Field test of edgewise restraint southern pine lumber drying

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Abstract

Laboratory and pilot-scale research has shown the efficacy of edgewise restraint as a means of reducing warp in pine dimension lumber drying, specifically for the 2 by 4 size. As a step toward development and commercialization of edgewise restraint technology, a field test was run at a cooperating southern pine sawmill. For the field test, pilot-scale equipment was applied to the commercial drying operation. Results showed a statistically significant reduction in crook and a positive improvement in grade mix retention.

Within southern yellow pine (SYP) dimension lumber production, the 2 by 4 dimension is produced in the greatest volume[1] and is arguably the most susceptible to warp, especially in the forms of crook and twist. Shmulsky et al.[2] detailed the causal agents associated with warp and its deleterious effects throughout the manufacturing and use chains. Minimization of warp directly increases the grade mix, increases the value of lumber for the manufacturer, and improves the performance of the lumber in service.

The edgewise restraint procedure employed herein focuses on diminishing the cause and effect relationship between moisture content (MC) and warp, especially as crook, which is prominent in SYP 2 by 4 lumber. This research program has run successful pilot-scale tests of edgewise restraint drying in the laboratory.[2,3] Reductions of warp and improvements of grade mix have been achieved for both red and yellow pine.

One of the necessary steps toward realizing the potential gains of edgewise restraint drying in the marketplace is field testing the pilot equipment. Field testing serves two primary purposes: 1) prove the concept in a commercial situation; and 2) generate commercial interest in further development of the technology. For the field test, cooperation was secured with a commercial SYP sawmill. This particular dimension mill runs a dual chipping/dual bandsaw headrig followed by a curve gang resaw. Optimized decision making technology was present throughout the conversion system. Annual production for the mill is roughly 210 million board feet (MMBF). The mill's high-temperature lumber kilns produce approximately 4.8 MMBF per week.

At the time of the field test, average small-end log diameter was 9.7 inches. Log quality and size were large enough that the 2 by 4 lumber produced did not contain a high proportion of juvenile wood. Not surprisingly, the lumber degrade below No. 2 and better due to warp was relatively low, estimated at less than 7 percent for the mill. The drying operation was well automated, kilns were in good working order, and handling and stacking were consistently good. Dry-end personnel were well trained, experienced, and entirely helpful.

Objective statement

Evaluate the performance of an edgewise restraint system in a commercial lumber kiln while minimizing interruption in commercial operations.

Procedure

Edgewise restraint was provided by a system of pneumatically driven steel bars oriented vertically along the edge of the

[1] Southern Forest Products Association (SFPA). 2002. 1998 Southern pine lumber grades and sizes. SFPA, Kenner, LA.

[2] Shmulsky, R., R.W. Erickson, P.H. Steele, and D. Buckner. 2005. Warp reduction of SYP lumber by restrained drying. Forest Prod. J. 55(9):37-41.

[3] Erickson, R.W. and R. Shmulsky. 2005. Warp reduction of yellow pine two-by-fours via restrained drying. Forest Prod. J. 55(9):84-86.

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Figure 1. — Restraint device secured on test lumber package.

Figure 2. — Restraint lumber package incorporated in full kiln charge readied for drying.

kiln package (**Fig. 1**). Restraint bars were located at approximately 3.2-foot intervals along the lumber length, i.e., six sets of restraint bars were used for the 16-foot-long lumber. Pneumatic cylinders provided active pressure throughout kiln-drying. Gauge pressure was regulated between approximately 85 and 100 psi. This range provided a maximum wood-to-steel contact pressure of approximately 40 psi, based on the restraint device parameters. This contact pressure value is considerably lower than the crushing strength for SYP lumber, thus no compression damage was developed along the edges of the boards that were in direct contact with the device. The total maximum compressive force applied to the 17-course-tall, 16-foot-long package was approximately 23,600 pounds. Each individual course, and thus each individual board, received approximately 1,390 pounds of edgewise restraint force. This force level was sufficient to overcome inherent friction forces and squeeze each course of green boards tightly together for drying. This pressure level was sufficiently high enough to drive the boards into a rigid edge-to-edge slab, to hold them fast throughout drying, but not so high as to cause edge damage by crushing.

The field test was conducted in conjunction with normal operations of the commercial mill. A single lumber package of 2 by 4, 16-foot-long lumber was outfitted with the restraint device and incorporated into a full kiln charge (**Fig. 2**). The test lumber package contained 1,632 BF as 153 pieces and was 17 courses tall with 9 boards per course. An unrestrained kiln pack of 2 by 4, 16-foot-long lumber was stacked next to the restrained package and served as control for the experiment.

