KILN DRYING MAPLE FOR STRUCTURAL USES

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ABSTRACT

Structural lumber products are traditionally manufactured from softwoods. However, with shrinking supplies of softwood lumber and abundant supplies of hardwood lumber, there is increasing interest in the use of hardwoods for structural applications. One factor that will be important in both the technical and economic feasibility of using hardwoods for structural lumber is drying. This paper presents some results on developing accelerated kiln schedules for drying hard maple 2 by 6s for structural uses.

INTROOUCTION

In the grading practice of hardwood dimension lumber, about 30 to 50 percent are visually determined as "low-grade" lumber, which generally has low value. Currently there are limited options for using this low-grade hardwood material. The two primary options are pulp chip (valued at about $100/MBF) and pallets (valued at about $250/MBF). A potential higher value use for this low-grade hardwood is structural lumber, either for individual boards or used in trusses or I-joists.

In recent years, the USDA Forest Products Laboratory, University of Minnesota, Duluth and Michigan Technological University have been cooperatively working with some private industry partners to develop value-added structural uses for low-grade hardwood materials. The goal of the research was to provide technical and economic basis for converting low-grade, low-value hardwood lumber into high value structural components that can be used in a variety of structural applications. Several technical and economic difficulties were overcome to allow substitution of hardwoods for traditional softwood species. Highlights of this research include the following:

- Determine lumber yield and recovery information
- Developing shorter, cost-effective drying schedule
- Evaluating engineering properties of lumber from northern hardwood species
- Assessing performance of fasteners to be used
- Developing engineering designs for I-beams and trusses
- Demonstrations of prototype I-beams and trusses
- Conducting preliminary financial assessments

One factor that is important in both the technical and economic feasibility of using hardwoods for structural lumber is drying. This paper presents some results on developing accelerated kiln schedules for drying hard maple lumber for structural uses (Simpson et al. 1998, Simpson and Wang 2001).

BACKGROUND

Traditionally, kiln schedules for maple lumber were developed for lumber intended for appearance-type products, such as furniture, cabinetry, millwork, and flooring. This means that the kiln schedules are conservative, slow, and designed to virtually eliminate even minor drying defects, such as small surface checks, or discolorations from excessive kiln temperatures. In structural products, surface checking and discoloration are not considered defects. So it is not necessary to use conservative and slow kiln schedules. Instead, an accelerated kiln schedule that is more severe, faster, and more efficient should be considered.

Additional factors that will shorten drying time compared with traditional hardwood schedules are the higher final moisture content (MC) and wider allowable MC distribution of 15 to 19 percent in structural lumber compared with 6 to 8 percent for traditional hardwood uses. Drying from 15 to 19 percent MC to 6 to 8 percent is a significant portion of total drying time and would be eliminated in lumber for structural uses. An effective kiln schedule would make a positive contribution to the economics of producing structural lumber products from low-grade hardwood lumber.

The main objective of the study reported herein was to develop accelerated kiln schedules for standard 2 by 6 hard maple lumber that is more severe, thus faster than traditional maple schedules, but still maintain the quality necessary for use in trusses, I-joists, or other structural products. Another objective was to convert the moisture content-based kiln schedule developed to a time-based kiln schedule.

DEVELOPMENT OF ACCELERATED MC-BASED SCHEDULE

The general approach for developing accelerated schedule was to compare kiln schedules of increasing severity, with the starting point being the traditional schedule for lumber intended for appearance-type products (Forest Products Laboratory 1993). The basis of comparison was drying time and warp assessed by both laboratory observations and visual grade according to the Southern Pine Inspection Bureau (SPIB) rules for structural lumber (Southern Pine Inspection Bureau 1994).

Drying materials were hard maple 2 by 6s, 2.44 m (8ft.) long. The lumber was sawn from cants remaining after the high-grade boards were sawn from the outer parts of the logs. The lumber grades were 3A, 3B, and Below Grade. The initial MC of lumber was about 60 percent in average.

Five schedules were tested, starting with the traditional maple schedules with an initial dry-bulb temperature of 120°F. The initial dry-bulb temperature was increased by 10°F in each of the more severe schedules (Table 1). The stacks were top-loaded with concrete blocks to 31 lb/ft^2, which was equivalent to the weight of about three courses of green lumber. Air velocity was in the range of 500 to 600 ft./min. The target moisture content was 19 percent.

Table 1. Initial dry-bulb and wet-bulb temperatures of experimental kiln schedules.

		Starting dry-bulb temperature		Starting wet bulb temperature	
Run No.	Code	(°F)	(°C)	(°F)	(°C)
1	HM120	120	49	113	45
2	HM130	130	54	123	51
3	HM140	140	60	133	56
4	HM150	150	66	143	62
5	HM160	160	71	153	67

Bow, crook, twist, and cup were measured on each board after drying. The boards were then surfaced and graded by an SPIB quality supervisor into one of five groups: Select Structural, No.1, No.2, or No. 3, and Economy.

