KFS Journal, Vol. 21(6), 2010: 499-504

Heat Treatment of Dimension Lumber and Roundwood Used for Hanok Above 170℃[1]

Ho-Yang Kang[2]

ABSTRACT

Korean traditional buildings, Hanok, are mostly constructed with dimension lumbers and roundwoods. They are hardly kiln-dried without severe defects, thus usually air-dried from some months to an year. Dimension lumbers and roundwoods were heat-treated above 170℃ and drying defects were examined. Temperature rising curves of all dimension timbers used for this study show one or two deflection points. The time when the temperature at 37.5mm depth reached at 100℃ for spruce dimension heat-treated at 170℃ was twice longer than that heat-treated at 190℃. There were many internal checks in roundwoods of 148mmΦ, while surface checks were apparently closed at the end of heat treatment. The drying time of 300x300mm dimensions with 65mm hole was shorter than that without hole by half.

Key words**:** Heat treatment, Spruce, Western hemlock, Douglas-fir, Inflection point, Internal check.

요 약

한국의 전통가옥인 한옥은 대각재와 원형목으로 만든다. 이들은 열기건조하면 심각한 결함이 발생하기 때문에 보통 수개월에서 1 년까지 천연건조하는데 그래도 사용중 결함이 생긴다. 열처리기술을 이용하여 이들을 170℃이상에서 건조하면서 건조결함을 조사하였다. 온도곡선은 모두 하나 또는 두개의 변곡점을 나타냈다. 표면에서 37.5mm 깊이지점이 100℃에 도달하는데 걸리는 시간은 열처리온도 170℃ 과 190℃가 두 배의 차이를 나타냈다. 열처리 후에 148mmΦ 원형목에 내부할렬이 많이 발생한 것이 발견되었으나, 이에 빈해 표면할렬은 거의 닫혀 있었다. 이러한 표면할렬의 변화를 300x300mm 대각재의 사진을 통해 관찰하였다. 중공재와 무중공재의 건조시간을 비교하였더니 두 배의 차이를 나타냈다.

1. INTRODUCTION

Korean traditional buildings, Hanok, are mostly constructed with dimension lumbers and roundwoods. They are hardly kiln-dried without severe defects, thus usually air-dried from some months to an year.

An radio frequency/vacuum unit developed in BC Canada was used to dry electricity poles. Pole sections of 165- to 240-mm in diameter and 2.0- to 2.4-m in length were dried from their initial

Received for publication: Jul 17, 2010 ; Reviewed: Aug 15, 2010 ; Accepted: Nov 17, 2010.
1) This study was supported by Technology Development Program of the Ministry of Agriculture and Forestry, Republic of Korea.
2) College of Agriculture and Life Science, Chungnam National University, Daejeon 305-764, Korea. (E-mail: hykang@cnu.ac.kr).

sapwood moisture content (MC) of over 80 percent to a final MC of less than 25 percent by RF/V unit in less than 16 hours. RF/V drying produced poles with a uniform final MC (Fang, Ruddick and Avramidis, 2001). RF/V unit is very expansive and high energy consumer

A heat-treatment apparatus was recently made in Korea and was used to develop color-change technology for domestic species, such as Korean red pine, Korean pine, and Larch (Kang, 2008a). It was found that the device can be used for rapid drying dimension timbers.

Heat-treatment changes the colors of 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).

Simpson(2005) revealed a good linear relationship of air-drying time between a group of round cross-section ponderosa pine logs and a group of square timber. It allows the conversion of previously published estimates of air-drying times to air-drying times of square timbers.

Builders were surveyed to explore perceptions regarding small-diameter roundwood (SDR). Findings suggest that, of the 130 builders surveyed, most are likely to use SDR in recreational buildings when it meets the following criteria: 1) a pleasing aesthetic that blends in with the environment; 2) easy and convenient to work with; 3) readily available and long lasting; and 4) when they are em- powered to make SDR purchase decisions (Cantrell, Paun and LeVan-Green, 2004).

In this study dimension lumbers and roundwoods were heat-treated above 170℃ and drying defects were examined to investigate if they could be accepted as the components of Hanok.

2. MATERIAL and METHODS

Two experiments were conducted for this study. For the first experiment dimension lumbers of 200x75mm and 95x95mm in cross section and roundwoods of 148mm in diameter were used. For the second experiment dimension lumbers of 300x300mm in cross section and roundwoods of 300mm in diameter were used. Some timbers of the second experiment were core-drilled with 65mm-diameter screw to increase drying rate. The length of all test timber was 900mm according to the length of the heat-treatment apparatus, whose details are described in the previous paper (Kang, 2008a).

