Steaming of red oak prior to kiln-drying: effects on moisture movement

Technical Note

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Abstract

Red oak boards *(Quercus* spp.) were steamed prior to kiln-drying to determine the effect of steaming on initial moisture content (MC), moisture distribution, and drying rate. Four hours of steaming in a saturated steam atmosphere caused a drop of approximately 10 percent in initial MC, a reduced moisture gradient through the thickness of the boards, and an increase in drying rate during the early stages of kiln-drying, when compared to unsteamed oak boards.

Steaming of lumber has been proposed as an aid in drying for decades (4). Early reports indicated that stock which had been steamed dried faster than unsteamed stock. However, this was attributed more to the fact that after steaming the center of the material had a large supply of heat available to assist drying, rather than to a structural or chemical change in the wood that increased permeability (4).

More recent investigations report conflicting results. Simpson (7-9) reports decreased drying times for oak steamed prior to kiln-drying versus oak not steamed prior to kiln-drying. When drying from green to 30 percent moisture content (MC), the reduction in drying time of the steamed samples was 23 to 30 percent. It was reported that the drying gradients of steamed versus unsteamed oak showed different characteristics. The unsteamed oak showed a restricted movement of free water from the interior to the surface, but the steamed oak showed no such restriction. It was concluded that the difference in drying gradients was the result of an increase in permeability in the steamed oak samples (8). Elwood and Eckland (2) reported that the longitudinal permeability of oak steamed for 4 hours increased by a factor of 20 compared to unsteamed oak. However, Cutter and Phelps (1) reported no difference in air permeability of red oak dried by high-pressure steam drying.

Kubinsky (3) steamed northern red oak and under microscopic investigation found occasional cracks in the cell walls, and a reduced fiber lumen size in the steamed samples. The reduced lumen size was attributed to a disruption in the warty layer by steaming, resulting in increased swelling of the fiber walls. Phelps and Cutter (5) found no evidence of anatomical disturbances when high-pressure steam-dried oak samples were studied using a scanning electron microscope.

This study was initiated to seek more information regarding the underlying reason for the apparent increased drying rate of oak after steaming.

Materials and methods

Red oak *(Quercus* spp.) boards, 5/4 inches thick, 6 to 8 inches wide, and 10 to 12 feet long, were obtained green from the sawmill. Each board was cut into four sample boards and MC samples were taken from each end of each sample board. Two samples from each board were marked for steaming, and two were marked as controls. The initial MC of each sample board was determined by averaging the MC of the samples from each end of each sample board and ovendry weight was calculated for each sample board. A total of 72 sample boards were prepared.

The boards to be steamed were placed in an autoclave, on 1/2-inch stickers, and steamed at 212°F under saturated conditions for 4 hours. After steaming, the boards were double-wrapped in heavy plastic to prevent moisture loss, and allowed to cool for 48 hours. The boards were

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weighed and an average MC was determined for the steamed, cooled boards. The control boards were then air-dried until the average MC was approximately equal to the MC of the steamed boards. All boards were end-coated and placed in a forced-air dry kiln, where they were dried using a T4D2 kiln schedule (6). All boards were removed from the kiln and weighed three times each week to determine the drying curve for the steamed and control boards.

A second load was dried, using the same methods just described. However, in the second load, samples were removed each week, and the moisture distribution across the thickness of the boards was determined. This was done by taking a l-1/2-inch section from the center of a board and slicing the section into five pieces through the thickness of the section. The MC of each slice was determined, giving the moisture distribution at five points from surface to surface through the thickness of the boards. Six steamed and six control boards were sampled each week. Each week's average steamed and unsteamed MC for each board position was plotted by average board MC. The MC of each board position for steamed and unsteamed boards was interpolated for average board MCs of 20 percent, 40 percent, and 60 percent.

Results

Effect on initial MC

The MC of 20 boards from each kiln charge was measured before steaming and after the cooling period. The MC of the boards from kiln charge 1 was reduced from 81 percent to 70 percent by steaming. The boards from kiln charge 2 showed a similar drop in MC: from 85 percent to 75 percent. These results differ from those of an earlier report which stated that "steaming did not change the initial MC by more than a few percent" (8). The difference can be accounted for by the difference in procedures. The earlier report deals with the MC change immediately before and after steaming. This current report takes into account the time required to dissipate the heat in the boards from steaming (the boards were wrapped in plastic and cooled for 48 hr.).

