Experimental Assessment of Humidity Controlling the Performances of Moisture Adsorbing/Desorbing Building Materials

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Abstract

The climate of South Korea is that of high temperatures and high humidity in the summer season and low temperatures and low humidity in the winter. Humidifiers and dehumidifiers are used to create a cool indoor environment, and the demand for building materials with moisture adsorption/desorption functions is increasing. To investigate the performance of moisture adsorption/desorption new mineral fiber boards, a chamber test and mock-up test were performed and compared to mineral fiber boards. As a result of the chamber test and mock-up test, the new mineral fiber board showed the effect of maintaining indoor humidity regularly through humidity adsorption/desorption by the chamber test and mock-up test.

Keywords: Moisture adsorption/desorption property, Interior surface materials, Mineral fiber board, Chamber test, Mock-up room test, Relative humidity

Introduction

Relative humidity levels influence indoor environmental quality and occupants' thermal comfort. At a very low humidity level, there may be complaints of dry noses, mouths, eyes, and skin, and increases of respiratory illnesses [1]. In particular, various types of porous building materials with moisture adsorption/desorption properties have been introduced to the market in countries which have a hot and humid climate. Previous studies have been conducted to evaluate the hygric buffering capability of various types of building materials as follows: Abadie and Mendonca [2] have evaluated moisture performance of building materials commonly found in buildings, including concrete and cement, plasterboard, brick, particle, fiberboards and wood. In the NORDTEST project[3], an experimental protocol has been proposed that specifies a moisture buffer value that includes in its definition the surrounding air vapor concentration variation [2, 4, 5]. Other experimental methodologies to evaluate the hygrothermal performance of building materials have been proposed by the Japanese Industrial Standard (JIS) [6] and the International Standards Organization (ISO) [7]. The purpose of this study is to evaluate and compare the moisture adsorption/desorption performances of interior building materials through chamber tests and mock-up room tests.

2. Methods

2.1. Tested building materials

The ordinary mineral fiber board was manufactured as a ceiling board and it was made of mineral fibrous wool as its base material together with some additives. It was manufactured through mixing, molding, drying, cutting, carving, surface finishing and spraying procedures. This mineral fiber board was evaluated as a good fire resistant, sound absorbing, and thermal insulation material [8].

The new mineral fiber board was made of mineral fibrous wool and activated China clay as an additive. Due to its high degree of microporosity, the activated China clay has a high capacity of moisture adsorption/desorption capacity within the normal indoor temperature and relative humidity ranges. Therefore, the new mineral fiber board can control the indoor relative humidity level by adsorbing moisture when the indoor moisture level is high and by desorbing when it is low [9, 10].

The gypsum board is widely used for surface material of interior walls and ceilings in the construction industry. It was manufactured through the process such as calcining gypsum into plaster, producing slurry from the plaster, and passing the slurry through machines for shaping, setting, and cutting into a board.

Table 1 Physical properties of tested materials

2.2. Measurements in Chamber

The moisture control performances of the three different materials were measured in a test chamber which was built in accordance with the ISO 24353:2008(E). The test chamber suggested in the ISO standard, which includes an electronic balance, a moisture-proof box with a programmable air conditioner and a thermometer. Fig. 1 shows the actual test chamber used in this study and it consists of an electronic balance, a moisture-proof box with a thermostat, a temperature sensor, a humidity gauge, and a humidifier.

For preconditioning and testing of a specimen, the ambient temperature was set to 23±0.5℃, and the ambient relative humidity was maintained to 50±1% of the value of relative humidity of 50%.

Fig. 1 Exterior and interior views of test chamber

Then, moisture adsorption/desorption tests were performed by maintaining the relative humidity levels inside the chamber as shown in Table 2. First, moisture adsorption test was carried out at 75% RH for 12 hours. Then, desorption test was performed at 50% RH for additional 12 hours.

During the 24 hour moisture adsorption/desorption tests, the mass change of the test specimen was measured at a 10 minute interval to the nearest 0.01g. Then, the mass was recorded at the end of the first 12 hour period as the result of moisture adsorption process, and at the end of the second 12 hour period as the result of desorption process.

