EXPERIMENTAL CHARACTERIZATION OF SHRINKAGE AND DENSITY OF *TAMARIX APHYLLA* WOOD

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Athel (*Tamarix aphlylla*) is one of the important species planted for fixing the dune sands in the Iranian hot desert region. The variations in physical properties of Athel wood were studied on ten 48-52 year-old trees from the southeastern part of Iran (Zabol region). The samples were taken at breast height and from the entire disc surface. The physical properties, including oven-dry density (686 Kg m^{-3}), basic density (521 Kg m^{-3}), tangential shrinkage (7.13%), radial shrinkage (4.14%), longitudinal shrinkage (1.96%), volumetric shrinkage (13.23%), fiber saturation point (25.4%), maximum humidity content (125.60%), tangential to radial shrinkage ratio (1.72), percentage of cell wall (46.06%) and porosity (53.93%), were determined. The relationship between wood density and shrinkage (tangential, radial and longitudinal) and maximum moisture content was determined by Pearson matrix correlation analyses. It was found that the relationships density–shrinkage and density–maximum humidity content were positive and negative, respectively. The correlation coefficient between wood density and longitudinal shrinkage was found to be higher than those of the relationships wood density–tangential shrinkage and wood density–radial shrinkage.

Keywords: *Tamarix aphylla*, density, shrinkage, fiber saturation point, maximum moisture content, cell wall, porosity

INTRODUCTION

Tamarix is a genus of the family *Tamaricaceae* and is composed of 54 species, native of the old world, with a major center of speciation in Pakistan, Afghanistan, Iran, Turkmenistan, southern Kazakhstan, and another in the eastern Mediterranean area[1]. There are 18 species and 1 variety of *Tamarix* in China, mainly found in northwestern China, Inner Mongolia and northern China.[2]

One of the most known species of this genus is *Tamarix aphylla*, which is widespread throughout southeastern Europe, North Africa and Central Asia.[3] It is drought-resistant and tolerant of alkaline and saline soils and grows along irrigation ditches in the bottomlands.[4,5] In Greece and Turkey, this non-commercial species is very common in the coastal areas, on beaches and islands mainly in the form of shrubs.[6]

Tamarix aphylla is a fast-growing, moderately sized evergreen tree, up to 18 m high with erect tapering trunk, with a 60-80 cm diameter at breast height and with many stout spreading purplish brown and smooth branches. Its wood is close-grained, light-colored, fibrous and fairly hard, with high shock resistance; it also splits readily when first cut and polishes well.[1,3]

Nowadays, the end uses of *Tamarix aphylla* wood are diverse. In the USA, Athel wood is used for fuel. It is also capable of taking a high polish and has been proposed for fence posts.[7] Moreover, it has been found to be a suitable raw material for making particleboards and can be used as biomass for sugar production.[8,9] Athel wood is additionally utilized for firewood and charcoal.[3] It may also be suitable for making ploughs, wheels, carts, tool handles, brush-backs, ornaments, turnery and fruit boxes. Its twigs are used for basket making, while its bark is a rich source of tannins and mordant for dyeing.[3]

In Iran, this species was planted for fixing the dune sands in the Iranian hot desert region about 60 years ago. While there are studies on the physical and mechanical properties of Athel wood growing in Greece,[10] currently, the information available on the properties of Athel wood growing in Iran is very scarce. Determining its properties may provide significant initial data to researchers and offer interesting opportunities for future research. The objectives of this study have been to determine the physical properties of Athel wood growing in the southeast of Iran and to examine the relationships between wood density and volumetric shrinkage and between wood density and maximum moisture content.

EXPERMENTAL

Materials and methods

All the Athel trees (*Tamarix aphylla*) were randomly selected, taking into account stem straightness and absence of obvious decay, according to TS 2476, *i.e.* defect-free, clear and normally grown (without zone lines, reaction wood, decay and insect damage, or fungal infection) from a plantation in the southeast of Iran (Zabol region). This area is located at an average altitude of 470 m, at 61° 25' E and 31° 05' N. The mean annual precipitation in the experimental area is below 100 mm/year; the yearly average temperature is of 22 °C. Ten 48-52 year-old trees were cut from the same site. The stem height and diameter of the trees were of 12-13 m and 40-45 cm, respectively.

