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Principle of mechanical properties of Oak (*Quercus castaneifolia C.A.* Mey) at different regions of northern part of Iran

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[2] *Wood Samples Were Obtained From Four Locations Included Asalem, Visar, Sangdeh and Golestan, North of Iran*

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Key words: Iranian Oak, *Quercusc astaneifolia*, Static bending strength, Impact strength, Shear strength.

Abstract

In this study, mechanical properties of Oak (*Quercus castaneifolia*) at four different locations of Caspian forests (North of Iran) were investigated. The locations were including Asalem (37°56´55. N, 48°52´84. E), Visar (36°28´3.N, 51°32´5. E), Sangdeh (36°05´28. N, 52°25´41. E) and Golestan (36°25´41. N, 51°35´25. E). The test materials were derived from randomly chosen trees. Mechanical properties such as static bending strength, compression strength parallel to grain, impact strength and shear strength are measured on two moisture levels: green and air-dried (12% moisture content). The results obtained for the species at different geographical locations, ages, and mechanical properties. According to our findings in this research, there are positive relationships between wood density and static bending (modulus of rupture and modulus of elasticity) and the relation between wood density and other mechanical properties was not significant. Total of oak wood can be utilized in more structural application due to good density and high mechanical properties.

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Introduction

Forests of Iran with an area of about 12.4 million hectares comprise 7.4% of the whole country area. While the forest cover of Iran is considered poor as compared with other countries, it is a unique country regarding plant diversity and genetic reserves. The phyto-geographical regions that concern the flora of Iran are the following: the Irano-Turanian, Saharo-Sindian regions and Euxino-Hyrcanian province of the Euro-Siberian region.

Approximately 8000 plant species have been identified in Iran. Climatic diversity especially from the land structure viewpoint is such that geographers have called Iran the global climates bridge (SaghebTalebi, 2004). This climatic diversity has given rise to at least five distinct forest zones; Hyrcanian forest zone which has encompassed humid commercial and industrial forests, Arasbaran zone with semi-humid forests which has been canonized as a global biosphere reserve due to its plant diversity, Zagros forest zone with semi-arid to temperate forests and a rich collection of oak species, Irano-Turanian forest zone, an arid forest with juniper, wild pistachio and almond and finally the Khalijo-Omanian vegetation zone which makes up arid tropical forests and has a different appearance from the others.

In order to determine the best use of Iranian wood species as a source of raw material, especially for wood industry, a comprehensive mechanical study appeared to be necessary. One of the important and commercial species in Iran particularly in Hyrcanian forest zone which is mostly being used in wood industry is *Quercus castaneifolia* also commonly known as Iranian Oak. So, this study was conducted to determine some mechanical properties of Iranian Oak tree grown at different regions of the Caspian forests in the north of Iran. This area covers from Astara in the northwest to Gorgan vicinity in the northeast of Iran. Based on the latest data from the Iranian Forests and Rangelands Organization (IFRO), this area is approximately 800 km long and 110 km wide and has a total area of 1.85 million hectare comprising 15% of the total Iranian forests and 1.1% of country its area. Within the Caspian forests *Quercus castaneifolia* grows at a zone with length of 100 km and width of 25 km to 50 km. Hyrcanian forests stretch out from sea level up to an altitude of 2800 m and encompass different forest types thanks to their 80 woody species (trees and shrubs). The area is rich in hardwood species in which the way that Oak tree is one of the important species.

This forest has remarkable significance due to its production and economical value and has better been preserved as compared to other communities. In this research, some physical and mechanical properties of Oak tree such as static bending strength, compression strength parallel to grain, impact strength, shear strength, indigenously grown in Hyrcanian zone (selected four locations, included: Asalem, Visar, SangdehandGolestanwere determined and these data were compared with other research results, available in the literature. There are many similar studies for the woods of other places in the world that for a concise review one can consult with the references of this article except Gunduz *et al.* (2009).

Material and Methods

The trial trees from which the wood samples were taken were obtained from four locations included Asalem, visar, Sangdeh and Golestan in Hyrcanian zone (Fig. 1A.) in the Northwestern Caspian Sea region of Iran (Fig. 1B.).