Table 2 Relative humidity levels inside chamber

2.3. Measurements in mock-up rooms

The hygric performances of the interior building materials were also tested in mock-up rooms. Fig. 2 shows the exterior view and floor plans of the mock-up rooms. As shown in Table 3, the ordinary mineral fiber boards were installed for the ceilings of the rooms 1 and 3, while the new mineral fiber boards were installed for the ceilings of the rooms 2 and 4. The walls and floors of the four mock-up rooms were finished by gypsum boards.

Three different measurement conditions were setup in the four mock-up rooms. In the first case, electric humidifiers were operated in the rooms 1 and 2 in order to simulate high-humidity summer conditions. In the second case, open water basins were placed in the rooms 1 and 2. In the third case, no humidifier or open water basin was used in the mock-up rooms 3 and 4 in order to simulate low-humidity winter conditions. Fig. 2 shows the three different humidification methods in the mock-up rooms. Then, the indoor humidity levels and temperatures with the new mineral fiber board and ordinary mineral fiber board were measured under the three different conditions by a temperature/humidity logger (Sato, SK-L200TH-II) placed outside the rooms. Fig. 3 shows the whole measurement schedule in the mock-up rooms.

In the mock-up case 1 (with electric humidifiers), the rooms 1 and 2 were measured for six days from February 28 to March 5, 2008. The room temperatures in both rooms were maintained at 21℃ to 24℃ by radiant floor heating. The electric humidifier in each room was operated for two days and the average humidification rate was 0.125 ℓ/h. In the mock-up case 2 (with open water basins), the rooms 1 and 2 were measured for 28 days from March 10 to April 6, 2008. The room temperatures in both rooms were also maintained at the same temperatures as in the case 1. In each room, about three liters of water was naturally vaporized from the open water basin over the 28 days at an average vaporization rate of 0.0045ℓ/h.

In the mock-up case 3 (with no humidifier), the rooms 3 and 4 were measured for 39 from February 28 to April 6, 2008. In this case, the room temperatures in the two rooms were maintained at about 21℃ to 26 ℃. The room temperature was a little higher than that of the rooms 1 and 2 because no sensible heat was transformed into latent heat due to no moisture source.

Table 3 Mock-up room conditions for three measurement cases

Fig. 2 Mock-up rooms

Fig. 3 Humidification methods in mock-up rooms

Fig. 4 Measurement schedule in mock-up rooms

3. Results

3.1. Results from Chamber measurements

Fig. 5 shows the mass changes in the three specimens during the moisture adsorption and desorption processes inside the chamber. As shown in the figure, a dramatic change in the mass was noted with the new mineral fiber board between the adsorption and desorption processes. The performances of moisture adsorption and desorption can be clearly explained by Table 4 which shows the measured masses and calculated moisture contents from the chamber tests.

Fig.5 shows the moisture adsorption and desorption contents for this case, and the values of the new mineral fiber board were always higher than those of the other materials.

The moisture adsorption/desorption rate calculated by ISO 24353 in the measured moisture adsorption/desorption contents during the 24 hour test period. As clearly indicated the graphs, most of the moisture was adsorbed and desorbed during the first three hours of each process.

Table 4 Results from chamber measurements

Fig. 5 Mass changes in specimens during moisture adsorption and desorption processes in chamber measurements

3.2. Results from mock-up room measurements

Fig. 6 shows the relative humidity profiles for mock-up case 1 in which the ceilings of rooms 1 and 2 were treated by the ordinary mineral fiber board and the new mineral fiber board, respectively, and an electric humidifier was operated in each room. As shown in the figure and Table 5, the average relative humidity of the room 2 with the new mineral fiber board was about 13.9%p lower than that in the room 1. Fig. 7 shows the relative humidity profiles for mock-up case 2 where open water basins were placed in the rooms 1 and 2. As shown in the figure and Table 5, the average relative humidity of room 2 was 11.9%p lower than that of room 1.

