Beech and Walnut Wood

Subjects: Forestry

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Beech (Fagus orientalis Lipsky) forests in Iran are one of the most important sources of the hardwood species used for lumber, furniture, and interior object design due to its hardness, wear resistance, strength, and excellent bending capabilities.

beech density shrinkage static bending walnut

1. Introduction

Wood and wood products are some of the most important materials that have been traditionally used for building constructions, veneers, flooring, boatbuilding, furniture, cabinetry, musical instruments, plywood, and turned objects [1][2]. To date, wood is still an essential material for several applications due to its mechanical properties, workability, and thermal isolation properties. However, wood may also have some negative properties, including low dimension stability related to weather changes. Additionally, some mechanical properties such as strength and hardness are not identical in all directions of the grain, which can be aggravated by internal defects [3]. Thus, the use of wood for specific applications needs deep knowledge about its physical and mechanical properties. In this context, wood density is one of the most important features in the selection of trees and could be considered the main factor for understanding wood quality. For instance, some studies have proposed that the average density of beech wood is higher than 0.7 g/cm^3 [1][4].

The Hyrcanian region, located south of the Caspian Sea, covers ~50,000 km2 of the northern provinces in Iran. Due to the characteristic climate with high precipitation and the fertility of the soil, this region is well-known for plant diversity and fast growth. In particular, Iranian beech is one of the main inhabiting species in this area, which occupies 30% of the surface [5]. Although the beech wood species has a moderate durability against microorganisms [6][7][8], it is one of the main wood sources in many European countries [1][4][9][10][11][12], and this wood is mostly used in plywood, veneer, furniture, and construction [13] and has high potential for pulping and bio-pulping [14].

Walnut tree species are cultivated in many countries around the world due to their strength and beautiful color patterns [15][16][17][18]. Among these properties, the Persian walnut produces edible fruits which is being planted in many countries like southeastern Europe and western Central Asia [16][17][19]. This wood is mainly used for furniture, construction panels, and veneer products [15][20][21]. On the other hand, Iran is the third most important country in terms of walnut wood production, after China and the United States [18].

Due to the traditional use of wood species for several applications worldwide, it is necessary to acquire specific knowledge of the physical and mechanical properties of wood, such as the modulus of elasticity (MOE), modulus of rupture (MOR), and other strength properties with great significance for wood products and construction [22]. Nowadays, many diverse methods are used to evaluate wood properties such as color measurement [23], tomography [24] and thermography [25][26], near-infrared (NIR) spectroscopy [27][28], and wave propagation methods [29][30]. Some studies have investigated the physical and mechanical properties of beech wood, such as the modulus of rupture, modulus of elasticity, shear strength parallel to the grain, density, and shrinkage [10][11][31][32][33][34][35]. For instance, Saurat and Gueneau [36] reported that the mechanical strength of European beech was higher compared to that of American beech wood. Regarding walnut wood, research has also been conducted on the physical and mechanical properties of this valuable species, such as density, shrinkage, modulus of rupture, modulus of elasticity, shear strength parallel to the grain, compression strength parallel to the grain, and tensile strength parallel to grain [20][21][37][38][39].

2. Physical Properties

The results of the physical and mechanical properties of beech and walnut wood are shown in Table 3. As can be seen for walnut wood, a significant difference was observed between the dry density, radial shrinkage, tangential shrinkage, and volumetric shrinkage. Moreover, significant differences between Iranian and Georgian beech were also found in terms of physical properties except radial shrinkage. A significant difference between these species was reported (Table 1). The significant differences in the physical properties of the wood species from the four different regions and between the two types of beeches are mainly due to the density of the wood, because the density directly affects most of the physical and mechanical strengths of the wood. Moreover, growth conditions and environmental factors, especially altitude, weather, and the age of the tree, may cause changes in wood properties [12].

Table 1. Physical properties of the studied wood species.

