Effect of Wood Drying Conditions on Occurrence of Collapse During Drying

Mahdi Shahverdi
Department of Wood Science and Technology, Faculty of Natural Resources, University of Tehran, Karaj, Iran; Young Researchers Club, Islamic Azad University, Karaj Branch, Iran

Saeed Eshaghi
Department of Wood Science and Technology, Faculty of Natural Resources, University of Tehran, Karaj, Iran

Hadi Gholamiyan
Department of Wood Science and Technology, Faculty of Natural Resources, University of Tehran, Karaj, Iran

Seyed Ali Haji Mirza Tayeb
Department of Wood Science and Technology, Faculty of Natural Resources, Islamic Azad University, Karaj Branch, Iran

Abstract

In this study, the susceptibility of poplar wood (P. nigra) to collapse during drying was investigated. Thus, the poplar boards with nominal dimensions of 100 × 50 × 25 mm (L T R) were dried using three different drying schedules (A, B and C). The initial dry-bulb temperature of 82 °C was selected for the schedule C and also 60 °C for schedules A and B. After drying, the severity of collapse was determined in the cross section of the boards by scanning electron microscope (SEM). The results of this study revealed that the poplar wood is almost sensitive to collapse during drying. In contrast to the boards dried by the schedules A and B, severe collapse and cell wall degradation occurred in the boards dried by schedule C. Furthermore, the results of this research showed that the suitable selection of initial dry-bulb temperature for a drying schedule is effective to control the occurrence of collapse in poplar wood.
Keywords  Poplar, Collapse, Wood drying, Dry bulb temperature, Drying schedule

Introduction

One of the important defects during the drying is occurrence of collapse which is in fact due to deformation and compressing of wood cells. In case of severe collapse, surface of dried boards will be uneven and wrinkle. The outbreak of such a collapse can be due to compression stresses in internal parts of wood that have exceeded from compression resistance of wood or due to surface tension of liquid in wood lumen cells.

This defect happens in initial phase of wood drying and usually will not be seen until wood converting process. Its reason is because of high temperature in initial phase of drying process, thus in susceptible species to collapse it is better to use low temperature in initial drying phase. Also to decrease this phenomenon before putting woods in kiln we can dry them in air till bellow saturation point. The collapse in wood can be almost treated as well using conditioning and steaming. Collapse can usually be a source of different amounts of shrinkage that can cause internal checks (honey combing). Since it can lead to quality loss in dried boards as a result of occurrence of stress and crack, it is considered as a significant defect.

There are lots of factors that affect the severity of collapse during the drying process. Beside the drying condition, drying schedule or method that is used for drying, wood species characteristics especially permeability coefficient and free water capillary flow rate are effective parameters on collapse occurrence.

Because of its significant influence on dried board quality in service condition many researches have been carried out about it (Tiemann 1, Yang and Fife 2, Zhuang et al. 2005, Holmes and Kozlik 3, Yang 4, Innes 5, Innes 6, Chafe and Ilic 1992). Obataya et al. (2005) investigated the effect of wood drying condition on collapse in Arundo donax species. They found out that the drying process in low temperature in this species cause a lower level of collapse. Recent researches have showed that the severity of collapse in Eucalyptus dried boards is highly related to drying temperature. Innes (1995) investigated the possibility of collapse occurrence in Eucalyptus regnans F. Mull in lower than allowable temperature and reached to desirable results. Blakemore and Langrish (2008) studied the effect of pre-drying on reviving the collapse in “Eucalyptus regnans F. Muell” and “E. delegatensis R.T. Baker”. They understood that in order to gain maximum collapse reviving, before equalizing the moisture gradient between surface and pith should be 5 and as a maximum be 8-10 %. Also they stated that collapse directly or indirectly influences boards drying rate. Innes (1995) did a study on Tasmanian Eucalypt to present a model for predicting of stress and strain resulted of collapse occurrence in dried boards. He then claimed that at the beginning of wood drying process when lumens are full of free water, internal tensions sharply increase and lead to collapse. Blakemore and Langrish (2008) did a survey on the effect of collapse phenomenon on the diffusion coefficient in Eucalyptus regnans F. Muell, E and delegatensis R.T.Baker. Chafe (1986) studied radial changes in collapses, volume shrinkage, moisture content and density in Eucalyptus regnans F. Muell.
According to that, by 85% of sample radius collapse from bark to pith, started with an increase and suddenly highly decreased. Chafe (1990) in a study investigated variation in collapse and shrinkage by eliminating of extractives through hot water, cold water, hot methanol and NAOH treatments in *Eucalyptus regnans* F. Muell. Collapse phenomenon in heartwood increased after hot water treatment but there was a decrease after cold water treatment, but its variations in radial direction were similar in both treatments. In sapwood there was a little change in collapse and shrinkage after methanol, hot and cold water treatment. Chafe (1995) studied the effect of preheating and drying with continuous and discontinuous methods on internal checking, shrinkage and collapse in *Eucalyptus regnans* F. Muell. The results showed that boards that dried with discontinuous method are more capable to collapse. In this research also investigated collapse occurrence during drying process in poplar wood (*P. nigra*).

