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# THE EFFECTS OF HEAT TREATMENT ON THE MODULUS OF RUPTURE AND MODULUS OF ELASTICITY OF SCOTS PINE (*Pinus sylvestris* L.) WOOD

**ABSTRACT**

In this study, test samples were prepared from Scots pine (*Pinus sylvestris* L.) wood after then they were exposed to heat treatment at 130, 145, 160, 175, 190 and 205°C for 3, 6, 9, 12 hours. Modulus of rupture (MOR) and modulus of elasticity (MOE) values of samples were determined. Data obtained from experimental study were evaluated by multiple variance analysis. It was seen that the heat treatment applications affected the properties of MOR and MOE values of wood samples.

**Keywords:** Scots Pine, Heat treatment, Modulus of Rupture, Modulus of Elasticity, Wood

# SARIÇAM (*Pinus sylvestris* L.) ODUNUNUN EĞİLME DİRENCİ VE EĞİLMEDE ELASTİKİYET MODÜLÜ ÜZERİNE ISIL İŞLEMİN ETKİSİ

**ÖZET**

Bu çalışmada sarıçam odunundan hazırlanan deney örnekleri 130, 145, 160, 175, 190 ve 205°C sıcaklık, 3, 6, 9 ve 12 saat süre ile ısıl işleme maruz bırakılmıştır. Daha sonra deney örneklerinin eğilme direnci ve eğilmede elastikiyet modülü değerleri belirlenmiştir. Bu değerler çoklu varyans analizi kullanılarak değerlendirilmiştir. Isıl işlem uygulamalarının ağaç malzemenin eğilme direnci ve eğilmede elastikiyet modülü üzerine etkili olduğu görülmüştür.

**Anahtar Kelimeler:** Sarıçam, Isıl İşlem, Eğilme Direnci, Eğilmede Elastikiyet Modülü, Ahşap

## 1. INTRODUCTION (GİRİŞ)

Wood is a complex material which is constituted mainly of three biopolymers; lignin, cellulose and hemicelluloses. And also, these polymeric components, wood have many extractives in more or less large quantities including several classes of organic compounds like sugars, flavonoids, tannins, terpenes, fats or waxes [1, 2, 3, 4, 5, 6 and 7].

The wood preservation methods have been commonly used for a long time. The most important method is chemical treatment involved the impregnation of different chemical substances. But, these methods have toxic effects due to using chemical. Because of these problems, heat treatment application method is a very promising alternative preservation technique [8].

Heat treatment application is one of the processes used to modify the properties of wood [9]. This wood modification method serves to increase the natural quality properties of wood, such as dimensional stability, resistance to bio-corrosion. The heat treatment process include exposing wood to temperatures can be applied to ranging from 160 to 260°C [10]. The heat treatment the wood value by decreasing equilibrium moisture content, and also improving dimensional stability [11, 12, 13 and 14].

Akyıldız et al. reported that values of EMC (equilibrium moisture content) decreased with increasing temperature and time of heat treatment. In study of them, oak, chestnut, calabrian pine and black pine woods were used and they were exposed to heat treatment techniques [15].

Weight loss of beech (Fagus sylvatica) wood, treated at increasing temperatures, was 8.1% and 9.8% at 150°C and 200°C, respectively reported mass losses of 6.4, 7.1 and 10.2% for Betula pendula treated at 205°C for 4, 6 and 8 h [16 and 17].

## 2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

The aim of this paper is to investigate the effect of heat treatment on modulus of rupture and modulus of elasticity of Scots pine wood.

## 3. MATERIALS AND METHODS (MALZEME VE YÖNTEM)

Firstly, logs were obtained from Karabuk region, in Turkey. Secondly, the test samples were prepared from logs. Thirdly, test samples were exposed to heat treatment at 130, 145, 160, 175, 190, 205°C and 3, 6, 9, 12 h. in a small heating unit controlled with ±1°C sensitively. After the heat treatment, treated and untreated samples were conditioned to 12% moisture contents in a conditioning room at 20oC±2oC and 65% (±5) relative humidity. Then, the modulus of rupture and modulus of elasticity of test samples were determined by using related standards [18 and 19].

Data for each test were statistically analyzed. The analysis of variance (ANOVA) was used to test for significant difference between factors and levels. When the ANOVA indicated a significant difference among factors and levels, a comparison of means was done employing a Duncan test to identify.

## 4. RESULTS AND DISCUSSION (SONUÇLAR VE TARTIŞMA)

The air dry density of Scots pine is found as 0.62g/cm$^3$. The average values of MOR and MOE determined from test samples are given in Table 1. And the heat treatment conditions were shown in Table 1, too.

