Mokchae Konghak 31(3) : 17~23, 2003

# Physical and Mechanical Properties of Sawdust Board Made of Thinning Logs (Ⅱ)[*1]

## - The Effect of Density and Additive Quantity of Powder Phenolic Resin -

Seung-Won Oh[*2,†]

## ABSTRACT

As a fundamental study of developing sawdust board from thinning softwood logs from three species (*Pinus densiflora* S. et Z., *Larix leptolepis* G. and *Pinus koraiensis* S. et Z.), this study examined the effect of board density and resin content on physical and mechanical properties of sawdust board. As the board density increase, thickness swelling, bending strength, and Brinell hardness increased while water absorption decreased. With increasing the resin content, the bending strength and hardness increased while water absorption and thickness swelling decreased. The board made of *L. leptolepis* was slightly low in its water absorption, and the one made of *P. koraiensis* was a little high in its bending strength, while there was no definite difference between each kind of trees in their hardness values.

*Keywords*: phenolic resin, sawdust board, water absorption, bending strength

## 1. INTRODUCTION

The use of waste remnant logs of forestland which can be potential to use under the situation for lack of wood resource in our country is of significance in the maximizing and industrializing aspects of wood resource. Statistical data in 2000 showed that thinning logs, 256,115 $m^3$ in 24,029 ha, of these remnant logs of forestland were produced. Further, 50% or more of the stored quantity of forest tree of the nation is Ⅲ age-class and below, so it can be judged that an enormous amount of thinning logs will be produced in the tending process in the future.

However, there are various defects by its property in a thinning log, which cause difficulty developing a use of products as well as technical difficulty in processing, and for that reason it is limited to be used for low value-added uses—mining timber, pulp, building materials etc. On the other hand, recently its production volume increases steadily, showing brisk development of particle boards, and wood compound boards such as MDF (medium density fiberboard) and the like. Therefore, by using these thinning logs, it is necessary to take an interest in industrialization through saving

*1 Received on November 11, 2002; accepted on December 5, 2002
This study was financially supported by Agriculture R & D Promotion Center.
*2 College of Agriculture, Chonbuk National University, Chonju 561-756, Korea
† Corresponding author : Seung-Won Oh (ohsw@moak.chonbuk.ac.kr)

the local wood resource and expanding the demand for them, by developing a new use to make efficient use of high-added value materials such as a functional board, building assistant materials etc. Accordingly, this study was conducted to explore the effect of the physical property of a board, when sawdust was made using some coniferous trees which were occupying a large majority of the thinning logs produced in this country, followed by that a sawdust board was made as a basic research for developing new materials, and then the board density and phenolic resin were treated differently in making boards.

## 2. MATERIALS and METHODS

### 2.1. Materials

This experiment used thinning logs of *Pinus densiflora* S. et Z., *Larix leptolepis* G. and *Pinus koraiensis* S. et Z. as raw materials.

### 2.2. Board Preparation

After making sawdust according to each kind of trees, using a circular saw, it was sorted by not more than 1mm in sawdust size, and moisture content was kept at 5% or less. The adhesives used in this work, while boards were making, was powder phenolic resin (Kolon Chemical Co., Ltd. KNB-100PL), the melting point of 8～95°C, gelation time of 80～120 sec., and its resin solids was 99%. Each board sized 26×26×1.4 cm was made, for which powder phenolic resin and sawdust were get into a zinc box and mixed well, put into a square stainless mold on the hot plate of a thermal compressor, and molded in thermal compression after hight of the sample's upper was regulated under a certain condition. The condition of making a board was as follow: the resin content: 10%, press at a temperature: 190 °C, pressure: 40 → 20 → 10 kgf/cm$^2$, and press time: 6 → 5 → 4 min. To investigate the properties of sawdust board according to the density, under these condition above mentioned 5 boards, whose target density of 0.4, 0.5, 0.6 and 0.7 g/cm$^3$ were made for each unit. And to investigate the properties of sawdust board according to the resin content, same condition above mentioned 5 boards, whose the resin content of 5, 10, 15 and 20% with a target density 0.6 g/cm$^3$. Two stop bar were used to obtain the thickness of boards, during the process of compression. And then, to prevent between the upper and lower parts of boards and the hot plate from sticking, a teflon sheet (thickness 1mm) was covered on the upper and lower parts of samples to make it easy to separate a board from the hot plate.