DRYING TIME

The actual initial dry-bulb temperature and drying times are given in Table 2. As expected, drying time did decrease with increasing initial kiln temperature. Drying time ranged from 5.93 days at 120°F initial temperature to 3.74 days at 160°F.

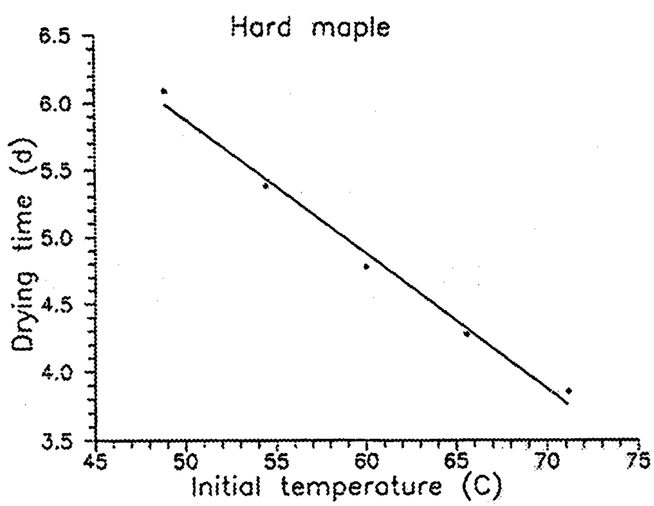
It was noted that a direct comparison between different initial temperature groups was not rational because of the difference in board width, thickness, specific gravity, initial MC, and air velocity. In addition, using manual kiln control, it is not practical to make each schedule change at the exact MC level of the schedule steps for different runs. It was also not practical to end all kiln runs at exactly 19 percent final MC. Therefore, for a true estimate of time savings by increasing drying time, we used a computer simulation program (Hart 198 1) to adjust the drying to a common base of identical board width, thickness, specific gravity, initial MC, all step-change MC values to those in Table 1 , air velocity, and final MC.

Table 2. Actual initial dry-bulb temperatures and drying times.

Run No.	Code	Actual initial dry-bulb temperature (°F)	(°C)	Drying time (days)
1	HM120	120	49	5.93
2	HM130	133	56	5.11
3	HM140	137	58	5.36
4	HM150	153	67	4.31
5	HM160	157	69	3.74

Figure 1 shows kiln-drying times normalized to common conditions as a function of initial kiln temperature. Drying time from 60 to 9 percent MC decreased linearly as drying temperature increased. Drying time was reduced 37 percent by increasing the initial temperature, and subsequent step temperature, from 120°F (49°C) to 160°F (71°C).

Figure 1. Kiln drying times normalized to common conditions as a function of initial kiln temperature.



DRYING QUALITY

The percent age of lumber in each experimental group that lost grade because of warp is given in Table 3. Several patterns in these data can be observed. Twist caused more downgrade than did the other forms of warp. Downgrade from cup was almost non-exist, and downgrade from crook was also small. There is no apparent pattern for the effect of drying temperature on downgrade from warp. HM 140 boards had considerably more downgrade from bow and twist than any other group. There is no apparent explanation for this deviation.

Table 3. Boards that loss grade from warp in drying hard maple 2 by 6s.

Code	Number of boards	Bow %	Crook %	Twist %	Cup %	Total warp
HM120	125	5.6	0.1	4.0	0	9.7
HM130	158	3.2	0	3.2	0	6.4
HM140	148	14.9	0	14.9	0	29.8
HM150	150	2.7	0	7.3	0.7	10.7
HM160	152	2.5	1.3	5.6	0	3.4

DEVELOPMENT OF TIME-BASED SCHEDULE

For structural lumber, there are less rigorous quality requirements compared to appearance-grade lumber. Therefore, the optimized MC-based schedule can be converted into a time-based schedule, similar to the type used in the softwood structural lumber industry. Time-based schedule is more efficient than MC-based schedule because kiln conditions are changed at pre-determined time intervals without feedback information from the lumber.

Three kiln runs were performed with 2 by 6s hard maple for converting the MC-based schedule developed previously to a schedule based on time. The time-based schedule was developed from the relationship between MC and time found in the first phase of study. This relationship is shown in Figure 2, along with notations for the time-based schedule. The kiln schedule was followed by three different equalizing periods (12, 24, and 48 h) at 180°F dry-bulb and 170°F wet-bulb temperatures.

Average final MC values for the three kiln runs, in order of progressively increasing equalizing time, were 13.4, 14.2, and 13.2 percent, with corresponding standard deviations of 1.91, 2.75, and 1.64 percent. Because there was no progressive decrease in standard deviation with increasing equalizing time, we cannot conclude that longer equalizing time is necessary to reduce variation in final MC.

The final MC values observed were a little lower than would be necessary for structural lumber. Structural lumber is commonly kiln dried to a target MC of 15 percent. To estimate the time required for the lumber to reach 15 percent MC in stead of the actual lower final MC for the three kiln runs, we pooled the initial and final MC data of the runs and generated a drying curve that is a composite of the three experimental kiln runs using the computer simulation program (Hart 1981) (Figure 3). As Figure 3 indicates, the drying time to 15 percent MC was about 11 5 h instead of the 120 h estimated in the schedule.