The two lumber packages, control and restraint, were loaded side by side at the end of the kiln charge. The balance of the charge consisted of 2 by 4 and 2 by 10 lumber of varying lengths from 8 to 20 feet. The commercial kiln schedule was not modified for the field test. Maximum dry-bulb temperature was programmed at 235°F (exiting air). Wet-bulb temperature was set to ramp up to an initial high of 190°F during the first 3 hours and then to cut back to 170°F for the duration of drying. Airflow through the lumber was approximately 1,400 feet per minute. The kiln was shut down when the temperature drop across the load reached 9°F. Total drying time was 22 hours. The pneumatic edgewise restraint pressure was released from the lumber as soon as the lumber was dry in order to roll the charge out of the kiln. Therefore the lumber was not cooled under active restraint pressure. After 16 hours, the kiln charge was broken down, the control and restraint packages were measured, and the balance of the charge was taken to dry storage before going to the planer mill.

Table 1. — Final MC percent median, mean, standard deviation (SD), and fifth and 95th percentiles.

	Restraint	Control
	----------(%)----------	
Median	7	8
Mean	7.1	7.6
SD	1.8	2.5
5th percentile	5	5
95th percentile	10	12

Assessment

After drying, the MC of the control and restraint lumber was measured with a capacitance-type meter that was calibrated for SYP. Warp as crook, twist, and bow was measured to the nearest 1/20 inch in the rough-dry condition. In practice, it is often difficult to precisely separate the three forms of warp (crook, bow, twist) in a given board. Care was taken to be as fair and consistent as possible in the measurement technique from board to board. The following procedure was used for warp measurement:

1. Each piece was positioned on a warp table to examine the extent of each warp type.
2. If the amount of warp appeared so small that a meaningful determination seemed implausible, a judgment of "no warp" was assigned.
3. When a measurement was judged to be required, it was made to the nearest 1/20 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 face of the wedge.

Results and discussion

Average final MC values for the control and restraint packages were 7.6 and 7.1 percent, respectively (**Table 1**). The final MC values were generally lower than those called for in the grading rules but were not inconsistent with long-term equalization. Also, when mixed lumber sizes are dried together, such as the 2 by 4 and 2 by 10 herein, it is not uncommon for the smaller size pieces to become drier than the larger size pieces.

Direct warp results are summarized in **Table 2**. Statistical comparisons (t-tests) were made between the nonrestraint control and restraint packages for each warp type. Results showed that a statistically significant reduction in mean crook, 0.26 vs. 0.36 inch, was achieved via restraint drying.

Table 2. — Mean, median and variation of warp by type.[a]

		Restraint	Control	*p*-value for difference
		----------(in)----------		
Crook	Mean	0.26	0.36	0.006*
	Median	0.20	0.30	
	SD	0.25	0.36	
Bow	Mean	0.29	0.24	0.292
	Median	0.25	0.20	
	SD	0.38	0.33	
Twist	Mean	0.15	0.12	0.293
	Median	0.0	0.0	
	SD	0.25	0.22	

[a]Values followed by an * indicate *p*-values less than 0.05 and were considered statistically significant. SD = standard deviation.

This result was desired because the crook allowance in the Southern Pine Inspection Bureau (SPIB) grading standards, by definition, is only one-third the allowance for bow. No statistically significant change in average bow or twist was noted.

Next, the boards were graded, based on warp, as No. 1, No. 2, No. 3, or Reject. To that end, limitations on crook, bow, and twist were used in grading the rough dry lumber. **Table 3** illustrates the lumber grade distributions for the control and restraint packages based on SPIB rules.[4] These results showed that restraint increased No. 1 grade lumber by 5.1 percent and increased No. 2 and better grade lumber by 2.5 percent.

Table 3. — Percent of boards in each grade.

Grade	Restraint	Control
	----------(%)----------	
No. 1	94.6	89.5
No. 2	2.7	5.2
No. 3	2.7	3.9
Reject	0.0	1.3

These field-test results indicate that the restraint system was effective at reducing average crook, it was effective at improving grade mix retention after kiln-drying, and restraint pressure can be removed immediately after drying, before the lumber is pushed out of the kiln. These results are consistent with previous research conducted in laboratory- and pilot-scale kilns, cited herein, as part of this program. Because these results prove the concept that restraint drying can be effectively implemented at the commercial scale, further development of the technology seems entirely prudent.

[4] Southern Pine Inspection Bureau (SPIB). 2002. Standard Grading Rules for Southern Pine Lumber. SPIB, Pensacola, FL.