, doi: 10.1177/0954406212470905.

**[12].** Nazerian, M., Moazami, V., Farokhpayam, S. and Gargari, R. M. 2018. Production of blockboard from small athel slats end-glued by different type of joint. *Maderas Cienc. y Tecnol.*; 20(2): 277–286, doi: 10.4067/S0718-221X2018005021101.

**[13].** Segovia, C., Zhou, X. and Pizzi, A. 2013. Wood blockboards for construction fabricated by wood welding with pre-oiled dowels. *J. Adhes. Sci. Technol.*; 27(5–6): 577–585, doi: 10.1080/01694243.2012.690616.

**[14].** Belleville, B., Segovia, C., Pizzi, A., Stevanovic, T. and Cloutier, A. 2011. Wood Blockboards Fabricated by Rotational Dowel Welding. *J. Adhes. Sci. Technol.*; 25(20): 2745–2753, doi: 10.1163/016942410X537323.

**[15].** Haseli, M., Layeghi, M. and Hosseinabadi, H. Z. 2018. Characterization of blockboard and battenboard sandwich panels from date palm waste trunks. *Measurement*; 124: 329–337, doi: 10.1016/j.measurement.2018.04.040.

**[16].** El-Mously, H. Rediscovering Date Palm by-products: an Opportunity for Sustainable Development, Materials Research Forum LLC, Materials Research Proceedings 11, 2019, pp. 3-61, doi: 10.21741/9781644900178-1.

**[17].** Ispas, M., Cosereanu, C., Zeleniuc, O. and Porojan, M. 2019. Flexural properties of blockboard reinforced with glass fiber and various types of fabrics. *BioResources*; 14(4): 9882–9892, doi: 10.15376/biores.14.4.9882-9892.

**[18].** Kartal, S. N. and Ayrilmis, N. 2005. Blockboard with boron-treated veneers: laboratory decay and termite resistance tests. *Int. Biodeterior. Biodegradation*; 55(2): 93–98, doi: 10.1016/j.ibiod.2004.08.001.

**[19].** Laufenberg, T., Ayrilmis, N. & White, R. 2006. Fire and bending properties of blockboard with fire retardant treated veneers. *Holz Roh Werkst*; 64: 137-143, doi: https://doi.org/10.1007/s00107-005-0041-4

**[20].** Raftery, G. M. and Harte, A. M. 2011. Low-grade glued laminated timber reinforced with FRP plate. *Compos. Part B Eng.*; 42(4): 724–735, doi: 10.1016/j.compositesb.2011.01.029.

**[21].** Altenbach, H. 2011. Mechanics of advanced materials for lightweight structures. *Proc. Inst. Mech. Eng. Part C J. Mech. Eng. Sci.*; 225(11): 2481–2496, doi: 10.1177/0954406211417068.

**[22].** Kilic, M. 2011. The effects of the force loading direction on bending strength and modulus of elasticity in laminated veneer lumber (LVL). *BioResources*; 6(3): 2805-2817.

**[23].** Burdurlu, E., Kilic, M., Ilce, A. C. and Uzunkavak, O. 2007. The effects of ply organization and loading direction on bending strength and modulus of elasticity in laminated veneer lumber (LVL) obtained from beech (Fagus orientalis L.) and lombardy poplar (Populus nigra L.). *Construction and Building Materials*; 21(8): 1720-1725, ISSN: 0950-0618, https://doi.org/10.1016/j.conbuildmat.2005.05.002.

**[24].** TSE, *TS 2474 - Wood-determination of ultimate strength in static bending*. Turkey: Turkish Standardization Institute(TSE), 1976.

**[25].** TSE, *TS 2478 - Wood-Determination of Modulus of Elasticity In Static Bending*. Turkey: Turkish Standardization Institute(TSE), 1976.

**[26]**. Wright, D. B. and Herrington, J. A. 2011. Problematic standard errors and confidence intervals for skewness and kurtosis. *Behav. Res. Methods*; 43(1): 8–17, doi: 10.3758/s13428-010-0044-x.

**[27].** Efe, H. and Kasal, A. 2007. Determination of Some Physical and Mechanical Properties of Various Wood and Wood Composite Materials. *J. Polytech*; 10(3): 303–311, Retrieved from: https://dergipark.org.tr/tr/pub/politeknik/issue/33026/367180.

**[28].** Altınok, M. and Kılıç, A. 2003. Determination of some mechanical performances of particle board covered with roll (continue press laminate) laminate. *Gazi Univ. J. Sci.*; 16(3): 559–566, Retrieved from: https://dergipark.org.tr/tr/pub/gujs/issue/7405/97150#article_cite.