2nd International Vocational Science Symposium., IVSS 2018
2. Uluslararası Mesleki Bilimler Sempozyumu, IVSS 2018

http://www.meslekisempozyum.com

IVSS 2018

© Mesleki Bilimler Dergisi (MBD) & Ankara Üniversitesi

Received date; reviewed; accepted date

Karbon Fiber (CFRP) ile Güçlendirilmiş Lamine Ağaç Malzemenin Bazı Mekanik Özelliklerinin Belirlenmesi

Cihan CİBO [1], Çağlar ALTAY [2], Ayhan ÖZÇİFÇİ [3], Ergün BAYSAL [1], Hilmi TOKER [1]

[1] Muğla Sıtkı Koçman Üniversitesi, Teknoloji Fakültesi, Ağaç İşleri Endüstri Mühendisliği Bölümü
[2] Adnan Menderes Üniversitesi, Aydın Meslek Yüksekokulu, Mobilya ve Dekorasyon Programı
[3] Aksaray Üniversitesi, Mühendislik Fakültesi, Endüstri Mühendisliği Bölümü

Sorumlu Yazar: ayhanozcifci@aksaray.edu.tr (Ayhan ÖZÇİFÇİ)

Özet: Bu çalışmada, karbon fiberle güçlendirilmiş lamine edilen ahşap yapıların bazı mekanik özelliklerinin etkisinin belirlenmesi amaçlanmıştır. Doğu kayını (*Fagus orientalis* L.) odunundan hazırlanan örneklere çift bileşenli epoksi yapıştırıcısı ve nem kürlenmeli poliüretan tutkalı kullanılarak lamine levhalar elde edilmiştir. Lamine levhaların mukavvemetini arttırmak için karbon fiber (CFRP) yapı malzemesi uygulanmıştır. Örneklere TS 2474 standardına göre statik eğilme, TS 2478 standardına göre eğilmede elastikiyet modülü ve TS 2477 standardına göre dinamik eğilme (şok) testleri uygulanmıştır. Deney sonuçlarına göre, en yüksek statik eğilme direnci değeri 132.80 N/mm² ile ahşap katmanlar arasında karbon fiber yapı malzemesi kullanılan ve epoksi yapıştırıcı ile yapıştırılan lamine levhalarda elde edilmiştir. En yüksek eğilmede elastikiyet modülü değeri 14004.83 N/mm² ile ahşap katmanlar etrafı karbon fiber yapı malzemesi ile kaplanmış ve ahşap katmanlar arası epoksi yapıştırıcısı ile yapıştırılan lamine levhalarda elde edilmiştir. En yüksek dinamik eğilme (şok) direnci değeri 0.62 kgm /cm² ile ahşap katmanlar etrafı karbon fiber yapı malzemesi ile kaplanmış ve ahşap katmanlar arası epoksi yapıştırıcısı ile yapıştırılan lamine levhalarda bulunmuştur. Sonuç olarak, karbon fiber yapı malzemesi ve epoksi yapıştırıcı, köprü, merdiven, kolon, kiriş ve çatı gibi yapılarda bölgesel takviye amacıyla eğilmeye ve baskıya maruz kalan bölümlerinde kullanılabilir. Ağaç malzemenin zarar görmesi, ahşap malzemenin dış yüzeyine verilebilecek ani etkilere karşı karbon fiber yapı malzemesi ve epoksi yapıştırıcı kullanılarak önlenebilir. Uygulanan yüzeye epoksi yapıştırıcının güçlü ve hızlı nüfuz etmesi ve karbon fiber yapı malzemesi ile artan mukavemeti sayesinde, özellikle ahşaptan yapılan zeminlerde yıpranma süresini uzatmak için kullanılabilir.

Anahtar Kelimeler: *Lamine Ağaç Malzeme, Karbon Fiber (CFRP), Yapıştırıcılar, Mekanik Özellikler.*

Determination of Some Mechanical Properties of Laminated Wood Material Reinforced with Carbon Fiber (CFRP)

Abstract: In this study, it was aimed to determine the effect of some mechanical properties of structural laminated wood reinforced with carbon fiber. Laminated sheets were obtained using moisture curing polyurethane and two component epoxy adhesives prepared from Oriental beech (*Fagus orientalis* L.) wood samples. Carbon fiber (CFRP) structural material was applied to laminated sheets in order to increase their strength. Static bending test was made according to TS 2474, bending in elasticity modulus was made according to 2478, and dynamic bending (shock) test was made

