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Effect of Raw Material of Core Layer on Property of Wood–porcelain Stone Composite Board

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In a search for an effective use of both scrap wood and porcelain stone scrap, we manufactured three–layer wood–porcelain stone composite board made from both materials. The objective of this study was to improve bending strength properties of the board. Pruned branch with leaf (BL), pruned branch without leaf (B), and root–stump (RS) were prepared as raw material of core layer of the board. In board manufacturing, three types of wood particles were prepared as follows: wood particles processed by using an industrial grinder (IG), by using crushing machine (CM), and wood particles mixed both of IG and CM with weight ratio of 1:1 (IC). The properties of the board were evaluated based on Japanese Industrial Standard. The main results obtained are as follows: the modulus of rupture values of the board manufactured with B and RS were larger than those of BL regardless of processing methods of raw materials. The modulus of elasticity values of the board manufactured with raw materials processed by using CM were smaller than those of processed by using IG and IC regardless of the types of raw materials. The internal bond strength values of composite board manufactured with B and RS were larger than that of standard value of type 18 Particleboard regardless of processing methods of raw materials. The thickness swelling values of all composite boards in this study were smaller than that of type 18 particleboard standard value.

INTRODUCTION

Prune wood from trees is generally processed into wood particles by using an industrial grinder after crushing with a chipper. In Japan, these wood particles are used as compost, animal bedding, mulching material, and as a soil–improvement agent (Yanagihara, 2005; Nomura, 2005). However, the majority is still incinerated or put into landfills (Public Work Research Institute, 2005). Therefore the recycling rate of scrap wood including pruned wood and demolition wood in Japan remains limited to about 68% (Ministry of Land, Infrastructure, Transport, and Tourism of Japan, 2006). For this reason, new uses for pruned wood are desirable.

In the porcelain stoneware manufacturing process, when porcelain stone raw material is made brown by drying and oxidation, it can no longer be used in its intended application. The level of ceramic waste, including porcelain stone scrap, in the ceramic manufacturing industry equates to about 30% of daily production (Senthamarai and Manoharan, 2005), which is a large amount of material with no commercial use. However, this scrap material is durable, hard, highly resistant to biological, chemical, and physical degradation, and shows extremely low water absorption (Esposito *et al*., 1995; Senthamarai and Manoharan, 2005; Diaz and Torrecillas, 2007). Therefore, the development of effective uses for brown porcelain stone scrap is desired.

In our previous study, in a search for an effective use of both pruned wood and porcelain stone scrap, we manufactured single–layer and three–layer wood–porcelain stone composite board made from both materials. As a result, we clarified that the three–layer composite board has excellent waterproof and incombustibility properties as compared with single–layer composite board. However, the bending properties of these boards were inferior to the type 18 particleboard standard value (Hermawan *et al*., 2009).

The objective of this study was to improve bending strength properties of wood–porcelain stone composite board. The focus of this study was on the effects of types and processing methods of raw material of core layer on the physical and mechanical properties of three–layer wood–porcelain stone composite board.

MATERIALS AND METHODS

Raw materials preparation

Three types of scrap wood collected around Fukutsu City, Fukuoka Prefecture, Japan were prepared as raw material of the board. In our previous study, we used pruned branch with leaf (BL) as raw material for the core layer (Hermawan *et al*., 2009). In addition, pruned branch without leaf (B) and root–stump (RS) were also used as raw material for the core layer in this study. In manufacturing of the board, we prepared three types of wood particles as follows: first, wood particles processed by using an industrial grinder (IG); second, wood particles processed by using crushing machine (CM); and third, wood particles mixed both of IG and CM with

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weight ratio of 1:1 (IC). These wood particles were then oven–dried at 105 ℃ for 24 *h*. The average moisture content (MC) of wood particles was 6.8%. To investigate the size of the particles, 100 particles of each type of raw material processed by using CM were chosen at random, and the length and width of these particles measured by digital caliper. Figure 1 shows the distribution of the length and width of wood particles of each type, respectively. From these results, BL has smaller size than those of B and RS. This tendency was also admitted similarly in wood particles processed by using IG.

