Physical properties and fiber dimension in Stem, Branch and root of Alder Wood

Article *in* Fresenius Environmental Bulletin · January 2015

2 authors:

Majid Kiaei
Islamic Azad University, chaloos branch, Iran

Roger Moya Roque
Costa Rican Institute of Technology (ITCR)

PHYSICAL PROPERTIES AND FIBER DIMENSION IN STEM, BRANCH AND ROOT OF ALDER WOOD

Majid Kiaei[1,]* and Roger Moya[2]

[1]Young Researcher and Elite Club, Chaloos Branch, Islamic Azad University, Chaloos, Iran
[2] Instituto Tecnológico de Costa Rica; Escuela de Ingeniería Forestal;P.O. Box: 159-7050, Cartago-Costa Rica;

ABSTRACT

The aim of this study was to determine physical properties and fiber dimensions in stem, branch and root wood for alder (*Alnus glutinosa L)* species. For this purpose, three normal alder trees were selected from Khanican forest in north of Iran. Disks were taken from three parts such as stem, branch and root of trees. Testing samples were randomly taken at disk surfaces to examine the physical properties (according to the ISO standard for oven-dry density and volumetric shrinkage) and fiber dimension (fiber length, fiber diameter and lumen diameter according to the Franklin method). Analysis of variance (ANOVA) indicated that the wood samples had significant difference on the wood density, volumetric shrinkage, fiber length, fiber diameter and lumen diameter. The highest wood density, volumetric shrinkage and fiber length was found in stem wood, whereas root wood had a lighter density, larger fiber diameter and larger fiber lumen diameter. The branch wood had the lowest fiber dimensions (fiber length, fiber diameter and lumen diameter) compared to other wood sample parts. The relationship between wood density and volumetric shrinkage were determined by regression model. These relationships in root wood were very weaker compared to stem wood and branch wood.

KEYWORDS: *Alnus glutinosa*, fiber length, fiber diameter, fiber lumen diameter, stem, branch, root.

1. INTRODUCTION

The cell size and relative cell dimensions have a major influence on the quality of pulp and paper products and on solid wood products [1-2]. The fiber length and width, wall thickness, and lumen size have an effect on the bulk, burst, tear, fold, and tensile strengths of paper [3]. However, there are definite correlations between tracheid length and certain lumber mechanical properties [4]. A positive and strong relationship between MOR and the tracheid length of hardwood and soft species was found by several researchers [4, 5]. There are positive relationships between fiber length and paper burst strength [6-9], tensile strength [6, 7], tear strength [6, 10] and folding endurance [9, 11]. Anatomical properties of root wood are different than stem wood and branch wood. Root wood has a high vessel number, wider diameter of vessel, and low fiber volumes [12]. Chemical composition analysis showed that the cellulose content in root wood is higher than stem wood. Average of lignin and extractive component in root wood is very high [13].

Different results have emerged from studies carried out to assess the properties of root, stem and branch wood. Wood density in root wood is lower than other wood samples (stem and branch wood) in many of hardwoods species [14]. Whereas, wood density and mechanical strength properties in root wood is higher compared to branch wood and stem wood in African hardwood species [15]. Okai et al. (2004) [16] on the physical and mechanical properties of stem and branch wood of tropical trees in Ghana reported that the branches of the two species emire (*Terminalia ivorensis*) and asanfina (*Anigeria robusta*) had higher densities and modulus of rupture (MOR) than their corresponding stems. Amoah et al (2012) reported that the root wood of iroko and emire exhibited the highest basic density compared to branch and stem wood [15]. Research on the tracheid dimension in root wood of southern pine reported that the rootwood tracheids were one-third longer, averaging 3.99 mm as compared to 2.97 mm for stumpwood tracheids. In transverse dimensions root tracheids were larger in diameter and had thinner walls and larger lumens than stem tracheids from the same stump. Cell diameter averaged one-third greater (52.48 µm) in root wood than in stump wood (38.76 µm). Average thickness of cell walls was 5.40 µm in roots and 6.55 µm in stumps. Lumen diameters averaged 41.69 µm in roots and 25.66 µm in stumps [17].

