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Vapor Permeability and Moisture Gradient on a *Paulownia* Wood for Inside Material of Furniture Making

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ABTRACT

This study was carried out to know the difference of vapor transmission on the thickness of Paulownia wood (*Paulownia tomentosa*). The behavior of moisture transmission of wood thickness direction is generally estimated by vapor permeability and vapor transmission resistance. In general, *Paulownia* wood is known to use of inside material for furniture making, because of the excellent ability of vapor adsorption and/or desorption. Quarter sawing Paulownia wood material is prepared and the thickness is 6.0 mm, 7.0 mm, 8.0 mm, 9.0 mm, 10.0 mm, respectively. The measurement of vapor transmission were conducted by the "cup method" in accordance with JIS (Japanese Industrial Standard) Z-0208. The experiment was made in the condition of 49.8 mmHg vapor pressure difference and 40℃ at constant temperature. From the experiment results, it was considered that Paulownia wood is very stable on moisture variation and any other material conditions. In this experiment we found that the vapor permeability and vapor permeance was reduced with the increase of wood thickness to vapor direction and vapor transmission resistance and specific vapor transmission resistance was increased with the increase of wood thickness to vapor direction. Besides moisture contents of adsorption and desorption side were about 5 percent and 14 percent, respectively. Mean value was 9.5 percent and about 10 percent in dry oven method. Moisture gradient was reduced with the increase of wood thickness for a small moisture difference of adsorption and desorption side.

Key words: Vapor permeability, moisture gradient, *Paulownia* wood, vapor transmission resistance, moisture content.

INTRODUCTION

It is important to know of the behavior of moisture vapor sorption to control of wood quality of wood furniture. Especially the behavior of moisture transmission is vapor adsorption and desorption process between wood walls. This vapor transmission property is evaluated by vapor permeability and vapor transmission resistance (Watanabe 1978; Lee et al. 1991). In general, there are many researches on vapor permeability for wood materials using architectural wall panels (Kato 1987). In wood science, many scientists studied a vapor transmission experiment to improve the residence performance, but the furniture results were not seen in this research field. Vapor transmission

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phenomenon cannot explain clearly based on only theory until now. Vapor permeability of wood calculated from the difference of vapor pressure between adsorption and desorption side of wood.

Paulownia wood is frequently used to furniture materials, especially inside of the furniture. The reason of use for furniture making is known to the low specific gravity and easy to moisture control. In this study, therefore, we investigated to the difference of vapor transmission on the thickness of *Paulownia* wood. In addition, the moisture gradient and moisture content with different thickness related to moisture vapor flow were also examined.

MATERIAL AND METHODS

Wood material was collected from *Paulownia wood* (*Paulownia tomentosa* Thunb.) with a mean density of 0.24 g/cm^3 and average moisture content of 7.4. Wood specimens were quart sawn disks of 70 mm diameters of five different thicknesses of 6.0 mm, 7.0 mm, 8.0 mm, 9.0 mm, and 10.0 mm.

Experimental procedure

The experiment of moisture vapor transmission was made by the "cup method" in accordance with JIS (Japanese Industrial Standard)-Z0208. The apparatus is shown in Fig.1. Prior to the experiment, wood materials had been dried in silica gel at 20 ℃ to a constant weight. Relative humidity inside the cup was kept at 0 percent by using calcium chloride. All samples were set up in the cup and sealed with wax around the edge for moisture vapor protection. Experiments were carried out in air-conditioned chamber. The experiment was made in an atmosphere of 90% RH, a temperature of 40℃, and a wind velocity of 0m/s. Soon after the experiment, moisture content both adsorption and desorption side was determined by slicing and dry oven method.

