Warp reduction of red pine two-by-fours via restrained drying

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Abstract

Warp in 2 by 4 lumber is a significant cause of loss in grade and value. Crook and twist are two of the largest factors. The softwood lumber grading standards (WWPA 1998)[1] for red pine Stud grade list maximum crook and twist deviations from true as 0.25 and 0.375 inches, respectively, for 8-foot material. Acceptable bow is stipulated as three times the value for crook, that is, 0.75 inch. Two-by-four material sawn from young trees, forest thinnings, and stem tops contains a significant proportion of juvenile wood and is particularly notorious for warp. At the planer mill, warped 2 by 4's represent a significant loss in value. In-service, replacement of warped 2 by 4's as wall studs or truss members is costly. In this research, a drying restraint system was evaluated as a means of warp reduction in red pine lumber. Boards were dried to approximately 7 percent moisture content, representative of final in-service conditions. Results showed a significant improvement in Stud grade recovery.

As larger proportions of softwood lumber are sawn from young small-diameter trees, the problems associated with wood quality increase. Juvenile wood makes up a large proportion of the wood material in the young small-diameter stems and thus lumber grade recovery suffers. Juvenile wood is particularly known for its ability to induce crook and other forms of warp in lumber. In some cases, crook is noted at the planer mill and the affected boards that are otherwise of high quality are downgraded from Stud grade to No. 3 grade. Furthermore, the knots in the young stems are generally not of sufficient size or number to cause downfall below No. 2 grade. For this lumber, warp is typically the single most important predictor of value. Improvements in grade recovery are made by controlling warp frequency and severity.

The economic value loss for the downgrade at the mill is significant, on the order of 50 to 150 U.S. dollars per thousand board feet. In many instances, warp develops in lumber that is stored at the planer mill for weeks or months. This storage practice often occurs when lumber prices decline and inventories accumulate. During storage, the lumber may continue to dry and associated stresses can build. Lumber in packages that are regraded after such storage often does not meet previous grade designations because of warp.

In other cases, the crook develops after the lumber has been shipped due to moisture changes at distribution centers, at lumberyards, or after installation. If the warp develops after the lumber is shipped, the boards may be rejected or sold at a discount. If the warp develops in service, costly claims to fix bowed drywall, cracked plaster, nail-pops, and warped siding can result. Warped lumber is also not well tolerated in engineered truss manufacturing operations, where straight and true members are critical for set-up, production, and ultimate performance.

Objective

The purpose of this study was to evaluate a system of edgewise restraint drying as a means of reducing crook in 2 by 4 red pine lumber.

Procedure

Among the commercial regional species (fir, pine, and spruce), red pine was selected because of its propensity to warp during drying. Two-hundred pieces of 2 by 4, 8-foot-long rough green lumber were obtained from Bemidji, Minnesota. The contributing sawmill produces a predominance of 2 by 4 lumber from small logs, averaging 5 to 6 inches in

[1] Western Wood Products Association (WWPA). 1998. Western lumber grading rules. WWPA, Portland, OR.

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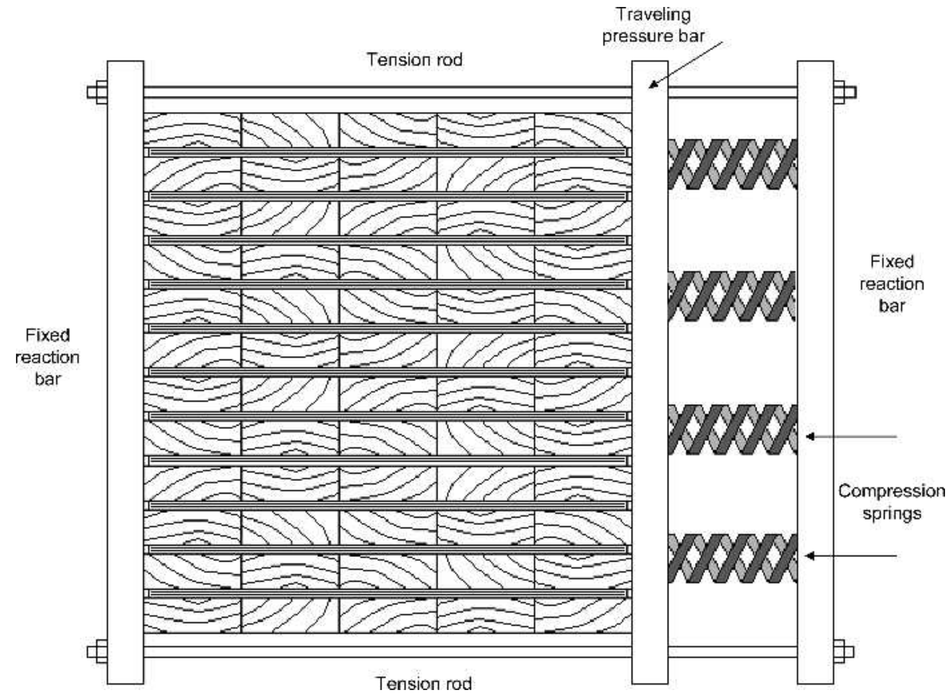

Figure 1. — Section view of one of the three restraint device clamps.

Table 1. — Final MC percent mean, variation, low, and high.

	Avg.	Standard deviation	Range
	(%)		
Restrained	7.1	0.5	6.0 to 8.5
Control	7.4	1.0	6.0 to 11.0

diameter. It was expected that warp potential for the lumber was high.