### Material and Methods

#### Sample preparation

Freshly cut poplar (*Populus nigra*) logs belonging to a forest close to Taleghan in Iran were studied. From that, the tangential boards were cut with dimensions of 120 x 40 x 40 mm (L T R) and to prevent moisture reduction, their cross sections coated by epoxy resin. Since there are lots of tension woods in *P. nigra* plus normal wood samples, some tension wood samples also were provided for more study (Tarmian et al. 2009). To providing more precise samples the macroscopic recognition of tension woods was done with Herzburg agent (Tarmian et al. 2009). This agent makes the tension wood zone purple partial to dark blue and also makes the normal zone to yellow.

#### Drying method

The boards were dried under three different drying schedules (A, B, C) by conventional method in laboratorial dryer. In schedule A, boards were dried under constant condition (temperature of 60 °C and relative humidity of 40%); in B, boards were under a time-based schedule with four steps and in C under two time-based schedules with two steps (tables 1 and 2). All the boards dried from green moisture till final average moisture of 6-8% and after drying process its curve depicted.

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (h)</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 24</td>
<td>60</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>24 - 48</td>
<td>65</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>48 - 72</td>
<td>82</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>72 - 84</td>
<td>82</td>
<td>50</td>
</tr>
</tbody>
</table>

*Table 1. The time-based schedule used for drying boards in condition B.*
Table 2. Time-based schedule used for drying boards in condition C.

<table>
<thead>
<tr>
<th>Step</th>
<th>Time (h)</th>
<th>Temperature (°C)</th>
<th>Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 36</td>
<td>82</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>36 - 46</td>
<td>82</td>
<td>40</td>
</tr>
</tbody>
</table>

Electron microscope studies

One sample was chosen for each treatment from dried boards with dimensions of 5 mm (L T R) for microscopic studies. Scanning electron microscope (SEM) was used for microscopic studies. The samples were put in gold coater apparatus for 15 - 20 minutes (SBC004) to be coated with gold in scale of nanometer. After that was brought to vacuum place of SEM to be vacuumed for 10 minutes (DFM960A) and finally microscopic pictures were taken.

Results and Discussion

Drying curve

According to schedule A initial average moisture in dried samples was 73.5% and boards during 120 hours reached final average moisture of 6%. In dried board with schedule B sample initial average moisture was 96% and after 84 h reached the final average moisture of 7%. Also in dried board with schedule C initial average moisture was 102% and boards during 64 h reached final average moisture of 8% (fig. 1).

![Drying Curve](image)

Fig. 1. Average boards drying curve from green moisture content to final moisture in all three schedules (A, B, C).

