

TOP LOADED RESTRAINT DURING DRYING

Bruce L. Kühnau
Technical Center
Weyerhaeuser Company
Longview, Washington

Dr. Robert W. Erickson
College of Forestry
University of Minnesota
St. Paul, Minnesota

Introduction

Recent years have seen an increase in the production of structural lumber from small softwood logs. Due to the presence of the pith and juvenile wood in a high percentage of the pieces, warp during kiln drying has become a serious problem. Schedule modifications, or new approaches to drying such as the use of CRT, are ways to try and minimize warp degrade. Another possibility is to use restraint, i. e. the transfer of sufficient force to the lumber during drying to hold it in place and thereby preventing or greatly reducing the amount of warp.

The idea of restraining lumber to prevent warp has been around a long time. In 1955, Snodgrass¹ concluded "There is no doubt that seasoning under restraint would correct or considerably reduce much of the twist in heart-center material."

There has been much published on the use of restraint. Articles by Koch² and Weckstein and Rice³ describe experiments using pre-surfaced lumber with mechanical restraining devices. These researchers concluded that there was a significant reduction in warp due to the restraint.

Observations on kiln dried lumber generally indicate more warp in the courses near the top of the car. This empirical evidence plus research data illustrates the beneficial effects of restraint. However, since only a few mills employ restraint, there must be difficulties in its application.

One difficulty in using many restraining devices is caused by shrinkage of the load during drying. With spring loaded or mechanical take-up systems, frequent adjustments are necessary to maintain the restraining force. Systems that require an operator to make such adjustments almost eliminates their use in production kilns.

Self-weighting devices as described in the October 1962 issue of the Timber Trades Journal⁴ need no adjustment during operation. The system automatically compensates for shrinkage in the height of the stack by a downward movement of platform and levers. The disadvantage of this system is a need for initial adjustments of the clamping device. Also the equipment is not simple to use and handling after use could be difficult.

Top loaded weights have been used for some time with success. Considerable application has been made of concrete slabs. Mackay and Rumball⁵ have experimented using reinforced concrete slabs with forces up to 330 psf (pounds per square foot, i. e. weight of restraining slab divided by surface area it is placed on).

The slabs are easily placed on top of the load and force applied during drying is not affected by shrinkage. The main difficulty in using top loaded restraint probably is in handling.

Mill Test of Top-Loaded Restraint

We would now like to share with you our experience in a test conducted at a southern yellow pine stud mill. The mill was designed to use concrete slabs as the top-loaded restraint. At this mill they are especially aware of the warp problem. This is because the studs must meet the exacting limitations on crook, bow, and twist for No. 1 grade lumber. The studs are sawn from small logs and veneer cores, both of which produce warp prone lumber.

Test Equipment and Production Facility

The layout of the drying facility is shown in Figure 1. The steel reinforced concrete slabs are stored on the deck between the stacker and unstacker. After sticking is completed, a concrete slab is placed on top of the car. The car is then transferred to the green end of the appropriate kiln. After kiln drying, the lumber is cooled in the dry storage area. The restraint is removed and placed in storage just before the car enters the unstacker.

The design not only simplifies handling of the slabs, but also empty kiln trucks and stickers. The kiln trucks are easily transferred to the stacker on tracks laid under the elevated restraint storage deck. The stickers are easily transferred by a conveyor belt directly to the stackers.

The cost of each restraining weight at this mill was \$285. The initial cost was lower but additional expense was incurred for safety reasons. Subsequent restraints could be made at a lower cost. Using an expected life of three years, and three kiln charges per week, the weights cost 9¢ per MBF. Operation and maintenance costs were figured to be 7¢ per MBF. This means that using the restraining weights at this mill cost 16¢ per MBF.

The restraints used were 8' x 8' concrete and steel slabs. The concrete was about 5" thick, this with the steel weighed approximately 3800 lbs. Dividing the weight by the surface area gives a restraint force of about 60 psf.

