Establishing kiln Drying Schedule for Beech (*Fagus Orientalis*) at 7.5 cm Thickness from Kelardasht Region

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Abstract

In order to establish kiln drying schedule for Beech (*Fagus Orientalis*) lumbers at 7.5 cm thickness commercially were cut from Kelardasht Forests located at elevation of 600m above sea level, in Northern Iran. Boards were kiln dried at three replications utilizing three kiln schedules of T5-C3 (Proposed by FPL for red Oak wood), T5-C4, T6-C4 for drying the lumbers down to the final moisture content of 8% in lower time and best quality. With due attention to effect of thickness in wood drying intensity, the t-test examine showed that there was no significant difference between the thickness of the three drying stage at 99% significant level. Therefore the results of this study can be applied for 7.5 cm thick boards. Primary dry bulb temperature each three schedules was adjusted at 41 °C and the final dry bulb temperatures was adjusted at 71, 71, 82°C respectively. basic Specific gravity and dry specific gravity were measured 52, 61 respectively. Longitudinal, radial, tangential and volumetric shrinkage were measured .46 %, 5.8%, 10.2%, 16.48% respectively. Quantity of defects including crook, bow, twist and three longest surface checks of the lumber were measured before and after the drying process in each stage. In order to analysis the lumber defects for estimating the best schedule, quality control graph were used. Analysis of results indicates that with either of three kiln schedules the extents of defects before and after drying were not statistically different and can be accepted. However the distribution of defects caused by third schedule (T6-C4) was more uniform in respect to average line as compared to other two schedules. In other words application of T6-C4 kiln schedule for
beech boards will reduce the drying time and improves dried wood quality (fig 5). At the end of this schedule, 24 hours equalization and 24 hours conditioning treatment is recommended.

Keywords kiln drying, beech, kiln schedule, drying defect, kiln sample

Introduction

From 164 million hectare area of Iran, forests are covered 12.4 million hectare (about 7.6 % Iran's surface) of it so that Beech is covered about 20 % of them. According to FAO definition Iran is counted among countries with low forest. In other to protection of this forest, increas of wood products service life is very necessary. For this way, drying of lumber in kiln at lowest time with optimal quality is very important.

The large number of tree species in the world, especially in the tropics, presents two problems in drying lumber. Some species have been used for timber products for decades, and dry-kiln schedules for these species have been recommended based on experience and research. However, recommended kiln schedules are not available for many less-utilized species, especially tropical species. A second problem stems from the sheer number of tropical species and their heterogeneous occurrence in the forest. As a consequence, it is not always practical to fill a dry kiln with a single species. The problem is the lack of a method to group species, based on similar drying characteristics, so that species can be mixed and dried together in the same dry kiln. The purpose of this study was to develop and evaluate a general kiln schedule (offer by FPL) to solve these two problems.

The strategy in selecting a kiln schedule is finding the right compromise between the desire to dry as fast as possible, which calls for severe drying conditions in the form of high dry-bulb temperatures and large wet-bulb depressions (low relative humidity), and the desire to minimize drying defects, such as surface checks and honeycomb, by using lower temperatures and smaller wet-bulb depressions. Several wood properties are associated with the allowable severity of a kiln schedule, properties such as specific gravity, shrinkage, and mechanical properties perpendicular to the grain. Specific gravity is the only property that is widely reported in the literature. Hisada and Sato (1976), Hisada and others (1986), and Durand (1985) conducted analyses to relate known kiln schedules of Southeast Asian and African species to physical properties. They developed multiple linear regressions between several kiln schedule parameters as the dependent variables and physical properties as the independent variables.

Specific gravity was found to have the largest influence on schedule parameters. In general, they found good agreement between the recommended and estimated schedules, but noted that the estimated schedule for some species deviated considerably from the recommended schedule. Jankowski (1992) developed a rapid and simple test to indicate the probable performance of wood species in kiln drying by comparing the test performance of six known species in relation to their recommended schedule. Results showed that the selected schedules were adequate for the species tested.
For many years, kiln schedules for temperate and tropical hardwoods have been developed by numerous people in research institutions and industry throughout the world. Many schedules are summarized in Hildebrand (1970), Pratt and Turner (1986), Boone and others (1988), and USDA (1991). These schedules are recommended as conservative starting points a safe reference to be adjusted upward in severity with experience. A typical kiln schedule consists of several steps. An initial dry-bulb temperature and initial wet-bulb depression begin the drying at some green moisture content. These conditions are held until a predetermined moisture content level is reached; then, the first change (increase) is made in the wet-bulb depression. At subsequent moisture content levels during drying, additional increases in the wet-bulb depression are made. During the latter stages of the kiln schedule, increases are made in both the dry-bulb temperature and the wet-bulb depression. For hardwoods native to the United States, extensive pilot testing and widespread commercial use have demonstrated that the general schedules for hardwoods developed by the Forest Products Laboratory are satisfactory for the drying of 51-mm (2-in.) and thinner hardwood lumber and other products. They form a base from which an operator can develop the most economical schedule for a particular type of kiln. (Rasmussen 1961). Despite this generalized description, we can be reasonably confident that years of collective experience have confirmed those species that are sensitive and require a mild schedule and those that can tolerate severe schedules.

How the schedules for tropical hardwoods were assigned is less clear. The major references are Hildebrand (1970), Kukachka (1970), McMillen and Bois (1972), Chudnoff (1984), Pratt and Turner (1986), and Boone and others (1988). The origin of some of these schedules is unknown, but as explained by McMillen and Bois (1972), some were derived from schedules published in Great Britain and are listed most recently by Pratt and Turner (1986). The schedules were developed mainly by drying tests at the Princes Risborough Laboratory, but also from data obtained elsewhere.