Porcelain stone mined in Amakusa City, Kumamoto Prefecture, Japan, was prepared as raw material for the face layer of the board. In this research, we used porcelain stone scraps that had been made brown by drying and oxidation. The average specific gravity of the scrap was 2.6. The main chemical elements of the scrap were: SiO_2 (77.20%), Al_2O_3 (15.39%), and Fe_2O_3 (0.73%). Scraps were classified using a sieve with a screen aperture of 2 *mm*; scraps passing the sieve were assumed to be porcelain stone particles and were used to manufacture the composite board.

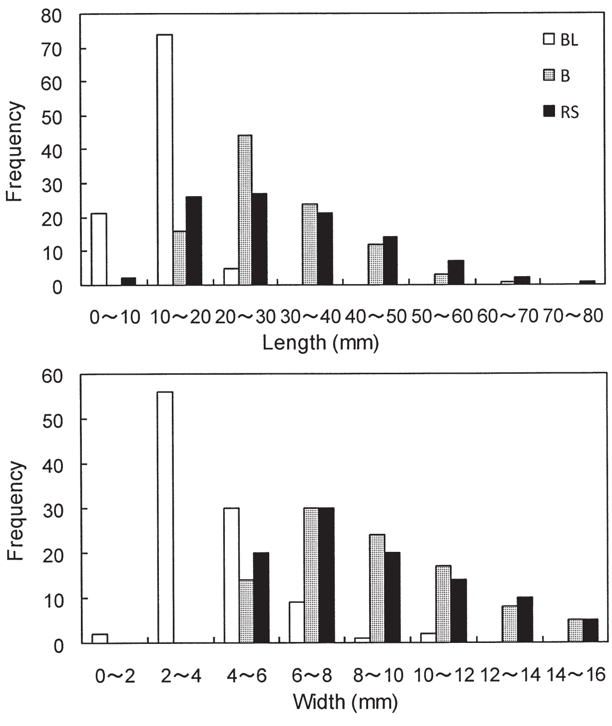

Fig. 1. Distribution of length and width of wood particles pro cessed using crushing machine.
Legend: BL, pruned branch with leaf; B, pruned branch without leaf; RS, root–stump

Board manufacturing

Three–layer composite board that had a surface layer of porcelain stone particles and a core layer of wood scrap particles was manufactured. The manufacturing conditions of the board are listed in Table 1. Poly (diphenylmethane diisocyanate) (p–MDI) resin was used as adhesive. Based on the weight of oven–dry particles, resin content of 12% adhesive was applied to manufacture both face and core layer of the board. Manufacturing methods of the board were the same as those in our previous study (Hermawan *et al.*, 2009).

Board evaluation

The physical and mechanical properties of the boards were evaluated based on the Japanese Industrial Standard for Particleboards (JIS A 5908, 2006). A static bending test was conducted using a Universal Testing Machine. Four specimens (220×30×10 *mm*) were prepared for the static bending test in the dry condition. Three–point bending was applied over an effective span of 150 *mm* at a loading speed of 5 *mm/min*. Four specimens (50×50×10 *mm*) were prepared for both of internal bond (IB) strength and thickness swelling (TS) tests, respectively.

RESULTS AND DISCUSSION

Bending strength properties, IB strength and TS value corresponded to a target density of 0.80 g/cm^3 calculated based on the regression–line equation from the relationship between each performance value obtained by evaluation tests and density of the specimen.

In addition, for the sake of comparison of the physical and mechanical properties of the manufactured board in this study, the standard values of type 18 particleboard (PB) of JIS A 5908 are also shown to the following figures.