Rough green lumber was separated into two matched packages: one for control and one for restrained drying. Each package contained 96 boards. For conventional drying, lumber was stacked on 0.75-inch-thick stickers, spaced 2 feet apart. Boards were stacked tightly edge to edge. For the restrained drying, lumber was loaded in the restraint device that provided continuous edge pressure to the lumber and held the boards in each course tightly together (**Fig. 1**). It was anticipated that this edge pressure would reduce crook. Spacing between the three restraint clamps was approximately 4 feet, that is, the lumber was restrained at each end and in the middle. The restraint device was mechanically actuated via steel coil springs. The device provided a maximum edgewise pressure of approximately 10,000 pounds. As the board shrank, the springs relaxed and the restraint pressure declined. Also, as the metal springs were heated in the kiln, their respective forces declined.

A related restrained drying technique by Koch (1972)[2] has been reported. In that case, however, crook restraint during drying was limited because boards were dried in fixed-width channels. As board widths decreased due to shrinkage, the crook restraint became less effective.

Each package was dried at the same kiln conditions: 230°F dry bulb and 180°F wet bulb. Air velocity through the kiln packages was approximately 600 feet per minute. Moisture content (MC) was monitored with full-length sample boards. Packages were dried and then equalized to a final MC between 7 and 9 percent. Drying from green took approximately 19 hours. Equalization was run for approximately 27 hours at 190°F dry bulb and 170°F wet bulb, conditions that produce an equilibrium MC (EMC) of approximately 7.5 percent. This equalization yielded boards that largely fell in the MC range of 6.5 to 8.5 percent. A small number of boards finished slightly outside that range on the high end. MC results are shown in **Table 1**. Hoadley (1980)[3] and Koch (1972)[2] recommend a kiln-dried MC range of 7.5 to 10 percent in order to establish dimensional stability for interior lumber. Producers are understandably reluctant to kiln-dry to this MC level for many reasons. First, MC and warp are inversely related in a seemingly exponential manner, thus grade recovery declines due to warp if no restraint system is employed. Second, lumber for preservative treatment should be less dry to limit the degree of pit aspiration. Third, kiln-drying for longer periods is more costly and reduces kiln throughput. Finally, the greater shrinkage associated with drying to lower MC leads to more skip at the planer (which reduces grade recovery) or requires larger green target sizes at the sawmill (which lowers sawing yield). The restraint procedure employed herein focuses on eliminating or greatly diminishing the cause and effect relationship between MC and warp.

The drying and equalization schedule was followed to simulate the final EMC to which the studs equalize in service. During equalization, the heat and humidity acted as plasticizers to alleviate any traditional shell-to-core drying stresses. In commercial mill situations, final MC values are higher, averaging approximately 15 to 17 percent. In that case, however, further (unrestricted) drying occurs after shipment and such drying is fertile ground for warp.

Warp assessment

Approximately 72 hours after being removed from the kiln, the boards were measured for crook, twist, and bow to the nearest 1/32-inch in their rough-dry condition. The following procedure was used for warp measurement:

1. With the board resting on a horizontal warp table, it was sequentially positioned in order to visually examine for the presence of each warp form.
2. If the amount of warp appeared so small that a meaningful determination seemed implausible, a judgment of "no warp" was assigned.

[2] Koch, P. 1972. Utilization of Southern Pines, Vol. I: The Raw Material and Vol II: Processing. Agri. Handb. 420. USDA Forest Service, Superintendent of Government Docs, Washington, DC.

[3] Hoadley, R.B. 1980. Understanding Wood. The Taunton Press, Inc., Newtown, CT.

Table 2. — Warp results.

		Total avg. warp	Boards with measurable warp	Avg. warp for boards with measurable warp	Boards in Stud grade
		(in)	(%)	(in)	(%)
Crook	Restrained	0.066	28	0.225	92
Crook	Control	0.137	29	0.454	72
Twist	Restrained	0.326	86	0.369	59
Twist	Control	0.336	72	0.461	51
Bow	Restrained	0.177	44	0.395	97
Bow	Control	0.163	42	0.381	100

3. When a measurement was judged to be required, it was made to the nearest 1/32-inch via insertion of an inclined plane wedge. With the wedge inserted to the point of mild refusal, the reading was read off the calibrated vertical face of the wedge.

In practice, it is often difficult to precisely separate the three forms of warp (crook, bow, twist) in a given board. The only available approach was to be as fair and consistent as possible in the measurement technique from board to board.

Results and discussion

Warp results were analyzed in four steps and results are presented by warp type (crook, bow, and twist) in **Table 2**. First the average warp was calculated. Next the proportions of boards with warp vs. no-warp were tabulated. These proportions are listed as the percent of boards with measurable warp. Third, for the boards with measurable warp, average warp levels were compared via statistical t-tests. Finally, the proportion of boards that was within the guidelines for Stud grade is listed. In each case, the three forms of warp were analyzed independently of each other despite the fact that some boards had multiple warp types. This analysis procedure seemed the most prudent for isolating restraint-induced improvements by each warp type.

With respect to crook reduction, the restraint system was highly effective (p-value: 0.000) as compared to the control. Stud grade recovery increased from 72 to 92 percent based on crook reduction. Statistically significant average twist reduction was also noted (p-value: 0.000). Stud grade recovery increased from 51 to 59 percent based on twist. No difference in bow was detected between the restrained and control charges (p-value: 0.707).

Additionally, the system reported herein shows a reduction in average total crook of 55 percent (0.066 in vs. 0.12 in) and a reduction in average total bow of 16 percent (0.177 in vs. 0.21 in) as compared to the restraint-dried yellow pine lumber reported by Koch (1972).[2]