Experimental Design

The stud mill test was designed to compare restrained and unrestrained cars with respect to grade recovery. Restraint was of two types: One employed restraint during lumber drying and cooling; the other used restraint during drying but before cooling it was removed. The study design also included obtaining data relating dollar value to average moisture content.

The test was designed to look at quality changes for each quarter car height. The loads were stacked with five stickers on 2' spacing. Each quarter car section (375 boards) was then color coded. We then dried the load with a CRT schedule in about 27 hours. Next, the load was cooled for at least 48 hours, either with or without restraint. The

load was then unstacked by quarter car sections. Moisture content and grade recovery data was obtained in the process.

Four charges were dried with the placement of test cars in the six positions shown in Figure 2. The test cars were located toward the middle of the charge in order to eliminate any possible problems associated with end baffling. There was one car of each treatment per track. Fully restrained and unrestrained cars were alternated from run to run to even out any potential drying differences due to location. By necessity, cars from which the restraint was removed for cooling were always located in positions 3 and 4.

Data Collection

For data analysis, all pieces after surfacing and grading were placed into one of the following groups: Stud grade, No. 3, No. 4, or a group consisting of rejects and reworks.

The stud grade consisted of both 7 and 8 foot pieces. Seven foot pieces were usually a result of mismanufacture. Few, if any, 8 foot lower grade pieces would jump up to stud grade if trimmed to 7 foot.

The No. 3 group included 7 and 8 foot pieces graded as No. 3's. Trimming will not usually upgrade an 8 foot No. 4 to a 7 foot No. 3.

The No. 4 group consisted of only 8 foot No. 4 pieces. There were no other grading groups combined into this category. Almost any remaining piece that was 8 foot long could be placed in this group.

Reject and rework boards were placed in one group. The rejects were pieces that were rejected because of severe warp or mismanufacture. The number of rejects was usually small and the exact cause for rejection was not recorded. The rework boards were anything that could not be placed into any of the grading groups. A piece was placed in rework because of one or more of the following: warp, wane, short boards, splits, shake, skip, unsound wood, etc. Many of the rework pieces were 7 foot and can be considered as 7 foot No. 4's. Others could be reworked into higher grades of shorter lengths, i. e., 4 and 6 foot.

To determine the economic impact of the restraint, prices were calculated for each group. Calculations are based on the price schedule shown below.

<u>Grade</u>	<u>\$/MBF</u>
Stud	105
#3	60
#4	45
Rework and Rejects	30

The value for rework and rejects is arbitrary. Because no separate calculations were made for 7 foot boards, the total dollar value will not be exact. For comparing dollar values, differences between groups are more important than exact total value. Calculations of dollar values were made as follows:

$$\$/\text{MBF} = (105) (\% \text{ stud}) + (60) (\% \#3) + (45) (\% \#4) + (30) (\% \text{ rework and rejects})$$

Results and Discussion

Due to the fact that quality is closely related to final moisture content, it is appropriate to discuss this relationship before the restraint results.

Figure 3 shows a plot of the \$/MBF value of each quarter car against its average final moisture content. Top units for the unrestrained and restraint removed (during cooling) were omitted because of the substantial effect of the low restraint upon dollar value. The line is a least squares linear curve fit with a correlation coefficient of 0.66. The slope of the line represents a degrade factor of \$2.17 per MBF for each one percent moisture content change.

The correlation coefficient is low but the results indicate a definite relationship between dollar value and final moisture content. For this reason, results of tests such as this restraint study must be compared at the same moisture content.

Results of the restraint study shown in Table 1 with data from all four test charges being combined. The last column on the right gives dollar values adjusted to 10% M.C. This adjustment constitutes an attempt to eliminate the effect of moisture content on the dollar values.

Because of unequal moisture content, the effect of removing restraint prior to cooling is not clear. The results presented in Table 1 show a reduction in quality when comparing the restraint removed during cooling to the no restraint. The large difference could be due to the lower average moisture content. Corrections to 10% M.C. were made but the results still indicate poorer quality. The disruption of weight removal might cause some shifting and allow increased warp. It is difficult to imagine that removing the restraint could cause such significantly poorer quality. The large differences suggest that either the M.C. correction factor is in error, and/or there is a different lumber population, and/or there is a true dollar reduction. At this point, a conclusion is impossible.

