# Shrinkage and grade retention in restraint-dried thick dimension loblolly pine

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**Abstract**

Loblolly pine dimension lumber 2.5 inches thick was milled and dried to assess the effects of restraint drying on warp and shrinkage response. Results showed a statistically significant reduction in average warp as crook, bow, and twist for the restraint-dried material. Lumber grade mix, based on warp criteria, was higher for the restraint-dried material. Shrinkage for the restraint-dried material was less than that for the unrestrained control planks.

As part of an ongoing program aimed at improving lumber value retention through the processing chain, a system of restraint drying has been developed. The pilot-scale restraint device has been described previously.[1] This device has shown efficacy as a means of reducing warp, especially as crook, in 2 by 4 dimension lumber both in the laboratory and at a commercial facility. A schematic of the cross section of the restraint device is provided (**Fig. 1**).

A significant market exists for thick dimension stock, especially as bridge stringers, heavy decking, and other industrial applications. The costs associated with grade loss, from No. 2 grade and better to No. 3 grade and lower are on the order of $100 to $150 ($U.S.) per thousand board feet (MBF). All forms of warp can cause loss in lumber value, but the allowances for crook are often the most stringent. Thus, there is a pressing financial need to maintain lumber straightness throughout drying, especially with respect to crook reduction.

## Objective statement

The objective of this study was to evaluate a system of restraint drying as a means of reducing warp in 12-foot-long, 2.5-inch-thick loblolly pine lumber.

## Procedure

Five loblolly pine trees were selected and felled. Tree age ranged from 28 to 35 years. Tree diameter ranged from 15 to

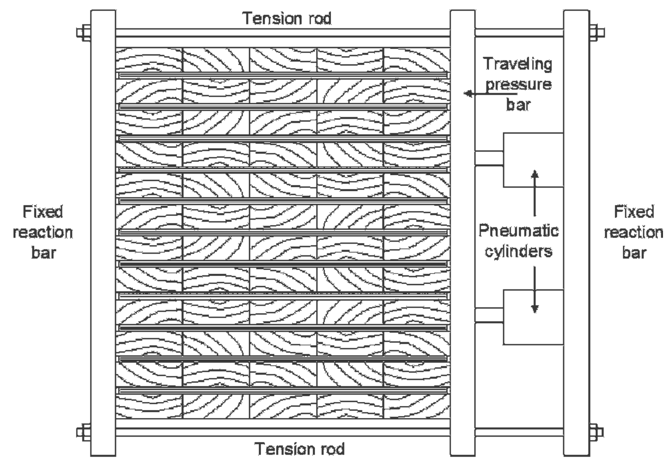


*Figure 1. — Schematic of the restraint device fixed on a package of stickered lumber.*

22 inches at breast height. Trees were grown in an open field and therefore log form was fair, i.e., there were numerous branches and much taper. It was anticipated that these growth characteristics would contribute to warp in the test lumber. The felled trees were bucked into 12-foot-long logs. Each tree yielded 3 logs, thus 15 total logs were produced.

The logs were sawn into four-sided cants and then into lumber on a portable band-type sawmill. Only 6-, 8-, and 10-inch widths were produced. The ends of the cants were color coded with spray paint and tracked such that from each log approximately half of the lumber served as control and half as treatment. This segregation of material assured thorough matching of material between the control and restraint kiln packages.

Rough, green 12-foot-long lumber was then stacked on 0.75-inch-thick stickers spaced every 2 feet. Each lumber

[1] 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):84-86.

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package was 32 inches wide. This course width was developed using varying combinations of the 6-, 8-, and 10-inch-wide lumber. Each package was finished with 11 full lumber courses. As such, each package contained 880 BF. Average plank width per package was 7.9 inches.

As each course was established, reference marks were drawn, the course was clamped together, the total width was measured, and the clamp was released. These green course width measurements were utilized as part of the shrinkage calculations.

