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Mechanical properties of beech wood (*Fagus orientalis* Lipsky) naturally grown in north of Iran

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Abstract

The aim of this study is to determine some mechanical properties (compression strength parallel to the grain and static bending strength) of beech wood (*Fagus orientalis* Lipsky) and to compare them with other beech species. In the tests randomly selected logs taken from the trunk 2- 4 m height were obtained from trees naturally growing in Noshahr region (North of Iran) and tested according to ASTM Standard. The results showed that the mean compression parallel to the grain was 685 kg cm^{-2} and static bending strength 1292 kg cm^{-2}. These results were compared with other available values in the literature. As a result of this comparison, it was observed that beech trees growing in Iran and other beeches have similar mechanical properties and density.

Keywords: Beech (*Fagus orientalis* Lipsky), compression strength, static bending strength, Iran

Introduction

Wood is one of the most widely used materials not only in wood processing industry, but also in other fields of industry (construction, chemistry, machinery, etc). Wood as material is very advantageous: it is easily processed (compared to metals and stone), strength of resistance, hardly affected by acids and alkali, has low heat conductivity, characterized by good adhesion properties, pleasant appearance and good finishing. However, it has some negative features: under changing moisture content wood swells or shrinks, its strength, hardness and other mechanical properties differ in different directions; usually wood has defects, which worsen the quality of wood and its product (Fridley *et al*., 1996; McDonald *et al*., 1996)[1-2]. Therefore, to use this material property and efficiently, it is necessary to know its physical and mechanical properties.

The beech (*Fagus orientalis* Lipsky) is one of the most important commercial hardwood species in Iranian forestry, and has covers about 17.4% of Iran's forests (Parsapajouh,1971). Beech wood is classified as a medium density hardwood and thus, it is heavy, hard, strong, high in resistance to shock, and is highly suitable for steam bending (Bozkurt & Erdin, 1997). Beech shrinks substantially and therefore requires careful drying. Mostly it is used for flooring, furniture, brushes, blocks, handles, veneer, woodenware and toys (Bozkurt & Erdin, 1997). When treated with preservatives, beech wood is suitable for railway ties (Yaltirik,1993). Therefore, in this research, some mechanical properties of beech wood, indigenously grown in Noshahr (Northern Iran), were determined and these dates were compared with other research results, available in the literature.

Materials and methods

In this research, the number of six normal trees from Veysar-Noshahr site (the forests in northern Iran) selected and from each three, one log from the trunk 2-4 m height was cut. The testing samples from mature wood for calculating static bending (modulus of rupture) and compression parallel to the grain according to ASTM-D143-94 were prepared. The age and diameter of trees were 100 years-old and 35 cm, respectively. The altitude of sea level was 1200 meter in the studied site. the prepared samples were then conditioned room at a temperature of 20°C and 65±5% relative humidity until the specimens reached an equilibrium moisture content of about 12 %. The load was applied in the tangential direction**.** Finally, strength properties, oven-dry density, air density and static quality of testing samples were determined in this material. The MOR (modulus of rupture) of the specimens was calculated by the following equation:

$$\sigma_{sbs} = \frac{3.P_{max}.L}{2.b.h^2} \ (kgcm^{-2})$$

where σ_{sbs} is MOR ($kgcm^{-2}$), P_{max} is the maximum load at break point (kg), L is the length of span, b is the width of specimen (cm), and h is the thickness of the specimen (tangential to annual ring) (cm). In addition, the compression strength parallel to the grain was calculated by the following equation (Bozkurt & Erdin, 1997):

$$\sigma_{cpl} = \frac{P_{max}}{F} \ (kgcm^{-2})$$

Where σ_{cpl} is the compression strength ($kgcm^{-2}$), P_{max} is the maximum load at the break point (kg) and F is area of cross section of a specimen on which force was applied (cm^2).

