portunities for investment diversification were provided to persons and companies whose incomes were not primarily derived from farming, and gains realized upon resale were taxed at the lower capital gains rather than ordinary income tax rate.

Inflation itself seems to have been the most significant magnet attracting investors to America's farmland. Investors who entered the market seeking a good inflation hedge were rewarded handsomely, for the land market has yielded returns far exceeding the inflation rate. Over the period from 1972 to 1977, per-acre values rose 15.6 percent per year compared with an average annual general price increase of 7.1 percent. As soon as the news of a good inflation hedge is out, it becomes an even better hedge, for prices are bid up in the scramble for shares.

Foreign investors too have been attracted to America's land boom. There is as yet, however, little solid information on the extent of their contribution to higher land prices.

Thus, land fever, caught in the 1970's by investors of all types, has helped cause the surge in land prices. It may be that a cooling off, catching up period must follow.

The major demand for farmland, however, is not from nonagricultural investors but from farmers who seek to expand their operations. According to the USDA, 63 percent of all farm-tract purchases in 1976 were for farm expansion. The pressure to expand in order to take advantage of economies of scale has been an ongoing force, internal to agriculture. For example, farmers have long sought to spread the high cost of modern equipment over more acres. Demand for land for expansion purposes has become even more intense in recent years. High commodity prices in 1973 and 1974 gave farmers ready cash to purchase additional parcels as well as the incentive to do so. Escalating land values greatly increased their net worth and borrowing capabilities to obtain still more land.

A final clue to the escalation phenomenon is that the largest gains between 1972 and 1977 were in the Midwest grain states. North Dakota, Minnesota, Iowa, Illinois, Indiana, and Ohio all experienced increases of over 160 percent. The leader was Iowa at 225 percent, followed by Illinois at 204. By February 1978, Iowa's percentage increase since 1972 was up to 239. Some Iowa corn land now sells for over $3500 an acre. Such high land values must be closely connected with expanded world markets for our major agricultural exports—feed grains, cereals, and soybeans.

The world food crisis of 1972 and 1973 and the growth of foreign markets resulted in extremely favorable commodity prices in 1973 and 1974. The world was open to commodity traffic in many directions, and North America has a comparative advantage in agricultural products. The increased demand coincided with a low volume of stocks in storage, producing rapid increases in prices. Farmers' hopes for the permanence of these favorable prices further stimulated their desire to expand, and exaggerated commodity price expectations became capitalized into the value of the land.

## Conclusion

The price of American farmland has been propelled sky-high by forces both internal and external to agriculture. Income-generating potential remains a basic land-value determinant, but that income is buffeted by world-wide happenings—climatic, political, and monetary. The impact of inflation has been to accelerate land values far beyond inflation itself. Many other factors—farm expansion, urbanization, rural parcelization, foreign investments in U.S. land, conglomerate corporations entering agriculture, vertical integration in the food system, and so on—have all made their contributions, adding fuel to the fire.

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# Warp reduction in young-growth ponderosa pine studs

Donald G. Arganbright □ James A. Venturino □ Michael R. Gorvad

*Conventional kiln-drying under restraint with an initial plasticization treatment reduced fall-down from 51.0 percent to 34.4 percent.*

Increasing amounts of lumber are being cut each year from young, small-diameter ponderosa pine trees. Unfortunately, this material tends to warp severely when it is dried. Downgrading as a result of warp for commercial operations has been as high as 60 percent.

Investigations aimed at finding practical methods for reducing warp in softwood construction lumber fall into three general areas: alternate drying schedules, altered sawing patterns, and drying under restraint.

Except for the first, each of these techniques has led to significant reductions in warp. Drying under top-load restraint appears more practical than other methods because it is either less expensive or easier to integrate into a production system.

The most promising of these techniques is high-temperature drying under restraint. Unfortunately, it has never been tried on ponderosa pine. High-temperature drying without restraint is frequently said to lead to less warp, but there is little data to confirm this. There is, on the other hand, considerable data for radiata pine showing the effectiveness of top-load restraint.

This study was initiated on the premise that top-load restraint was the simplest, most practical method for reducing warp in ponderosa pine. The study: (1) established which form of warp is most prevalent; and (2) compared the effectiveness of a 200 lb/ft² top-load restraint when studs are air dried, kiln dried at conventional temperatures, or high temperature dried.

## Materials and preparation

Each test unit was 3 feet wide by 8 feet long by 38 inches high. This resulted in approximately 150 boards or about 800 board feet per test run. Approximately 10,000 board feet of material was obtained from a cooperating mill in northern California. Care was taken at the mill in selecting the material to insure that as much distortion-prone material was included as possible. All material was shipped to the U.C. Forest Products Laboratory in Richmond, California, where each board was numbered and alternately placed into one of 12 drying units.