There are no reports on wood different properties among root, branch and stemwood for Iranian hardwood species especially for alder wood. Therefore, the aim of the present study was: a) to determine the physical properties and fiber dimension properties in the three wood samples parts such as stem, branch and root wood for alder species (*Alnus glutinosa)* and to examine the relationship between wood different properties in Mazandran region of Iran.

* Corresponding author

2. MATERIALS AND METHODS

2.1 Wood samples

Three alder trees (*Alnus glutinosa*) with breast height diameters 20, 21.5, and 22 cm, with 37, 39 and 39 growth rings at breast height, respectively were harvested in the western part of Mazandran region, north of Iran. Discs were taken from three part of each tree include stem (at breast height), branch and root parts. After removing pith part for every disc, sample testing was randomly prepared at disc surface (after 20 years – old for stem wood). Thirty samples for each part were used to determine the physical properties and fiber dimensions (3 part × 30 samples = 90 according to ISO standard. Examination of fiber dimension was carried out after the physical properties had been determined.

2.2 Fiber dimensions

The material was macerated using the Franklin method (1946) [18] to examine fiber dimensions. The pieces of fiber were cut with a scalpel and placed in test tubes in a solution of 1:1 acetic acid and oxygenated water of 30 volumes. The samples were dried in a stove at 60 ºC for approximately 1 week. The disaggregated particles were washed in water, stained with aqueous safranin at 1% for 3 min, dehydrated with alcohol at 96% and xylol. Subsequently, the fibers were dried, placed on slides and fixed with Canada balsam. From a samples, 30 fibers (3 part ×30 samples × 30 fiber =2700 fiber) were selected to determine fiber dimension (fiber length, fiber width, and fiber lumen diameter), which used from Leica Image Analyzer System (Figure 1).

2.3 Physical properties

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:

$$D_0 = \frac{M_0}{v_0}$$

$$\beta_v = \frac{v_s - v_0}{v_s} \times 100$$

where D_0 , M_0 , v_0 , β_v and v_s are the oven-dry density, weight and volume of the specimen (in dry state), volumetric shrinkage and volume of the saturated specimens, respectively.

2.4 Statistical analysis

One-way analysis of variance (ANOVA) was carried out to establish the effect types of wood sample parts on physical properties and fiber dimension and the differences were quantified through the Duncan test ($p \leq 0.05$). In order to examine relationship between various properties were used from regression models. In order to examine relationship between various properties were used from regression models.

3. RESULTS AND DISCUSSION

3.1 Fiber length

The average fiber length in root wood, branch wood and stem wood are shown in Figure 2. The fiber length averaged 1.31± 0.188 mm in stem, 0.940 ± 0.128 mm in branch and 1.25 ± 0.173 mm in root wood. Maximum and minimum of fiber length in stem, branch and root alder wood were 1.02-1.64, 0.639-1.12 and 0.890-1.44 mm, respectively. The analysis of variance (ANOVA) indicated that the effect of wood sample parts on the fiber length was significant (F=22.346, Sig=0.002). The highest and lowest of fiber length were found in stem and branch, respectively. No statistically significant difference was detected between

