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# Improving the Dimensional Stability of Spruce and Birch Boards by Heat-Treatment at 190 and 210℃[1]

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## ABSTRACT

It is known that heat treatment decreases the hygroscopicity of wood. Thus heat-treated wood is good for outdoor construction due to its improved dimensional stability. This study is to investigate the hygroscopicity and discoloration of spruce and birch boards heat-treated above 190℃. The equilibrium moisture contents (EMCs) at all relative humidities decreased with the increase of heat treatment temperature and/or time for both spruce and birch. It was revealed that heat-treatment temperature affected more on the hygroscopicity thaan heat-treatment time. The average basic densities decreased for the spruce specimens, but increased for the birch specimens with an increase of the treatment time and/or temperature. The same heat treatment condition (190-8) made the birch specimens darker than the spruce specimens.

***Key words***: Heat treatment,*Picea spp*., *Betula platyphylla* Var. japonica, Sorption isotherm, Colorimetry.

## 1. INTRODUCTION

Heat-treatment at 220℃changed the colors of the three major domestic softwoods to high quality dark brown (Kang, 2008a and 2008b). They likely substitute for tropical hardwoods. Heat treatment reduces the growing stress of wood, increases the crystallinity of cellulose, decreases equilibrium moisture content, and improves the dimensional stability (Tejada et al., 1997). It has been reported that the crystallinity of wood heat-treated at high moisture content was increased as twice as that at oven-dry condition (Bhuiyan et al., 2000).

Heat treatment decreases the hygroscopicity of wood, which, however, is recovered by steaming at 100℃. It proves that heat treatment does not increase the crystallinity of cellulose, but makes amorphous material changed chemically (Obataya et al., 2000).

A heat-treatment apparatus was recently made and was used to develop color-change technology for domestic species, such as Korean red pine, Korean pine, and Larch (Kang, 2008a). Their colors were turned dark brown when heat-treated at 220℃ for 10 hr. That the heat-treatment also improves the dimensional stability of wood was proved by using a saturated salt solution method (Kang, 2008b).

Heat-treated wood is good for outdoor construction due to its improved dimensional stability. But r ain and UV discolor wood. Lignin between cellulose is photo-chemically degraded and

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washed out easily. Cellulose left on wood surface results in the increase of hygroscopicity (Kalnins and Feist, 1993).

The stability of wood is evaluated by measuring the dimensional change due to the change of the environmental conditions. Alternatively equilibrium moisture content could be a predictor of the dimensional stability since the hygroscopicity of wood is linearly related to it. Saturated salt solution method has been used to obtain a sorption isotherm by measuring EMCs at various relative humidities (Lee et al., 2008).

The object of this study is to investigate the hygroscopicity and discoloration of spruce and birch boards heat-treated above 190℃.

## 2. MATERIAL AND METHODS

Spruce(*Picea spp*.) and birch (*Betula platyphylla* Var. japonica) were chosen for this study. The sample boards of 30-mm thickness and various width were air-dried for more than three months. Heating treatment were conducted in the heating chamber recently fabricated (Kang, 2008a). All boards were cut into 1,000mm long to fit the length of the heating chamber.

The boards of spruce were heat-treated at 190℃ for 8 hours including 2-hour warm-up period. After the first heat-treatment some boards were selected and heat-treated again at the same conditions for comparison. The birch boards were also heat-treated at two different conditions: 190℃ for 8 hours and 210℃ for 12 hours. All treatment times include 2-hour warm-up period.

Two boards were selected from each of two heat-treatment levels for each species. Two control boards of each species were also selected for comparison. Six small samples of nominally 30×30×30mm were cut from each selected boards. Some extra samples were taken for color measurement. The color of the specimens was measured with a HunterLab MiniScan XE Plus. Its light source was Xenon flash lamp with a wave length of 400-700 nm. Three measurements were taken from each specimen. Color difference index (ΔE*) was calculated using Eq. [1].

$$\Delta E^* = \sqrt{(L_1^* - L_0^*)^2 + (a_1^* - a_0^*)^2 + (b_1^* - b_0^*)^2} \quad [1]$$

where,
ΔE* : color index
L* : lightness index
a* : redness index
b* : yellowness index
(1 represents the heat-treated specimens and 2, the controls.)

The matching specimens were divided into six groups. Thus each group consisted of 12 small specimens (two boards × three heat-treatment levels × two species) These six groups were allocated to six desiccators containing six different saturated salt solutions for the sorption experiment. The desiccators were placed in a room at 20℃ as long as the specimens were equilibrated. The relative humidities of the salt solutions used for this study are listed in Table 1 (Hoadley, 1980). The dimensions and weights of the specimens were measured before and after the sorption experiment. Thereafter all specimens were oven-dried at 103±2℃ and their moisture contents were calculated retrospectively.