### 2.3. Physical and Mechanical Properties Determination

The board prepared, was cut to 12×12×1.4 cm size, and then conditioned in a constant temperature and humidity(temperature: 20±1°C, humidity: 65±5%), using in four specimens with the target density of ±0.01 g/cm$^3$ each by a category of measurement, its water absorption, thickness swelling, bending strength etc were measured on the basis of KS F 3104 and Brinell hardness using Brinell Hardness Tester (B 960909, DAEKYUNG TECH & TESTER Mfg. CO., LTD.).

## 3. RESULTS and DISCUSSION

### 3.1. Water Absorption

The results measuring the water absorption of the board according to the density and the resin content of it after soaking in the water at 20±

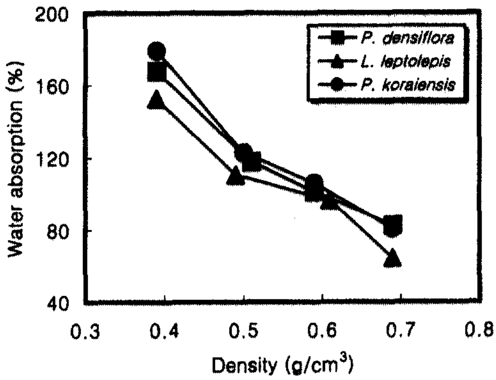


Fig. 1. Relationships between water absorption and density of board(resin content 10%).

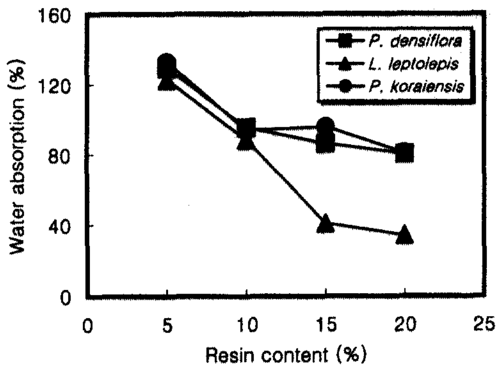


Fig. 2. Relationships between water absorption and resin content of board(density 0.6 g/cm$^3$).

1 °C for 24 h is shown in Figs. 1 and 2. When the density of the board increased from 0.39 g/cm$^3$ to 0.69 g/cm$^3$, the water absorption decreased: 167.6~82.6% for *P. densiflora* board; 152.5~64.3% for *L. leptolepis* one; 179.8~80.7% for *P. koraiensis* one. It can be judged from the results above that the water absorption is reduced in response to an increase in density which, as it go up, makes a board tissue compact and its pore, the pathway of moisture absorption, small. Lee & Yoon (1994) had reported in their research on the physical property of the sawdust board made of MDI resin that the greater specific gravity had made its linear expansion and amount of water absorption decrease. Yoshida *et al.* (1986) also had reported in their research of the physical property of the board made of a lauan that the more its density had increased, the more the water absorption had decreased straightly. This study showed similar trend with two reports mentioned above. In comparison among tree species, the water absorption of the board made of *L. leptolepis* was slightly low.

Moreover, the more the resin content increased from 5% to 20%, the more the water absorption decreased: 129.4~80.6% for *P. densiflora* board; 122.7~34.2% for *L. leptolepis* one; 132.9~81.1% for *P. koraiensis* one. These results, regarding from it, were because that even in the same density, the more a mixed quantity of resin made resin hinder the water absorption of boards as stopping up the pathway of moisture. Lee & Yoon (1994) had informed that the statistic significance between the additive quantity of resin in sawdust and the dimensional stability of it had been admitted, so as the additive quantity of resin had increased from 3% to 9%, the water absorption had been on the decrease, to which this research had same tendency. In comparison between each kind of trees, the absorption of *L. leptolepis* board was slightly low.