Table 1. The average values of the MOR and MOE values
(Tablo 1. MOR ve MOE değerlerinin ortalama değerleri)

| Heat Treatment Conditions | | MOR ($N/mm^2$) | | MOE ($N/mm^2$) | |
|---|---|---|---|---|---|
| Temperature (°C) | Time (hour) | Mean | Std. Deviation | Mean | Std. Deviation |
| 0 | 0 | 81,82 | 5,51 | 8088,08 | 1989,20 |
| 130 | 3 | 76,28 | 7,46 | 8474,79 | 1519,81 |
| | 6 | 78,85 | 14,10 | 8436,58 | 1525,66 |
| | 9 | 75,93 | 13,16 | 8110,78 | 1441,31 |
| | 12 | 72,22 | 14,05 | 7915,15 | 1541,06 |
| 145 | 3 | 81,38 | 15,00 | 8478,68 | 1446,95 |
| | 6 | 77,36 | 5,98 | 5447,49 | 640,82 |
| | 9 | 76,52 | 11,88 | 5477,48 | 950,14 |
| | 12 | 71,05 | 15,77 | 5467,64 | 1118,57 |
| 160 | 3 | 74,82 | 9,19 | 5200,05 | 652,46 |
| | 6 | 72,48 | 12,32 | 5117,91 | 564,28 |
| | 9 | 68,45 | 8,78 | 5264,71 | 653,65 |
| | 12 | 65,22 | 10,91 | 5172,07 | 876,50 |
| 175 | 3 | 68,90 | 15,74 | 5143,92 | 1097,93 |
| | 6 | 63,08 | 14,48 | 5127,01 | 852,03 |
| | 9 | 57,42 | 14,96 | 4769,17 | 999,07 |
| | 12 | 56,50 | 11,55 | 5028,90 | 573,50 |
| 190 | 3 | 68,97 | 6,79 | 5874,68 | 952,98 |
| | 6 | 59,02 | 8,81 | 4833,24 | 681,39 |
| | 9 | 50,36 | 10,03 | 4811,57 | 638,09 |
| | 12 | 45,04 | 10,38 | 4964,62 | 627,17 |
| 205 | 3 | 64,80 | 8,48 | 5654,15 | 609,76 |
| | 6 | 59,08 | 15,52 | 5389,69 | 830,70 |
| | 9 | 49,17 | 11,57 | 5328,68 | 946,73 |
| | 12 | 43,10 | 9,95 | 4876,17 | 644,20 |

It can said that the both MOR and MOE values decrease while increase of the temperature and time of heat treatment. The maximum decreases to all parameters were recorded at the treatment of 160°C for 9h. The lowest modulus of rupture value was obtained from samples treated at the 205°C and 12 h. (43,10$N/mm^2$). The lowest modulus of elasticity value was obtained from the same heat treatment conditions. Heat treatment decreases mechanical properties of wood, but the properties of dimensional stability and the biological durability of wood increases by using the heat treatment.

It can be said that the temperature of heat treatment has a greater influence than the time of heat treatment on the MOR and MOE values of test samples.

The variance analysis of MOR and MOE based on heat treatment was conducted. Multiple variance analysis was used to determine the difference between the test sample. The results of variance are given in Tablo 2.

Table 2. The Results of variance analyses
(Tablo 2. varyans analiz sonuçları)

| | Source | Type III Sum of Squares | df | Mean Square | F-Value | Sig. |
|---|---|---|---|---|---|---|
| MOR ($N/mm^2$) | Temperature (°C) | 31509,04 | 5 | 6301,81 | 45,45 | 0,00 |
| | Time (hour) | 10338,69 | 3 | 3446,23 | 24,86 | 0,00 |
| | Temp. * time | 3160,62 | 15 | 210,71 | 1,52 | 0,10 |
| | Error | 51301,55 | 370 | 138,65 | | |
| | Total | 1825813,03 | 395 | | | |
| MOE ($N/mm^2$) | Temperature (°C) | 497391527,01 | 5 | 99478305,40 | 93,91 | 0,00 |
| | Time (hour) | 50775236,11 | 3 | 16925078,70 | 15,98 | 0,00 |
| | Temp.* time | 80696219,84 | 15 | 5379747,99 | 5,08 | 0,00 |
| | Error | 391951166,01 | 370 | 1059327,48 | | |
| | Total | 14875315433,76 | 395 | | | |

According to the variance analysis, the effects of heat treatment conditions such as temperature of heat treatment and time, and the interaction of them were found statically meaningful at 95% significance level. To comparisons of these means were run by employing Duncan's test and it was seen in Table 3.