The species used for both experiments were Douglas-fir, western hemlock and spruce. Their initial moisture contents ranged from 110% to 25% because they were partly kiln-dried. The wide variation of the initial moisture contents did not seriously influence the results of this study because wood drys very fast above 170℃.

Two heating temperatures of 170 and 190℃ were applied. Heat treatment times were 20 and 12 hours for 170 and 190℃, respectively, which included 2-hour rising time. After heat treatment all timbers were cooled for more than 10 hours.

Thermocouple probes of copper-constantan were implanted to monitor the temperatures within the test timbers. The implantation depth in 200x75mm dimensions was 37.5mm from the surfaces, while that in 95x95mm dimensions was 47.5mm from the surfaces (Fig. 1). For 148mm-diameter roundwoods temperatures were monitored at both 37.5 and 75mm from the surfaces. Heat-treat timbers were cut at the middle and photos were taken to observe drying defects.

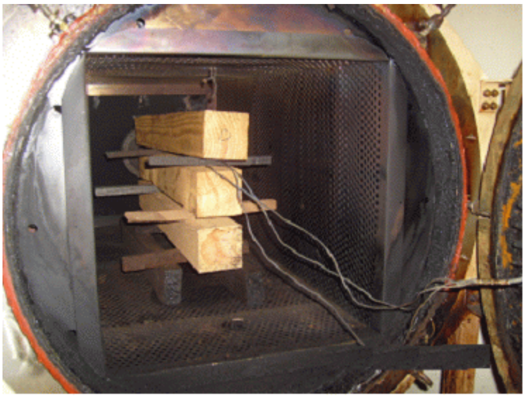

Fig. 1. A photo of the heat-treatment appratus and dimensions with thermocouple probes.

3. RESULTS and DISCUSSION

3-1 First experiment

The temperature rising curves of 75x200mm and 95x95mm dimension lumbers are plotted in Fig. 2. Temperatures increase steeply from the beginning and inflect at 80-90℃. It is interesting to notice the difference between 170 and 190℃. There is a almost straight line after the inflection point for 190℃, but there is another inflection point for 170℃.

However the plots of roundwoods show discrepancy from dimension lumbers. There is no second inflection point in roundwoods (Fig. 3). The first inflextion points exists between 90 and 100℃ at 37.5mm and between 80 and 90℃ at 75.0mm.

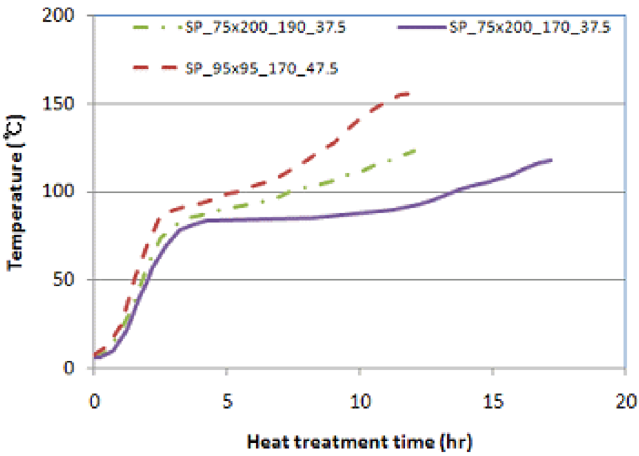

Fig. 2. Plots of temperature change during heat-treating spruce dimension lumbers at 170 or 190℃.

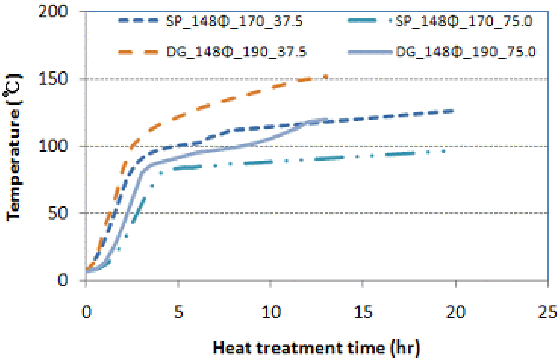

Fig. 3. Plots of temperature change during heat-treating spruce and Douglas-fir dimension roundwoods at 170 or 190℃.