## 3.2. Thickness Swelling

The boards made of all kinds of trees were soaked in the water of 20±1°C for 24 h, and then the results of the thickness swelling according to the density of each board and the resin content were shown in Figs. 3 and 4. As the density of a board increased from 0.39 g/cm$^3$ to 0.69 g/cm$^3$, the thickness swelling also increased: *P. densiflora* board was 7.2~15.8%; *L. leptolepis* one was 7.4~14.9%; *P. koraiensis* one was 7.0~11.9%. In case of the board made by resin in same additive quantity, it is a general opinion that the greater its specific

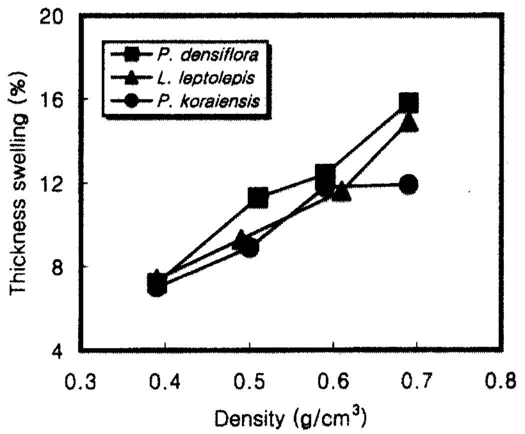


Fig. 3. Relationships between thickness swelling and density of board.

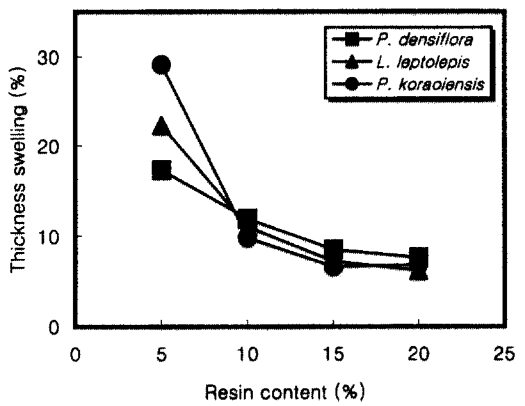


Fig. 4. Relationships between thickness swelling resin content of board.

gravity causes the dimensional stability to degenerate (Sun *et. al.*, 1994). Roffael and Rauch (1972) had reported in their research of the experiment that the thickness swelling of a particle board had been soaked, using phenolic resin, for 30 min~15 days in its specific gravity 0.5~0.9, going up respectively, had resulted in that the bigger the thickness swelling had tended to increase in response to the increase of time in specific gravity of 0.5~0.7, and in 24-hour or more in soaking a board, the rate in specific gravity of 0.7 or more had been smaller than that of 0.7 or less. Yoshida *et al* (1986) had also informed that the thickness swelling of particle boards had increased slowly, and the board made of particle which had been not treated with acetylene had been relatively high in it. The study was in accord with these results above. In comparison between each kind of trees, the board made of *P. koraiensis* was slightly low in the thickness swelling. Besides, as the thickness swelling based on the quantity of mixing resin increased from 5% to 20% in resin mixture in the same density, that of each board decreased: 17.3~7.6% for *P. densiflora*; 22.3~6.2% for *L. leptolepis*; 29.1~6.8% for *P. koraiensis*. It, very possibly, was because that the resistance against the particle swelling was stronger as cohesion between particles went up if the quantity of adhesive was added more and more. Lee & Yoon (1994) had informed that the thickness swelling of sawdust board made by applying the additive quantity with MDI resin differently had been shown that the quantity of 3% had been 2.2 times higher than that of 9%. They had reported that these results had similar tendency to the results of the research by Sun *et al.* (1994). Moreover, the results of the research was also same to the study which had been conducted by Kawai *et al.* (1986) that the thickness swelling of boards had remarkably reduced as resin additive rate had gone on the increase, which had made the dimensional stability of boards improve. In comparison in the thickness swelling as to each kind of trees, there was no definite difference between the trees; however, the board made of *P. koraiensis*, whose rate of mixing resin was 5%, which marked the highest its thickness swelling of the board was 29.1%.