FIGURE 1 - Fibers of stem wood in *Alnus glutinosa*

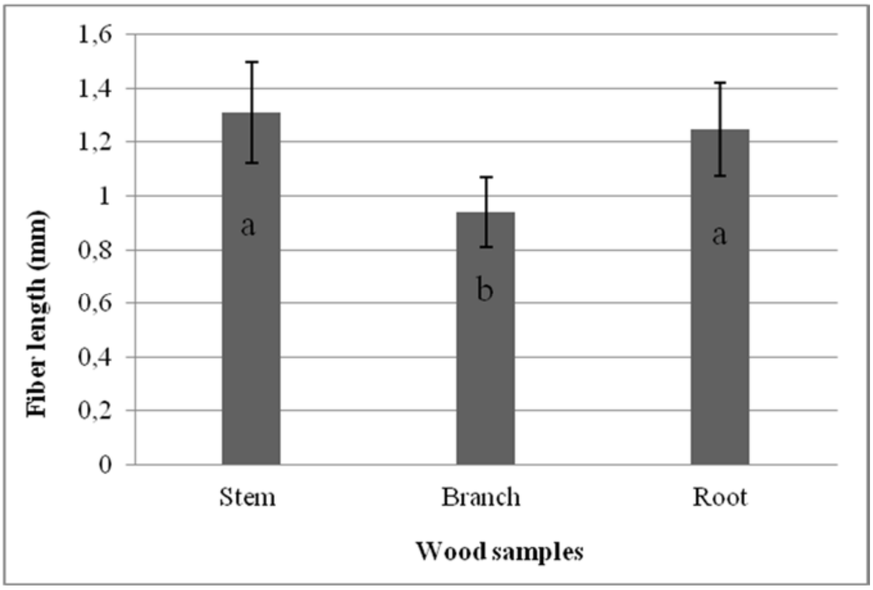

FIGURE 2 - The average of fiber length in stem, branch and root wood

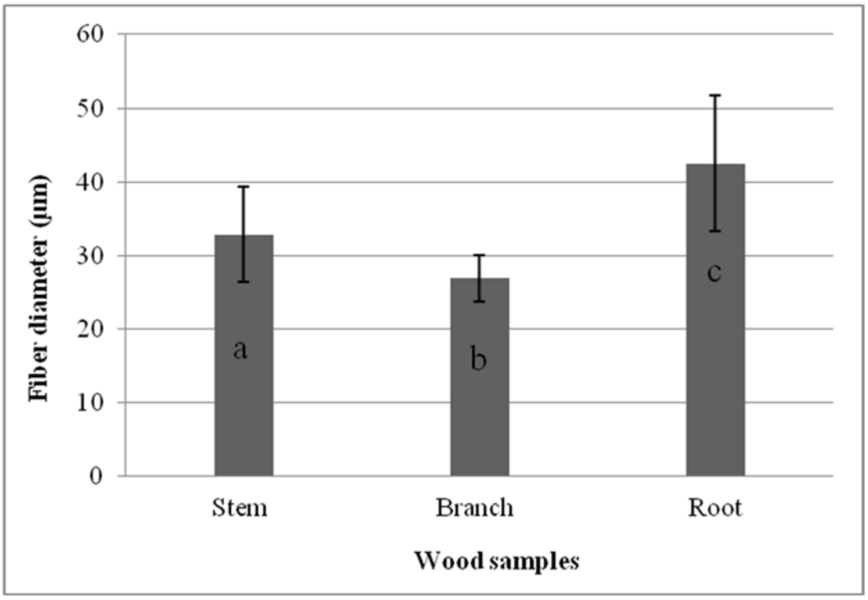

FIGURE 3 - The average of fiber diameter in stem, branch and root wood

stem and root wood samples in fiber length. These results were previously reported by several researchers. For example, Manwiller (1972) [17] and Dunham et al. (2007) [19] reported that the branch wood have shorter tracheid/fiber than the stem wood. Generally, there are different results about fiber length in stem, branch and root wood. Fegel (1941) [20] and Dunham et al. (2007) [19] reported that root wood may have shorter or longer tracheids than the bole, or Psaras and Sofroniou (2004) [21] reported that the fiber length in root wood (620 µm) is higher than stem wood (590 µm) for *Phlomis fruticosa* species.

3.2 Fiber diameter

The average fiber diameter in root wood, branch wood and stem wood are shown in Figure 3. The fiber diameter averaged 32.87 ± 6.41 µm in stem, 26.92 ± 3.16 µm in branch and 42.52 ± 9.15 µm in root wood. Maximum and minimum of fiber diameter in stem, branch and root alder wood were 26.08-49.05, 20.34-31.83 and 24.14-59.72 µm, respectively. The analysis of variance (ANOVA) indicated that the effect of wood sample parts on the fiber diameter was significant (F=20.873, Sig=0.004). The highest and lowest of fiber diameter were found in root and branch wood, respectively.