First of all, by taking ASTM D143 (2001) standard into consideration, the average diameters of all trees at hillside were determined in two trial areas of the above-mentioned regions. From each of those trial areas, three trees with a straight trunk and representing the average diameters of trees at were sawn. For more details one can consult with Table 1.

Then, 1 m long end-matched log sections were prepared from the whole tree, sawn from different heights of tree between 2 and 4 m from the base (Fig. 2) as mentioned in ASTM D143 (2001). Test specimens were prepared for the determination of static bending strength, compression strength parallel to the grain, impact bending strength and shear strength parallel to the grain. The test was performed on a universal testing machine (Instron Model of 1186). Specimens were conditioned at a temperature of 20 °C and 65 ± 5% relative humidity and the equilibrium moisture content of about 12%. The test was performed on 100 specimens for increasing the accuracy of the experiments. The densities of wood samples were tested according to ASTM D2395 (2001).

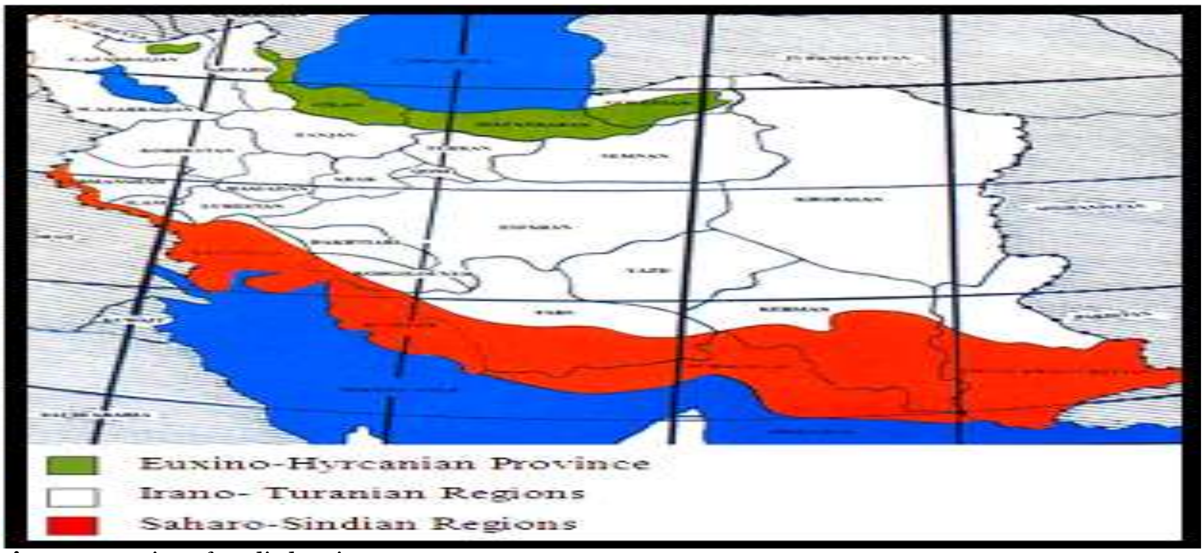

Fig. 1A. Location of studied regions.