Overall averages show the full restraint produced 1.6% higher stud grade recovery compared to no restraint. This was worth an additional gross value of \$0.91 per MBF. Subtracting the cost of using restraint (16¢ per MBF) produced a net increase of \$0.75 per MBF. Fortunately, these two treatments dried to nearly the same average moisture content. For this reason, a direct comparison was used without adjusting to 10% M.C.

For the top quarter section dollar improvement of FR over NR was \$1.88 per MBF. Statistically, there was an 80% level of confidence that the 60 psf restraint was better for this comparison. The improvement in the upper middle quarter was \$0.79 per MBF for the FR treatment. Unlike the top section, this and subsequent comparisons are not at the same M.C. The value for the lower two sections was for all practical purposes unchanged, with the use of top-loaded restraint.

Lower sections of lumber in the kiln car are always restrained because of lumber above them. This restraining force can be calculated.

Table 1. Results by Treatment for Restraint Study.

Level	Treatment*	Grade Distribution %				\$/MBF	MC	\$ MBF @ 10% M. C.
		Stud	#3	#4	RR			
Top 1/4	NR	58.4	19.1	13.3	9.2	81.51	9.8	81.94
	FR	62.8	14.1	13.9	9.2	83.39	9.8	83.82
	RR	52.0	20.0	16.2	11.8	77.39	8.9	79.78
Upper Middle 1/4	NR	63.6	15.5	12.9	8.0	84.29	10.0	84.29
	FR	64.8	15.1	13.1	7.0	85.08	10.2	84.65
	RR	53.6	20.4	16.4	9.6	78.78	8.5	82.04
Lower Middle 1/4	NR	70.3	12.4	11.6	5.7	88.15	10.8	86.41
	FR	70.6	14.3	9.6	5.5	88.69	11.2	86.09
	RR	60.0	19.0	12.2	8.8	82.53	9.5	83.62
Bottom 1/4	NR	74.9	8.9	10.4	5.9	90.36	12.4	85.15
	FR	75.3	10.5	8.1	6.1	90.81	12.5	85.39
	RR	66.2	14.2	12.8	6.8	85.83	10.6	84.53
Avg. for entire car	NR	66.8	14.0	12.0	7.2	86.08	10.8	84.42
	FR	68.4	13.5	11.2	7.0	86.99	10.9	84.99
	RR	58.0	18.4	14.4	9.2	81.13	9.4	82.49