## 3.3. Bending Strength

Figs. 5 and 6 showed the results measuring

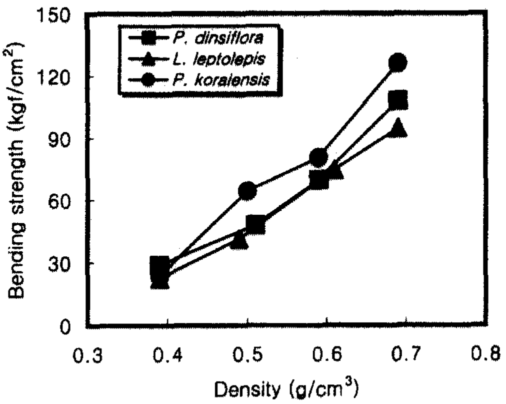


Fig. 5. Relationships between bending strength and density of board.

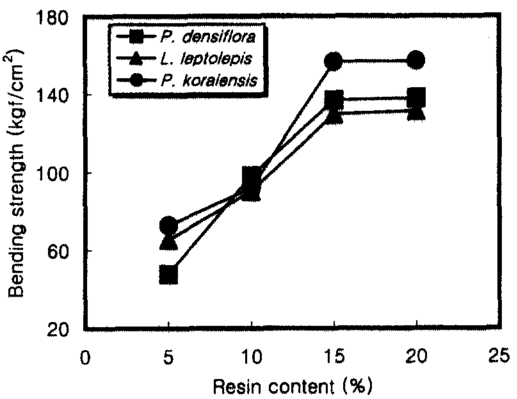


Fig. 6. Relationships between bending strength and resin content of board.

bending strength as to the density of boards made of each kind of trees and the resin content. As the density of a board was on the increase from 0.39 g/cm$^3$ to 0.69 g/cm$^3$, the bending strength of each board also increased as follows: 28.7~108.0 kgf/cm$^2$ for *P. densiflora*; 22.3~94.7 kgf/cm$^2$ for *L. leptolepis*; 23.3~125.9 kgf/cm$^2$ for *P. koraiensis*. Lee & Yoon (1994) had made a report that the bending strength of the sawdust made of MDI resin had risen as its specific gravity had grown more and more; Yoshida *et al.* (1986) had also reported that the greater the bending strength and the modulus of elasticity in response to the increase of the density of the particle board made of a lauan, which had same tendency to the property of general materials. The results of this research was consistent with those results mentioned above. The board made of *P. koraiensis* was slightly high in bending strength in comparison with the trees.

In addition, the bending strength as to the resin content was that, in the same density, the greater the rate of resin mixture, the stronger the bending strength: 47.7~137.8 kgf/cm$^2$ for *P. densiflora*; 65.4~131.3 kgf/cm$^2$ for *L. leptolepis*; 72.9~156.8 kgf/cm$^2$ for *P. koraiensis*. These results were the same tendency as the researches of Lee & Yoon (1994), Kawai *et al.* (1986), Park *et al.* (2001), which had clarified that when a board has made the more the additive quantity of resin had made its bending strength big as the cohesion between the samples went on the increase. And then the respective bending strength of the resin content of 15% and 20% showed similar values by all kinds of trees. From the results above, there was insignificant meaning in the resin mixed rate of 15% or more regarding bending strength when a sawdust board was made. In comparison among the trees species, the board made of a *P. koraiensis* produced sightly strong in its bending strength.