From the measurement cases 1 and 2 where the artificial humidification was maintained to simulate a high-humidity summer condition, it was proven that the new mineral fiber board could be an effective dehumidifier during the summer season.

Fig. 8 shows the relative humidity profiles of mock-up case 3, measured during the same period as the case 1, in which the ceilings of rooms 3 and 4 were treated by the ordinary mineral fiber board and the new mineral fiber board, respectively, and no humidifier was operated in each room. As shown in the figure, the average relative humidity of room 4 was 8.2%p higher than that of room 3.

From these measurements, it was proven that the newly developed mineral fiber board could be an effective humidifier during the low-humidity winter seasons. Considering that variety of humidity increasing activities, such as cooking, dish washing and cloth drying occur in housings during the winter season, the new mineral fiber board will effectively adsorb indoor moisture generated from these activities, then desorb it back to the space when indoor humidity level is low.

Table 5 Test results with mock-up rooms

Fig.6 Relative humidity profiles of case 1(with electric humidifier)

Fig.7 Relative humidity profiles of case 2 (with open water basin)

Fig.8 Relative humidity profiles of case 3 (natural condition)

4. Conclusion

Relative humidity levels influence indoor environmental quality and occupants' thermal comfort. As an effective way of controlling relative humidity fluctuations without adding energy costs, various types of porous building materials with moisture adsorption/desorption properties have been widely introduced to the market in countries with a hot and humid climate. In this study, the adsorption/desorption properties of an ordinary mineral fiber board, a newly developed mineral fiber board, and a gypsum board were investigated and compared by a series of chamber tests and mock-up room tests. From the chamber test, it was found that the moisture content of adsorption/desorption process of new mineral fiber board was about three times as great as that of ordinary mineral fiber board. In the mock-up room tests, the effects of the interior building materials on indoor humidity were investigated under three different conditions with electric humidifiers, open water basins, and no moisture source. From the measurement cases where the artificial humidification was maintained to simulate a high-humidity summer condition, it can be said that the new mineral fiber board can be an effective dehumidifier during the summer season. On the other hand, in the mock-up rooms with no moisture source, the indoor humidity level with new mineral fiber board was higher than that with the ordinary mineral fiber board. The results indicated that the moisture adsorbing/desorbing building materials can help maintain the comfort indoor humidity levels throughout different seasons so that the energy for humidification and dehumidification could be saved. In this study, the performance of one kind of moisture absorbing/desorbing material was evaluated by using accurately controlled chamber and mock-up rooms. Therefore, further studies are needed to evaluate its performance in the real-scale housing unit and to evaluate the performance of various building materials.

Acknowledgement

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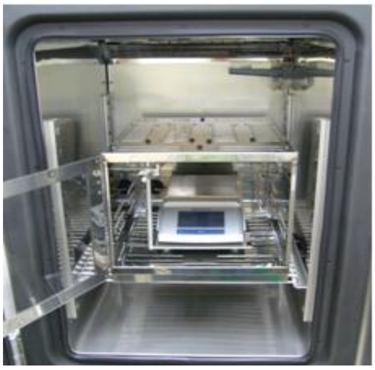
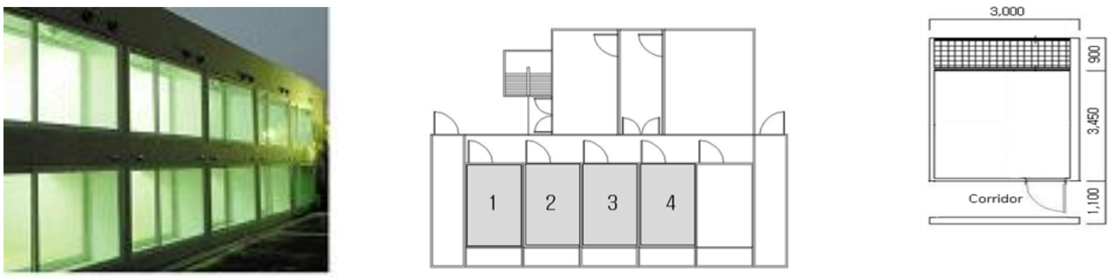
a) Exterior view



b) Interior view

Fig. 1 Exterior and interior views of test chamber



a) Exerior view

b) floor plan

c) floor plan detail

Fig. 2 Mock-up rooms

a) electric humidifier (rooms 1 and 2)

b) open water basin (rooms 1 and 2)

c) none (rooms 3 and 4)