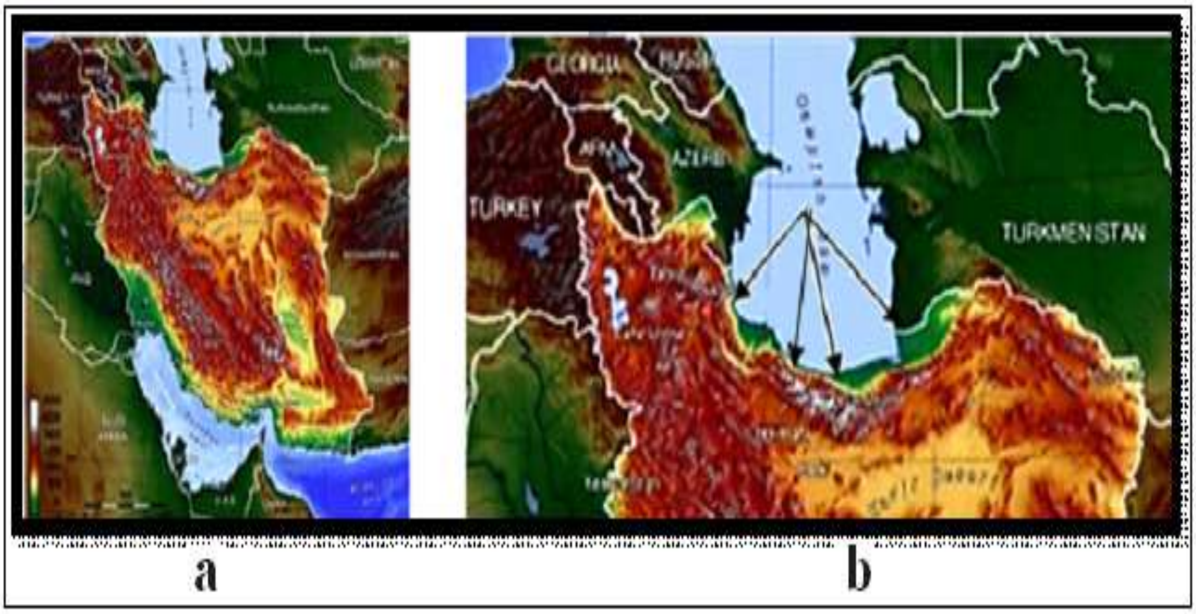

Fig. 1B. a, map of Iran; b, site sampling are shown by black colored arrows.

Static bending strength

The test of bending strength perpendicular to the grain, i. e. modulus of rupture (MOR = σu), was conducted due to ASTM D143 (2001) when the dimensions of the samples are 25 × 25 × 400 mm³. The bending test was performed on the same universal testing machine. The load was used to the radial surface of samples and the loading speed was 1 mm/min and for this test while 100 samples were prepared for each place. In order to calculate the MOR of the specimens the following Eq. 1 (TS, 1976) is used:

$$(1) \qquad \sigma_u = \frac{3P_uL}{2bh^2}\left(\frac{N}{mm^2}\right)$$

Where $\sigma_u$is MOR (N/mm^2), P_u is the maximum load break point (N), L is the length of span (360 mm), b is the width of samples (mm), and h is the thickness of the samples (mm). The bending strength of the samples whose moisture content deviated from 12 % was adjusted by the following Eq. 2 (Bozkurt and Göker, 1996):

$$(2) \qquad \sigma_{12} = \sigma_a\left(1 + 0.04\ (M - 12)\right)\left(\frac{N}{mm^2}\right)$$

Where σ12 is the bending strength at 12 % moisture content. σ_a is the bending strength at the actual moisture content (M).

Compression strength parallel to the grain

For calculating the compression strength parallel to the grain the following Eq. 3 (Bozkurt and Göker, 1996) should be used:

$$(3) \qquad \sigma_u = \frac{P_u}{A}\left(\frac{N}{mm^2}\right)$$

Where $\sigma_u$is the compression strength and A is the area of the specimen cross section on which force was applied. In this case, the compression strength of the specimen was adjusted as Eq. 4:

$$(4) \qquad \sigma_{12} = \sigma_a(1 + 0.06\ (\mathrm{M} - 12))\left(\frac{N}{mm^2}\right)$$

Where σ_{12} is the compression strength, σ_a is the compression strength at actual moisture content level and M is the moisture content.

Impact bending strength

The impact bending strength of the specimens were measured on an impact tester (Instron model PW5) while impact bending strength was determined according to ASTM E23 (1994) and the specimen size was 10 × 10 × 70 mm^3. The impact bending strength was calculated by Eq. 5 (Berkel, 1970):

$$(5) \qquad W_t = BL(cos\beta - cos\delta)(Nm)$$

Where W_t is the impact bending strength, B is the hammer weight, L is the distance between the pendulum axis and point of impact of striking edge in the center of the specimen, β is the angle rise hammer without sample and δ is the angle rise hummer with sample.

Furthermore with Eq. 6 the standard impact bending strength W_{st} can be determined:

$$(6) \qquad W_{st} = \frac{A_{st}}{A_t}W_t$$

Where A_{st} is the standard area hammer weight, A_t is the area in testing position and W_t is the impact bending strength.