Figure 2. Drying curve for nominal 2 by 6s hard maple lumber derived from the accelerated MC-based schedule and converted to a schedule based on time.

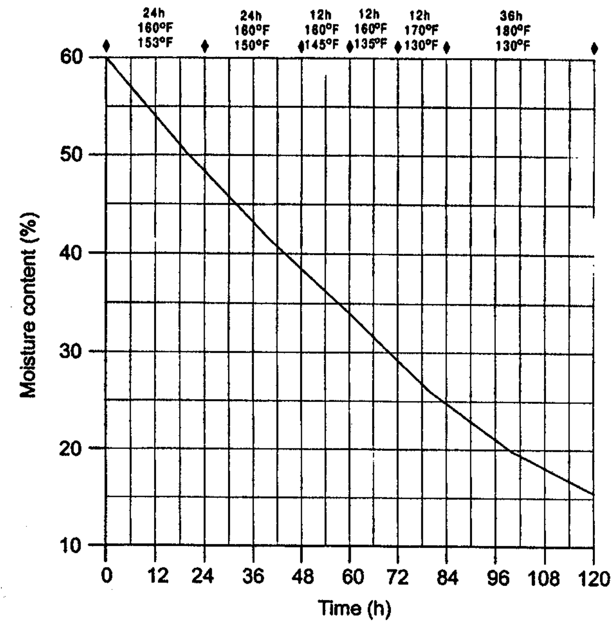


Figure 3. Composite drying time curve representing three kiln runs, with drying time to actual moisture content below 15 percent.

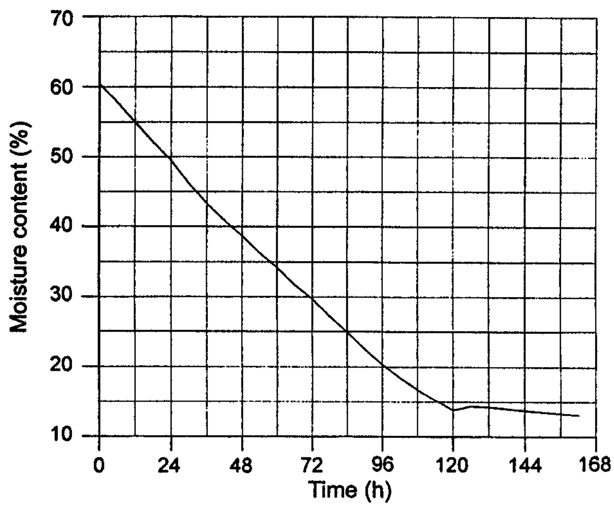
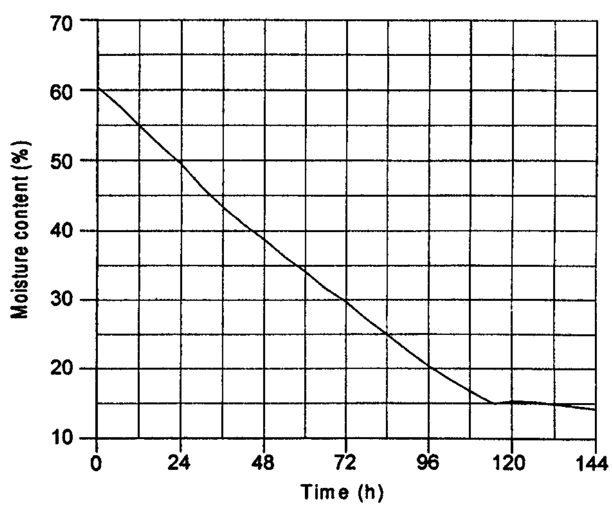


Figure 4. Drying curve representing three kiln runs adjusted to 15 percent final moisture content.



The drying curve shown in Figure 4 was obtained by shortening the last' step of the schedule from 36 to 31 h, so that lumber moisture content reached 15 percent in a total time of about 115 h. Figure 4 also shows that in equalizing time of about 15 h (bring total drying plus equalizing time to about 130 h) will decrease average final moisture content to 15 percent after the moisture content is increased by adding moisture to the over-dried boards and then decreased as the under-dried boards continue drying and the over-dried boards no longer gain moisture.

CONCLUSIONS AND RECOMMENDATIONS

Drying temperature had no apparent effect on the magnitude of warp in hard maple or on the amount of lumber that was downgraded because of warp. A fast kiln schedule, starting at 160°F dry-bulb temperature and 153°F wet-bulb temperature, cab be used;

The time-based kiln schedule converted from the optimized MC-based schedule, followed by a 15 hour equalizing period, will result in a final MC of about 15 percent. This schedule is recommended as a start point for individual kiln operators, with adjustments to be made according to observations over a number of production kiln runs.

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