Properties	Noor Walnut (*Juglans regia*)	Shahrekord Walnut (*Juglans regia*)	Mashhad Walnut (*Juglans regia*)	Mako Walnut (*Juglans regia*)	Sangdeh Beech (*Fagus orientalis*)	Georgia Beech (*Fagus orientalis*)
Dry density (g/cm^3)	0.62 {0.03} [1] (120) [2]	0.59 {0.03} (120)	0.625 {0.02} (120)	0.58 {0.02} (120)	0.61 {0.12} (327)	0.65 {0.027} (38)
Axial shrinkage (%)	0.192 {0.061} (120)	0.181 {0.195} (120)	0.223 {0.083} (120)	0.206 {0.101} (120)	0.32 {0.15} (327)	0.58 {0.243} (38)
Radial shrinkage (%)	6.24 {0.881} (120)	5.68 {0.595} (120)	6.225 {0.408} (120)	5.813 {0.455} (120)	5.359 {0.31} (327)	5.47 {0.403} (38)

Properties	Noor Walnut (*Juglans regia*)	Shahrekord Walnut (*Juglans regia*)	Mashhad Walnut (*Juglans regia*)	Mako Walnut (*Juglans regia*)	Sangdeh Beech (*Fagus orientalis*)	Georgia Beech (*Fagus orientalis*)
Tangential shrinkage (%)	10.7 {1.124} (120)	8.91 {1.155} (120)	9.779 {0.726} (120)	8.781 {0.714} (120)	10.649 {0.84} (327)	12.15 {0.405} (38)
Volumetric shrinkage (%)	17.04 {1.32} (120)	14.54 {1.23} (120)	16.26 {1.06} (120)	15.42 {0.71} (120)	16.433 {0.71} (327)	18.73 {0.384} (38)

Table 2. Statistical analysis of physical properties.

Type	Dry Density	Axial Shrinkage	Radial Shrinkage	Tangential Shrinkage	Volumetric Shrinkage
ANOVA of four walnut	0.000	0.122 ^{ns}	0.031	0.000	0.000
t-test of beech	0.000	0.000	0.128 ^{ns}	0.000	0.000

Significant difference at level of 5%. ^{ns} not significant.

The results for the dry density of wood from the Noor and Mashhad regions were 0.62 and 0.625 g/cm^3, respectively, which are close to the values reported by Bachtiar et al. [20] of 0.65 g/cm^3 for walnut woods in Eastern Europe and by Bachtiar et al. [39] of 0.67 g/cm^3 for walnut woods in the Caucasus. Furthermore, the results for the dry density of wood from the Shahrekord and Mako regions were 0.59 and 0.58 g/cm^3, respectively, which are similar to the value reported by Castro et al. [38] of 0.52 g/cm^3 for walnut wood in Italy. However, some previous studies have reported values above 0.7 g/cm^3 for the dry density of walnut wood [21][37]. The values of radial, tangential, and volumetric shrinkage of the four types of walnut woods in this study were approximately equal to those reported by Castro et al. [38].

The dry density values of the beech wood collected from Sangdeh and Georgia were 0.61 and 0.65 g/cm^3, respectively. These results are similar to the properties reported by Akrami et al. [4] for *F. sylvatica* in Germany (0.64 g/cm^3), for oriental beech in Iran [34] (0.59 g/cm^3), and for *F. sylvatica* [35] and beech in the USA (0.64 g/cm^3) [33]. However, several authors have demonstrated slightly higher dry density values (0.68 g/cm^3) for beech trees (*F. sylvatica*) grown in Europe [1][10][11][31]. Overall, the obtained result for radial shrinkage in this research was similar to that of Kretschmann [33]. In addition, the tangential and volumetric shrinkage results of the Sangdeh beech obtained in the current study (10.65% and 16.43%, respectively) were lower than the findings described by Kretschmann [33], where the high shrinkage was attributed to the lower density of Sangdeh beech. On the other hand, the tangential and volumetric shrinkage results of the Georgian timbers were similar to the results reported by Lo Monaco et al. [31].

