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Effect of Pretreatments and Drying Methods on Abnormal Shrinkage of Wood

Ho-Yang Kang†1 and Min-Gyoung Lee1

ABSTRACT

Collapse is an abnormal shrinkage resulting in uneven, rough surfaces and/or warping of sawn timber. The maximum abnormal shrinkages of the oak and persimmon specimens were obtained by the quasi-equilibrium drying and were compared with the other drying methods. The effect of steaming and freezing treatments on the shrinkage of wood was also investigated. The Quasi-equilibrium drying used in this study was proved as a good tool to make the maximum abnormal shrinkage of wood. The maximum abnormal volumetric shrinkage possibly caused by collapse could be 16.3% and 14.3% for the oak and persimmon specimens, respectively. In general the steaming-treated specimens shrank less than the controls for the oak specimens, but did more for the persimmon specimens. The volumetric shrinkages of the freezing-treated specimens were more various between the drying methods than those of the control and steaming-treated specimens.

Key words: Steaming, freezing, abnormal volumetric shrinkage, collapse, *Quercus serrata, Diospyros kaki* Thumb.

INTRODUCTION

Collapse is generally considered to be one of the worst kinds of damage that often results in uneven, rough surfaces and/or warping of sawn timber. It is the excessive shrinkage of timber which can start well above the fiber saturation moisture content of wood and take place also in the hygroscopic range (Bariska 1992). Evidences indicate that collapse also occurs in living trees.
Collapse is generally associated with excessively high dry-bulb temperatures in the early stages of drying (Rasmussen, 1961.). Because at a high temperature the transverse tension strength of the wood substance in green state is very low, separations and collapse at microscopic and macroscopic level are highly probable (Chafe 1995).

It was reported that compression, shearing and tension strength of water saturated eucalypt and poplar decrease with increasing temperature (Giordano and Currb 1961). This temperature effect on wood strength would be explained by the fact that the thermal expansivity of water saturated spruce is positive above 63℃, the softening temperature of lignin, while below this temperature it is negative (Salmen 1990).

Steaming increases permeability and drying rate in wood and reduce drying time. However such a treatment also may reduce the strength of wood and increase shrinkage and collapse.

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1) College of Agriculture, Chungnam National University, Daejeon 305-764, Korea.
† Corresponding author: Ho-Yang Kang (Email: hykang@cnu.ac.kr).

Increased drying rate has been attributed to conformational changes in heartwood extractives whereas the causes for reduced strength and increased shrinkage are thought to lie with changes in chemical bonding of cell wall constituents or heat degradation of hemicelloses and lignin (Chafe 1993; Yang 1998; Obataya et al. 2004).

Freezing with dry ice reduced the radial shrinkage of 1-inch black walnut boards 20 percent, and tangential shrinkage about 10 percent when kiln-dried to a final average moisture content of 9 percent (Erickson and Petersen 1969).

Shrinkage is a phenomenon of plasticization, so it is time-dependent. However in contrast to the effect of temperature and pretreatment, the effect of drying time on shrinkage is less known. In this study a quasi-equilibrium drying was simulated by drying specimens in a stainless tube sealed with wood disks, causing highest tension stress on cell. Highest capillary force can be obtained when relative humidity approaches 100%.

The objective of this paper was to obtain the maximum abnormal shrinkage of wood by a quasi-equilibrium drying and compare with the other drying methods. The effect of steaming and freezing on the shrinkage of wood was also investigated.

MATERIAL AND METHODS

White oak (*Quercus serrata*) and persimmon (*Diospyros kaki* Thumb) were selected for this study. These two species are known as refractory and susceptible to collapse.

Fifteen boards of 30 x 100 x 300 mm were cut from fresh logs for each species. They were all flat-sawn heartwood. The boards were divided into three groups for steaming, freezing and control. The boards of control group were soaked in fresh water until the treatments were done.

For steaming treatment green boards were stacked in an autoclave with water and boiled at 100℃ for 4 hours. For freezing treatment green boards were stored a laboratory freezer at -40℃ for 48 hours.