3.3 Lumen diameter

The average of lumen diameter in root wood, branch wood and stem wood are shown in Figure 4. The fiber lumen diameter averaged 19.73 ± 5.92 µm in stem, 14.40 ± 3.28 µm in branch and 30.10 ± 7.8 µm in root wood. Maximum and minimum of fiber lumen diameter in stem, branch and root alder wood were 12.96-31.83, 9.68-19.52 and 12.11-49.87 µm, respectively. The analysis of variance (ANOVA) indicated that wood sample parts had significant effect on the lumen diameter (F=20.205, Sig=0.005). The highest and lowest of fiber lumen diameter were found in root and branch wood, respectively. Results of lumen diameter and fiber diameter are in agreement with a study carried out by Manwiller (1972) [17]. According to the results of lumen diameter and fiber diameter it can be said that the fiber cell wall thickness in stem wood was higher compared to the branch wood and root wood in alder species.

3.4 Wood density

The average oven-dry density in root wood, branch wood and stem wood are shown in Figure 5. Among the wood types of alder, the root wood recorded the lowest av-

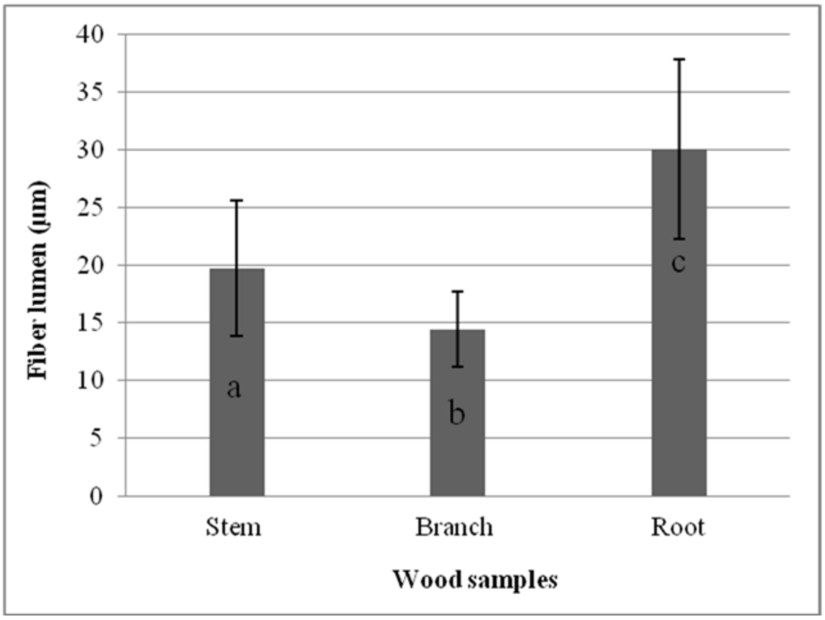

