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Moisture absorption and desorption characteristics for woodceramics

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Moisture absorption and desorption characteristics for woodceramics (WCS) that consists of porous carbon impregnated with phenol resin have been studied. Commercially available humidity controlling material (DKN) was also used for comparison. WCS could absorb more moisture than DKN, so that it was confirmed that WCS has ability as a humidity controlling material. However, the absorption rate of WCS was very small compared with that of DKN. Hence it is necessary to enhance the rate for practical applications. It was also found that the absorption and desorption ability is dependent on the thickness of WCS.
Key words: woodceramics, humidity conditioning, moisture, absorption, desorption

1. INTRODUCTION

Humidity is one of the most important factors that influence dwelling environment. Humidity causes dew condensation and also affects the activity of microorganism such as virus, fungus, and ticks. In general, human beings feel comfortable when the humidity is in the range of 40-70%RH. The virus will become active when it is lower than 40%RH, while fungus will be generated when it is higher than 70%RH. Hence, one can purchase architectural materials that inhale moisture at high humidity and exhale it at low humidity.

Woodceramics (WCS) is in principle a porous carbon fabricated by burning wood which impregnated with phenol resin. WCS has various attractive properties such as electromagnetic shielding and infrared light emission. Recently, WCS attracts interests as ecological materials, since it can be made from organic materials and can also be recycled. WCS may be used as a humidity conditioning material because it has porosities. However, the moisture absorption and desorption ability of WCS has not yet been studied.

In this study, a humidity controlling ability of WCS was investigated in comparison with commercially available humidity conditioning materials. The thickness dependence of the humidity conditioning ability was also investigated.

2. EXPERIMENTAL

2.1 Test specimens

We prepared WCS by impregnating phenol resin into medium-density fiberboard (MDF) followed by sintering in air. We fabricated two kinds of samples with calcination temperatures of 650 °C and 800 °C. The samples were manufactured into boards with dimensions of about 50 mm×50 mm×18 mm. For the moisture absorption and desorption tests, only a single side of 50 mm×50 mm wide was exposed to moisture, and the other side was covered by an aluminum tape. As a reference, humidity conditioning material, the product of the Daiken Corp. (DKN), was used. Similar moisture absorption and desoprtion experiments were also conducted for medium-density fiber boards to study the effect of the resin impregnation. The surface of the as-prepared WCS is highly dense due to the presence of phenol resin, and thereby the porosities of WCS is filled with the resin. We therefore polished the sample surface by about 1mm and performed the same experiments to compare with untreated WCS. Table 1 shows the samples used in this research along with their abbreviations.

Table 1 Samples used in this study

sample detail	abbreviation
Woodceramics carbonized at 650 °C	W65
Woodceramics carbonized at 650 °C and polished	W65P
Woodceramics carbonized at 800 °C	W80
Woodceramics carbonized at 800 °C and polished	W80P
Humidity conditioning material manufactured by Daiken Corp.	DKN
Medium Density Fiberboard	MDF

There is no specific JIS standard concerning the thickness of the samples subjected to moisture absorption and desorption tests. However, we expect that the thickness would affect the ability, and thus it is necessary to study the relationship between the sample thickness and the humidity conditioning ability. The thickness of the as-prepared WCS was 18 mm. We then prepared the samples with different thickness by polishing the sample surface. In this experiment, the sample thickness was varied from 18 to 9 mm with 1 mm interval. The thickness of a reference humidity conditioning material (DKN) was 8mm.

2.2 Moisture absorption and desorption test

The humidity conditioning ability of WCS has been evaluated with a so-called closed box baffle method (also known as a cyclical temperature response method) [1]. In this study, it was determined with "humidity response method" that applies the weight change of the sample attended to moisture absorption and desorption [2]. We monitored temperature, humidity, and weight of the sample by a thermometer, a hygrometer and an electric balance, respectively.

To make the uniform sample conditions before the measurements, all the samples were held at 130 °C for 1 hour in a drying box. Then the samples were held at 25 °C under the humidity of 53%RH until the weight became constant. The humidity was subsequently increased to 75% and held for 24 hours. Next the humidity was decreased and held there for another 24 hours. This process was repeated for four times. The amount of the moisture absorption and desorption was measured from the change in the weight of the sample during the experiment.

Figure 1 shows schematic illustration of the moisture absorption and desorption test. The normalized amount of the moisture absorption was obtained by dividing the weight change over the surface area.