Physical properties

From each tree, 10 cm long sample discs were taken from the same height level – at breast height. Rough boards with 25 mm thickness were radially sawn in the four directions of the radius, on the entire disc surface. Then test specimens were cut from these rough boards with the dimensions of 20 × 20 × 20 mm, according to ASTM D143-94 used for measuring oven-dry density, basic density, tangential shrinkage, radial shrinkage, longitudinal shrinkage, volumetric shrinkage, T/R shrinkage, fiber saturation point, maximum moisture content, percentage of cell wall and percentage of porosity (Figure 1).

The specimens were soaked in distilled water for 72 h to ensure that their moisture content was above the fiber saturation point, and then their dimensions were measured in all three principal directions, with a digital caliper to the nearest 0.001 mm. The specimens were weighed to the nearest 0.001 g for saturated weight and the saturated volume was calculated based on these dimension measurements. Finally, the samples were oven-dried at 103 ± 2 °C to 0% moisture content. After cooling in desiccators, the oven-dry weights of the specimens were measured. The wood physical properties were calculated using the following equations:

$$D_0 = (M_0 \div V_0) \times 100 \quad (1)$$

where D_0, M_0 and V_0 are the oven-dry density, weight and volume of the specimen (in dry state), respectively.

$$D_b = (M_0 \div Vs) \times 100 \quad (2)$$

where D_b is the basic density, M_o is the oven-dry weight and Vs is the saturated volume of the specimen.

$$\beta_V = [(V_S - V_0) / V_S] \times 100 \quad (3)$$

$$\beta_T = [(T_S - T_0) / T_S] \times 100 \quad (4)$$

$$\beta_R = [(R_S - R_0) / R_S] \times 100 \quad (5)$$

$$\beta_L = [(L_S - L_0) / L_S] \times 100 \quad (6)$$

$$\text{Ratio T/R shrinkage} = \beta_T / \beta_R \quad (7)$$

where β_L, β_R, β_L and β_v are the longitudinal shrinkage, radial shrinkage, tangential shrinkage and volume shrinkage, L_s, R_s, T_s and V_s are the longitudinal, radial, tangential dimensions and the volume of the saturated specimens, respectively, and L_0, R_0, T_0 and V_0 are the longitudinal, radial, tangential dimensions and volume of the dried specimens, respectively.

$$FSP = \beta v / D_b \quad (8)$$

$$M_{max} = (1.5 - D_b) / (1.5 \times D_b)\ (\%) \quad (9)$$

where FSP and M_{max} are the fiber saturation point and maximum moisture content, respectively.

$$V_c = D_0 / Dc \times 100 \quad (10)$$

$$V_H = 100 - V_c \quad (11)$$

where V_C, D_C and V_H are percentage of cell wall (%), oven-dry density of the cell wall (1.5 g cm^{-3}) and porosity (%), respectively. Finally, descriptive statistics (Max, Min, Stdev, Mean) were used for data analysis.

RESULTS AND DISCUSSION

The descriptive statistics of the physical properties found for *Tamarix aphlla* wood samples are shown in Table 1 and Figure 2. These results have been compared with corresponding values for Athel wood grown on the island of Lesvos in Greece (Table 2).

