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Development of Humidity Control Building Material using Porous Soil "Allophane"

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Recently, problems related to humidity of indoor air have been increased with the change of lifestyles and architectural methods. A humidity control building material using porous soil "allophane" has been developed to improve humidity conditions in living space. Allophane is contained in Kanuma-tsuchi soil and the material is produced by firing mixed soil and the specimen had two times higher of the moisture adsorption-desorption amount than that of natural wood. The firing condition was determined from heat properties of the soil and bending strength of the specimen. Temperature-humidity in a model house with the specimen was measured and the effect on reducing dew condensation and high humidity was confirmed from the measurement through a year.
Key words: allophane, Kanuma-tsuchi soil, humidity control, building material, firing

1. INTRODUCTION

Japan is located at the northern end of Asian monsoon area, so it is very sultry in summer. In traditional Japanese houses, problems related to humidity had been naturally prevented. This is the reason why the houses are open to the outside and made of the moisture breathing natural materials such as woods, papers and soils.

In recent years, energy consumption at public welfare is growing because of wishing an amenity life by people whereas the consumption at industries is saved because of much effort by enterprises[1]. Under such circumstances, current houses are highly airtight and energy saving. But the indoor air tends to be very wet or dry on account of using artificial materials which cannot breath moisture. Furthermore problems of allergic mold/tick or dew condensation sometimes arise in the houses.

To solve these problems, the authors have developed a humidity control building material using natural soils. In this paper, a design of the material was processed and the effect was investigated when applied it into a model house for a year.

2. EXPERIMENTAL

2.1 Characterization of raw materials

Kanuma-tsuchi soil was used as a resource of allophane. Adsorption isotherm of raw materials were measured by the weight change method. The following measurements were conducted under these conditions, TG-DTA (10℃/min), XRD (2°/min) and BET specific surface area (the 1-point method). Firing condition was 600～1,000℃ for 2 hours in a box-type electronic furnace. The amount of moisture adsorption-desorption was obtained by measuring a weight change of the sample after 24 hours in 90% R.H. from in 50% R.H. at 25°C.

2.2 Evaluation of specimen

A specimen having the dimensions of 303 x 303 x 5.5 mm^3 was produced by firing the green compact in a RHK. Bending strength was measured by the 3-points method (span: 180mm, cross head speed: 2.0 mm/min). The amount of moisture adsorption-desorption was measured in the same way as raw materials.

2.3 Specifications of model houses

Two model houses were executed, one is applied the humidity control building material "house A" and the other is applied vinyl wall coverings "house B" (Fig.1).

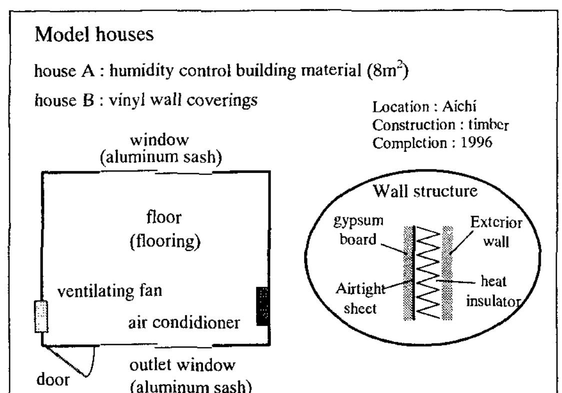

Fig.1 Specification of model houses.

They are timber construction of the volume about $20m^3$ (6 tatamis' area) having a door and an outlet window at the south side and a window at the north side. An air conditioner and a ventilating fan were located, too.

The following materials were used as the parts, wood siding boards (exterior), flooring and decorated gypsum boards (interior). Glass-wool and airtight sheets were also used.

2.4 Test using the model houses

Conditions of dew condensation in winter season and humidity control in summer season were examined using the two model houses with proper temperature control and fumidification.

The test conditions are shown in Table I. In winter season, a humidifier was run from 17:30 to the next 8:30 supposing the perspiration by two adults. The amount of 60g/h was set on the assumption that 1/2 of it were adsorbed into interiors in the room [2]. The condition of dew condensation on all the windows was observed at 8:30 and measured the amount. The measurements were conducted for 21 days from Jan. 28th to Feb. 26th in 1998. In summer season, an air conditioner set the temperature of 27°C was run from 9:00 to 21:00. After that, the room was humidified from 21:00 to the next 9:00 without air conditioning supposing the perspiration by the persons sleeping. The measurement was conducted for almost one month at August, 1998.

In which case, the humidity-temperature in the house was measured every ten minutes.