DOI:

according to 2477 standards. According to results of the experiments, the highest static bending strength value (132.80 N/mm^2) was obtained in laminated sheets used carbon fiber building material between wooden layers and bonded with epoxy adhesive. The highest elasticity modulus in bending value (14004.83 N/mm^2) was determined in laminated sheets bonded with epoxy adhesive between wooden layers and covered with carbon fiber structural material around sheets. The highest dynamic bending (shock) strength value (0.62 kgm/cm^2) was found in laminated sheets bonded with epoxy adhesive between wooden layers and covered with carbon fiber structural material around sheets. Consequently, carbon fiber building material and epoxy adhesive can be used in sections which are exposed to bending and stress such as bridge, stair, column, beam, and roof for local reinforcement. Damage of wood material can be prevented by using carbon fiber construction material and epoxy adhesive against the sudden effects that might be caused to the outside of the wood material. Due to the strong and fast penetration of the epoxy adhesive on the applied surface and the increased strength with the carbon fiber building material, it can be used to extend the wear time especially on the floors made of wood.

Keywords: *Laminated Wood Material, Carbon Fiber (CFRP), Adhesives, Mechanical properties.*

1. Introduction

Wood laminating materials are obtained by bonding two or more layers with adhesive and joining the fiber directions of the layers parallel or perpendicular to each other. Preparing the fiber directions in parallel is widely used. Different type of wood, variable number of floor, different size, shapes, and coat thicknesses can be applied in lamination (Kurtoglu, 1979). If lamination technique is applied as an alternative to wood material, also if the lapel coatings used in laminates are impregnated, the service life will increase (Ozcifci, 2001). The wooden lamination technique ensures that the wood material is more resistant to external factors. Nowadays, carbon fiber reinforced lamination processes are used in a wide range of fields from the construction sector to the furniture sector.

Carbon fibers are mostly used in the construction industry for column cladding and curtain methods. In addition to these, they are used in more various methods around the world. These materials, commonly known as carbon fiber (carbon fiber), are a new generation materials of lightweight, high strength, thin, fast and practicable, corrosion resistant, long lasting durability adjustable by changing the sequencing orientation of the fibers (Güler and Subasi, 2012). When carbon fiber material is used in wood materials, it seems to have a property of increasing strength. Borri and Corradi (2005) studied on behaviors under loads of wood structural systems reinforced with carbon fiber reinforced polymers. They obtained positive results from carbon fiber-reinforced materials.

Roberto et al. (2004) investigated on the structural classification of reinforced parts with fiber-reinforced composite plates of fully damaged wooden columns. The bending tests performed revealed that there was a 60% improvement in fiber reinforced composite sheets in the resultant data. Chen (1999) studied the mechanical performances of fiber-reinforced wood assemblies reinforced with glass-fiber reinforced wood joints in numerical analysis of numerical analysis and experimental works under the microscope. In the experimental studies made, the strengthening surfaces were observed under the microscope and it was observed that there was a serious improvement in the stress intensity in the joint regions.

In this work, it is aimed at how the carbon fiber (CFRP) reinforcement application used for reinforcing wooden structural elements influences some mechanical properties of laminated elements.

2. Material and Method

2.1. Wood Material

As a test material, Oriental beech (*Fagus orientalis* L.) was used. It is a material that full-dry density (D_0) 0. 68 g/cm^3, air-dry density (D_{12}) 0.72 g/cm^3. Also, its elasticity module is 15700 MPa, bending strength (σE) is 120 MPa, tensile strength in parallel with the fibers (σg) is 132 MPa, the compression strength parallel to the fibers (σB) is 60 MPa (Bozkurt and Erdin, 2000).

2.2. Adhesives

Epoxy adhesive was provided by Dost Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It is a double component adhesive which is used for adhering solid materials to glossy surfaces, resistant to chemicals, providing excellent adhesion to concrete, wood, steel and plastic materials and reaching the desired mechanical strength very quickly. It was used with carbon fiber for the bonding of epoxy concrete elements, iron, steel and similar metals, types of wood and glass and assembly operations exposed to heavy and medium loads. Its density is 1.5 g / cm^3 at 20 ^{o}C and its viscosity is 1100 mPas. Usage of 200 g/m^2 in compliance with the company's proposal (www.kompozit.net, 2017).