Four end-matched 30×30×30mm specimens were cut from each of the treated and control boards and weighed. Their volumes were measured by the water displacement method and they were dried by four different methods. They are quasi-equilibrium, microwave-oven, dry-oven and air drying methods.

For the quasi-equilibrium drying the specimens were put in the stainless tubes of 75mm diameter and 200mm length. The openings were tightly sealed with 10mm-thick wood disks, Moisture in the stainless tubes transported through only the wood disks by diffusion, which made the specimens dried very slowly. The specimens in the stainless tubes were dried in a 103℃dry-oven for 40 days.

For the microwave-oven drying a 1-kw home microwave-oven was used. The specimens were taken out of the microwave-oven and weighed every five minutes until their predicted moisture contents were 20%.

The dry-oven specimens were air-dried for a while before drying in a dry-oven to prevent cracking. The air-drying specimens were placed in a room for a month to equilibrate with the room condition.

Finally all specimens were oven-dried to have the same moisture content. They were weighed, wax-coated and weighted again. Their volumes were measured by the water displacement method and calibrated for compensating the volume of the excess wax.

The volumetric shrinkage based on green dimension was calculated as eq.[1].

$$\alpha_v = \frac{V_g - V_{od}}{V_g} \times 100\% \quad \cdots\cdots\cdots [1]$$

Where, α_v = volumetric shrinkage (%)
V_g = green volume (cm^3)
V_{od} = oven-dry volume (cm^3)

RESULTS AND DISCUSSION

The green MC and Sg of the treated specimens

Based on the green volumes and weights measured after the treatments and oven-dry weights, the green MC's and specific gravities were calculated as listed in Table 1. Steaming and freezing changed slightly the green MC's and specific gravities of the specimens. These two parameters of the persimmon specimens were changed after the treatments more than those of the oak specimens.

Table 1. The green MC's and specific gravities of the treated specimens, based on the green volumes and weights measured after the treatments and oven-dry weights

Species	Treatment	Green MC (%)		Green specific gravity	
		Average	Standard deviation	Average	Standard deviation
Oak	Control	68.7	1.6	0.721	0.011
	Steaming	69.8	1.3	0.724	0.010
	Freezing	65.7	2.7	0.720	0.009
Persimmon	Control	84.3	3.8	0.573	0.015
	Steaming	102.7	8.9	0.562	0.031
	Freezing	96.8	2.5	0.568	0.015

The volumetric shrinkages of the controls

The volumetric shrinkages of the oak controls were similar to those of the persimmons (Fig. 1). The drying methods except the quasi-equilibrium drying did not show any discrepancies. Their average volumetric shrinkages were 21.9% and 22.0% for the oak and persimmon specimens, respectively, whereas those of the quasi-equilibrium drying were 38.2% and 36.3% for the oak and persimmon specimens, respectively. Thus the maximum abnormal volumetric shrinkage possibly caused by collapse could be 16.3% and 14.3% for the oak and persimmon specimens, respectively.

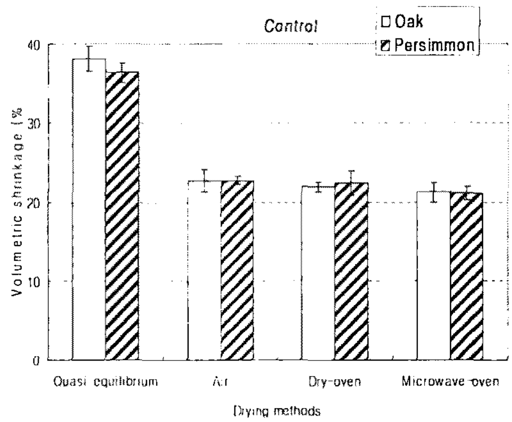

Fig.1. The volumetric shrinkages of the control oak and persimmon specimens dried at the four different methods.