*NR - No Restraint on test cars

FR - Fully Restrained test cars

RR - Restraint Removed during cooling

FIGURE 1
DRYING FACILITY
USING CONCRETE RESTRAINTS

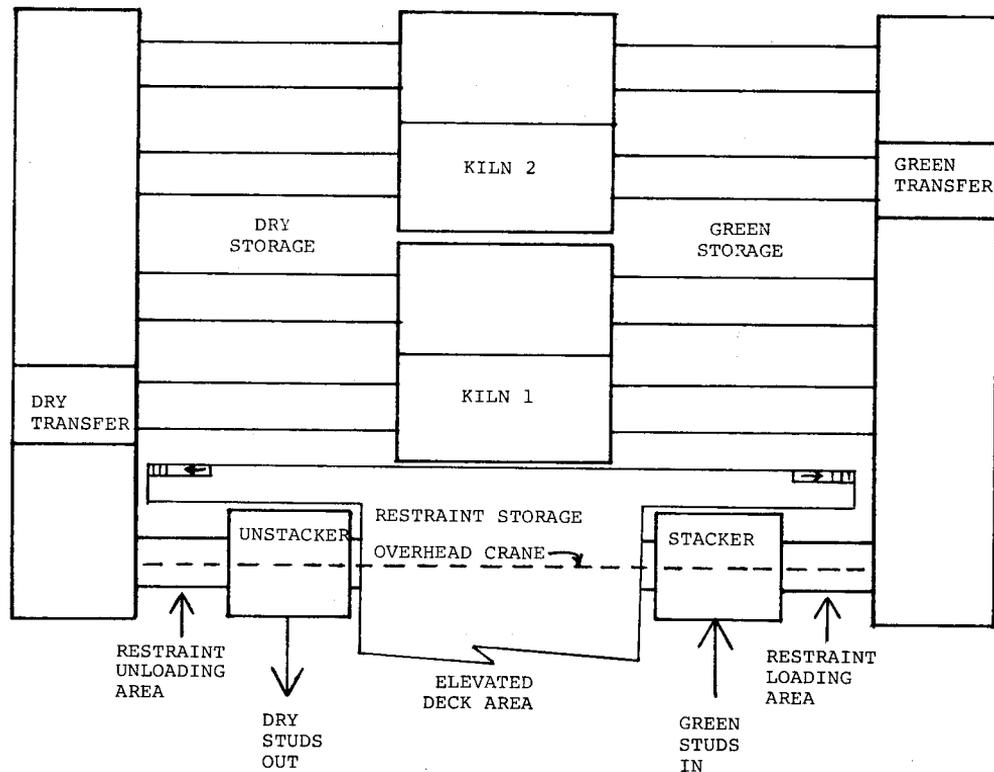


Table 2. Comparison of Various Restraint Levels to the Unrestrained Top Quarter Section.

Source of Restraint	Force psf	\$ Improvement for Quarter Section
Concrete Slab	60	1.88
Lumber wt. of top 1/4	100	2.35
Lumber wt. of top 1/4 plus concrete slab	160	2.71
Lumber wt. of top two 1/4 units	200	4.47
Lumber wt. of top two units plus concrete slab	260	4.15
Lumber wt. of top three 1/4 units	300	3.21
Lumber wt. of top three units plus concrete slab	360	3.45