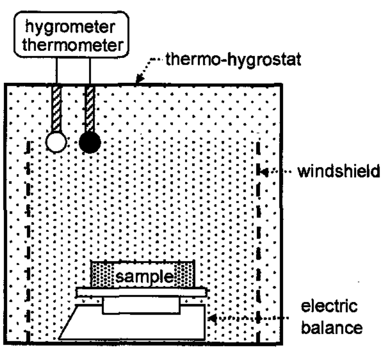

Fig.1 Schematics of moisture absorption and desorption tests.

3. RESULTS AND DISCUSSION

3.1 Post-planting care

Figure 2 shows moisture absorption curves at 53%RH for a commercial conditioning material (DKN). It took 6 hours for the material to reach the saturated state in moisture absorption, for which the saturation value was 49.3 g/m^2.

Figure 3 shows moisture absorption curve s at 53%RH for MDF and WCS carbonized at 650 °C. It is observed that the saturated amount of moisture absorption of WCS is much higher than that of the commercial material, so that WCSs seems available for practical applications as humidity controlling materials. However, the time needed to reach saturation for WCS is much longer than that of DKN. The saturation time for moisture absorption was 6 days for W65P, 18 days for W65 and 8 days for MDF. Hence, it will be necessary to drastically increase the absorption rate of WCS for practical applications.

It is, however, interesting to note that the amount of the saturation value in moisture absorption for WCS was much larger than that of the commercial humidity controlling material. The moisture absorption value of WCS exceeds 600 g/m^2, while a typical value of DKN is of order 50 g/m^2. Therefore, WCS is attractive for future applications.

It is also interesting to notice that the saturation value of WCS is different between samples. In the present experiment, W65 showed the highest saturation value. The amount of moisture absorption for W65P was smaller than that of W65 due to the decrease of thickness.

Figure 4 shows SEM micrographs of W65 and W65P. The porosity of WCS has the tendency to increase with increasing the depth from surface. In the surface of W65, most pores are filled with phenolic resin, which may cause a decrease in the moisture absorption rate. In contrast, pores of W65P are not filled with phenol resin, due to the surface polishing treatment. Thus an improved moisture absorption rate in W65P is ascribed to the presence of open pores in the surface region.

Figure 5 shows moisture absorption curves at 53%RH for WCS's carbonized at 800 °C with and without surface polishing. The moisture absorption did not saturate for both samples even after 20 days. The amount of moisture adsorption was 1246 g/m^2 for W80 and 844 g/m^2 for W80P at the maximum. Although the absorption was not saturated, we terminated the experiment.

It is known that the specific surface area increases when the calcination temperature increases [3]. The amount of moisture absorption is increased with increasing a specific surface area. As a result, the saturation value of the amount of moisture adsorption for WCS carbonized at 800 °C was larger than that sintered at 650 °C.

It is known that the specific surface area increases when

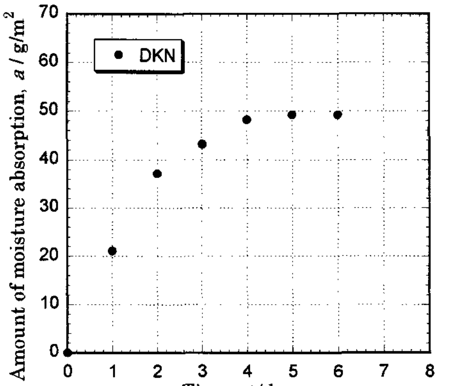

Fig.2 Moisture absorption curve at 53%RH for commercial DKN.

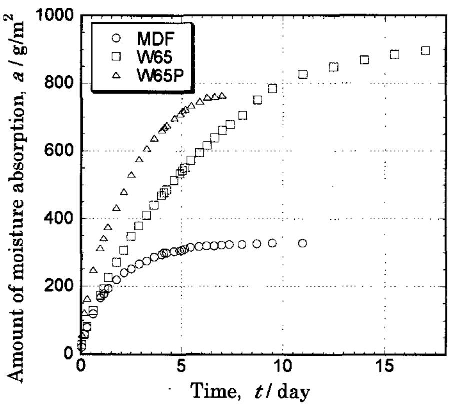

Fig.3 Moisture absorption curves at 53%RH for MDF and WCS carbonized at 650 °C.