FIGURE 4 - The average of lumen diameter in stem, branch and root wood

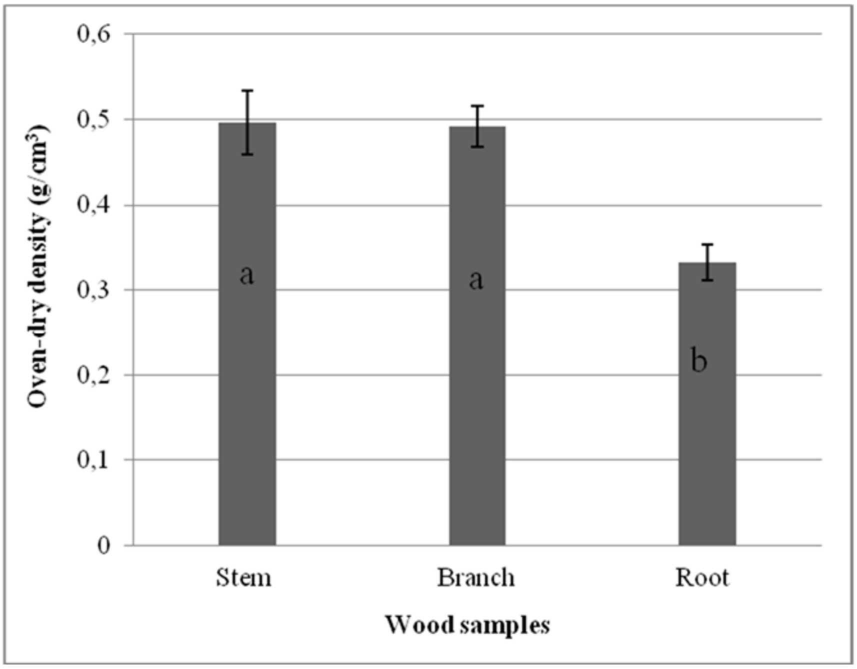

FIGURE 5 - The average of oven-dry density in stem, branch and root wood

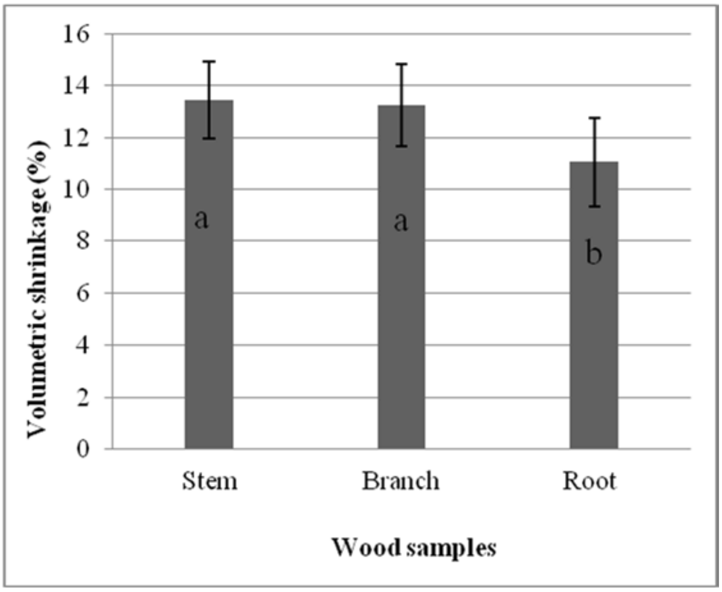

FIGURE 6 - The average of volumetric shrinkage in stem, branch and root wood

erage oven-dry density (0.333 ± 0.021 g/cm^3), ranging between 0.294 and 0.375 g/cm^3. Stem wood recorded the highest (0.496 ± 0.038 g/cm^3), varying between 0.444 and 0.595 g/cm^3. The average wood density in branch wood was 0.492 ± 0.024 g/cm^3, varied ranging between 0.458 and 0.559 g/cm^3. The analysis of variance (ANOVA) indicated that wood sample parts had significant effect on the oven-dry density (F=202.223, Sig=0.001). There was no significant difference between branch wood and stem wood in oven-dry density.

Several scientific studies have reported that the vessel diameter and vessel length of root wood is higher than that of branch wood and stem wood [12, 21]. There also are inverse relationship between wood density and volumetric shrinkage in alder wood [14, 22, 23]. Therefore, decreasing the wood oven-dry density in root wood can be related to its higher vessel diameter.