Bending strength properties

Figure 2 shows the effect of raw materials of the core layer on the modulus of rupture (MOR). The MOR values of the board manufactured with B and RS were larger than those of BL regardless of processing methods of

Table 1. Manufacturing conditions

Taget density (g/cm^3)	Raw material of the core layer	Processing method	Weight ratio between wood particles and porcelain stone particles (%)	Resin content (%)
0.80	Pruned branch with leaf (BL)	Industrial grinder (IG)	50:50	12
	Pruned branch without leaf (B)	Crushing machine (CM)		
	Root–stump (RS)	Mixed industrial grinder and crushing machine (IC)		

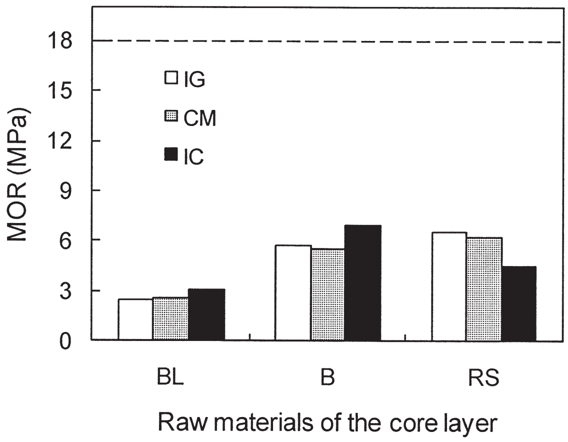

Fig. 2. Effect of raw materials of the core layer on the modulus of rupture (*MOR*).
Legend: BL, pruned branch with leaf; B, pruned branch without leaf; RS, root–stump; IG, industrial grinder; CM, crushing machine; IC, wood particles mixed both of IG and CM with weight ratio of 1:1; long dash, standard value of type 18 PB JIS A 5908.

raw materials. This was likely due to the weakness of strength properties of wood particles of BL because these particles contain leaf. Barboutis and Philippou (2007) reported that composite board manufactured using small stems, branches and leaf had lower bending strength properties compare to those using industrial wood particles. In addition, the MOR values of all composite boards in this study were smaller than that of type 18 PB standard value.

Figure 3 shows the effect of raw materials of the core layer on the modulus of elasticity (MOE). The MOE values of the board manufactured with raw materials processed by using CM were smaller than those of processed by using IG and IC regardless of the types of raw materials. This is because wood particles processed by using CM were larger size than those of processed by using IG and IC. In compressing the composite board with hot press, wood particle of the large size caused the defects to the porcelain stone layer of the board so that the thickness of the face layer not formed uniformly. Based on our previous study, MOE of three–layer composite board was affected by weight ratio of porcelain stone particles, and become larger with increased weight ratio of porcelain stone particles (Hermawan *et al.*, 2009). Therefore, the MOE value decreased due to the large size of wood particles processed by using CM. In addition, the MOE values of all composite boards were smaller than that of type 18 PB standard value.

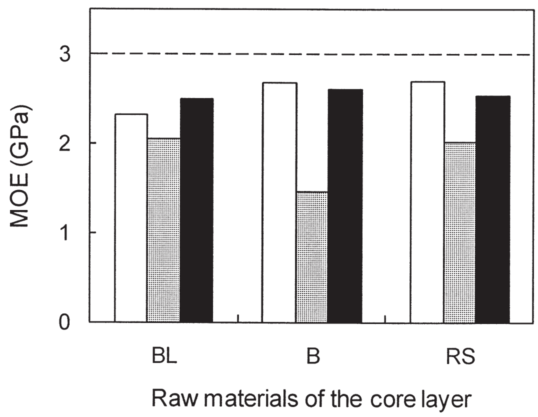

Fig. 3. Effect of raw materials of the core layer on the modulus of elasticity (*MOE*).
Legend: symbols are shown in Fig. 2.