Wood density is an important wood property for both solid wood and fiber products from conifers and hardwoods.[11] It is affected by the cell wall thickness, the cell diameter, the earlywood to latewood ratio and the chemical content of the wood.[12] Panshin and de Zeeuw reported that density is a general indicator of cell size and a good predictor of strength, stiffness, ease of drying, machining, hardness and various papermaking properties.[13] Oven-dry and basic densities of Athel wood were found to be of 0.686 and 0.521 Kg m^{-3}, respectively. The detrmined average oven-dry density was a little higher than that of the wood grown on the Greek island (0.660 Kg m^{-3}). It is well known that wood is an anisotropic material, which presents differential dimensional changes in different wood directions longitudinal, radial and tangential). The magnitude of shrinkage and swelling is affected by the amount of moisture gained or lost by wood, when the moisture content fluctuates between zero and fiber saturation point.[14,15] The tangential, radial and longitudinal shrinkage of Athel wood were determined as being of 7.13, 4.14 and 1.96%, respectively. The values determined in the present study for volumetric shrinkage and tangential shrinkage were of 13.23% and 7.13%, respectively, which is a little lower than the corresponding values for the wood grown in Greece (14% and 10.8%, respectively), while that for radial shrinkage is higher (4.14% compared to 3.2%). In addition, the ratio of tangential shrinkage to radial shrinkage in the Greek Athel wood is much higher, compared to the value obtained in the present study – 3.8 compared to 1.72.

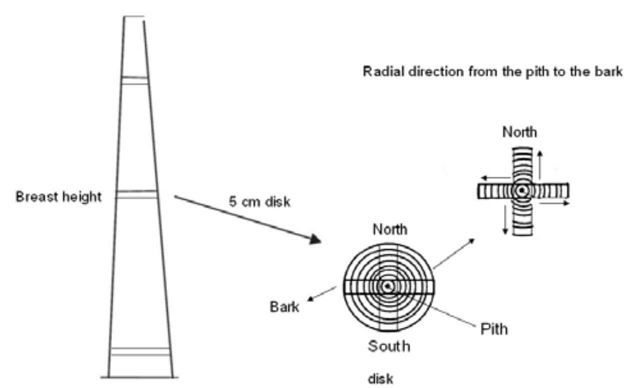

Figure 1: Sawing pattern used on each stem section for the analysis of physical wood properties

Table 1
Descriptive statistics for physical properties of Athel wood

Properties	Mean	SD	CV
Oven-dry density (Kg m^{-3})	686	29.63	4.31
Basic density (Kg m^{-3})	521	23.23	4.45
Tangential shrinkage (%)	7.13	0.912	12.79
Radial shrinkage (%)	4.14	0.782	18.88
Longitudinal shrinkage (%)	1.96	0.542	27.65
Volumetric shrinkage (%)	13.23	1.27	9.59
Ratio T/R shrinkage	1.72	0.266	15.46
Fiber saturation point (%)	25.42	2.39	9.40
Maximum moisture content (%)	125.6	6.78	5.39
Percentage of cell wall (%)	46.06	2.43	5.27
Porosity (%)	53.93	2.91	5.39

SD: Standard deviation, CV: coefficient of variation

Table 2
Physical properties of Athel wood grown in Iran and Greece

Properties	In Iran (this study)	Greece*
Oven-dry density (Kg m^{-3})	686	660
Tangential shrinkage (%)	7.13	10.8
Radial shrinkage (%)	4.14	3.2
Volumetric shrinkage (%)	13.23	14
Ratio T/R shrinkage	1.72	3.8

*Mantanis and Birbilis [11]