Figure 2

Typical Loading of Kiln Cars

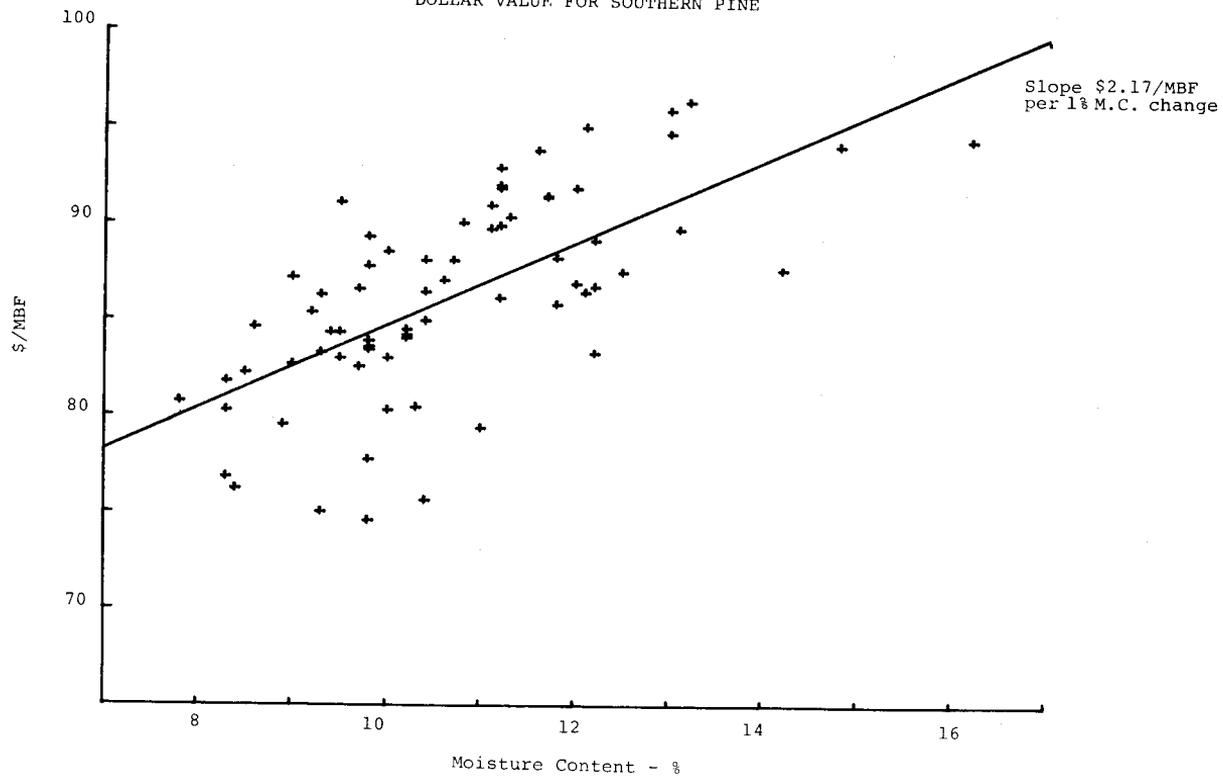
Dry End of Kiln

1 Non Test	2 Non Test
3 Restraint Removed	4 Restraint Removed
5 Unrestrained	6 Fully Restrained
7 Fully Restrained	8 Unrestrained
9 Non Test	10 Non Test
11 Non Test	12 Non Test

Green End of Kiln

FIGURE 3

MOISTURE CONTENT
VS.
DOLLAR VALUE FOR SOUTHERN PINE



Then dollar values can be compared to various amounts of restraint. Table 2 shows dollar improvement of various restraint levels compared to the unrestrained top quarter section. The restraining force of each quarter car section calculated at 50% M. C. was approximately 100 psf.

Dollar values for Table 2 are made at the adjusted value of 10% M. C. The assumptions of restraining force and the M. C. adjustment make exact dollar comparison inappropriate. The table is given only to indicate that a restraining force larger than 60 psf should increase dollar value.

The last three values in Table 2 show a decrease in value. A conclusion might be that as the restraining force becomes excessive, there is degrade due to compression. For this test no visual compression failure was observed. If 4 foot sticker spacing was used instead of 2 foot then compression failure might have caused the decreased value. It is felt that the decrease in this test was due to something other than compression failure, such as the M. C. adjustment.

Summary and Conclusion

Since quality or dollar value and M. C. are closely related, no discussion of quality is correct without bringing in moisture content. The numbers generated in this study indicate a loss of over \$2 per MBF for each 1% M. C. change. This value was specific for southern pine studs in the moisture content change of 17 to 8%. This means that if ample restraint is used but the load is overdried by a few percent you have negated most of the value gained due to the restraint.

The test results presented here show that restraint can improve quality, especially in the top courses which are free from the weight of superimposed lumber. The numbers derived in this study are specific for southern pine studs dried to about 11% M. C. The dollar value is dependent on the relative price structure. Other species, dimensions, and prices would undoubtedly result in a different value of restraint. However, the merits of restraint in increasing quality are clearly established. There may also be additional benefits in the form of improved planer performance and higher production rates due to fewer severely warped pieces.

With proper design, top loaded restraint can be simple to use and effective in production application. To use restraint at a mill that cuts various lengths or uses unit stacks would cause application difficulties. For these mills, it might be better to use a different restraining system.

To get the most out of any restraining system, we suggest using at least 100 psf. This means that if you have a kiln car 8 feet wide and 16 feet long, use at least 12,800 lbs. Because of the large weight needed, think about the application and safety aspects before using restraint.

1. Snodgrass, James D. Young-Growth Douglas-Fir: Is It Predisposed To Warp? Forest Products Journal, December 1955, pp. 406-412.
2. Koch, Peter. Process for Straightening and Drying Southern Pine 2 x 4's in 24 Hours. Forest Products Journal, May 1971, 20(5) pp. 17-24.