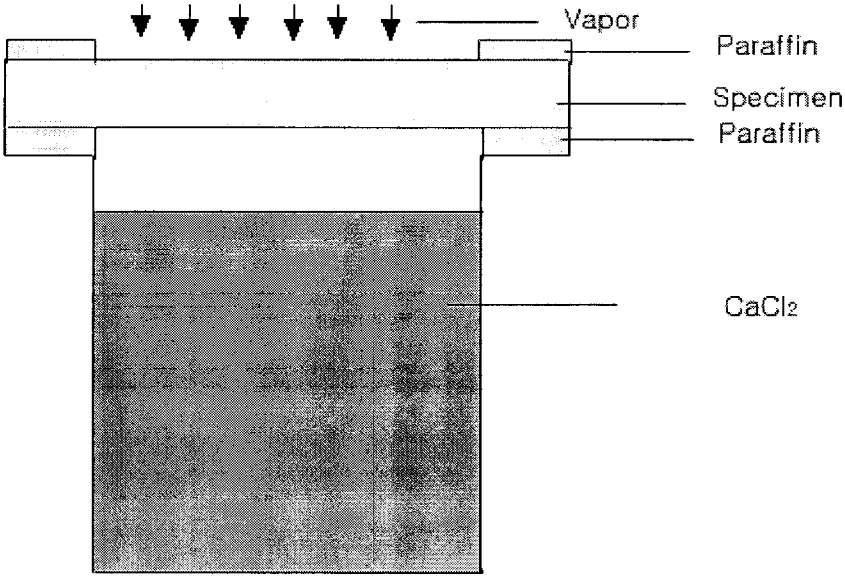

Fig.1. Schematic representation of the vapor permeation cup (JIS Z-0208).

RESULTS AND DISCUSSION

Vapor permeability and vapor transmission resistance

The behavior of vapor transmission of wood is explained by vapor permeability and vapor permeance and vapor transmission resistance. These two physical properties were calculated using the amount of vapor transmission and the vapor pressure differences between adsorption side and desorption side of the wood specimen. Detailed equations are expressed previous papers (Lee et al. 1991 and Lee 1996).

The relationships between permeate times and the amount of moisture vapor movement are plotted in Fig.2.

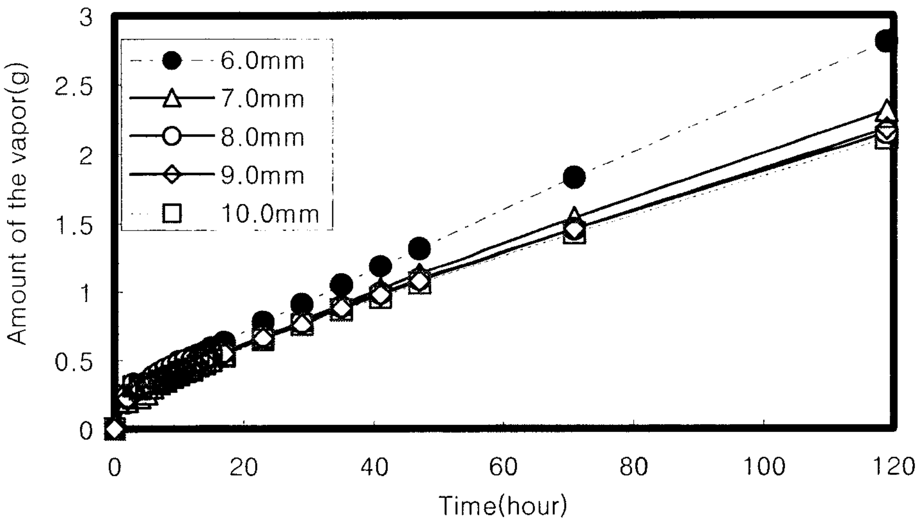

Fig.2. Moisture vapor permeation curves of test specimens of various thicknesses ; the amount of moisture transmission versus permeation time.

From this figure, the velocity of moisture vapor transmission per sorption area and time can be obtained. The velocity of vapor permeation of the 6 mm thickened sample was much larger than that of thicker ones. The calculated results using vapor permeation Equations are illustrated in Table 1. The vapor permeability and vapor permeance were decreased with the increase of thicknesses of the specimens. In general, however, it is known that the vapor permeability is increased with the increase in thickness of the specimens. It is examined that the reason of this phenomenon is for the specific physical property of *Paulownia* wood (Kang et al. 2008). The cell cavity such as cell lumen of this wood occupies the larger portion with a small area of cell wall. Porosity of this wood species is high. It is assumed that the transmission velocity of moisture vapor in this region is faster than that of the other wood of high density. In this experimental range, the difference of wood thicknesses on moisture vapor transmission cannot be measured. Therefore, it is assumed that sorption property of *Paulownia* wood is very excellent material as furniture elements for its porosity.