Fig. 4 shows heat-treatment times when temperatures monitored by thermocouples reached at 100℃. The spruce dimensions of 75x200mm heat-treated at 170 and 190℃ took 13.7 and 7.5 hours, respectively. They were measured at the same depth of 37.5mm. Thus it can be postulated that temperature increase by 20℃ reduces heat transfer time in wood by half. The spruce and Douglas-fir roundwoods of 148mmΦ dried at 170 and 190℃ took 5.2 and 2.5 hours, respectively, measured at the same depth of 37.5mm (Fig. 4). There are more than twice difference in time between two temperatures. Thus it possibly confirms the postulation although they are different species. It is also observed that the time of the square dimension of 95x95mm was 5.5 hours, which was much smaller than that of the rectangle dimension of 75x200mm, 13.7 hours, although the drying temperature was the same and the measuring depth of the former was deeper than the latter (Fig. 4).

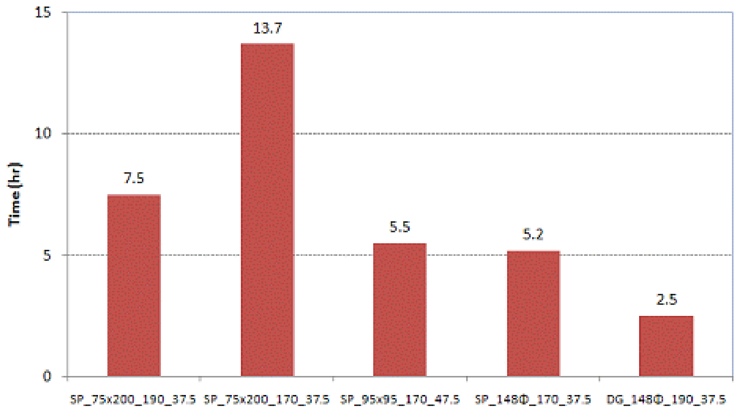

Fig. 4. heat-treatment times when temperatures monitored by thermocouples reached at 100℃.

There were many internal checks in three roundwoods of 148mmΦ, which were heat-treated at 170℃ for 20 hours, while all surface checks were apparently closed (Fig. 5). They were almost oven-dried. The internal checks in these large roundwoods are not critical for the posts and beams of hanok because the wood components of hanok is normally designed enough to endure the load.

Fig. 5. Photos of three species roundwoods of 148mmΦ heat-treated at 170℃.

3-2 The second experiment

The western hemlock dimensions with hole dried much faster than those without hole (Fig. 6). The drying times from green to oven-dry were 80 and 160 hours for those with hole and those without hole, respectively. As a result, the former is twice shorter than the latter.

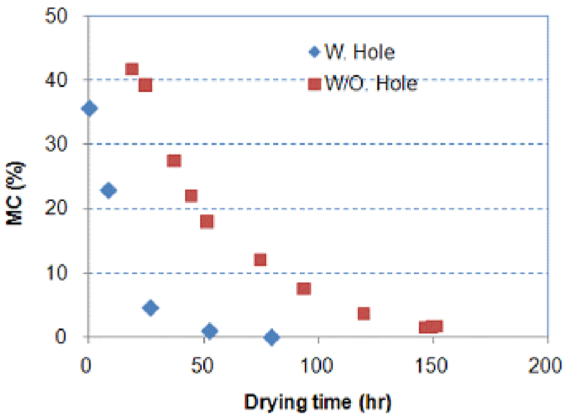

Fig. 6. Plots of drying curves of western hemlock dimensions with and without hole.

A large crack occurred at the first day during heat-treatment at 170℃ (Fig. 7). It is slowly closed as wood is dried. Fig. 7 show its progress of western hemlock dimension of 30x30mm. The widths of the largest cracks ranged from 4 to 6mm while their width were less than 1mm at 5th day.

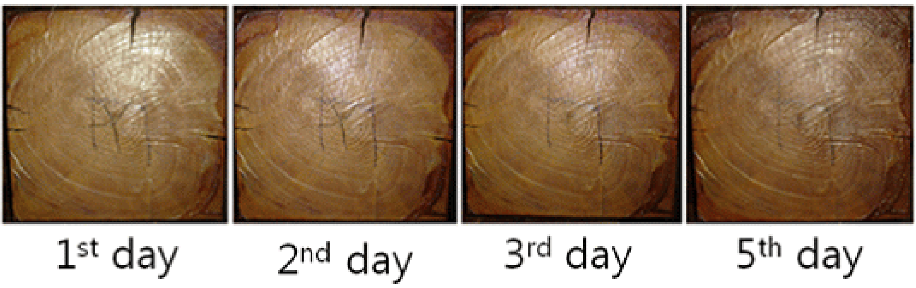

Fig. 7. Photos of western hemlock dimensions heat-treated at 170℃.

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