Results and discussion

Statistical analyses were carried out for each test, namely, compression strength parallel to the grain and static bending and the values are presented in Table.1. In this section, these results

Table 1. Descriptive statistics of the results of beech wood naturally grow in Noshahr site

Beech wood	$_{Sbs12}{}^{a}\sigma$	$_{cpl\ 12}{}^{b}\sigma$
Number of sample	100	100
Mean	1292	685
Standard deviation	457	43.29
Min	567	501
Max	2866	712
[a] static quality, [b] oven-dry density		

(Table 1) and other available research results (Table 2) will be compared. According to Table 2, beech trees grown in Noshahr site have the highest static bending strength among all of the beech species in that table. However, compression strength is lower than that for Tokat beeches, but higher than that for Andirin, Black sea and Sinop beeches and European beeches. The variations in the mechanical properties in the same species are due to different factors, such as growth conditions and ecological factors. In particular, exposure, altitude, soil and climate conditions can affect the mechanical properties of wood. Sample size and

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Table 2. Comparison of some mechanical properties of Noshahr beech with other beech

Tree species	Arw [a]	D_{12} [b]	cpl 12 [c] σ	Sbs12 [d] σ	Reference
FO (Noshahr-Iran)	-	0.635	685	1292	This study
FO (Andirin-Turkey)	1.51	0.663	606	1204	Bektas *et al*., 2002
FO(Black sea Turkey)	1.64	0.669	572	1123	Malkocoglu, 1994
FO (Sinop-Turkey)	-	0.660	644	870	Berkel,1941
FO (Tokat-Turkey)	-	0.663	763	1052	Gursu,1960)
FS (European)	1.64	-	648	-	Horvat, 1969)
FS (European)	2.22	0.698	527	1102	Cividini, 1969
FS (European)	-	0.716	521	1105	Stoyanoff & Entcheff,1949

[a] static quality, [b] oven-dry density, [c] static bending/compression strength parallel to the grain, [d] compression strength parallel to the grain/oven-dry density.

Table 3. Some values of the beech wood species

Tree species	I_s [a]	D_0 [b]	p [c]	q [d]	Reference
FO (Noshahr-Iran)	10.83	0.608	1.88	1126	This study
FO (Andirin-Turkey)	9.14	0.631	1.98	961	Bektas *et al*., 2002
FO(Black sea-Turkey)	8.55	0.645	1.96	887	Malkocoglu, 1994
FO (Sinop-Turkey)	9.75	0.633	1.35	1017	Berkel,1941
FO (Tokat-Turkey)	11.5	0.589	1.38	1295	Gursu,1960)
FS (European)	7.55	0.669	2.09	788	Cividini, 1969
FS (European)	7.28	0.671	2.12	776	Stoyanoff & Entcheff,1949

[a] static quality, [b] oven-dry density, [c] static bending/compression strength parallel to the grain, [d] compression strength parallel to the grain/oven-dry density; Fs: *Fagus sylvatica*

properties (e.g. ring orientation), and the test procedure can also affect the test results. Medium density hardwood, such as beech, can be classified as low, fair and good quality according to their static quality value (I_S, ratio between compression strength parallel to the grain and wood air density × 100). In this case, I_s>7 is low quality, 7<I_s<8.5 is fair quality and 8.5<I_s is good quality. According to this classification, the beeches that grow in Noshahr region are good quality along with the other beeches in Table 3, but European beeches are fair quality. For an ordinary wood species, the p value, the ratio between static bending strength and compression strength, is considered to be 1.75 (As,1992). In the present study, it was found that the calculated p value for Noshahr region is higher than this 1.75, including Black sea, Andirin and European beeches. However, the p values of other beeches are lower than the accepted P value (Table 3). Therefore, beeches trees in Andirin have good quality wood as indicated by the higher p value. Another criterion for the evaluation of the wood properties is the value of q, a ratio between compression strength and density (As,1992; Bektas, 1997; Bektas *et al*., 2002). Each wood species has a specific q value but there is no classification; nevertheless, this value is used to compare the wood with other non-wood materials and it is used in some calculations for industrial applications. According to this criterion, Noshahr beech has a higher value than the other beeches except Sinop beeches.

Conclusions

In this study, the mechanical properties (compression and static bending) of beech trees in Noshahr site were determined and these results were compared with those of other researcher beech wood in different regions. The test results proved that beech trees in Noshahr have medium-touch, elastic and good quality wood. The low density of the beech trees in the studied site was related to higher altitude. These differences may be explained by some regional conditions that, affects the growth characteristics and properties of the wood.

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