Effect on MC distribution

The MC distribution within a board is altered by steaming. Figure 1 illustrates the effect of steaming on the MC distribution within a board. The graph in Figure 1 compares the MC distribution of two boards; one steamed and cooled, and the other air-dried to the same average MC as the steamed board. The distribution of moisture in the steamed board is more uniform through the thickness, with a much lower MC in the center of the board than the unsteamed board. This is due to the migration

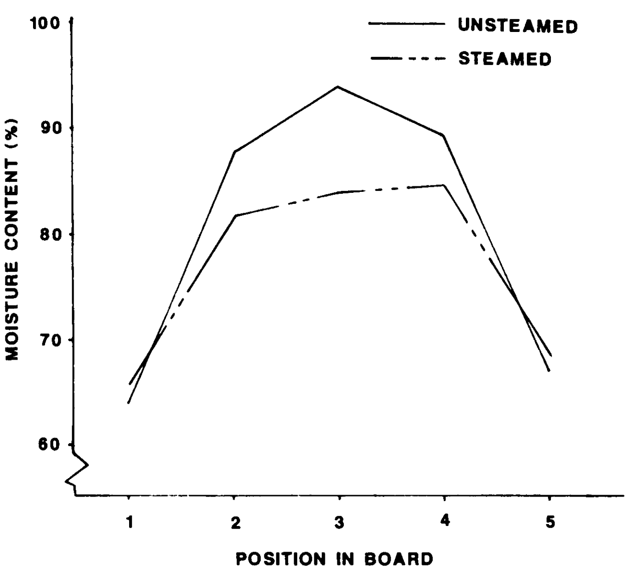

Figure 1. — MC distribution across the thickness of a steamed board and an unsteamed board at five locations (points 1 and 5 represent the shell and point 3 represents the center).

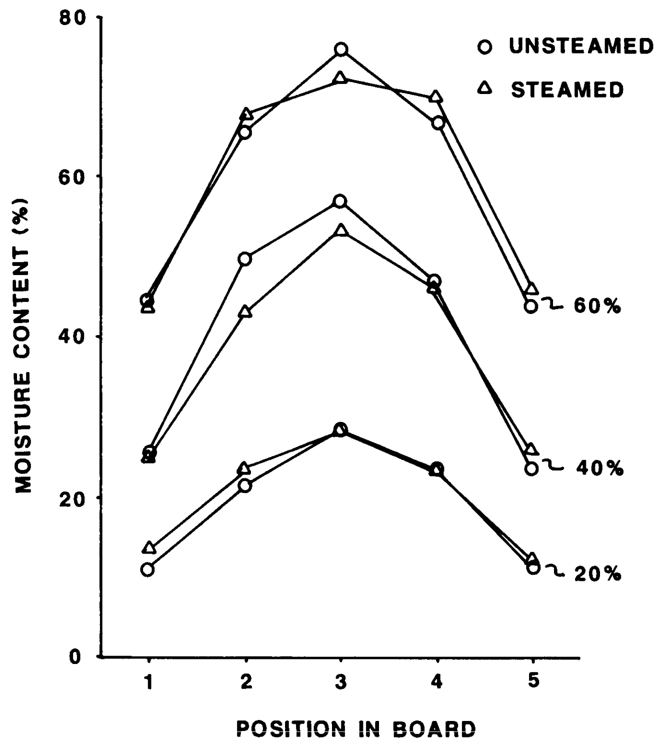

Figure 2. — MC gradients of three boards with average board MCs of 20 percent, 40 percent, and 60 percent.

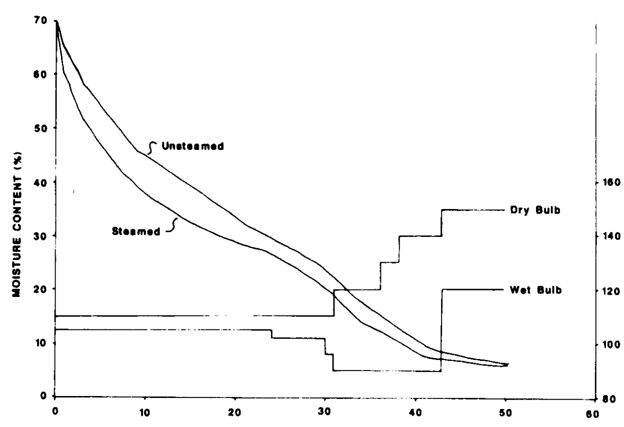

Figure 3. — Charge 1 drying curve for steamed and unsteamed lumber.