Effect of the steaming treatment

In contrast to the controls the streaming-treated persimmon specimens shrank more than the oak specimens (Fig. 2). The average volumetric shrinkages of the quasi-equilibrium drying were 36.5% and 38.0% for the oak and persimmon specimens, respectively, while those of the rest drying methods were 20.7% and 24.2% for the oak and persimmon specimens, respectively. In general the steaming-treated specimens shrank less than the controls for oak, but did more for persimmon. It may be attributed to the changes of the green and/or oven-dry volumes after the steaming treatment.

The green specific gravities in Table 1 confirm that the volume of oak specimens is decreased after steaming treatment, but that of the persimmon specimens is increased. The specific gravity is increased as volume is decreased and vice versa. The increase of the volumetric shrinkage may be partially attributed to the reduction of extractives due to the steaming treatments (Chafe 1993).

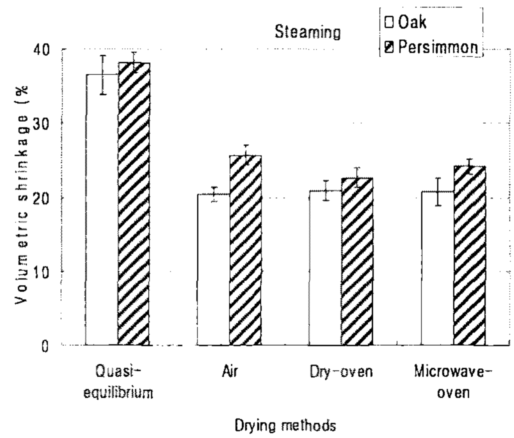

Fig.2. The volumetric shrinkages of the steaming-treated oak and persimmon specimens dried at the four different methods.

Effect of the freezing treatment

As the steaming-treated specimens the freezing-treated persimmon specimens shrank more than the oak specimens (Fig. 3). The average volumetric shrinkages of the quasi-equilibrium drying were 35.1% and 39.8% for the oak and persimmon specimens, respectively, while those of the rest drying methods were 21.6 and 24.2% for the oak and persimmon specimens, respectively. The volumetric shrinkages of the freezing-treated specimens were more various between the drying methods than those of the control and steaming-treated specimens. In general the freezing-treated specimens shrank less than the controls for oak, but did more for persimmon as the steaming-treated specimens. As explained above it may be also attributed to the changes of the green and/or oven-dry volumes after the treatment. It is known that the freezing treatment makes micro-cracks in cell walls (Erikson and Petersen. 1969).

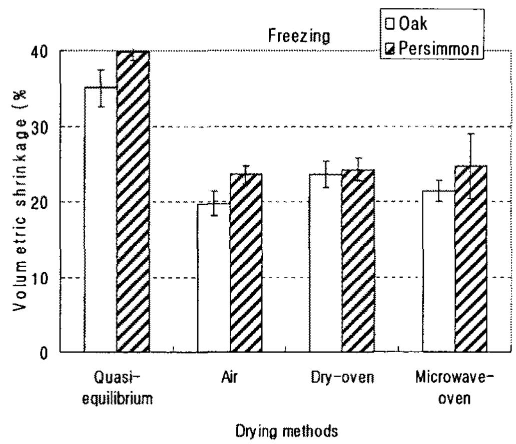

Fig.3. The volumetric shrinkages of the freezing-treated oak and persimmon specimens dried at the four different methods.

CONCLUSIONS

Abnormal volumetric shrinkages of the oak and persimmon specimens treated and dried with various methods were investigated. The conclusions obtained from this study are:

1. The Quasi-equilibrium drying used in this study was proved as a good tool to make the maximum abnormal shrinkage of wood.
2. Steaming and freezing treatments changed slightly the green MC's and specific gravities of the specimens.
3. The maximum abnormal volumetric shrinkage possibly caused by collapse could be 16.3% and 14.3% for the oak and persimmon specimens, respectively.
4. In general the steaming-treated specimens shrank less than the controls for the oak specimens, but did more for the persimmon specimens.
5. The volumetric shrinkages of the freezing-treated specimens were more various between the drying methods than those of the control and steaming-treated specimens.

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