Moisture curing polyurethane adhesive was provided by SBC Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It is adhesive that has resistant to water and moisture, solvent-free, one-component polyurethane based. Also, it is preferred in sea and lake vehicles, metal and wood parts of the installation and repair. Its density is 1.11 ± 0.02 g / cm^3 at 20 oC and 14,000 ± 3,000 mPas at 25 ^{o}C. It hardens in 30 minutes at 20 ^{o}C ± 2 temperature and 65 ± 3 relative humidity environment. According to the manufacturer's recommendations, this adhesive is recommended to be applied to the package viscosity and to the surfaces at a rate of 150 g /m^2 until the absorption is high, as well as slightly moisturizing the dried surfaces (Altinok, 1988).

2.3. Carbon Fiber (CFRP) Construction Material

In this study, the carbon fiber building materials have a density of 300 g/m^2 with 1.2 mm thickness in the dimension and form suitable for the strengthening work to be carried out. This material was provided by Dost Kimya Industrial Raw Materials Industry and Trade. Ltd. Co. It is a high abrasion resistance and extremely rigid material that high resistance compared to steel, very low density compared to metal. In addition, chemical resistance is high, light and unlimited size is suitable for production. Carbon fiber reinforced composite materials are generally used for used in aircraft industry, in rocket and satellite construction, in automotive industry, and in the construction of many sporting goods (Yildizhan, 2008).

2.4. Preparation of Experimental Examples

Experimental samples are provided according to TS 2470 standards by 'Random selection' method from timber enterprises in Karabük industry. Then, laminated sheets were obtained adding moisture curing polyurethane and two component epoxy adhesives and carbon fiber construction material. Component a (resin) and component b (hardener) of the two component epoxy adhesive used in the study were mixed 1/1 rate until a light gray color and applied with a spatula to the applied surface at 200 g/m^2. At the same time, care has been taken to cut the carbon fiber material properly with a modeling knife for the purposes of the fibers do not break off. The cut carbon fiber construction material was bonded with epoxy adhesive between and around of laminated sheets. The samples

were subjected to press 2.5 kg/cm^2 press pressure, 200 ^{0}C degree temperature and under 60 minute wait period. Then, the specimens were brought to the intended dimensions in appropriate standards for each test group. The types and numbers of laminated sheets belong to test types was given in Table 1.

Table 1. Number of laminated samples belonging to experimental species.

Experiment Type	Sample type	Number
Static bending strength and elasticity modulus in bending	Epoxy between wood layers and carbon fiber around wood layers	10
	Polyurethane between wooden layers and carbon fiber around wood layers	10
	Carbon fiber and epoxy between wood layers (CFRP+epoxy)	10
	Epoxy between wood layers	10
	Polyurethane between wood layers	10
Dynamic bending (shock) strength	Epoxy between wood layers and carbon fiber around wood layers	10
	Polyurethane between wooden layers and carbon fiber around wood layers	10
	Carbon fiber and epoxy between wood layers (CFRP+epoxy)	10
	Epoxy between wood layers	10
	Polyurethane between wood layers	10

2.5. Test Method

2.5.1. Air-Dry Density

The moisture content of the test samples was determined according to TS 2471, densities was determined according to TS 2472 standards. The test specimens were weighed on a 0.01 g precision scale after waited until being allowed to reach constant weight at 20 ± 2 °C and 65% relative humidity in cabinet. After, the dimensions were measured by caliper in ± 0.01 mm sensitivity. Air-dry density (δ_{12}) value was determined in the following formula that according to air-dry weight (M_{12}) and air-dry volume (V_{12}) values.

$$\delta_{12} = \frac{M_{12}}{V_{12}} = g/cm^3 \quad (1)$$

2.5.2. Static Bending Strength and Elasticity Modulus in Bending Strength Test

Bending test was made according to TS 2474, elasticity modulus in bending was made according to TS 2478. The following equations have been used in the calculation of the bending strength and elasticity modulus in bending:

$$F_m = \frac{3xF_{max}\,x\,L}{2\,x\,b\,x\,h^2}\ (N/mm^2) \quad (2)$$

Here in;

F_m=Bending strength (N/mm^2)
F_{max} = Maximum force at break (N)
L = Distance between supporting axes (mm)
b= Width of the test sample (mm)
h= Height of the test sample (mm)

$$E_m = \frac{L_1^3 \ x\ (F_2 - F_1)}{4\ x\ b\ x\ h^3\ x\ (a_2 - a_1)} \left(\frac{N}{mm^2}\right) \quad (3)$$

Here in;