The kiln schedules recommended in the literature are not from a uniform experimental design of replicated, controlled experiments where standard, precise observations were made to establish critical schedule parameters, such as initial dry bulb temperature, initial wet-bulb depression, moisture content for the first wet-bulb depression change, and the subsequent increases in dry-bulb temperature and wet-bulb depression. Furthermore, it is possible that some recommendations were made on incomplete observations. An example would be failure to experimentally bracket the dividing point between a schedule that is too severe and one that is too mild. This could occur in a situation where a schedule is applied, no defect is observed, and the schedule is declared appropriate even though it is not optimized. For these reasons and the general lack of knowledge about criteria that led to schedule recommendation, it does not seem justifiable to apply statistical analyses that lead to probability-based inferences on the credibility of schedule estimates. The procedure we use is simple least squares curve fitting. Also, keep in mind that conservative schedules are used as the base for establishing the relationship to specific gravity. The intent of these schedules is to serve only as a starting point to be adjusted upward in severity as experience is gained with the species in question.
Material and Method

Three charges of Beech (fagus orientalis) lumbers (at 7.5 cm thickness commercially were cut from Kelardasht Forests located at elevation of 600m above sea level, in Northern Iran (table 1)) were kiln dried in this study. Each charge contained 110 pieces, or approximately 3 m³. Prior to drying, the course and location within the course were recorded for each board to determine if position was correlated with warp and/or moisture content. Each board was in the green condition and measured for bow, crook, twist and surface check prior to drying. The research kiln was an, steam heated, cabinet dryer and a computer control system. Three drying schedules T5-C3 (Proposed by FPL for red Oak wood), T5-C4, T6-C4 were selected. The drying schedules are listed in figure 1. The physical restraint consisted of large steel plates, totaling of 329 kg, which created an evenly distributed top-load weight of 100 kg/m². Standard kiln sample board procedure was used to monitor MC, using twelve sample boards per charge, six on each side of the load. When the average of the readings from the kiln sample 6 to 10 percent moisture content, the charge was pulled from the kiln, the weights were immediately removed from the restrained charges, and the lumber was left to cool for three hours. Following the cooling period, each board was evaluated for warp, number of growth rings, presence/absence of pith, and moisture content. Note that the total number of growth rings were counted and recorded for the entire thickness of each board. Warp measurements consisted of bow, crook, and twist which were measured to within one millimeter on the plane table. Average moisture content for each board was recorded (table 2, 3 and figure 2 &3).

Results and Discussion

Time required to dry the Iranian beech lumber from green to 8 percent ranged from 13 day for lumber dried entirely at 49°C to 9 day for the third schedule (figure 1). We met our target MC of 6 to 8 percent fairly closely as measured by sample board averages. The combined time for equalizing and conditioning varied from 17 to 72 h for schedule 1 to 3. The first schedule required 35 h equalizing, but boards were conditioned for 72 h. Total drying time for third schedule shorter than expected. The boards dried to 20 percent MC more quickly than expected, perhaps because their initial average MC was lower than that of boards in the other schedules.

Time to dry to 30 percent MC was somewhat longer than anticipated, and equalizing 35 h longer than equalizing in other schedules. This was due in each case to high MC in one sample board containing heartwood.

Drying times for the various treatments of beech were about the same as for red maple (Boone 1986), which ranged from 50 h to dry from green to 6 percent MC by the conventional-temperature schedule.

Analysis of results indicates that with either of three kiln schedules the extents of defects before and after drying were not statistically different and can be accepted. However the distribution of defects caused by third schedule (T6-C4) was more uniform in respect to average line as compared to other two schedules (fig 4). In other words application of T6-C4
kiln schedule for beech boards will reduce the drying time and improves dried wood quality (fig 5).

At the end of this schedule, 24 hours equalization and 24 hours conditioning treatment is recommended.

References


Table 1- Boards dimensions

<table>
<thead>
<tr>
<th>Load Number</th>
<th>Number of boards</th>
<th>Thickness (mm)</th>
<th>Width (cm)</th>
<th>Length (cm)</th>
<th>Volume (m³)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>110</td>
<td>76</td>
<td>14.6</td>
<td>266.7</td>
<td>3.26</td>
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<tr>
<td>2</td>
<td>110</td>
<td>74</td>
<td>14.4</td>
<td>265.2</td>
<td>3.11</td>
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<tr>
<td>3</td>
<td>110</td>
<td>77</td>
<td>14.5</td>
<td>263.1</td>
<td>3.23</td>
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</table>

Table 2- Moisture Content of board's charges

<table>
<thead>
<tr>
<th>Load Number</th>
<th>Initial MC (%)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>MC&lt;sub&gt;I&lt;/sub&gt;</td>
<td>MC max</td>
</tr>
<tr>
<td>1</td>
<td>43</td>
<td>62.5</td>
</tr>
<tr>
<td>2</td>
<td>34</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>35</td>
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</table>

Table 3 - Total percent of boards at final MC

<table>
<thead>
<tr>
<th>load number</th>
<th>MC range (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>lesser than 6</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10-12</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>more than 10</td>
<td></td>
</tr>
</tbody>
</table>
First load

Second load

Third load

FIGURE 1- kiln-drying schedule at various times
FIGURE 2- Moisture gradient of boards
FIGURE 3- MC changes at various times
FIGURE 4- quality control graphs at various kiln schedules
FIGURE 5- drying rate at various kiln schedule