Table I Test conditions using model houses

Winter season	8:30-17:30 : Not humidified 17:30-next 8:30 : humidified (60g/h), Not temp. controlled
Summer season	9:00-21:00 : air conditioned (27°C), Not humidified 21:00-next 9:00 : Not air conditioned, humidified, Not temp. controlled

3. RESULTS AND DISCUSSION

3.1 Selection of a law material

The definition of humidity control materials indicates hereafter that they have the capacity of controlling relative humidity, adsorbing moisture when wet in the surroundings and desorbing when dry. Fig.2 shows the adsorption isotherm of typical ceramic powders for moisture.

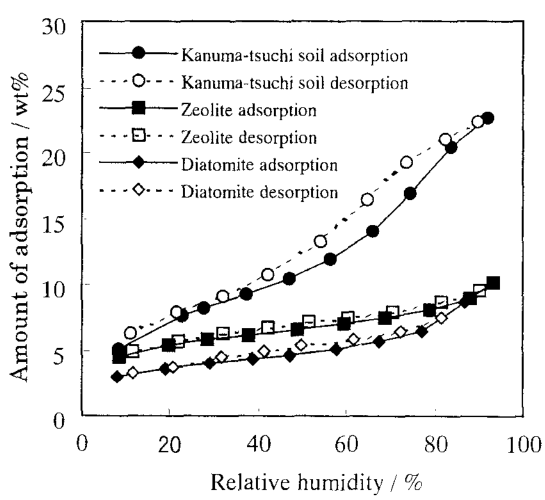

Fig.2 Adsorption isotherm of ceramic powders for moisture.

Kanuma-tsuchi soil has a larger amount of moisture adsorption-desorption than those of zeolite and diatomite which are popular for their humidity control performance. Then Kanuma-tsuchi soil was selected as a raw material of the humidity control building material.

3.2 Firing conditions of the material

Fig.3 shows the TG-DTA curve for Kanuma-tsuchi soil.

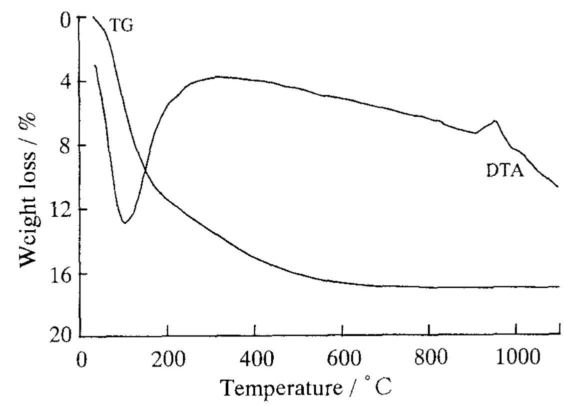

Fig.3 TG-DTA curve for Kanuma-tsuchi soil.

Dehydration of adsorbed water accompanying an endothermic reaction and a weight loss occurred until 200°C and dehydration of structural water continued until 600°C. No weight change was found at higher temperature and an exothermic reaction probably depending on crystallization occurred at the temperature range of 900- 1,000°C. It is therefore considered that the structure of Kanuma-tsuchi soil greatly changes above 900°C.

Fig.4 shows the relation between firing temperature and the amount of adsorption moisture for Kanuma-tsuchi soil.

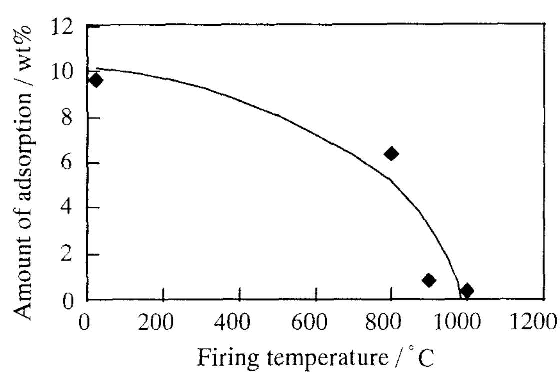

Fig.4 Amount of moisture adsorption for Kanuma-tsuchi soil.

The amount of adsorption-desorption moisture for the fired soil became smaller with firing temperature and it decreased almost 70% at 800°C, 10% at 900°C and 1% at 1,000°C compared to the non fired soil. It was clarified that the amount decreased rapidly above 900°C.

Then the phase compositions of Kanuma-tsuchi soil before and after firing were examined by XRD (Fig.5).