Shear strength parallel to the grain

For calculating the shear strength the following equation (Bektaß, 1997) was used:

$$(7) \qquad \sigma_u = \frac{P_u}{bL}\left(\frac{N}{mm^2}\right)$$

Where $\sigma_u$is the shear strength, P_u is the maximum load at the break point, b is the thickness of specimens and l is the length of the samples. Eq. 8 was used for taking different moisture contents (M) into account:

$$(8) \qquad \sigma_{12} = \sigma_a\left(1 + 0.03(M - 12)\right)\left(\frac{N}{mm^2}\right)$$

Where σ_{12} is the shear strength at a moisture content of 12%, σ_a is the shear strength at the actual moisture content and M is the moisture content.

Results

According to Table 1, Iranian Oak tree grown in four locations in the Hyrcanian zone included Asalem (Density of 681 kg/m^3), Visar (678 kg/m^3), Sangdeh (664 kg/m^3) and Golestan (692 kg/m^3). The results of the mechanical determinations on introduced test samples were represented in Table 2. Oak tree grown in Visar and Oak grown in Golstan had the highest bending strength (Fig. 3) and lower static impact bending strength (Fig 4), respectively. Shear strength was the highest in the Sangdeh trees grown at altitudes between 0-1000 m in Iran. Furthermore, the variation in the mechanical properties in the same spices was 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 properties (e.g. ring orientation) and the test procedure can also affect the test results. For all these reasons, some properties of Iranian Oak tree wood showed a slight different to those of other ones. Table 3 demonstrates the comparison of the present result that obtained from experiment with those of available in the open literature.

As seen the compression strength parallel to grain for the Oak of Asalem is higher to that of Green (1989) which is related to USA Oak tree. Moreover it was seen that this mechanical property is higher for North American Oak tree.

Table 1. Characteristics of tree in different Iranian locations.

Location	Characteristics	Tree A	Tree B	Tree C
Asalem	Age (a)	55	60	65
	Diameter (cm)	60	65	70
	Lengh (m)	12	10	10
Visar	Age (a)	68	63	64
	Diameter (cm)	65	64	64
	Lengh (m)	11	10	12
Sangdeh	Age (a)	60	70	68
	Diameter (cm)	55	60	63
	Lengh (m)	10	11	11
Golestan	Age (a)	60	59	64
	Diameter (cm)	58	60	64
	Lengh (m)	11	10	10

Table 2. Statistic of the mechanical test results of Iranian Oak tree.

Location	Statistical parameter	Static bending strength (MPa)	Compression strength parallel to the grain (MPa)	Impact strength (Kg.m)	Shear strength (MPa)
Asalem	Number of sample	100	100	100	100
	Average	105.2	63.27	2.76	15.11
	Minimum value	75.89	46.88	2.70	11.68
	Maximum value	140.89	79.66	2.82	19.45
Visar	Number of sample	100	100	100	100
	Average	133.16	58.56	5.112	14.95
	Minimum value	75.89	35.25	4.46	10.87
	Maximum value	152.39	82.25	5.75	19.26
Sangdeh	Number of sample	100	100	100	100
	Average	82.74	40.01	2.51	18.25
	Minimum value	68.15	23.35	2.4	8.45
	Maximum value	93.51	55.81	2.79	14.47
Golestan	Number of sample	100	100	100	100
	Average	82.15	63.06	3.37	14
	Minimum value	70.33	48.65	3.32	11.12
	Maximum value	91.45	78.58	3.33	17.25

Discussion

In this study, the effect of different locations on the physical properties and mechanical features of Oak wood (*Quercus castaneifolia*) were studied. Analysis of variance indicated that the different locations had significant effect on the wood properties. Based on the result of this study, Oak wood of Visar region had higher strength properties than other regions in Iran. Mechanical properties of Oak wood including modulus of rupture (133.16 N/mm^2) and

Compression strength parallel to the grain (58.56 N/mm²) were determined. According to Parsapajoh (1999) report, the modulus of rupture in Oak wood of Visar Location was higher than the modulus of *Zelcova carpinifolia* (128.93 N/mm²) and *Carpinus betulus* (116 N/mm²) wood. Hornbeam and oak wood are important species in Iran for wood production, pulp and paper making.