3. Weckstein, S. A. and Rice, W. W. A System for Controlling Warp When Kiln-Drying Plantation-Grown Red Pine, Forest Products Journal, September 1970, 20(9), pp. 70-74.
4. A Self-Weighting Device to Reduce Distortion During Seasoning, The Timber Trades Journal, October 1962, p. 67.
5. Mackay, J. R. Graham and Rumball, Bruce L. Drying of Distortion Prone Juvenile Core Radiata Pine for House Studs, The Australian Timber Journal, July 1971, Vol. 37 No. 6, pp. 43-57.

QUESTIONS AND ANSWERS

- Q. Did you determine whether the studs remain straight later on as their moisture content changed?
- A. No, we didn't. We didn't look at them after shipping or at a later time.
- Q. I was involved in a similar study a few years ago in Australia with Radiata pine. We tested three loadings, 110, 220, and 330 pounds per square foot and we had to go to 220 pounds per square foot area to obtain decent results. Therefore, I am interested to see the required weight for different species.
- A. This is a good point. I think in using restraint, if you increase the restraining force by an increment minimum amount, your dollar value isn't going to increase linear. The first 60 pounds are going to give you a dollar value of say \$2.88 per thousand board feet. If you double the restraining force to a 120 pounds per square foot surface area you are not going to double the dollar value, maybe only \$3.00. If you gradually approach a zero slope, this value could be well above 200 pounds per square foot and would be very dependent upon the type of lumber you are cutting. But, use of a restraining force of 200 pounds per square foot is a lot of weight.
- Q. When you were testing the value of your lumber, was this related to twist, or are there other factors that we aren't taking into account?

About a year ago I was involved in an inquiry in the Interior and they had a very severe twist problem. It turned out primarily the use of a severe kiln schedule. They were going immediately to a 60 or 80 degree depression and the top 8 or 10 courses were seriously twisted. As they went to a more moderate schedule which was approximating CRT, basically all their problems disappeared. In other words, are we dealing with a schedule that makes twist a serious factor or are we dealing with a schedule that minimizes it?

- A. We used a CRT schedule which wasn't severe and we dried southern yellow pine in 27 hours.

We didn't look at warp specifically but the gross effect. I think the largest factor of restraint is reducing crook, because the crook is a limiting defect in production of studs. Secondly, restraint probably reduces twist and if there was any benefit on bow, maybe very minor.

- Q. Would the restraining blocks cause any sticker indentation on the lower levels of the restrained kiln cars?
- A. We did not notice any indentation using about 60 pounds per square foot surface area. When you calculate the weight of the lumber load, I figured 50% moisture content, which was half way through the drying schedule on southern yellow pine, each quarter kiln car section weighed approximately 100 pounds per square foot. So, the lower section of the kiln cars in the unrestrained load had approximately 400 pounds per square foot restraint, and if you had 60 pounds per square foot it's not really a significant change to the lower section.
- Q. What size stickers were you using?
- A. These were 5/8 inch thick and 1 1/2 inches wide.
- Q. Do you sticker between the top lumber course and the weight restraint?
- A. Yes, to distribute the load down through the stack.
- Q. Was your lumber vertical or flat grain is question number one, and question number two, I may have missed something but I wasn't quite satisfied on how you arrived on the 100 psf that you recommended for the top loading?
- A. The lumber was cut from small logs on a chip-n-saw rig. My recommendation for using 100 pounds per square foot is due to test results presented here, review of the literature, and some other restraint studies that we have made in our laboratory.
- Q. What reduction in the life of the bearings in your kiln wheels?
- A. I have no idea.
- Q. If you put that much weight on a big load it would be significant.
- A. If you calculate the green weight of southern yellow pine at a 100 percent moisture content, you might be talking about 150 to 170 pounds for each quarter section. When you multiply this out by 4 quarter sections you might be talking 600 or 700 pounds per square foot. Addition of 60 pounds would have little effect.