Table 1. Relative humidities of saturated salt solutions at 20℃

| Saturated salt solution | RH (%) |
| --- | --- |
| $CaCl_2 .\ 2H_2O$ | 32.0 |
| NaBr | 58.0 |
| $(NH_4)_2SO_4$ | 80.5 |
| $ZnSO_4 .\ 7H_2O$ | 90.0 |
| $NaSO_4$ | 95.0 |
| $H_2O$ (distilled water) | 100.0 |

The oven-dried specimens were water-soaked for two weeks. Their masses were weighed and their volume were measured by the water displacement method. The basic densities of the specimens were calculated using Eq. [2].

$$\rho = \frac{W_{od}}{V_g} \quad \text{[2]}$$

where,
$\rho$: basic density ($g/cm^3$)
$W_{od}$ : oven-dry weight (g)
$V_g$ : green volume ($cm^3$)

## 3. RESULTS and DISCUSSION

### 3-1 Sorption isotherms

The moisture contents of the small specimens before the sorption experiment were varied between the heat treatments. The average moisture contents of the control (Cn), lightly-heated (Lt) and heavily-heated (Hv) spruce specimens were, respectively, 9.9, 7.4 and 5.5% while those of birch specimens were, respectively, 8.0, 3.6 and 1.8%.

The sorption experiment took more than 50 days. Fig. 1. shows that the specimens were equilibrated with the climates of the desiccators around 50 days.

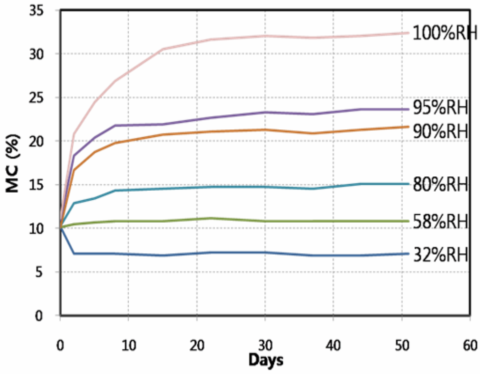


Fig. 1. Variation of the moisture contents of the specimens in the saturated salt solution desiccators during the sorption experiment.

The typical sorption isotherms of the controls and heat-treated specimens of spruce and birch are depicted in Fig. 2. It shows that the EMCs at all relative humidities decrease with an increase of heat treatment temperature and/or time for both species. The average EMC differences between the heat-treated and the control for spruce were 3.12 and 4.10% for 190-8 and 190-12, respectively, while those for birch were 2.92, 11.56% for 190-6 and 210-12, respectively. The hygroscopicity of the birch specimens was less reduced than that of the spruce specimens when heat-treated at 190℃ for 8 hours. However, the birch specimens lost the hygroscopicity significantly when heat-treated at 210℃ for 12 hours. It has been known from experience that a spruce board can not be heat-treated at 210℃ to avoid to be charred. The isotherms of the spruce specimens in Fig. 2 show that an increase of heat-treatment time only does not change much the hygroscopicity. Thus it could be concluded that heat-treatment temperature affects more on the hygroscopicity that heat-treatment time.

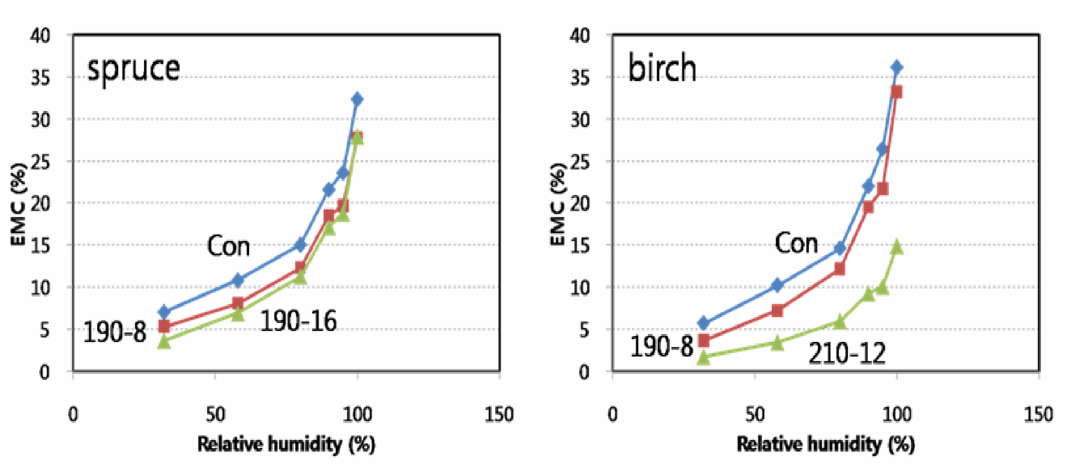


Fig. 2. Sorption isotherms of the spruce and birch specimens heat-treated above 190℃ and the controls.