Due to limited kiln capacity, a portion of the test material remained solid-piled until a kiln was available. To avoid mold and stain development, this portion of the material was hand-dipped with a commercial anti-stain solution, completely sealed in plastic and stored out-of-doors.

Four reinforced-concrete blocks—16 inches thick by 8 feet long by 3 feet wide—were formed to provide the desired top load (200 lb/ft²).

## Procedures

A total of 12 test runs was made. For comparative purposes a control or unrestrained test was made for each of the different drying methods. There was one replication for each drying method.

The air-drying tests with restraint were used because of the simplicity of the method and its ease of incorporation into many mill situations. Conventional and high-temperature drying with restraint were used because of their reported potential.

All test units were stuck flush at both ends and on center with ½-inch-thick by 1½-inch-wide stickers (spacers) and placed on an asphalt work area. The humidity of the air was relatively high due to the laboratory's close proximity to the ocean. Therefore, drying was slow for these units.

The kiln runs were made using two 1000-board-feet experimental dry kilns, one operating at conventional temperatures and the second capable of reaching 240° F.

Both conventional and high-temperature kiln schedules used in the restrained loads were subjected to a four-hour pre-plasticization period before starting the schedule.

Each charge was dried to the same final moisture content of 15 percent, so that the majority of the pieces would be below the 19 percent moisture content required by American Lumber Standards. Twenty boards on the outside edges of the units were periodically metered with an electrical resistance meter to determine when the test unit had reached the desired moisture content. The units were allowed to cool for 24 hours after drying before the concrete block was removed.

After drying and at the time when warp was assessed the moisture content of each piece was again measured with an electrical resistance meter. All boards were examined by Western Wood Products Association grading standards for warp. Those exceeding the limits in any one type of warp were classed as "out-of-grade" and the actual amount of warp in each of these was then remeasured.

## Results

Kiln drying at conventional temperatures, *with restraint,* produced the best results: 65.6 percent of the boards met grade (see table 1). Conventional kiln drying without restraint led to the greatest fall-down, with only 49.0 percent of the two charges making grade.

Restraint seemed to have little beneficial effect when the material was air dried. The percent of boards making grades was 58.1 when no restraint was used and 55.6 when restraint was used. Comparisons of the air-drying tests with the other two methods should be made in light of the fact that the average final moisture contents of these runs was higher than the kiln-drying runs. It is felt that the level of degrade for the air-drying runs would have been much higher had their moisture content been reduced, as would often be the case in summer/fall air drying.

High-temperature drying at first glance

Fig. 2. Amount of warp in 1/32s-of-an-inch versus moisture content.

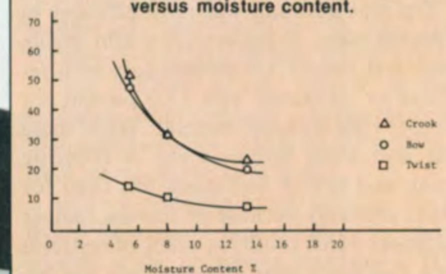


Fig. 1. Air-drying units with and without top-load concrete restraint blocks.

TABLE 1. Percentage of Boards Meeting Grade Requirements

| Test run no. | No. of pieces | Final moisture content | | No. of boards | | Ranking of recovery | Percent of boards | | Average percent for duplicate runs | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Avg. | Std. dev. | In grade | Out of grade | | In grade | Out of grade | In grade | Out of grade |
| NR-1AD | 148 | 16.2 | 2.84 | 81 | 67 | 7 | 54.7 | 45.3 | 58.1 | 41.9 |
| NR-2AD | 150 | 14.3 | 1.77 | 92 | 58 | 3 | 61.3 | 38.7 | | |
| R-3AD | 147 | 13.7 | 1.54 | 83 | 64 | 5 | 56.5 | 43.5 | 55.6 | 44.4 |
| R-4AD | 150 | 15.0 | 2.39 | 82 | 68 | 6 | 54.7 | 45.3 | | |
| NR-5CKS | 150 | 12.6 | 2.28 | 74 | 76 | 11 | 49.3 | 50.7 | 49.0 | 51.0 |
| NR-6CKS | 150 | 10.8 | 1.50 | 73 | 77 | 12 | 48.7 | 51.3 | | |
| R-7CKS | 149 | 11.9 | 2.59 | 96 | 53 | 2 | 64.4 | 35.6 | 65.6 | 34.4 |
| R-8CKS | 150 | 12.0 | 2.81 | 100 | 50 | 1 | 66.7 | 33.3 | | |
| NR-9HTS | 150 | 13.4 | 3.58 | 75 | 75 | 10 | 50.0 | 50.0 | 50.3 | 49.7 |
| NR-10HTS | 150 | 10.1 | 0.90 | 76 | 74 | 9 | 50.7 | 49.3 | | |
| R-11HTS | 149 | 8.7 | 0.45 | 78 | 71 | 8 | 52.3 | 47.7 | 54.4 | 45.6 |
| R-12HTS | 149 | 9.1 | 2.54 | 84 | 65 | 4 | 56.4 | 43.6 | | |