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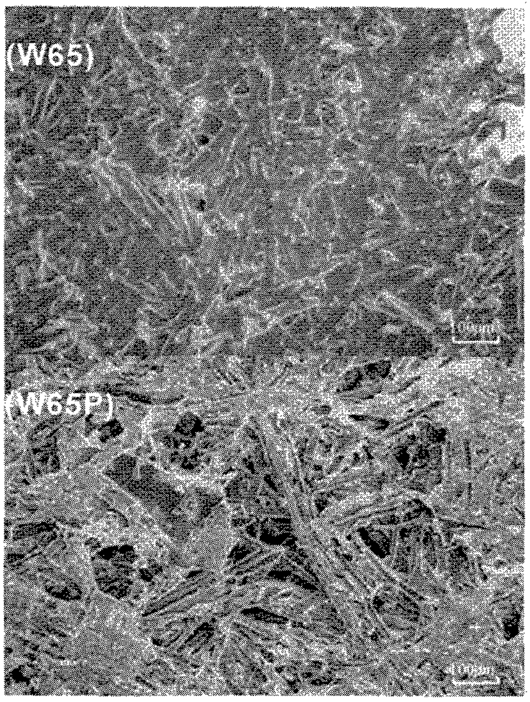

Fig.4 SEM micrographs of W65 and W65P.

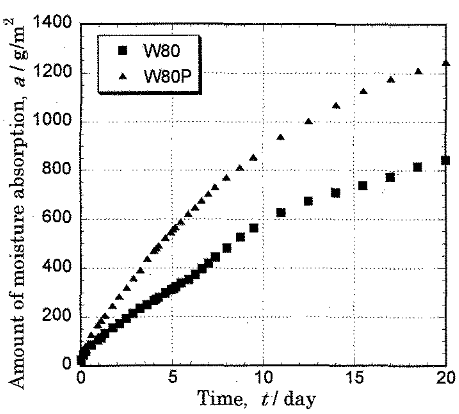

Fig.5 Moisture absorption curves at 53%RH for WCS carbonized at 800 °C with and without surface polishing.

Table 2 shows the average rate of moisture absorption in the region where the amount is below 400 g/m^2. The average rate was calculated by collinear approximation. It is suggested that W65P showed the highest absorption rate, while W80 showed the lowest value. Lowest absorption rates of the WCS carbonized at 800 °C are probably ascribed to chemical change of the resin. At high calcination temperatures, the components other than carbon such as oxygen, hydrogen, and nitrogen are generated when organic compound like phenol resin is carbonized [4]. As a result, wood-derived composition is constricted. Although the surface area per unit volume increases as calcination temperature increases, pores begins to contract and thereby the moisture adsorption is inhibited.

Table 2 Average rate of moisture absorption in the regionwhere the amount is below 400 g/m^2

sample name	W65	W65P	W80	W80P
average rate (gm^{-2}/h)	5.04	9.91	2.22	4.6

3.2 Humidity cycling test

Figure 6 shows the results of humidity cycling test for WCS carbonized at 650 °C and DKN. During humidity adsorption and desorption cycles, the amount of moisture adsorption of WCS has gradually increased. As W65, the average amount of moisture absorption fluctuation during one cycle; from 75%RH to 53%RH after the 4th day was about 54.0 g/m^2. That for W65P was 84.6 g/m^2. In contrast to W65 and W65P, the moisture absorption and desorption behavior of DKN was stable quickly, and from the 2nd day, DKN constantly inhale and exhale the moisture of about 39.9 g/m^2 in 24 hours.

Although both WCS samples did not show the saturation in the moisture adsorption, the amount kept increasing. This is due to the fact that the adsorption rate of the WCS exceeded the desorption rate. It is also notable that the average amount of moisture absorption fluctuation for W65 was considerably smaller than that for W65P, probably due to the presence of filled pores at the surface region.

Humidity cycling tests for W80 and W80P were not conducted in the present study, because one can easily expect their poor performance.

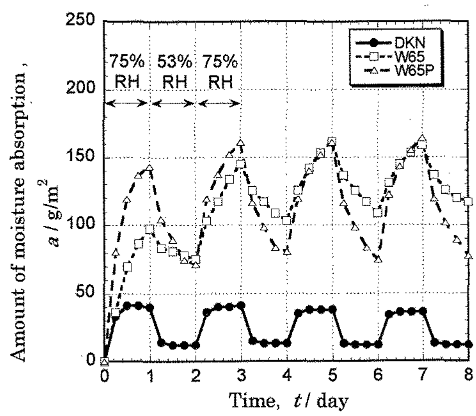

Fig.6 Result of humidity cycling test for WCS carbonized at 650 °C and DKN.

