EXPERIMENT FOR SYNTHETIC EVALUATION OF MOISTURE BUFFERING EFFECT IN A ROOM

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ABSTRACT

There are many research works for the moisture buffering effect of the building materials. However, there are few reports for the moisture buffering of the indoor contents such as wooden furniture, textiles and paper products except for the building materials in a room. In order to utilize the moisture buffering effect in the whole room, it is important to evaluate the synthetic moisture buffering including the indoor contents.
In this paper, the experiment for moisture buffering of the contents in a room such as textiles and paper products is described. The objective of the experiment is to propose the evaluation method of the synthetic moisture buffering in a room. In the experiment, the test chamber (4.62 m^3) installed the hygrothermal material on the interior surface is used. This chamber is located in the climate room to control the ambient conditions. The hygrothermal materials and various contents such as textile and papers are furnished in the test chamber. The response of indoor humidity change in humidifying in the test chamber is evaluated by two evaluation methods. These two methods are compared and discussed for the possibility of practical use as an evaluation method in the actual residential room.

KEYWORDS

Experiment. Chamber test. Moisture buffering effect. Indoor contents. Evaluation.

INTRODUCTION

Humidity in indoor spaces is one of the most important factors for determining the indoor air quality, and many health related problems in the indoor environment e.g. the SBS, can be associated with high indoor humidity and "damp buildings" (Clausen et al. 1999). Recently, the material that has good moisture absorption and adsorptions has been used in many museums as finishing materials on the walls of storage rooms and the interior of display cases for passive humidity control (Arai et al. 1995). These materials have a possibility to control the indoor humidity in the residential spaces. The humidity level in a building depends on a combination of factors such as moisture sources, ventilation and air movement, reservoirs and sinks, heating, insulation, external conditions as well as building materials and occupants. Among these, the moisture buffering effect of the materials in a building is an important factor. Many past research works for the moisture buffering effect of the building materials have been carried out (Mitamura et al, 2001). Actually, there are many hygrothermal materials such as wooden furniture, textiles and paper products except for the building materials in the residential spaces. However, there are few reports for the moisture buffering of the contents in the room. It is difficult to make clear the performance of moisture absorbing/desorbing such as contents because of the complex shape and many kinds of materials. In order to utilize the moisture buffering effect in the residential spaces, it is important to investigate the moisture buffering of the contents in a room and evaluate the synthetic moisture buffering including them in a room.

The experiment for moisture buffering of the contents in a room such as textiles and paper products was carried out. The test chamber (4.62 m^3) installed the hygrothermal material on the interior surface is used in the experiment. This chamber is located in the climate room to control the ambient conditions. The hygrothermal materials and various contents such as textile and papers are furnished in the test chamber. The response of indoor humidity change in humidifying in the test chamber is evaluated by two evaluation methods. First method is the integration of absolute humidity change during humidification between experimental data and simulated results in the case of no moisture buffering. Another method is to identify two indexes of moisture transfer and storage from experimental data. These two methods are compared and discussed for the possibility of practical use as an evaluation method in the actual residential room.

EXPERIMENTAL SETTING

Test chamber

The test chamber is located in the climate room at the Akita Prefectural University. In the climate room, it is possible to control indoor temperature ranging from 10 °C to 40 °C and also humidity from 30 %RH to 90%RH. This test chamber imitates a half size of a residential room in a house. The internal volume of the test chamber is 4.62 m^3 and its area of interior surface is 16.67 m^2. The walls, ceiling and floor of the chamber consist of inside construction panels (6 mm of plywood) and outside insulation material (100 mm of polystyrene). Interior surface is furnished with the hygrothermal materials (5 mm of hygroscopic ceramic panels) which are pasted on the plywood. In order to keep airtight in the chamber, aluminum sheet is installed between the polystyrene and the plywood. The inlet and outlet for mechanical ventilation are located at the bottom and top of each facing walls respectively. The small wind tunnel is connected with the outlet of the chamber to measure the ventilation rate accurately. The schematic view of the test chamber is shown in Figure 1.