appears to have been the least successful of the three methods. One should note, however, that these runs had on the average the lowest final moisture content. The percentage of boards in grade would probably have been significantly higher if the units had been dried to a higher final moisture content. As with air drying, the use of restraint appeared to have no effect. High temperature drying both with and without restraint were better than conventional kiln drying without restraint.

Crook was the single most serious type of defect, and the major cause of downgrading, with twist and bow of less importance, though still serious.

Top load restraint was most effective in reducing twist. In conventional kiln drying there was only a 1.0 percent loss with restraint as compared with 17.0 percent for the two runs without restraint. While there was also some improvement in reducing crook and bow it was much less than for twist, probably because of uneven lumber thickness which results in a lack of restraint on a thin piece near a thicker one and because insufficient use of stickers permitted boards to distort between the 4-foot sticker placement.

Another possible and yet relatively simple means for reducing the amount of crook would be the use of recently-developed serrated kiln sticks.

It has been observed by kiln operators and others that warp is usually less at the bottom of a charge than the top. It was expected in these tests that degrade would decrease the lower one goes into a unit since the restraint is greater due to the added weight of the tiers above. This was not confirmed. This may be due to the 38-inch height of the units and the difference in weight between the top course and bottom course. At the start of drying it was calculated that the top tier had 188 lb/ft² of restraint, while the bottom tier had 272 lb/ft².

Any increase in recovery would be offset by the loss of volume or throughput in the kiln as a result of the space taken up by the concrete slab. The 16-inch slab used in this study would reduce kiln throughput for an 8-foot-high charge by 16.7 percent. No attempt was made to determine the economic tradeoff between lower production and higher quality. It may be possible also to reduce the weight/ft² needed which would decrease the throughput loss from the space reduction.

It is felt that the amount of degrade due to warp is directly related to final moisture content. This was verified by a separate test made on 50 boards selected from those air-dried boards that did not meet grade (table 2). All three forms of warp increased with decreasing moisture content. Bow and crook appear to be more strongly dependent upon moisture content than twist, the former exhibiting roughly a 50-percent increase when moisture content was reduced from 13 to 8 percent. The increase was even greater for the change from 8 to 5.6 percent. Based on this data it seems that some control over fall-down is possible by keeping final moisture content as high as possible, consistent with shipping weight and customer constraints.

TABLE 2. Effect of Moisture Content on Warp Development

| No. of observations | Moisture content | | Warp in 32nds of an inch: Crook | | Bow | | Twist | |
|---|---|---|---|---|---|---|---|---|
| | $\bar{X}$ | $\sigma$ | $\bar{X}$ | $\sigma$ | $\bar{X}$ | $\sigma$ | $\bar{X}$ | $\sigma$ |
| 50 | 13.4 | 0.91 | 22 | 33 | 20 | 37 | 8 | 8 |
| 50 | 8.0 | 0.51 | 32 | 46 | 32 | 56 | 11 | 10 |
| 50 | 5.4 | 0.43 | 52 | 73 | 47 | 76 | 14 | 12 |

## Conclusions

The results of this study show that top-load restraint can reduce warp losses in young-growth ponderosa pine studs. In the best case, conventional kiln-drying under restraint with an initial plasticization treatment, fall-down was reduced from 51.0 percent to 34.4 percent, although this would probably be less when adjusted for the height of a commercial-size unit.

Greater improvements could probably be obtained with increased sawing accuracy and the use of five stickers in a course rather than three. The use of more stickers would help reduce the large losses due to bow and perhaps crook.

Drying to the highest possible final moisture content would also give greater recoveries, because warp was found to increase significantly as final moisture content decreased.

The use of restraint with air-drying or high-temperature drying did not appear to be effective. High-temperature drying, while somewhat better than conventional kiln drying without restraint, was not as effective as conventional kiln drying with restraint or air drying.

The 16-inch thick concrete slab used reduced kiln throughput roughly 17 percent. It is likely that a thinner block would work just as effectively, which would help minimize the problem of kiln capacity lost to the presence of the concrete slab.

The major cause of fall-down was found to be crook, with bow and twist being less important. Top-load restraint reduced losses due to twist, but had little or no effect on bow and crook.

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