## 3.4. Brinell Hardness

The results measuring Brinell hardness according to the density of boards, which were made, and the resin content were shown in Figs. 7 and 8. As a board was from 0.39 g/cm$^3$ to 0.69 g/cm$^3$ on the increase in density, the hardness of it also increased—225.8~365.2 kg/cm$^2$ for *P. densiflora*; 205.2~346.1 kg/cm$^2$ for *L. leptolepis*; 260.1~416.3 kg/cm$^2$ for *P. koraiensis*. In comparison between each kind of trees, the board made of *P. koraiensis* was a

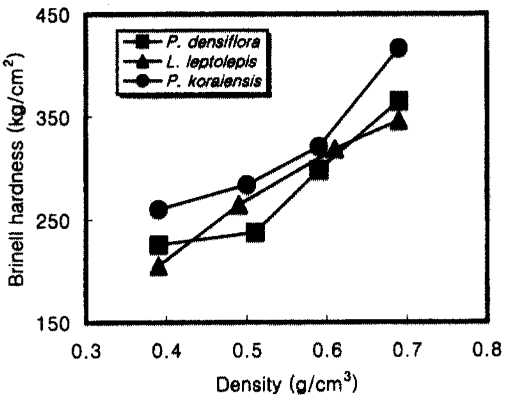


Fig. 7. Relaitonships between brinell hardness and density of board.

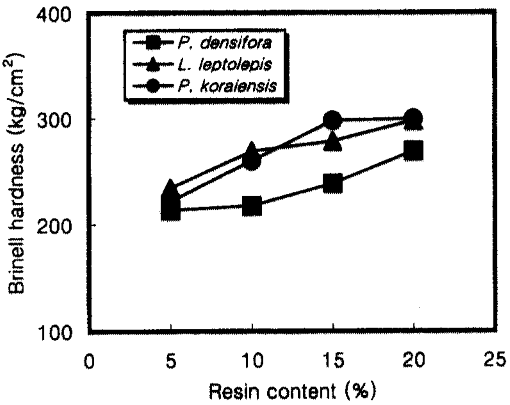


Fig. 8. Relationships between brinell hardness resin content of board.

little big in hardness. On the other side, as the resin content, in the same density, increased in 5~20%, the hardness of boards increased slowly 213.5~269.2 kg/cm$^2$ for *P. densiflora*; 234.2~297.9 kg/cm$^2$ for *L. leptolepis*; 221.7~299.5 kg/cm$^2$ for *P. koraiensis*. In comparison between the trees, similar harness values were shown without definite difference according to the resin content.

## 4. CONCLUSIONS

The study, so far, explored the effect which causes the physical and mechanical properties of boards after making sawdust differed in density of boards and in mixed quantity of powder phenolic resin using *P. densiflora*, *L. leptolepis*, and *P. koraiensis*. The following results were obtained:

1) Water absorption decreased as the density of boards and resin content increased, and the board made of *L. leptolepis* was slightly low in it.

2) Thickness swelling increased as the density of boards went up, and that, in contrary, decreased as the quantity of the resin added to the boards.

3) Bending strength increased as the density of boards and resin content grew more and more, and the board made of *P. koraiensis* was slightly greate in it.

4) Hardness increased as the density of boards and the quantity of resin added increased. However there was no definite difference between the trees in hardness values.

## REFERENCES

1. Kawai, S., H. Suda, M. Nakaji, and H. Sasaki. 1986. Production technology for low-density particleboard Ⅱ. Effect of particle moisture and resin content on board properties. *Mokuzai Gakkaishi* 32(11): 876~882.
2. Lee, P. W. and Yoon, H. W. 1994. The properties of sawdust board in using MDI(Methylene diphenyl diisocyanate) resin(I) - On the specific gravity, resin additive content and mat moisture content-. *The Korean society of Furniture Technology* 5(2): 51~61.
3. Park, J. Y. 2001. Development of building materials from wood wastes. Report of ARPC. Korea.
4. Roflael, E. and W. Rauch. 1972. Influence of density on the swelling behavior of phenolic - resin -bonded particleboard. *Holz Roh - werkst* 30(5): 178~181.
5. Sun, B. C. H., R. N. Hawke, and M. R. Gale.

1994. Effect of polyisocyanate level on physical properties of wood fiber composite materials. *Forest Products Journal* 44(4): 53~58.

6. Yoshida, Y., S. kawai, Y. Imamura, K. Nishimoto, T. Satou, and M. Nakaji. 1986. Production technology for acetylated low-density particleboard I. Mechanical properties and dimensional stability. *Mokuzai Gakkaishi* 32(12): 965~971.