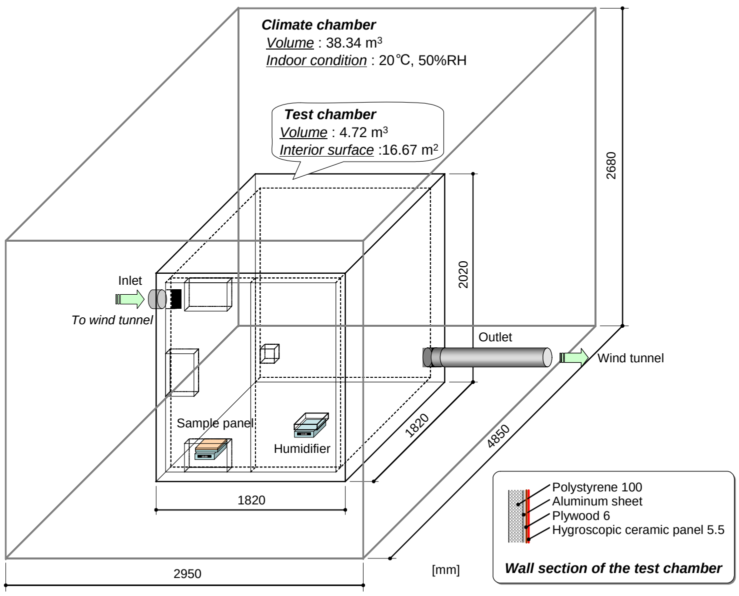

Figure 1: The schematic view of the test chamber

The test chamber is instrumented with sensors for measuring indoor air temperature, relative humidity, and surface temperature. Furthermore, indoor contents of papers, clothes, coverlet, books were weighed by the electronic balance in the test cell to estimate the quantities of moisture absorbed and desorbed during the experiment. The data acquisition system is located outside of the test chamber.

In the experiments, room air was humidified by evaporating moisture from a water reservoir that was heated by an electric heating element. The tray with the water reservoir was weighed by another electric balance to measure the quantities of humidification water.

Experimental program

Experimental schedule is shown in Figure 2. In this study, indoor humidity change in humidifying for 6 hours and after stopping humidification for 12 hours is evaluated. The quantity of humidification water is about 35 g/h. Cases for experiments are shown in Table 1. In the Cases 1 and 2, all surrounding walls are covered with vinyl sheets not to absorb and desorb moisture. In the other cases, only one side wall is exposed with indoor air and other walls are covered with vinyl sheets. For all experimental cases, ambient condition of the test chamber is 20 °C and 50 %RH. Indoor contents used for the experiment are papers, clothes and coverlet. Papers are 1000 pieces of copy papers that are bundled on the electric balance. Clothes are 9 T-shirts. The coverlet is a down filled quilt. These are hanged on a steel frame in the test chamber. Between experimental cases, the inside of the test chamber was exposed to the ambient air by opening the front wall for about 24 hours as a recovery period.

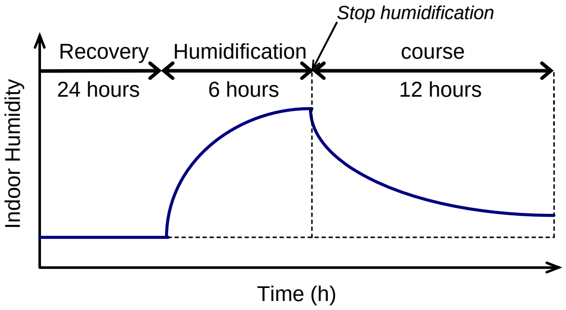

Figure 2: Experimental schedule

TABLE 1: Cases for experiments

	Wall conditions	Indoor contents	Remarks
Case 1	All surrounding walls are covered with vinyl sheets	*Non*	No hygroscopic condition
Case 2		Papers (1000 pieces of copy papers)	Only indoor contents
Case 3	Only one side wall is exposed with indoor air. (Other walls are covered with vinyl sheets)	*Non*	Reference case
Case 4		Papers (1000 pieces of copy papers)	Moisture buffering of indoor contents
Case 5		Clothes (9 T-shirts)	
Case 6		Coverlet (1.2*1.3 m)	
Case 7		Papers and clothes	

EVALUATION METHOD FOR MOISTURE BUFFERING EFFECT

Evaluation index "*S*"

In order to evaluate the moisture buffering effect, integration of absolute humidity change for 6 hours during humidification and for 6 hours after stop of the humidification is calculated from experimental results. The integration of absolute humidity change is calculated as area "*S*", which is defined as the difference of absolute humidity between the results with absorbing materials and without absorbing materials. Evaluation index "*S*" of moisture buffering effect is shown in Figure 3.Absolute humidity without absorbing materials is calculated by the following moisture balance equation (Eqn.1). Large value of this index "*S*" means that moisture buffering effect is large.