3.3 Thickness dependence of the moisture absorption and desorption ability

Table 3 shows the relationship between the sample thickness and the saturation value amount of moisture absorption for WCS carbonized at 650 °C in 53% RH. As the sample thickness decreases, the saturation value of stored moisture decreased. From table 3, it is obtained that WCS carbonized at 650 °C was adsorbed about 60 g/m^2 moisture per 1mm-thickness.

Table.3 Effect of the sample thickness on the saturation value of stored moisture at 53% RH.

thickness of sample (mm)	9	10	11	12	13	14	15	16
saturation value of moisture absorption (g/m^2)	583.4	652.2	703.8	765.6	778.3	888.1	924.3	988.4

Table.4 Relationship between sample thickness and the maximum and the minimum amounts of moisture absorption.

thickness of sample (mm)	9	10	11	12	13	14	15	16	DKN,8
maximum moisture absorption (g/m^2)	76.9	79.9	86.0	96.9	92.8	107.0	110.3	114.7	39.0
minimum moisture absorption (g/m^2)	5.6	3.2	8.8	14.5	11.3	23.3	24.2	24.9	12.3
amount of respired moisture (g/m^2)	71.3	76.7	77.2	82.4	81.5	83.7	86.1	89.8	26.7

Table 4 shows the relationship between the sample thickness, the maximum and the minimum amounts of moisture absorption and the amount of respired moisture. The maximum and the minimum amounts were obtained by averaging of maximum and minimum values during one cycle respectively. The amount of respired moisture is defined by subtracting the minimum value from the maximum value. The amount of respired moisture in 24 hours was thus ranged from 71 to 90 g/m^2. The results show that although the thicker samples could respire the more amount of moisture, its thickness dependence is small.

Figure 7 shows humidity cycling test results for samples with 9mm and 16 mm thick. The maximum amount of moisture adsorption for the sample with 9 mm thick was 76.9 g/m^2, and that for the sample with 16 mm thick was 114.7 g/m^2. Hence the moisture controlling ability is higher in the thicker sample. It is observed that the cyclic behavior of the sample with 9 mm thick is almost constant, when the sample was stored in 24 hours. In contrast, no saturation was observed for the sample with 16 mm thick in a period of 24 hour, and the moisture absorption kept increasing at 75%RH. This results indicated that the moisture absorption capacity depends on the thickness, which does not conflict with the results of table 3.

It is also interesting to note that the absorption rates for these two samples are almost the same. It shows that the absorption rate dose not have thickness dependence.

In addition, 9mm thick WCS's average amount of moisture absorption fluctuation during one cycle; from 75%RH to 53%RH was 71.3 g/m^2, which is much larger than the value of DKN with 8 mm thick (26.7 g/m^2). The results show that WCS has much better moisture adsorption ability than DKN.

4. SUMMARY

Moisture absorption and desorption ability of WCS was studied using a humidity-response method in comparison with commercial DKN.

WCS with polish surface could absorb moisture in the total amount of 767.3 g/m^2, while commercial DKN could absorb 49.3 g/m^2 at the humidity of 53%RH.

However, the absorption rate of WCS was much smaller than that of DKN. It took more than 18 days for WCS in the as-prepared state to saturate, however it is reduced to 6 days by surface polishing.

The total amount of moisture absorption of WCS was affected by the sample thickness, in that the absorption amount per unit thickness was constant to be 60 g/m^2.

The present experiment shows that WCS is attractive for moisture controlling materials, however, the absorption rate must be enhanced for practical applications.

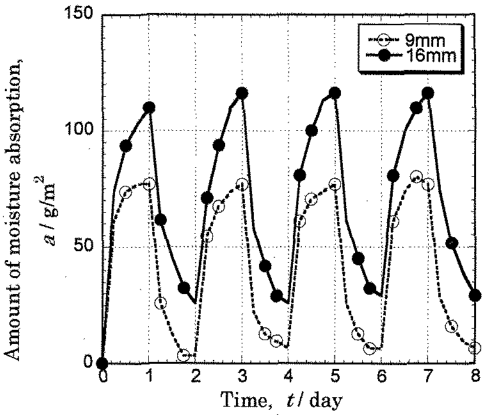

Fig.7 Humidity cycling test for WCS carbonized at 650 °C with different thickness.

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