## 3-2 Water soaking experiment

The average weights of the water the water-soaked specimens absorbed are plotted in Fig. 3. There are little differences between two species and three heat treatment conditions. All specimens were oven-dried before the water soaking tests.

The moisture content plots of the water-soaked specimens look different. The moisture contents of the spruce specimens were higher than those of the birch specimens, which may be attributed to the discrepancy of their densities (Fig. 4). It is quite interesting to notice that the spruce specimens of 190-16 had higher average moisture content than those of the control and 190-8, but the birch specimens of 210-12 had lower average moisture content than those of the control and 190-8. It maybe also partially explained by the discrepancy of their densities. The average basic densities decreased for the spruce specimens, but increased for the birch specimens with an increase of the treatment time and/or temperature (Fig. 5).

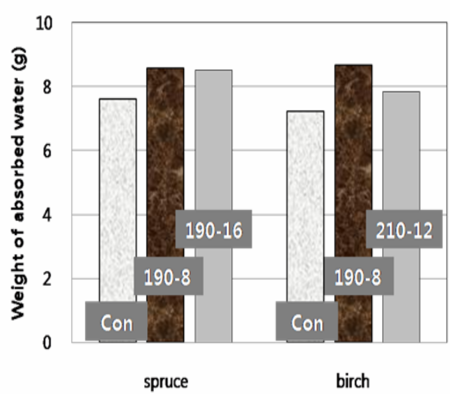


Fig. 3. The average weights of the water the water-soaked specimens absorbed.

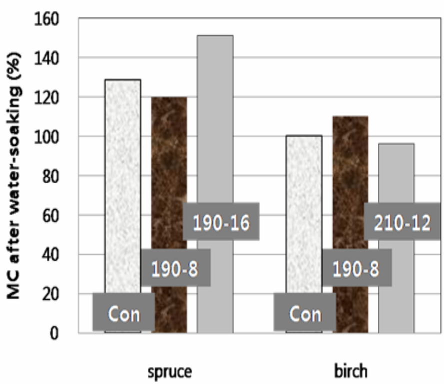


Fig. 4. The average moisture contents of the water-soaked specimens absorbed.

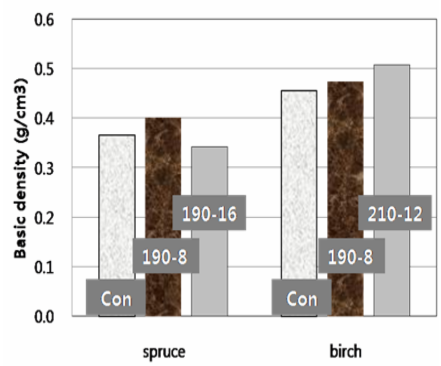


Fig. 5. The basic densities of the specimens.

### 3-3 Colorimetry

The same heat treatment condition (190-8) made the birch specimens darker than the spruce specimens (Fig. 6). It is due to the fact that the hardwood normally contains more extractives than the softwood. The color of wood is distinguishable if the color different index (ΔE*) is larger than 9. The average color difference index of spruce 190-8 was 9.1.

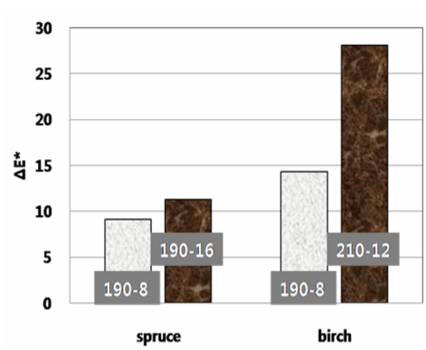


Fig. 6. Color difference indexes of the heat-treated specimens compared with the controls.

## 4. CONCLUSIONS

The hygroscopicity of spruce and birch heat-treated above 190℃was investigated by a saturated salt solution method. The conclusions obtained from this study are as followed:

1. The EMC's at all relative humidities decreased with an increase of heat treatment temperature and/or time for both spruce and birch, and heat-treatment temperature affects more on the hygroscopicity that heat-treatment time.
2. The water-soaked spruce specimens of 190-16 had higher average moisture content than those of the control and 190-8, but the water-soaked birch specimens of 210-12 had lower average moisture content than those of the control and 190-8.
3. The average basic densities decreased for the spruce specimens, but increased for the birch specimens with the increase of the treatment time and/or temperature.
4. The same heat treatment condition (190-8) made the birch specimens darker than the spruce specimens.

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