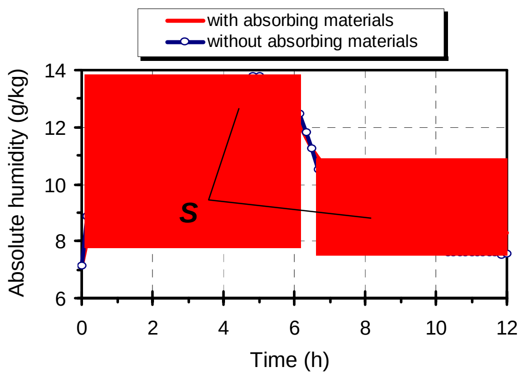

Figure 3: Evaluation index "*S*"

$$G\frac{dX_i}{dt} = W + V(X_o - X_i)dt \quad \text{(Eqn.1)}$$

where

G	is the mass of the indoor air (kg)
X_i	is the indoor humidity ratio (kg/kg)
X_o	is the outdoor humidity ratio (kg/kg)
W	is the moisture production (kg/s)
V	is the ventilation air (kg/s)

Evaluation indexes "*KS*" and "*CW*"

The model to analyze the room surface absorption capability of moisture was developed by Tsuchiya (1980). If condensation on the glass surface is ignored, the indoor humidity in this model is calculated by the following three equations (Eqn.2 to 4). In this model, the absorption of moisture by the room surface is limited to a thin layer over the solid surface (excepting the window glass). It is assumed that this thin layer attains instantaneous moisture equilibrium with respect to the room air moisture content, approximately following Eqn.2. So only the surface of the constructions is considered to calculate the moisture transfer between the room air and the constructions. The values for "*K*" (moisture transfer coefficient by the room surface) and "*CW*" (moisture capacity) in Eqn.3 and Eqn.4 are determined through short-term experiments. These values of "*K*" and "*CW*" are used as evaluation indexes for the moisture buffering effect.

$$G\frac{dX_i}{dt} = W - \frac{dw_{surf}}{dt} + \sum_{airsources} V(X_o - X_i) \quad \text{(Eqn.2)}$$

$$\frac{dw_{surf}}{dt} = KS(X_i - \phi_{surf}) \quad \text{(Eqn.3)}$$

$$\phi_{surf} = \frac{\phi_s}{41}\left(\frac{w_{surf}}{CW}T - 5.46\right) \quad \text{(Eqn.4)}$$

where

w_{surf}	is the moisture absorbed in the room surface (kg)
K	is the moisture transfer factor for the room surface ($kg/m^2s(kg/kg)$)
S	is the room surface area (m^2)
ϕ_{surf}	is the humidity ratio of the room surface (kg/kg)
ϕ_s	is the humidity ratio of the air saturated at temperature T (kg/kg)
CW	is the moisture capacity (kgK/kg)
T	is the room temperature (K)

RESULTS AND DISCUSSION

Indoor humidity

Indoor absolute humidity change is shown in Figure 4. Ventilation rates and quantities of humidification are shown in Table 2. The deviation of ventilation rate was not so large, but quantities of humidification indicated difference about 10 g/h between Case 5 and Case 6.

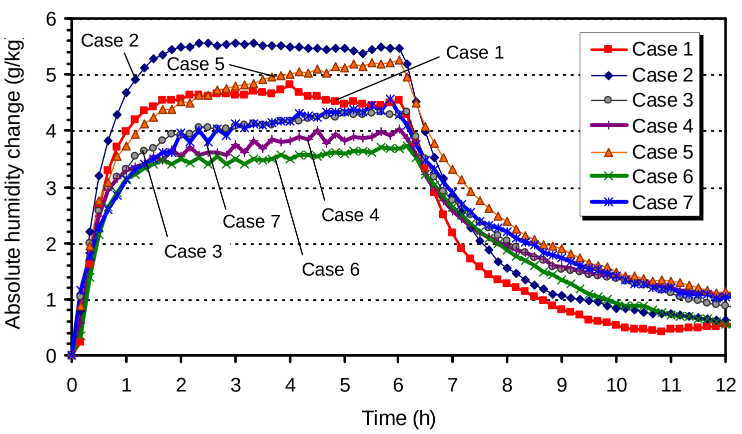

Figure 4 : Indoor absolute humdiity change

Increases of humidity in the Case 1 and Case 2 without hygrothermal material on the walls were larger than those of other cases during humidification. However, humidity in the Case 5 was also increased, because quantity of humidification was large comparing with other cases. On the other hand, increases of humidity in the Case 4, 6 and 7 furnished with indoor contents were from 3.5 to 4.5 g/kg. Smaller increase in these cases would be due to the moisture buffering effect of indoor contents.