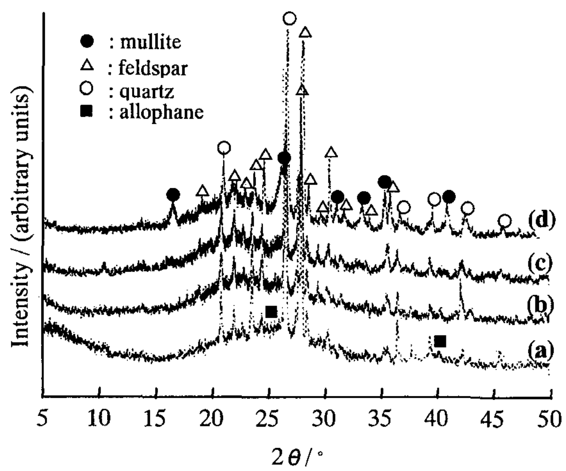

Fig.5 XRD patterns for Kanuma-tsuchi soil before (a) and after firing at 800°C (b), 900°C (c), 1,000°C (d).

Kanuma-tsuchi soil was mainly composed of allophane (halo as 2 θ =25°), quartz and feldspar.

It was found that the intensity of the halo decreased with temperature and mullite crystallized out at 1,000°C. From the facts, it is assumed that allophane crystallizes to decrease the amount of moisture adsorption-desorption.

While BET specific surface area of Kanuma-tsuchi soil was measured at several temperatures (Fig.6).

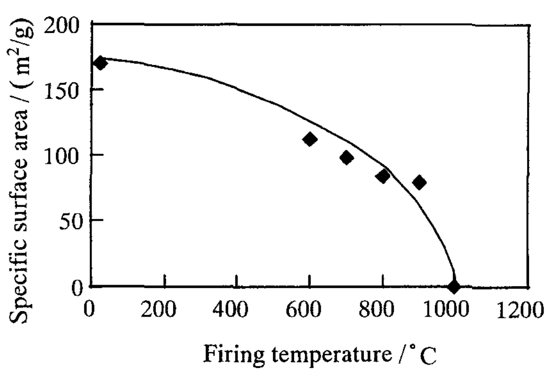

Fig.6 Relation between BET specific surface area of Kanuma-tsuchi soil and firing temperature.

The specific surface area of $170m^2/g$ before firing decreased to about a half at 700°C and drastically decreased around 900°C. The behavior is resemble to the amount of moisture adsorption-desorption. Thus it is considered that Kanuma-tsuchi soil begins sintering even below 900°C because the surface area decreases with firing. This is also supposed to decrease the amount of moisture adsorption-desorption. From the results above, desirable firing temperature is estimated to be below 900°C.

3.3 Properties of the specimen

Since the plasticity of Kanuma-tsuchi soil is weak, it is required to add another plastic material for forming (dry pressing). In this case, clay materials for traditional ceramics are mixed. Fig.7 shows the temperature dependence of bending strength of the fired specimen.

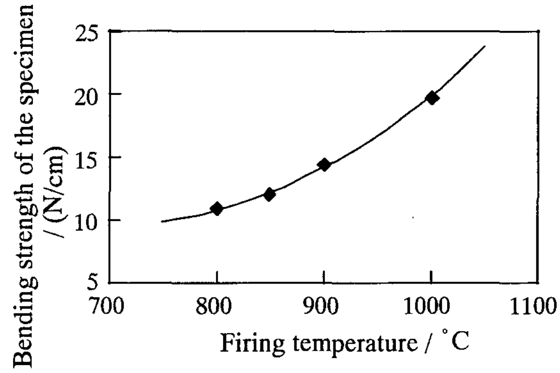

Fig.7 Temperature dependence of bending strength of the specimen.

It was seen that the strength increased with temperature. Strength is one of the most important properties for building materials. In regards to the specimen, the strength given above 800°C was sufficient for interior ceramic materials. The specimen (5.5mm thick) used in this experiment, which was fired around 800°C had two times higher of the moisture adsorption-desorption amount than that of natural wood with the same thickness (Table II).

Table II. Amount of moisture adsorption-desorption

humidity control building material	180 g /m^2
wood (cedar)	90 g /m^2

(25℃、50%R.H.→ 90%R.H. after 24 hours)

3.4 Evaluation in winter season

The temperature-humidity at the model houses in winter season are shown in Fig.8.

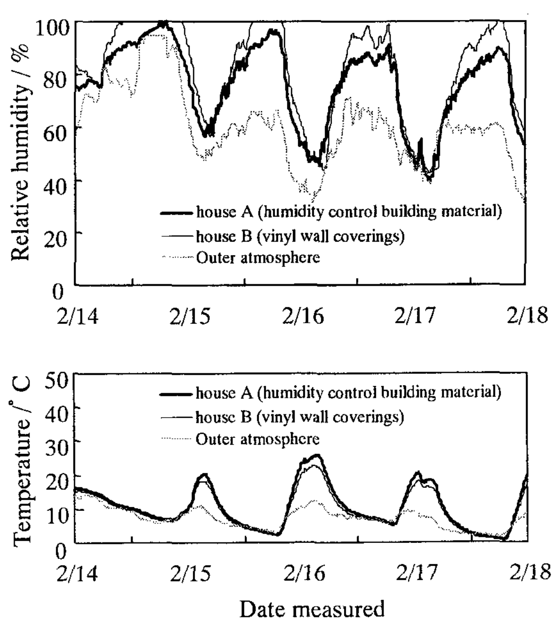

Fig.8 Temperature-humidity in winter season.