The drying rate in A, B, C was 0.57, 1.07, and 2.04 %/h respectively which in C for using high dry temperature (82°C) the most drying rate was seen. In boards dried with schedule A, for using low and constant dry temperature (60°C) drying rate was low.
Collapse severity
The provided microscopic pictures from dried board’s cross section with all three schedules A, B, C is shown in figures 3 to 14.
In boards dried with schedule A whether in tension or normal wood of *P. nigra* there were no collapse occurrence (figs. 3 to 6) and wooden cells (fibers and vessel elements) maintained their normal structure.

Figs. 3-6: SEM pictures provided from dried boards with schedule A; tension wood (3 and 5) normal wood (4 and 6).

In boards dried with schedule B in both tension and normal wood there is inconsiderable collapse occurrence and the normal structure of cells has a partial changing (figs. 7 to 10).
However there were no significant collapse in its real meaning and no cell deforming in any of B dried boards. Also microscopic study showed that boards dried with A and B schedules have intact cell wall without any crack or degradation.

In contrast to the boards dried with schedules A and B, all the boards dried with schedule C (tension and normal wood) showed a severe collapse (figs. 11 to 14). We can see cell deforming specially vessel elements in all boards dried with this schedule. Also in normal wood, fiber cell wall was damaged and we could see cell wall degradation. In tension wood due to severe collapse, the gel layer was detached from fiber cell wall.

Generally tension wood had more sustainability to collapse in comparison with normal wood. It seems that is because of smaller aperture of pit pairs in tension wood comparing with normal wood (Tarmian et al. 2009). Small diameter in aperture of pit pairs leads to increase in capillary tension and causes cellular collapse as a result.

The results in this research are consistent with Perre studies (2007) about collapse occurrence in eucalyptus tension and normal wood during the drying process. Despite the severe collapse in boards dried with schedule C in microscopic scale, there were neither severe collapse nor uneven surface in dried boards in microscopic observation and in other words there was no washboarding occurrence.
Some of the main factors that affect collapse occurrence during drying are compressing stress and capillarity tension. This defect will happen because of high dry temperature at the initial steps of wood drying process. In fact using high dry bulb temperature leads to faster free water bulk flow and higher compressing stress than wood compressing strength, and as a result causes collapse occurrence with wooden cell deformation. In schedules A and B for using lower dry bulb temperature (60°C) comparing with C that causes slower free water Emersion, there was no collapse occurrence in the boards dried by these schedules. The studying from Obataya et al. (2005) also showed that using low dry temperature has positive effect to decrease the collapse during the drying process.

Regarding to high drying rate (2.04 %/h) in dried boards with schedule C because of using high dry bulb temperature (82°C), there is sever collapse due to faster free water emersion and high capillarity tension.

The results of this research showed that dry bulb temperature in the kiln has a significant effect on collapse occurrence in P. nigra. In other words for fast water emersion (free water) from lumen by using high dry temperature (schedule C), the cell walls specially ones having weak walls cannot resist on stresses of surface tension which occur after missing water and as a result collapse will happen. On the contrary in lower temperatures the cell walls show better solidity and are more resistant to capillarity forces.
Conclusion

Generally the results of this survey showed that *P. nigra* is such a sustainable wood to collapse occurrence during the drying process. The results in the previous researches, (Tarmian et al. 2009, Rahimi et al. 2009) which talks about the possibility of honey combing (internal checks) in *P. nigra* during the drying are consistent with this statement; because of the collapse occurrence in wood and severe differential shrinkage as a result, the possibility of internal checks during the drying process will increase.

According to results obtained from this research, it can be concluded that choosing a suitable kiln dry bulb temperature in initial steps of drying process is effective to control the colapse in *P. nigra*. For drying of *P. nigra* with the aim of decrease and control of collapse and internal checks, the kiln dry bulb temperature should not be over 60°C.

Since the collapse in boards can be somehow removed in last steps of drying process using conditioning or steaming, it is suggested for the next study the suitable time for starting the conditioning treatment and its needed duration in *p. nigra* (specially with tension wood) will be investigated.

References