3.5 Volumetric shrinkage

The average volumetric shrinkage in root wood, branch wood and stem wood are shown in Figure 6. The volumetric shrinkage averaged 13.44 ± 1.50 % in stem, 13.23 ± 1.58 % in branch and 11.05 ± 1.71 % in root wood. Maximum and minimum of volumetric shrinkage in stem, branch and root wood were 11.15-17.41, 11.44-16.45 and 7.74-13.77 %, respectively. The analysis of variance (ANOVA) indicated that wood sample parts had significant effect on the volumetric shrinkage (F=17.408, Sig=0.002). The highest and lowest of volumetric shrinkage were found in stem and root wood, respectively. There was no significant difference between branch wood and stem wood in volumetric shrinkage.

The relationship between wood density and volumetric shrinkage in three parts of trees (stem, branch and root) are shown in Figure 7-9. Results indicated that shrinkage is

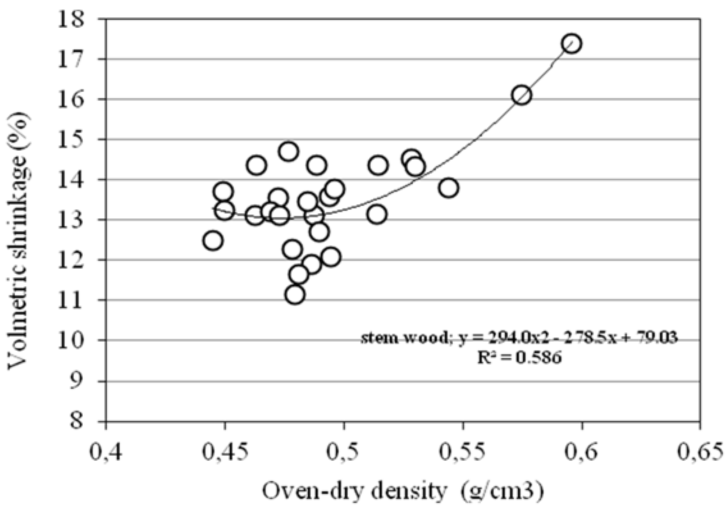

FIGURE 7 - The relationship between density and shrinkage in stem wood

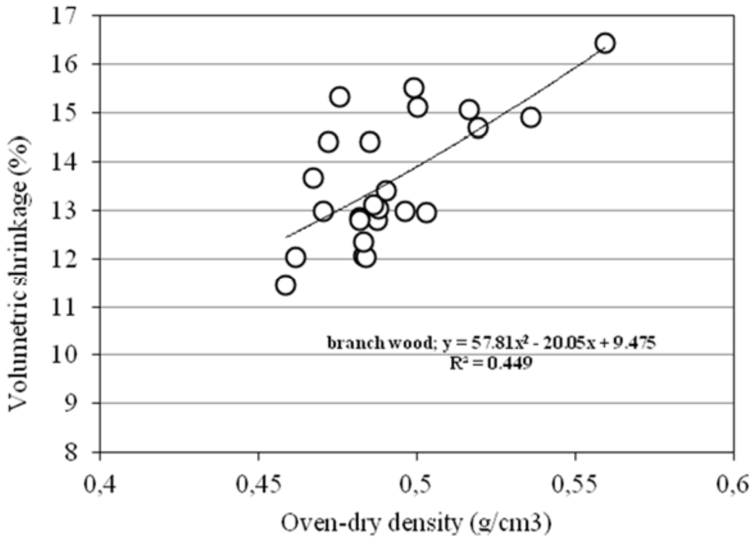

FIGURE 8 - The relationship between oven-dried density and shrinkage in branch wood