Fig. 3 Humidification methods in mock-up rooms

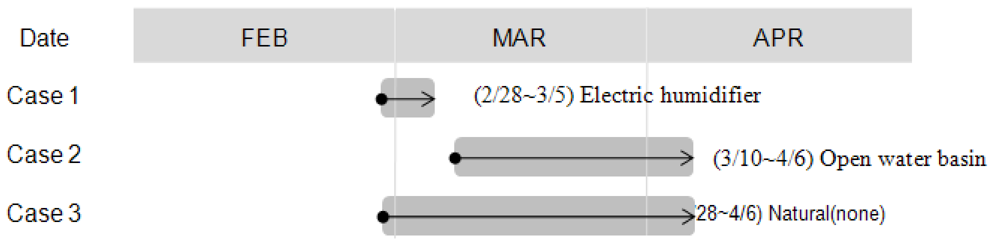


Fig. 4 Measurement schedule in mock-up rooms

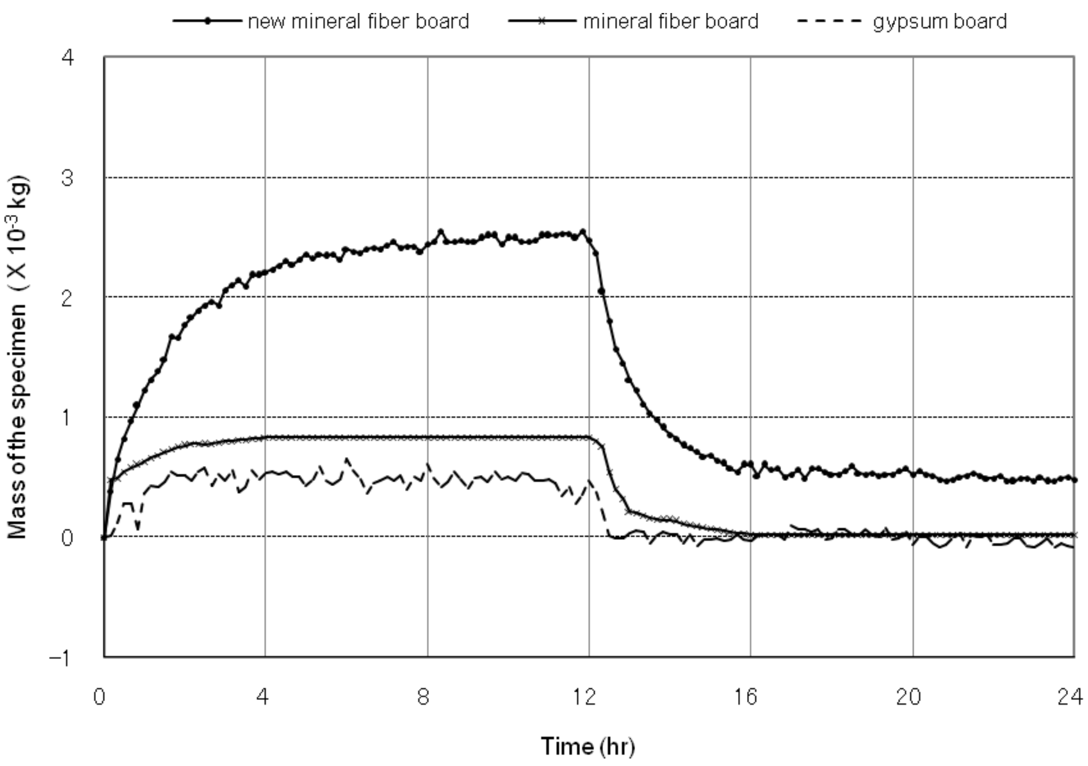


Fig. 5　Mass changes in specimens during moisture adsorption and desorption processes in chamber measurements