E_m= Elasticity modulus in bending(N/mm^2)
L_1= Distance between supporting axes (mm)
b= Sample width(mm)
h= Sample height (mm)
F_2-F_1= Load increase of load-deflection diagram ratios region (N)
a_2-a_1 = Due to the increase in strength, deflection difference in the middle of the sample length (mm)

2.5.3. Dynamic Bending (Shock) Strength Test

For the dynamic bending (shock) strength test, each test sample was obtained in four layers with dimensions of 5x20x320 mm. The test specimens were cut to dimensions of 20x20x360 mm according to TS 2477 standard. The dynamic bending strength was calculated with a pendulum hammer. Impact hammer with has 10 kg/m of work power, which is freely dropped from a certain height, is used to break some of the has kinetic energy in the first position to break the sample.

$$(\sigma_{DE}) = \frac{w}{bxh} = kg.m/cm^2 \quad (4)$$

Here,
w : Spend energy to break (kg.m)
b : Example width (cm)
h: Example height (cm), it expresses this information.

2.6. Statistical Evaluation of Data

Mechanical test results were evaluated by a computerized statistical program composed of analysis of variance and following DUNCAN test at the 95% confidence level. Statistical evaluations were made on homogeneity groups (HG), of which different letters reflected statistical significance.

3. Results and Discussion

3.1. Results of Air-Dry Density

The mean values of air-dry density for the laminated samples are given in Table 2.

Table 2. Mean values for air-dry density.

No	Sample type	Average (g/cm^3)
1	Epoxy between layers and CFRP around layers	1.79
2	Polyurethane between layers and CFRP around layers	1.68
3	CFRP and epoxy between layers (CFRP+epoxy)	1.77
4	Epoxy between layers (control)	1.72
5	Polyurethane between layers (control)	0.78

As a result of the experiments, the highest air-dry density value (1.79 g/cm^3) was obtained in laminated sheets bonded with epoxy between wood layers and covered with carbon fiber around wood layers. The lowest air-dry density value (0.78 g/cm^3) was found in laminated sheets bonded with polyurethane between wood layers (control).

3.2. Results of Static Bending Strength Test

The arithmetic average values of static bending strengthtest are given in Table 3.

Table 3. Arithmetic mean values of static bending strength test (N/mm^2).

No	Sample type	Bending strength (N/mm^2)	Standard deviation	Homogeneity group
1	Epoxy between layers and CFRP around layers	129.10	13.51	AB
2	Polyurethane between layers and CFRP around layers	124.96	20.06	B
3	CFRP and epoxy between layers (CFRP+epoxy)	132.80	29.73	A
4	Epoxy between layers (control)	101.10	3.46	C
5	Polyurethane between layers (control)	93.80	4.95	CD

According to Table 3, the highest static bending strength value (132.80 N/mm^2) was obtained in laminated sheets used carbon between wooden layers and bonded with epoxy adhesive. Mistak (2013) was examined that bending strengths by obtaining laminated sheets with Scotch pine wood material and different fiber fabrics. As a result, the highest strength (81.54 N/mm^2) was obtained in polyurethane-based resin and carbon fiber fabric (CFRP) reinforced Scotch pine samples. In a similar study by Premrov et al. (2004) obtained a 50% higher strength in bending strength of carbon fiber reinforced wood structural members. In literature, Radford et al. (2002) obtained 25% more strength after laminated wooden bridge beams were strengthen with glass-reinforced composites against bending and stretching. Accordingly, it is supported with the information in the literature that the carbon fiber material placed in the intermediate layers of the laminated elements increase the bending strength of samples. The reason for this is that the has high wear resistance of the carbon fiber construction material and has the high tear resistance of the epoxy adhesive can be said affect the bending strength positively in laminated samples.

Also statistically, polyurethane (control) and epoxy (control) samples were found in the same homogeneity group. However, no statistically significant difference in laminated sheets were found in covered with carbon fiber and Epoxy adhesive between wood layers, epoxy adhesive between layers and covered with carbon fiber around layers, polyurethane between layers and covered with carbon

fiber around layers. The results of the variance analysis to determine which factor the difference is due to in different groups are given in Table 4.

Table 4. Results of variance analysis of static bending strength test.

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value (p≤0.05)
Interaction	647908.13	1	647908.13	2151.01	0.00
Adhesive	327.070	1	327.07	1.086	0.03
Coating	10839.19	2	5419.59	17.99	0.00
Adhesive* Coating	24.996	1	24.99	0.08	0.02
Error	13554.45	45	301.21		
Total	702981.43	50			

According to the results, the effect of wood species, type of adhesive and adhesive-coating interactions on bending strength (p≤0.05) was found to be significant.