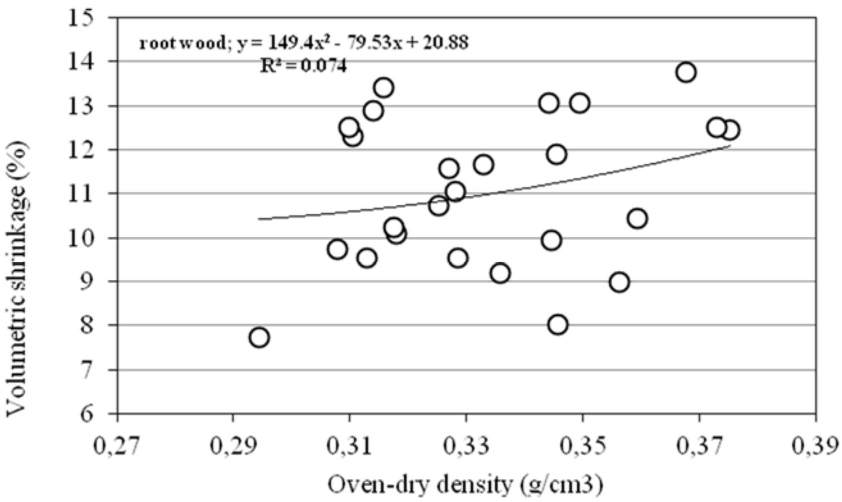

FIGURE 9 - The relationship between oven-dried density and shrinkage in root wood

TABLE 1 - Pearson correlation between fiber dimension and oven dried density in alder wood

Wood samples	Stem	Branch	Root	Total
Fiber length (FL)	0.114	-0.152	-0.441	-0.325*
Fiber diameter (FD)	-0.076	0.252	0.305	-0.615**
Lumen Diameter (LD)	-0.245	-0.032	0.189	-0.647**

* and ** were significant at 0.01 and 0.05%

positively and significantly related to wood density in stem and branch wood, whereas this relationship found in root wood is positive but not significant. The correlation coefficient between wood density and shrinkage in branch wood (R^2=0.449) is lower compared to the stem wood (R^2=0.586). Greater variation was found in relationship between density and shrinkage for root wood for alder wood. 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 S_2 layer [24]. However, the most important parameter affecting wood shrinkage is the wood density [25]. This present research indicated that the shrinkage in stem wood is higher than that of branch wood and root wood. High wood density have proportionately more cell and less lumen volume and they shrink and swell more due to the unique nature of the microstructures.

The effect of fiber dimension on the wood density of three parts of alder wood was determined by Pearson correlation (Table 1). Significant differences were no found between FL, FD and LD with wood density for each of wood samples, while in total of wood samples, there are significantly negative relationship between fiber length (r =- 0.325), fiber diameter (r = -0.615) and lumen diameter (r = -0.647) with wood oven-dried density. Two most effective variables on the oven-dry density in alder wood are fiber diameter (FD) and lumen diameter (LD). The highest of correlation coefficients between FL-density and FD – density was found in root wood, while the relationship between LD-density in the stem wood is higher compared to branch wood and stem wood.

4. CONCLUSION

This research examines the effect of wood sample parts on the physical properties and fiber dimensions of alder wood in north of Iran. The analysis of variance (ANOVA) indicated that the wood samples had significant difference on the fiber length, fiber diameter, and fiber lumen diameter. Root wood had the highest fiber diameter and fiber lumen diameter values. The lowest fiber dimensions were found in the branch wood. The highest and lowest wood density and volumetric shrinkage values were found in stem wood and root wood, respectively. The wood density and shrinkage in branch wood is close to the stem wood. There are positive relationship between wood density and shrinkage, whereas these relationships in root wood were weaker than stem wood and branch wood. These results indicated that Iranian root alder wood fibers are promising fibrous raw material for the fiberboard and paper production due to long fiber length, while had a low density. There is a lack of wood resources in Iran. Root wood fibers can solve these problems.

ACKNOWLEDGEMENTS

This article is derived from a M. Sc thesis of Fariborz Alinejad and Hossein Mahmoodkhani. The authors appreciate the support receive from the Chaloos Branch, Islamic Azad University, Chaloos, Iran.

The authors have declared no conflict of interest.

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Received: April 28, 2014
Revised: July 07, 2014
Accepted: July 21, 2014

CORRESPONDING AUTHOR

Majid Kiaei
Young Researcher and Elite Club,
Chaloos Branch
Islamic Azad University
Chaloos, Iran
IRAN

E-mail: Mjd_kia59@yahoo.com

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