The edge restraint procedure employed herein focused on diminishing or possibly eliminating the cause-and-effect relationship between moisture content (MC) and warp. Edgewise restraint pressure was exerted on the lumber package such that the individual planks in each course were driven tightly together into a rigid slab (**Fig. 1**). It was anticipated that this edge pressure would reduce warp, especially as crook. The restraint device was affixed to one of the two lumber packages. For 12-foot-long lumber, the device uses a series of five vertically oriented bars and pneumatic cylinders as a means of applying edge pressure to the restraint lumber package. As the lumber shrinks during drying, the cylinder pistons expand and thus maintain constant pressure throughout. The five bars were evenly spaced at approximately 3-foot intervals along the 12-foot-long lumber package. Pneumatic gauge pressure on the cylinders was approximately 105 psi. This pressure level provided a maximum wood-to-steel contact pressure of approximately 55 psi, based on the restraint device parameters. This contact pressure value is under the perpendicular-to-grain crushing strength for southern yellow pine lumber, thus no compression damage was developed along the edges of the boards that were in direct contact with the device. The total compressive force applied to the 11-course tall, 12-foot-long package was approximately 20,600 pounds. Each individual course, and thus each individual board, received approximately 1,870 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 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 two lumber packages were loaded side by side on an 8-foot-wide kiln tram and were dried together. The high-temperature kiln schedule closely simulated commercial conditions. Following an initial 2-hour warm-up period, dry- and wet-bulb temperatures in the kiln were maintained at approximately 235 and 175°F, respectively. Airflow through the packages was approximately 1,100 feet per minute. After 26 total hours, the kiln was turned off, the restraint pressure was released, and the kiln tram was rolled out of the kiln. Thus, the lumber was not under active restraint pressure during cool down.

## Results

After drying, lumber was measured for MC, shrinkage, and warp. Details of these results are provided by category.

The MC of each plank was measured with a capacitance-type meter that was calibrated for southern pine. Average final MC values for the control and the restraint packages were 13.8 and 15.3 percent, respectively. A t-test indicated that these average MC values were not statistically different, $p$-value = 0.092. Because the two packages were dried together, it was not possible to bring these values closer together without the use of an equalization period. Additional MC statistics are shown in **Table 1**.

As the lumber courses were broken down, they were measured for shrinkage by following the same procedure that was used during package construction. That is, the planks in each course were clamped together and measured at the reference marks. These final course width values were then compared to the initial course width values in order to calculate total shrinkage percentages (**Table 2**). A t-test indicated that the difference in average shrinkage between the two lumber packages was statistically significant, $p$-value = 0.007.

For assessment of warp, rough dry planks were measured for crook, bow, and twist on a flat and true warp table. Care was taken to be as fair and consistent as possible in the measurement technique from board to board. The following pro-

*Table 1. — Final MC percent median, mean, standard deviation, and 5th and 95th percentiles. Mean values were not statistically different,* p*-value = 0.092.*

| | Restraint | Control |
|---|---|---|
| Median | 14 | 13.5 |
| Mean | 15.3 | 13.8 |
| SD[a] | 5.3 | 2.3 |
| 5th percentile | 8.2 | 10.2 |
| 95th percentile | 25 | 18.7 |

[a]SD = standard deviation.

*Table 2. — Width and shrinkage response for each course of control and restraint dried lumber. The difference between the control and restraint dried lumber is statistically significant,* p*-value = 0.007.*

| | Control | | | Restraint | | |
|---|---|---|---|---|---|---|
| Course | Width initial | Width final | Shrinkage | Width initial | Width final | Shrinkage |
| | (in) | (in) | (%) | (in) | (in) | (%) |
| Top | 32.3 | 31.3 | 3.1 | 31.9 | 31.2 | 2.2 |
| 10 | 32.2 | 31.4 | 2.5 | 31.9 | 31.6 | 1.0 |
| 9 | 32.1 | 31.5 | 1.9 | 32.1 | 31.6 | 1.6 |
| 8 | 32.2 | 31.5 | 2.1 | 32.1 | 31.5 | 1.9 |
| 7 | 31.6 | 30.9 | 2.2 | 32.1 | 31.5 | 1.9 |
| 6 | 32.1 | 31.4 | 2.3 | 32.0 | 31.5 | 1.6 |
| 5 | 32.0 | 31.3 | 2.3 | 32.3 | 31.7 | 1.7 |
| 4 | 32.1 | 31.4 | 2.1 | 31.9 | 31.5 | 1.4 |
| 3 | 32.1 | 31.4 | 2.1 | 32.0 | 31.4 | 2.0 |
| 2 | 32.3 | 31.4 | 2.5 | 32.0 | 31.3 | 2.3 |
| Bottom | 32.3 | 31.3 | 3.1 | 32.1 | 31.3 | 2.4 |
| Avg. | 31.5 | 31.3 | 2.4 | 32.0 | 31.5 | 1.8 |
| SD[a] | 0.19 | 0.16 | 0.4 | 0.12 | 0.17 | 0.5 |

[a]SD = standard deviation.

*Table 3. — Direct warp results (in) and p-values for comparison of control and restraint dried lumber.*

| | Restraint | Control | *p*-value |
|---|---|---|---|
| | ------------(in)------------ | | |
| Crook (mean) | 0.26 | 0.55 | 0.000 |
| Crook (SD[a]) | 0.26 | 0.42 | -- |
| Bow (mean) | 0.06 | 0.20 | 0.000 |
| Bow (SD) | 0.14 | 0.22 | -- |
| Twist (mean) | 0.16 | 0.34 | 0.001 |
| Twist (SD) | 0.20 | 0.31 | -- |

[a]SD = standard deviation.