The relative humidity increased from evening to the next morning along with the temperature and humidifying in both houses. During the time, the humidity was higher than 90% in house B, whereas it is lower about 10% in house A than that in house B. This indicates that the humidity control building material actually regulates the humidity. And the humidity control effect was kept when the measurement was conducted.

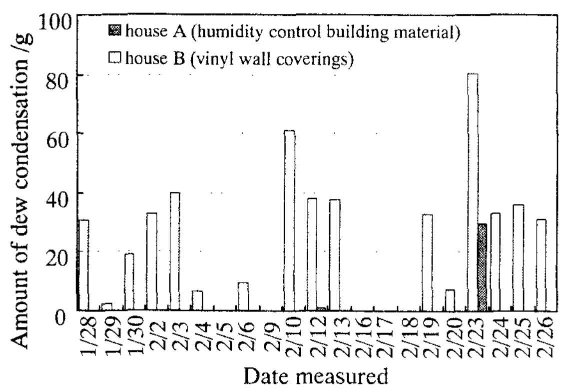

Fig.9 Conditions of dew condensation at windows.

Then conditions of dew condensation at windows in the model houses are shown in Fig.9. In house B, dew condensation was observed 17 days in 21 days measurement. The day average was 30-40 g and the sum was about 500 g. In contrast to that, that in house A was highly decreased and was observed only for 2 days. It is considered that the relative humidity is regulated to decrease the dew condensation when the humidity control building material is applied.

3.5 Evaluation in summer season

Fig.10 shows a typical temperature-humidity after turning off the air conditioner in summer season.

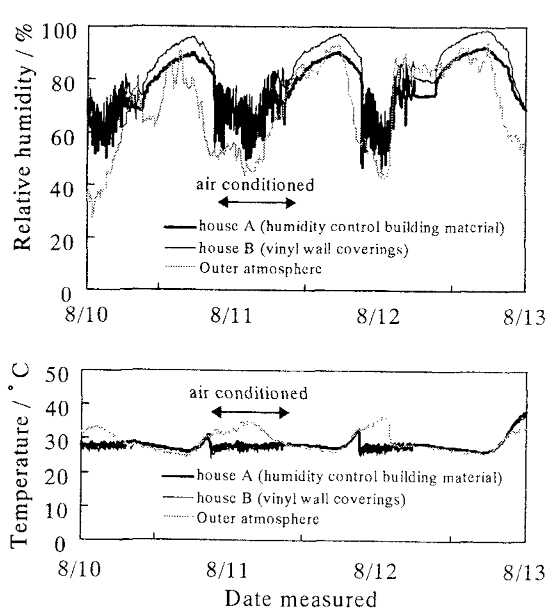

Fig10 Temperature-humidity after turning off air conditioner in summer season.

The relative humidity in house·A was about 10% lower than that in house B although the humidity was increased in both houses. It is realized that the material improved the humidity environment in the house same as in winter season. On the other hand, no difference of temperature-humidity in the houses was observed during air conditioning.

Furthermore, the temperature-humidity in rainy season was shown in Fig.11. The relative humidity in house A was about 10% lower than that in house B. It is expected for the material to reduce the discomfort and to restrain arising mold/tick under the high temperature-humidity condition.

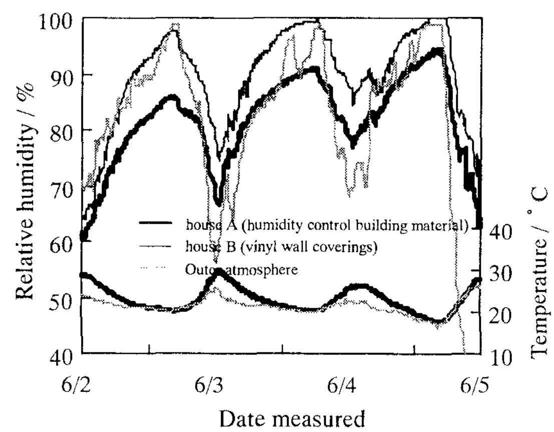

Fig.11 Temperature-humidity in rainy season.

References

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[2]T. Uemura, K. Kohara and S. Tokoro, "Material and Structure of the Wall for Humidity Control", wall coverings association of Japan, 1991, p.130.

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