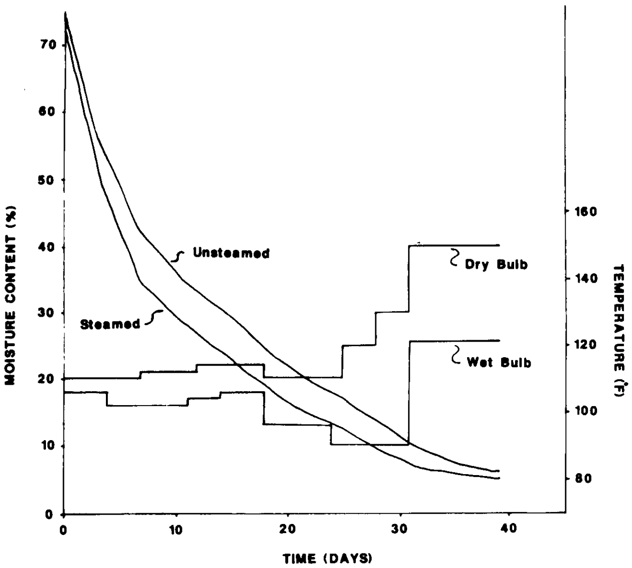

Figure 4. — Charge 2 drying curve for steamed and unsteamed boards.

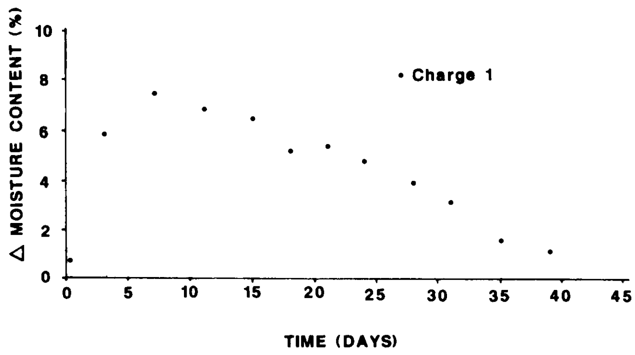

Figure 5. — Difference in average MC of steamed and unsteamed boards during the kiln-drying cycle (unsteamed MC – steamed MC).

of moisture from the center to the outside of the board during steaming and cooling.

Figure 2 also illustrates the change in moisture gradient due to steaming. The gradient is less severe in the steamed samples than in the unsteamed samples when the average MC of the boards is 60 percent and 40 percent. However, by the time the average MC of the boards reaches 20 percent, the moisture gradients of the steamed and unsteamed samples are nearly identical.

Effect on drying rate

Drying curves for the two kiln charges are shown in Figures 3 and 4. In both kiln charges, the drying rate of the steamed samples was greater than the unsteamed samples the first 6 to 8 days of drying. After the first 8 days of drying, the drying rate remained about the same for both steamed and unsteamed samples for approximately 10 days, after which the unsteamed samples had a greater drying rate than the steamed samples (Fig. 5).

Summary

Red oak lumber that has been steamed prior to kiln-drying will dry faster than red oak that has not been steamed. Steaming causes an initial drop in MC and alters the moisture distribution through the thickness of the lumber. The drying rate of steamed oak is higher during the initial stages of drying; however, in the latter two-thirds of the drying cycle, there is very little difference in drying rate between steamed and unsteamed oak. It is not clear if the altered moisture distribution or an increase in permeability, or a combination of both, is the cause of the faster drying rate in red oak lumber steamed prior to drying.

Literature cited

1. Cutter, B.E. and J.E. Phelps. 1986. High-pressure steam drying effects on permeability. Forest Prod. J. 36(6)19-20.
2. Elwood, E.L. and B.A. Eckland. 1961. Treatments to improve wood permeability as an approach to the drying problem. Proc. 13th Annual Meeting. Western Dry Kiln Clubs, Medford, Oreg.
3. Kubinsky, E. 1971. Influence of steaming on the properties of *Quercus rubra L.* wood. Holzforschung 25(3)78-83.
4. Loughborough, W.K. 1920. Steaming of lumber before and during kiln-drying. USDA Forest Serv., Forest Prod. Lab., Madison, Wis. 13 pp.
5. Phelps, J.E. and B.E. Cutter. 1985, High-pressure steam drying effects on vapor movement pathways. Proc. of North Am. Wood Drying Symp. Mississippi State, Miss. pp.140-144.
6. Rasmussen, E.F. 1961. Dry Kiln Operators Manual. USDA Agri. Handb. No. 188. USDA Forest Serv., Forest Prod. Lab., Madison, Wis. 197 pp.
7. Simpson, W.T. 1975. Effect of steaming on the drying rate of several species of wood. Wood Sci. 7(3)247-255.
8. ________.1976. Effect of presteaming on moisture gradient of northern red oak during drying. Wood Sci. 8(4)272-276.
9. ________ 1976. Steaming northern red oak to reduce kiln-drying time. Forest Prod. J. 26(10)35-36.