Vapor transmission resistance, meanwhile, should be proportional to the specimen thickness. In general, this value is expressed upward one straight line with the specimen thicknesses. But this straight line was slight slip from specimen thickness 9 mm in Fig.3. In principle, vapor transmission resistance is proportioned to the specimen thickness, but it showed a increasing tendency with the specimen thicknesses.

Table 1. Calculated results of vapor permeability and vapor permeance, and vapor transmission resistance for wood specimens of various thicknesses.

Thickness (mm)	Vapor permeability (g mm/m^2.h.mm Hg)	Vapor permeance (g /m^2.h.mm Hg)	Vapor transmission resistance (m^2.h.mm Hg/g)	Specific vapor transmission resistance (m.h.mm Hg/g)
6.0	3.17	0.069	14.49	14.50
7.0	2.53	0.046	21.74	21.51
8.0	2.27	0.037	27.03	26.89
9.0	2.34	0.035	28.57	28.95
10.0	2.24	0.030	33.33	33.39

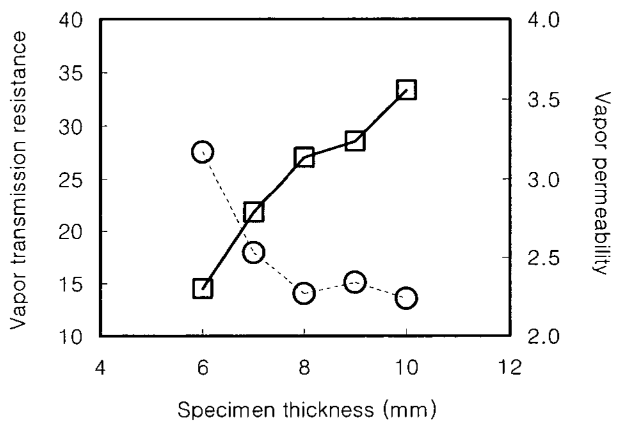

Fig.3. Experimental results of vapor permeability (○) and vapor transmission resistance (□) for wood specimens of various thicknesses.

Moisture content and moisture gradient

Moisture content of each specimen is illustrated in Table 2. From this Table, it can be found that the moisture content in both adsorption side (5%) and desorption side (14%) had approximately a constant values. This phenomenon is assumed that moisture vapor transmission speed was very fast irrespective of wood specimen's thicknesses. Therefore, the gradient of moisture content was reduced with the increasing of specimen thicknesses. Assumed equilibrium moisture content (EMC) at 40℃ was 19% and relative humidity (RH) was 90%. Experimental value of desorption side was shown 14% moisture content irrespective of wood specimens thicknesses. From these results, it is considered that *Paulownia* wood is very flexible wood material on moisture vapor adsorption and desorption properties. Therefore this wood is very excellent interior material as a furniture making elements for moisture sorption ability.

Table 2. The vapor permeability with various thickness of *Paulownia tomentosa*

Thickness (mm)	Moisture content (%)				
	adsorption side	desorption side	average	gradient (%)	dry oven method
6.0	6	13	9.5	1.2	10.1
7.0	5	14	9.5	1.3	10.0
8.0	5	14	9.5	1.1	10.2
9.0	5	14	9.5	1.0	10.4
10.0	5	14	9.5	0.9	9.9

CONCLUSION

The following results were found for the behavior of moisture transmission in *Paulownia* wood.

The vapor permeability and vapor permeance are decreased with increases in the thicknesses of the specimens. It was shown that the moisture content in both adsorption side and desorption side is approximately constant values, respectively. The gradient of moisture content is reducing with the increasing of specimen thicknesses.

It is concluded that the reason of this phenomenon was for the specific physical property of *Paulownia* wood. Because of high porosity, it is assumed that moisture vapor transmission speed was very fast irrespective of wood specimen's thicknesses.

Because of those properties mentioned above, *Paulownia* wood can be used for excellent interior material as a furniture making elements and very flexible on moisture sorption ability.

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