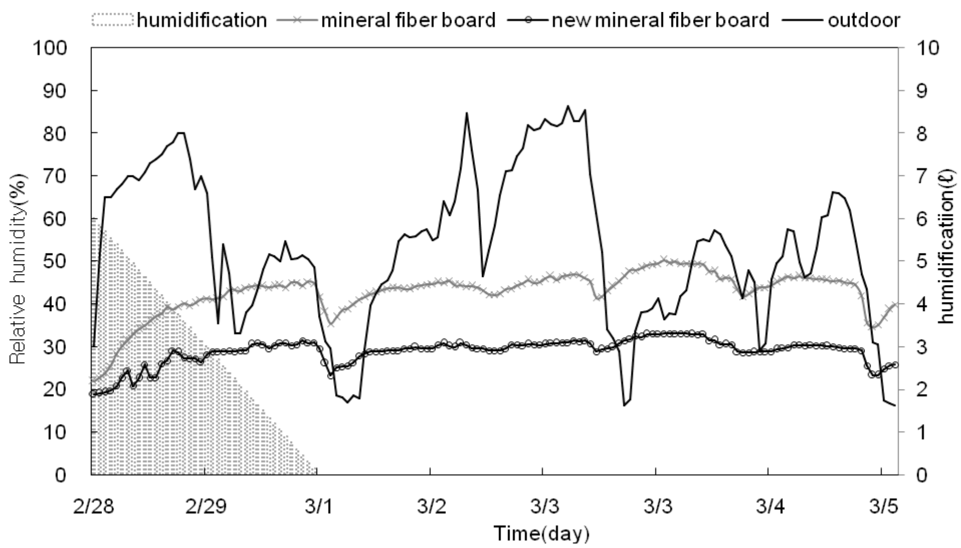


Fig.6 Relative humidity profiles of case 1(with electric humidifier)

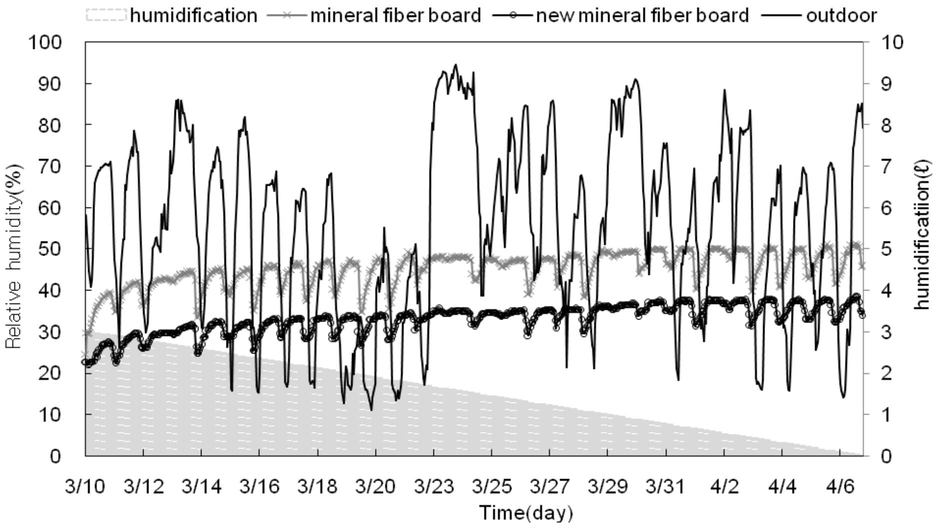


Fig.7 Relative humidity profiles of case 2 (with open water basin)