Table 3. Some mechanical properties of Iranian, Turkish and American Oak tree.

Oak tree species from	Air-dry density	Static bending strength	Compression strength parallel to the grain	Impact strength	Shear strength	References
	(kg/m^3)	(N/mm^2)	(N/mm^2)	(Nm)	(N/mm^2)	
Asalem, Iran	681	105.2	63.27	2.76	15.11	Present work
Visar, Iran	678	133.16	58.56	5.11	14.95	
Sangdeh, Iran	664	82.74	40.01	2.51	18.25	
Golestan, Iran	692	82.15	63.06	3.37	14	
North American (Red Oak Group)	670	121.8	58.31	-	13.23	USDA Forest Service – Forest Products Laboratory – One Gifford Pinchot Drive – Madison, Wisconsin 53726-2398
North American (Red Oak Group)	680	106.4	52.08	-	13.37	USDA Forest Service – Forest Products Laboratory – One Gifford Pinchot Drive – Madison, Wisconsin 53726-2398
North Carolina State University, Raleigh, NC, USA	610	96	46.6	-	12.3	Mechanical Properties of Wood B Kasal& 2004, Elsevier Ltd. All Rights Reserved.

The relationship between wood density and mechanical properties within a species has been studied by many researchers. A significant linear relationship between wood density and mechanical properties of timber was reported by Shepard and Shottafer (1992) and Zhang (1995). In the present study, there are positive relationships between wood density and static bending (modulus of rupture and modulus of elasticity); In addition, this relationship was stronger than the relationship between density and modulus of elasticity. In final, the relation between wood density and other mechanical properties was not significant. Total of oak wood can be utilized in more structural application due to good density and high mechanical properties.

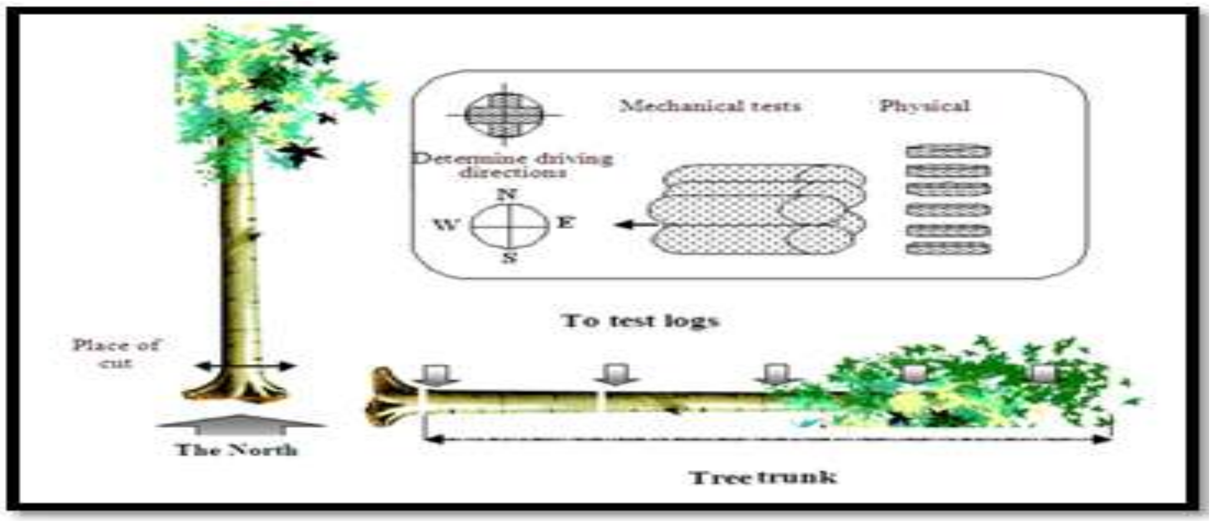

Fig. 2. Sampling method of trees.