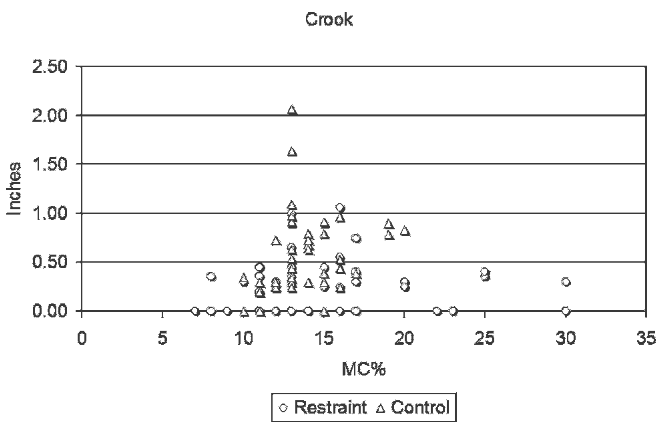


*Figure 2. — Plot of MC vs. inches of crook for the control and restraint-dried lumber packages.*

cedure was used for warp measurement. Each plank was positioned on a warp table to examine the extent of each warp type. If the amount of warp appeared so small that a meaningful determination seemed implausible, a judgment of "no warp" was assigned. When a measurement was judged to be required it was made via insertion of a calibrated 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. Statistical comparisons (via t-tests) were then made between the nonrestraint control and restraint packages for each warp type directly from the kiln. For each of the three warp types, improvement in lumber straightness was statistically significant. Comparison of control vs. restraint for crook, bow, and twist produced *p*-values of 0.000, 0.000, and 0.001, respectively. Further results are detailed in **Table 3**. A plot of MC vs. inches of crook for the control vs. the restraint-dried packs is provided (**Fig. 2**). Next, the planks were graded, based on warp, as No. 1, No. 2, No. 3, or Reject.[2] **Table 4** illustrates the lumber grade distributions for the control and restrained packages. These results indicate that for the control lumber, 56.9 percent was produced as No. 2 and better while 43.2 percent was No. 3 and lower. For the restrained lumber, 88.9 percent was produced as No. 2 and better and 11.1 percent was No. 3 and lower, directly from the kiln.

*Table 4. — Distribution of boards in each grade.*

| Grade | Restraint | Control |
|---|---|---|
| | ----------------(in)---------------- | |
| No. 1 | 77.8 | 45.5 |
| No. 2 | 11.1 | 11.4 |
| No. 3 | 8.9 | 22.7 |
| Reject | 2.2 | 20.5 |

## Discussion

While mean and median MC values were not statistically different, the variation in MC of the restraint-dried lumber was relatively high. **Table 1** illustrates that the 95 percentile for MC of the restraint-dried lumber is above 19 percent. This result is likely caused by somewhat impeded airflow through the restrained package. The shrinkage values seem to corroborate this idea because it appears that there was more shrinkage near the top and bottom courses of the restrained package where the airflow was highest, as compared to the middle courses.

Reduction of warp as crook, bow, and twist, was noted for the restraint-dried lumber. This improvement in lumber straightness directly translated into improvements in grade retention. It is important to note that the lumber was cooled without any restraint pressure. The restraint pressure was released immediately after drying. This fact suggests that the restraint technology could be incorporated into a commercial operation with relative ease because the restraint pressure does not need to be maintained in the cooling and rough dry storage sheds.

As an approximate measure of value increase, it was assumed that the monetary difference between No. 2 and better and No. 3 and lower is $100 per MBF. The restraint device evidently increased the proportion of No. 2 and better lumber from 56.9 percent to 88.9 percent, an absolute difference of approximately 33 percent. This equates to an added value of $33 per MBF. This result represents a substantially greater improvement in value for the thick dimension lumber tested here as compared to 2 by 4 lumber tested previously. This improvement is likely due in part to the fact that the crook tolerances for wide planks are more stringent than those for 2 by 4's. As such, similar improvements in average straightness of wider planks as compared to 2 by 4's result in better increases in grade and greater monetary gains. Future directions for this research program include: restraint drying of dimension stock intended for preservative treatment, restraint kiln-drying after treatment, and further development of a commercially viable prototype restraint system.

[2] Southern Pine Inspection Bureau (SPIB). 2002. Standard grading rules for southern pine lumber. SPIB, Pensacola, FL.