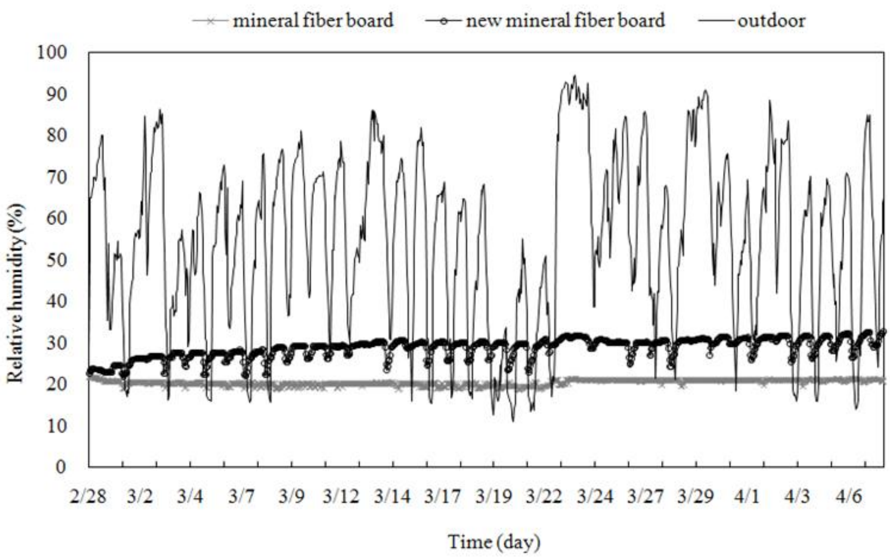


Fig.8 Relative humidity profiles of case 3 (natural condition)

Table 1 Physical properties of tested materials

Product	Material	Thickness (m)	Density (kg/㎥)	Moisture content (%)
Mineral fiber board	Mineral fibrous wool	0.012	300	1.3
New mineral fiber board	Mineral fibrous wool + Activated China clay	0.012	340	2.3
Gypsum board	Gypsum	0.0095	610	0.2

Table 2 Relative humidity levels inside chamber

Relative humidity (%)		
Preconditioning	Moisture adsorption process	Moisture desorption process
	Step 1	Step 2
50	75	50

Table 3 Mock-up room conditions for three measurement cases

	Case 1		Case 2		Case 3	
No.	Room 1	Room 2	Room 1	Room 2	Room 3	Room 4
Humidification Method	E.H	E.H	O.B	O.B	N	N
Ceiling	M	N.M	M	N.M	M	N.M
Floor	G	G	G	G	G	G
Wall	G	G	G	G	G	G

E.H : Electric humidifier O.B : Open water basin,

M: Mineral fiber board N.M : New mineral fiber board

G : Gypsum board N : Natural(none)

Table 4 Results from chamber measurements

Category	Mineral fiber board	New mineral fiber board	Gypsum board
A(㎡)	0.0625	0.0625	0.0625
m_o (10^{-3}kg)	0.00	0.00	0.00
m_a (10^{-3}kg)	0.83	2.47	0.47
m_d (10^{-3}kg)	0.02	0.48	0.00
$\rho_{A,a}(g/m^2)$	13.3	39.5	7.5

$\rho_{A,d}(g/m^2)$	13.0	31.8	9.1
$\rho_{A,s}(g/m^2)$	0.3	7.7	-1.6

Table 5 Test results with mock-up rooms

		Average Temperature (℃)	Average Relative humidity (%)	Average Absolute humidity (kg/kg`)
Case 1	Mineral fiber board	22.9±1.1	42.8±5.2	0.0074±0.0008
	New mineral fiber board	22.8±1.1	28.9±3.0	0.0049±0.0005
	Outdoor	4.9±3.7	53.0±17.9	0.0027±0.0008
Case 2	Mineral fiber board	21.9±1.2	45.0±4.2	0.0073±0.0005
	New mineral fiber board	22.1±1.1	33.1±3.5	0.0054±0.0005
	Outdoor	10.6±4.3	55.6±21.6	0.0041±0.0012
Case 3	Mineral fiber board	23.7±2.0	20.5±0.7	0.0036±0.0003
	New mineral fiber board	23.4±1.8	28.7±2.4	0.0050±0.0005
	Outdoor	9.2±4.7	54.8±20.7	0.0038±0.0012