3.3. Results of Elasticity Modulus in Bending Strength Test

The arithmetic mean values for the modulus of elasticity in bending strength of laminated samples are given in Table 5.

Table 5. The arithmetic mean values of elasticity modulus in bending strength (N/mm^2).

No	Sample type	Modulus of elasticity (N/mm^2)	Standard deviation	Homogeneity group
1	Epoxy between layers and CFRP around layers	14004.83	1418.97	A
2	Polyurethane between layers and CFRP around layers	13457.65	2828.57	A
3	CFRP and epoxy between layers (CFRP+epoxy)	13351.93	1758.35	A
4	Epoxy between layers (control)	9929.99	470.32	B
5	Polyurethane between layers (control)	9272.85	1112.31	B

According to Table 5, the highest elasticity modulus in bending value (14004.83 N/mm^2) was obtained in laminated sheets bonded with epoxy adhesives between wooden layers and covered with carbon fiber around sheets. A statistically difference was found between the results of the experiments and the laminated samples. The results of variance analysis to determine the effect of different species on the modulus of elasticity are given in Table 6.

Table 6. Results of variance analysis of elasticity modulus in static bending strength.

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value (p≤0.05)
Interaction	6.86	1	6.86	2356.95	0.00
Adhesive	3625972.67	1	3625972.67	1.24	0.00
Coating	1.83	2	9.16	31.46	0,00
Adhesive* Coating	30225.25	1	30225.25	0.01	0.00
Error	1.31	45	2912910.15		
Total	7.53	50			

It was determined that the effect of adhesive-type and adhesive-coating interaction on the modulus of elasticity in bending was statistically significant.

3.4. Results of Dynamic Bending (Shock) Strength Test

The arithmetic mean results related to dynamic bending (shock) strength values of the test specimens are given in Table 7.

Tab. 7. Arithmetic mean results of the dynamic bending (shock) strength test (kgm/cm^2).

No	Sample type	Shock Strength (kgm/cm^2)	Standard deviation	Homogeneity group
1	Epoxy between layers and CFRP around layers	0.62	0.24	A
2	Polyurethane between layers and CFRP around layers	0.53	0.20	B
3	CFRP and epoxy between layers (CFRP+epoxy)	0.56	0.21	AB
4	Epoxy between layers (control)	0.50	0.21	B
5	Polyurethane between layers (control)	0.36	0.20	C

The highest dynamic bending (shock) strength value (0.62 kgm/cm^2) was found in laminated sheets bonded with epoxy adhesives between wooden layers and covered with carbon fiber around sheets. It was obtained that reinforcement applications of bonded with epoxy between wood layers and covered with carbon fiber around wood layers have an effect on increasing the value of dynamic bending strength in general. Polyurethane and epoxy adhesive samples used as adhesives were found in different homogeneity groups. However, a statistically significant difference in samples was found between polyurethane between layers, epoxy between layers and covered with carbon fiber around layers.

According to this, the results of analysis of variance made to determine the effect of laminated groups on dynamic bending strength are given in Table 8.

Table 8. Results of variance analysis of the dynamic bending (shock) strength experiment.

Variance source	Sum of squares	Degrees of freedom	Average of squares	F (Account)	P value (p≤0.05)
Interaction	0.09	1	0.09	618.30	0.00
Adhesive	0.02	1	0.02	3.66	0.03
Coating	0.09	2	0.004	27.55	0.00
Adhesive* Coating	0.04	1	0.01	3.66	0.02
Error	0.02	45	0.01		
Total	0.12	50			

The effect on dynamic bending strength of coating type (p≤0.05) was found to be significant. Also, the effect of type of adhesive and adhesive-coating interaction on dynamic bending (shock) strength was found to be significant at 95% confidence interval.

4. Conclusions

According to results of the experiments, the highest static bending strength value (132.80 N/mm^2) was obtained in laminated sheets used carbon fiber building material between wooden layers and bonded with epoxy adhesive Also, an increase of 41.57% was observed compared to the control groups.The highest elasticity modulus in bending value (14004.83 N/mm^2) was determined in laminated sheets bonded with epoxy adhesives between wooden layers and covered with carbon fiber around sheets also an increase of 51.03% was observed compared to the control group.

The highest dynamic bending (shock) strength value (0.62 kgm/cm^2) was found in laminated sheets bonded with epoxy adhesives between wooden layers and covered with carbon fiber around sheets also an increase of 72.22% was observed compared to the control group.