Table 3. The Results of Duncan Test
(Tablo 3. Duncan Test sonuçları)

| Experimental Design | | MOR | | MOE | | |
|---|---|---|---|---|---|---|
| | | Mean ($N/mm^2$) | HG | Temp. (°C) | Mean ($N/mm^2$) | HG |
| | 205 | 54,03 | A | 175 | 5017,25 | A |
| | 190 | 55,84 | A | 190 | 5121,03 | A |
| | 175 | 61,47 | B | 160 | 5188,69 | A |
| | 160 | 70,24 | C | 205 | 5312,17 | A |
| | 130 | 75,82 | D | 145 | 6217,82 | B |
| | 145 | 76,57 | DE | 0 | 8088,08 | C |
| | 0 | 81,81 | E | 130 | 8234,32 | C |
| | 12 | 58,85 | A | 12 | 5570,76 | A |
| | 9 | 62,97 | A | 9 | 5627,07 | A |
| | 6 | 68,31 | B | 6 | 5725,32 | A |
| | 3 | 72,52 | B | 3 | 6471,04 | B |
| | 0 | 81,81 | C | 0 | 8088,08 | C |

*HG: Homogenous group

According to Duncan's test, the both MOR and MOE values were determined changing between 54, 03-81,81N/mm$^2$ and 5017,25-8234,32N/mm$^2$, respectively. It was seen that the same effect on the MOR value, when the applying level of temperature in 190 and 205°C. So, they were given the same homogenous groups. The change of MOR and MOE value are shown in Figure 1 and Figure 2, respectively.

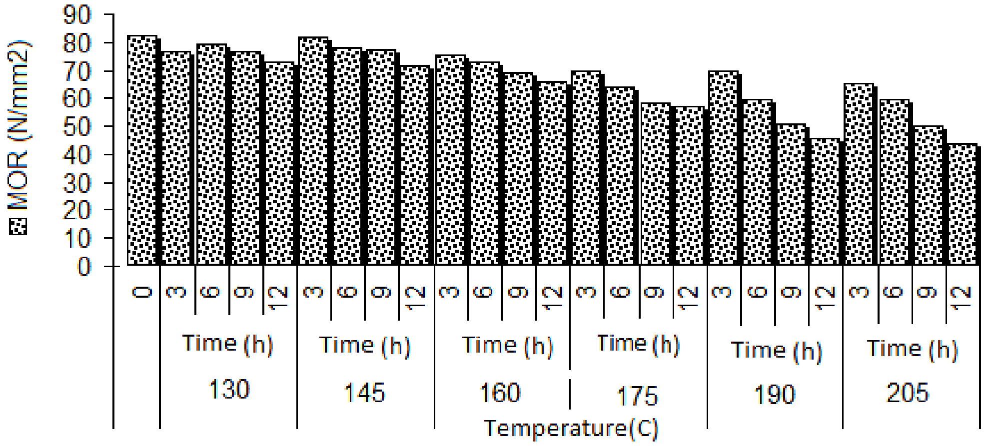


Figure 1. The values of MOR (N/mm$^2$)
(Şekil 1. MOR değerleri (N/mm$^2$))

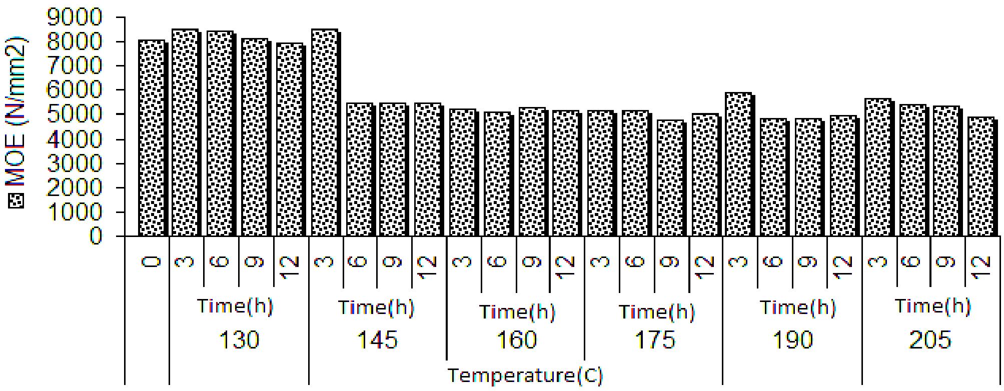


Figure 2. The values of MOE (N/mm$^2$)
(Şekil 2. MOE değerleri (N/mm$^2$))

## 5. CONCLUSIONS (SONUÇLAR)

The results of this study, it was found that MOR and MOE values decrease by each temperature and time of heat treatment. In addition, the results showed that as the increasing time and temperature of heat treatment, MOR and MOE values decreases compared to the control samples. And also, it could be stated that after affecting MOR and MOE values after applying at the 175°C and 9 hour. The data which obtained from study is suited the previous studies.

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