TABLE 2: Ventilation rate and humidification

	Ventilation rate (1/h)	Quantity of humidification (g/h)
Case 1	1.36	35.0
Case 2	1.06	36.7
Case 3	1.23	38.8
Case 4	1.35	37.7
Case 5	1.11	44.2
Case 6	1.11	33.4
Case 7	1.08	35.8

Weight change of the indoor contents

Weight change of the indoor contents is shown in Figure 5. It was cleared that weight change of clothes was larger than that of others. Comparing Case 2 and Case 4 that were furnished with papers, weight changes during humidification in both cases were almost same. However, after stop of the humidification, weight in the Case 2 was decreased and that in the Case 4 was almost constant. The reason would be an influence of hygrothermal materials on the walls. Weight change of the coverlet was constant about 9.5 g after 2 hours of humidification. It was guessed that moisture absorption of the coverlet reached equilibration.

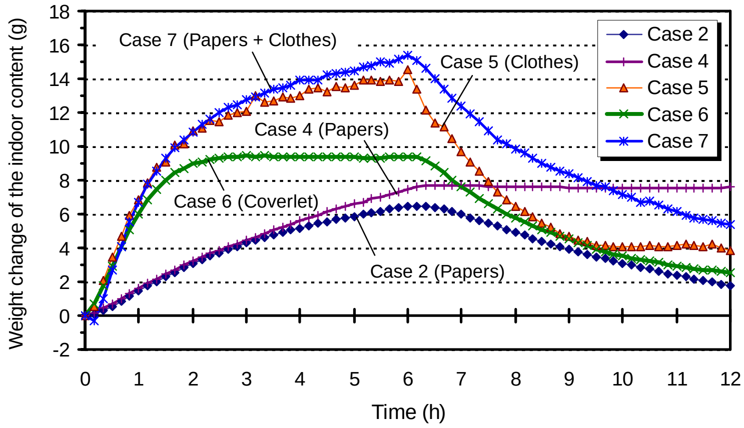

Figure 5: Weight change of the indoor content

Evaluation of the moisture buffering effect

Evaluation index "S"

Results of evaluation by index "*S*" is shown in Figure 6. It seemed that values of "*S*" were relevant to the weight change of the indoor contents. Value of "*S*" in the Case 2 was the smallest of all, because of no hygrothermal materials on the walls and only papers placed in the room. Although there were no indoor contents in the Case 3, value of "*S*" was comparatively large. Because the moisture buffering effect of the hygrothermal materials on the walls was large. Values of "*S*" in the Case 5 and Case 7 indicated large due to the moisture buffering effect of clothes.

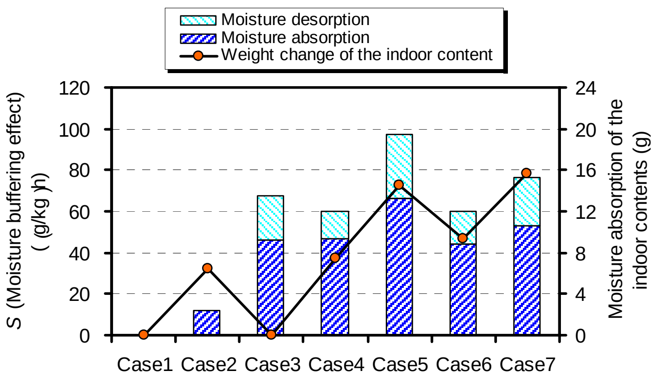

Figure 6: Evaluation of the moisture buffering effect by index "*S*"

Evaluation indexes "KS" and "CW"

Results of evaluation by indexes "*KS*" and "*CW*" is shown in Figure 7. The profile of index of "*KS*" was similar to results of evaluation by index "*S*". There is no much difference between the cases. However, value of "*CW*" was extremely large in the Case 3. It seemed that moisture buffering of hygrothermal materials on the walls in the Case 3 was larger than that of other cases.

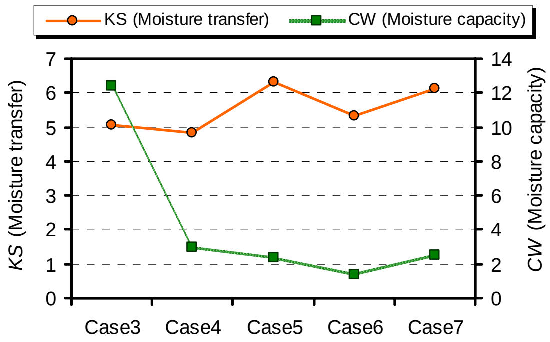

Figure 7: Evaluation of the moisture buffering effect by index "*KS*" and "*CW*"

CONCLUSIONS

Investigation of moisture buffering effect of the contents in a room was carried out using the test chamber in the climate control room. In order to evaluate the moisture buffering effect of the indoor contents, two evaluation methods were investigated and evaluation indexes were proposed. Results of evaluation by index "*S*" were similar to results of weight change of the indoor content. Evaluation results by indexes "*KS*" and "*CW*" did not made clear moisture buffering effect.

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