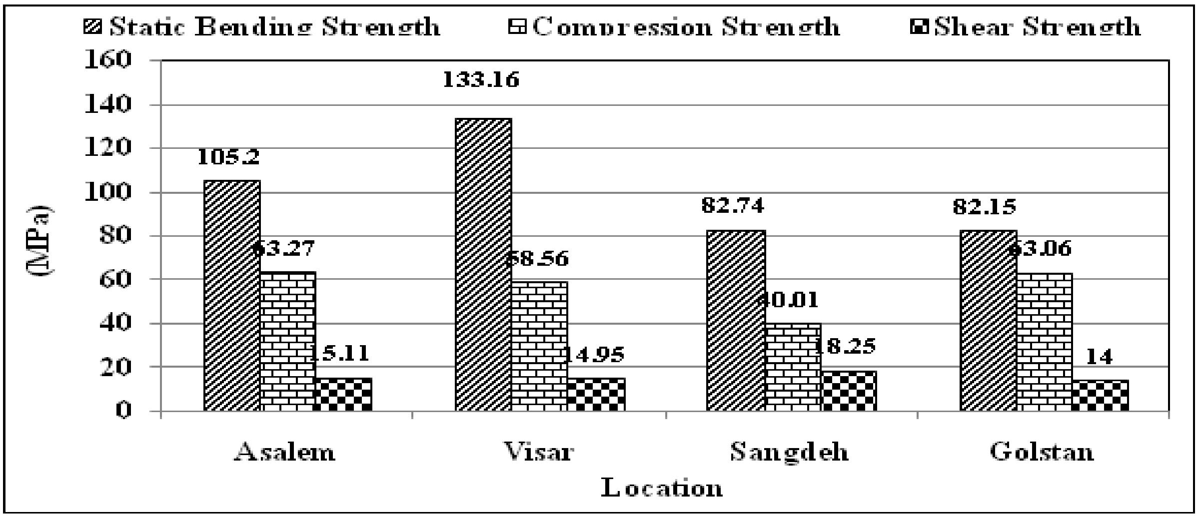

Fig. 3. The mechanical properties of Iranian oak.

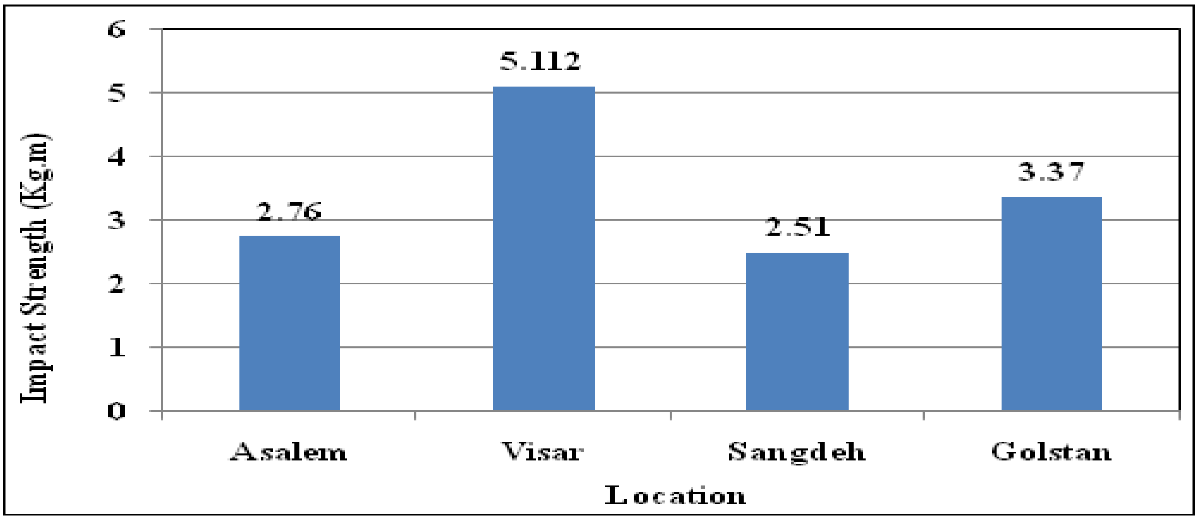

Fig. 4. The Impact bending of Iranian oak.

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