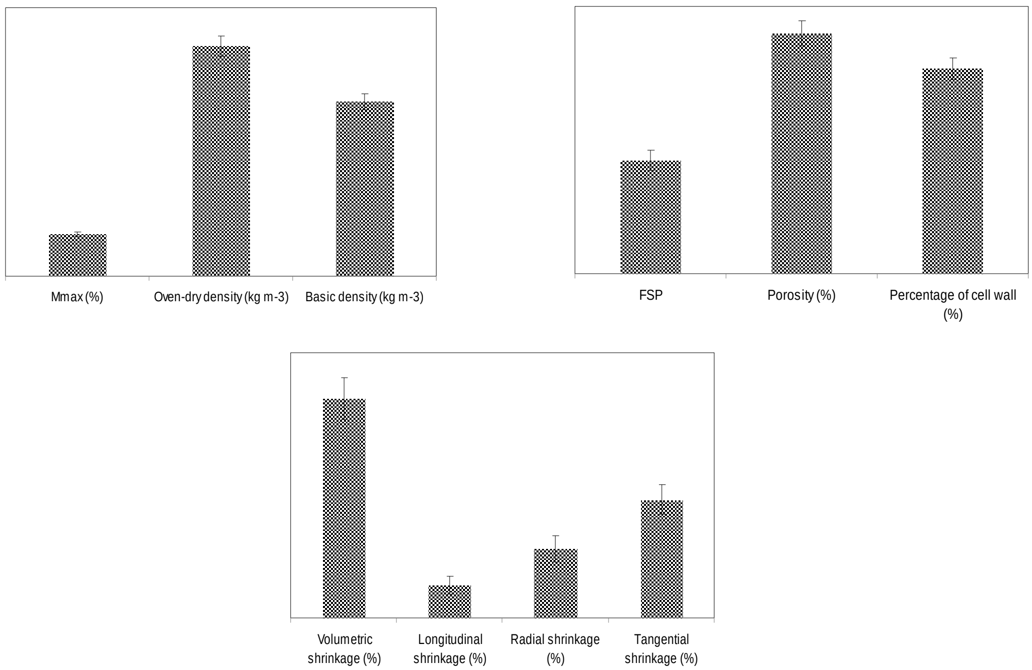

Figure 2: Physical properties of Athel wood

The water existing in wood may be either bound or free. As bound, it is bonded (via secondary or hydrogen bonds) within the wood cell walls. As free, it is simply present in the cell cavities. When wood dries, most free water separates at a faster rate than bound water, due to its accessibility and to the absence of secondary bonding. The moisture content at which the cell walls are still saturated, but virtually no water exists in the cell cavities is called the fiber saturation point. The fiber saturation point usually varies between 21 and 28%.[16] The value of the fiber saturation point was calculated by dividing volumetric shrinkage to basic density, and in the present study, it equalled 25.42%.

Table 3
Pearson correlation between wood different properties in Athel wood

Properties	Oven-dry density	Basic density
Tangential shrinkage	0.734*	0.769**
Radial shrinkage	0.918**	0.951**
Longitudinal shrinkage	0.931**	0.939**
Volumetric shrinkage	0.828**	0.859**
Maximum moisture content	-0.939**	-0.999**
Percentage of cell wall	0.944**	0.937**
Porosity	-0.944**	-0.937**

*correlation is significant at the 0.05 level
**correlation is significant at the 0.01 level

Simpson reported that the maximum moisture content in lumber is important because of its influence in controlling kiln-drying schedules.[14] From a practical standpoint, when determining kiln schedules, the largest number of moisture samples should be selected from the slowestdrying materials.[17] In addition, porosity is linearly and inversely related to wood maximum moisture content and wood density, respectively.[18] In the present study, the values of maximum moisture content, percentage of cell wall and porosity were found to be of 125.6, 46.06 and 53.93%.

The relationships between different wood properties were determined by Pearson matrix correlation (Table 3). Strong positive correlations were found between density and longitudinal, radial and tangential shrinkage and percentage of cell wall in Athel wood. The relationships found between density and porosity and maximum moisture content were negative. The volumetric shrinkage and swelling properties are affected by several wood factors, such as the heartwood to sapwood ratio or the fibrillar angle on the S2 layer.[19] However, the most important parameter affecting wood shrinkage is the wood density.[20]

CONCLUSIONS

This work focused on the main physical properties of *Tamarix aphylla* wood grown in the southeast of Iran (Zabol region). The wood density determined in the present study is higher than the wood density of Athel wood grown on the Greek island, while the volumetric shrinkage and the ratio of tangential to radial shrinkage is low. The variations in the wood properties of the same species are due to different growth factors, such as growth and ecological conditions. In addition, altitude, soil and climate are also very effective factors. Besides, tree age, sample size, ring properties (e.g. ring width, ring orientation), and the test procedure may also affect the test results. Therefore, more work on the chemical components, anatomical features and mechanical properties of this species is necessary for revealing its potential for other uses of interest.

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