Internal bond strength

Figure 4 shows the effect of raw material of the core layer on IB strength. The IB strength values of composite board manufactured with B and RS were larger than that of type 18 PB standard value regardless of processing methods of raw materials. In addition, IB strength values of the board manufactured with B and RS processed by using CM were larger than those of other processing methods. However, IB strength values of the board manufactured with BL were smaller than that of type 18 PB standard value. This is due to the weakness of strength properties of wood particles made from BL. From these results, it was clear that the existing of leaf in the core layer of the board influenced to the IB strength.

Thickness swelling

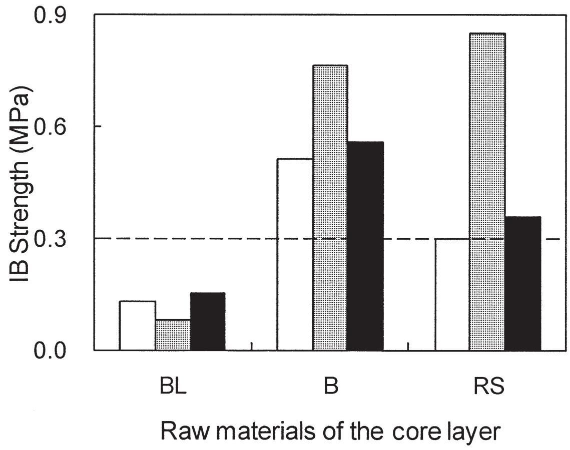

Fig. 4. Effect of raw materials of the core layer on internal bond (*IB*) strength.
Legend: symbols are shown in Fig. 2.

Figure 5 shows the effect of raw materials of the core layer on TS properties. The TS values of all composite boards in this study were smaller than that of type 18 PB standard value. In addition, TS values of composite board manufactured with RS were larger than those of other raw materials. However, the effect of the difference of raw materials on TS was not significant. Thus, our tests clarified that the water proof property of the board was excellent. It is considered that the degree of transformation of the face layer in compressing the board with hot press was slight because the porcelain stone particle is high specific gravity. Moreover, the porcelain stone particles have not almost absorption of water.

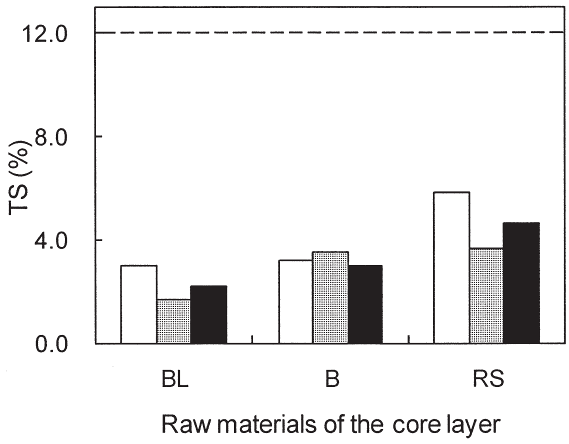

Fig. 5. Effect of raw materials of the core layer on thickness swelling (*TS*).
Legend: symbols are shown in Fig. 2.

CONCLUSIONS

In this study, the effects of types and processing methods of raw material of core layer on the physical and mechanical properties of three–layer wood–porcelain stone composite board were investigated. The results obtained are as follows:

1. The MOR values of the board manufactured with B and RS were larger than those of BL regardless of processing methods of raw materials.
2. The MOE values of the board manufactured with raw materials processed by using CM were smaller than those of processed by using IG and IC regardless of the types of raw materials.
3. The IB strength values of composite board manufactured with B and RS were larger than that of type 18 PB standard value regardless of processing methods of raw materials.
4. The TS values of all composite boards in this study were smaller than that of type 18 PB standard value.

From above–mentioned results, it is clear that bending strength properties of the board could be improved by manufacturing the board with wood particle of B and RS processed by using IG and IC as raw material of core layer. However, the bending strength properties of the board in this study were inferior to the type 18 PB standard value of JIS A 5908.

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