3. Mechanical Properties

The results of the mechanical properties of the beech and walnut wood are shown in Table 3. As can be seen for walnut wood, a significant difference was observed between bending strength, modulus of elasticity, and shear and tensile strength parallel to grain. In addition, significant differences between Iranian and Georgian beech were found for all mechanical properties. A significant difference between these species was reported (Table 4). The significant differences in the mechanical properties of the wood species from the four different regions and between the two types of beeches are mainly due to the different density of wood.

Table 3. Mechanical properties of the studied wood species.

Properties	Noor Walnut (*Juglans regia*)	Shahrekord Walnut (*Juglans regia*)	Mashhad Walnut (*Juglans regia*)	Mako Walnut (*Juglans regia*)	Sangdeh Beech (*Fagus orientalis*)	Georgia Beech (*Fagus orientalis*)
Bending strength (MPa)	96.23 {7.68} [1] (18) [2]	91.13 {6.99} (18)	100.54 {7.10} (18)	87.61 {5.06} (18)	88.17 {1.19} (46)	99.01 {5.21} (16)
Modulus of elasticity (MPa)	10092 {6.21} (18)	10084 {5.91} (18)	10049 {8.71} (18)	7504 {5.94} (18)	9308 {8.43} (46)	11224 [7.96] (16)
Compression parallel to the grain (MPa)	36.07 {4.25} (9)	32.47 {4.14} (9)	37.91 {4.58} (9)	33.88 {4.25} (9)	42.05 {6.62} (9)	57.05 {4.13} (16)
Shear strength parallel to the grain (MPa)	10.73 {0.74} (9)	9.92 {1.32} (9)	9.15 {0.41} (9)	8.95 {0.71} (9)	8.412 {0.65} (14)	10.47 [1.45] (16)
Tensile strength parallel to the grain (MPa)	131.4 {5.56} (9)	124.7 {7.48} (9)	127.97 {8.34} (9)	125.83 {4.65] (9)	82.51 {2.42} (12)	131.15 {7.10} (16)
Tensile strength perpendicular to the grain (MPa)	3.15 {0.56} (9)	3.1 {0.39} (9)	-	-	1.99 {0.39} (14)	3.71 {0.44} (16)
Screw withdrawal strength tangential (N)	4061 {3.53} (9)	3916 {3.77} (9)	4031 {3.86} (9)	3685 {4.22} (9)	4466 {4.78} (20)	-
Screw withdrawal strength radial (N)	4151 {4.12} (9)	4123 {4.61} (9)	4218 {2.63} (9)	3915 {3.98} (9)	4566.2 {4.42} (20)	-

Properties	Noor Walnut (*Juglans regia*)	Shahrekord Walnut (*Juglans regia*)	Mashhad Walnut (*Juglans regia*)	Mako Walnut (*Juglans regia*)	Sangdeh Beech (*Fagus orientalis*)	Georgia Beech (*Fagus orientalis*)
Impact bending (KJ/m^2)	120.3 {13.89} (9)	110.1 {7.21} (9)	-	-	129.9 {8.72} (10)	110.81 {1.37} (16)

[1] The numbers in curly brackets indicate standard deviation. [2] The numbers in parentheses indicate the number of samples used.

Table 4. Statistical analysis of mechanical properties.

Type	Bending Strength	MOE	Compression	Shear	Tensile Parallel	Tensile Perpendicular	Screw in Tangential	Screw in Radial	Impact Bending
ANOVA of four walnut trees	0.001	0.000	0.082 ^{ns}	0.001	0.025	0.825 ^{ns}	0.127 ^{ns}	0.618 ^{ns}	0.083 ^{ns}
t-test of beech	0.000	0.000	0.000	0.000	0.000	0.000	-	-	0.035

Significant difference at level of 5 %. ^{ns} not significant.

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