As a result, it can be used to reinforce structural elements such as wooden columns, beams, etc. on wooden floors, which are continuously and suddenly exposed to pressure by using carbon fiber material and epoxy adhesive between and around laminates. Carbon fiber can be preferred for timber structural sections subjected to stretching due to its high flexing and breaking properties. Also, due to the strong and fast penetration of the epoxy on the applied surface and the increased strength with carbon fiber, it can be used to extend the wear time especially on the floors made of wood.

5. Acknowledgement

This study was made use of M.Sc. Thesis of by Caglar Altay in the Graduate School of Natural and Applied Sciences, Karabük University.

6. References

Altinok, M., (1998), Ağaç İşleri Temel Makinelerde İşlenmiş Ahşap Yüzeylerin Yapışma Direncine Etkileri, Gazi Üniversitesi Teknik Eğitim Fakültesi, Politeknik Dergisi, 1(2):17-20.

Borri, A., Corradi, M., (2005), A Method for Flexural Reinforcement of Old Wood Beams with CFRP Materials, Composites Part B: Engineering, 36(2): 143-153.

Bozkurt, A. Y., Erdin, N., (2000), Odun Anatomisi, İstanbul Üniversitesi Orman Fakültesi, İstanbul, ss:298.

Chen, C. J., (1999), Mechanical Behaviour of Fiber Glass Reinforced Timber Joints, In: World Conference On Tımber Engineerıng Wcte, 31JULY-03 August, Canada.

https://www.kompozit.net/k/161/karbon-fiber-takviyeler, E.Tar: 02.05.2017.

Güler, C., Subasi, S., (2012), Karbon ve Cam Lifi İle Güçlendirilmiş Lamine Sarıçam (*Pinus Sylvestris* L.), Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi, Özel Sayı.

Kurtoglu, A., (1979), Yapıştırılmış Tabakalı Ağaç Malzemede Rutubet Değişimi Nedeniyle Gerilmelerin Oluşumu, İstanbul Üniversitesi Orman Fakültesi Dergisi, 29(2): 72-96.

Mistak, O., (2013), Sarıçam Ağaç Malzeme ve Farklı Fiber (FRP) Kumaşları İle Elde Edilen Lamine Ağaç Malzemelerin Mekanik Özelliklerinin Belirlenmesi, Yüksek Lisans Tezi, Karabük Üniversitesi, Fen Bilimleri Enstitüsü.

Ozcifci, A., (2001), Emprenye Edilmiş Lamine Ağaç Malzemenin Teknolojik Özellikleri, Doktora Tezi, Gazi Üniversitesi, Fen Bilimleri Enstitüsü.

Premrov, M., Dobrila, P., Bedenik, B. S., (2004), Analysis of Timber Framed Walls Coated with CFRP Strips Strengthened Fibre-Plaster Boards, International Journal of Solids and Structures, 41(24-25): 7035-7048.

Radford, D. W., Goethem D. V., Gutkowski R. M., Peterson, M. L., (2002), Composite Repair of Timber Structures, Construction and Building Materials, 16(7):417-425.

Roberto, L.A., Micheal, A. P., Sandford, T. C., (2004), Fiber Reinforced Polymer Composite-Wood Pile İnterface Characterization By Push-Out Tests, Journal of Composites for Construction, 8(4): 360-368.

TS 2470 (1976), Odunda Fiziksel ve Mekaniksel Deneyler İçin Numune Alma Metotları ve Genel Özellikler, Türk Standardları Enstitüsü, Ankara, 1-5.

TS 2471 (1976), Odunda Fiziksel ve Mekaniksel Deneyler İçin Rutubet Miktarı Tayini, Türk Standardları Enstitüsü, Ankara.

TS 2472 (1976), Fiziksel ve Mekaniksel Deneyler İçin Birim Hacim Ağırlığı, Türk Standardları Enstitüsü, Ankara.

TS 2474 (1976), Odunun Statik Eğilme Dayanımının Tayini, Türk Standardları Enstitüsü, Ankara.

TS 2477 (1976), Odunun Çarpmada Eğilme Dayanımının Tayini, Türk Standardları Enstitüsü, Ankara.

TS 2478 (1976), Odunun Statik Eğilmede Elastikiyet Modülünün Tayini, Türk Standardları Enstitüsü, Ankara.

Yildizhan, H., (2008), Polimer Matrisli Kompozitlerin Mekanik Özelliklerinin İncelenmesi, Yüksek Lisans Tezi, Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü.