The inference of window insulation and interior materials providing moisture control on indoor hygrothermal environment

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ABSTRACT

Improving insulation of existing houses is very important for the civilian sector to reduce CO2 emission. According to the Basic Energy Plan for Japan, one of the targets is the doublingof the number of existing houses to undergo energy saving modifications. However, it is hard to say that large-scale insulation improvement construction is common. The most popular method of improving insulation performance is insulation improvement of the existing windows. It is well-known that insulation performance of windows is lower than other areas of the house and improving insulation contributes to improvement of thermal comfort and heat load reduction. On the other hand, humidity environment after improving window insulation has not received much attention. As long as the entire outer surface of buildings is insulated, there is concern that humidity environment in low thermal-insulated places and space will be worsened.

In this research, humidity environment change of the entire reinforced concrete construction apartment buildings with no insulation after window insulation improvement was made clear using numeric calculation, and humidity environment improvement effect by the use of building materials to regulate indoor humidity was studied. The results are as follows.

1) Room temperature becomes higher by improving window insulation, and the amount of condensation on the window surface greatly decreases.
2) The amount of condensation on the window surface decreases by improving window insulation, but absolute room humidity increases.
3) In comparatively warm regions such as Tokyo, absolute humidity does not increase much by improving window insulation.
4) Without improving entrance door insulation, the amount of dew condensation on entrance doors increase by improving window insulation.
5) Frequency of appearance of high humidity zones can be reduced by using building materials to regulate indoor humidity in the living room or closets.
6) Slight condensation on the window surface after improving window insulation can be reduced by using building materials to regulate indoor humidity.
7) Building materials to regulate indoor humidity are not overlyeffectiveinreducing condensation on entrance doors.

KEYWORDS
Renovation of thermal insulation, Humidity environment, interior materials providing moisture sorption and desorption, Numerical simulation

INTRODUCTION

Improving thermal insulation of existing houses is very important for the civilian sector to reduce CO_2 emissions. According to the Basic Energy Plan for Japan (Anon), one of the targets is the doubling of the number of existing houses to undergo energy saving modification. However, it is hard to say that large-scale insulation improvement construction is common. The most popular method of improving insulation performance is insulation improvement of the existing windows. It is well-known that insulation performance of windows is lower than other areas of the house and improving insulation greatly contributes to improvement of thermal comfort and heat load reduction. On the other hand, the humidity environment after improving window insulation has not received much attention. Unless the entire outer surface of building is insulated, there is concern that the humidity environment in low thermal-insulated places and space will be worsened. In this research, humidity environment change of the entire building, which was made by renovating the thermal insulation of windows, was made clear using numerical calculation, and the humidity environment improvement effect by the use of building materials to regulate indoor humidity was studied.

OUTLINE OF NUMERICAL CALCULATION

NUMERICAL CALCULATION PROGRAM

THERB for HAM, an indoor temperature and humidity calculation program intended for many rooms, was used for calculation. Combined heat and moisture transfer model applied to THERB is non-equilibrium thermodynamic model made by conservation law of energy and moisture. It is characterized by using thermodynamic energy (water potential), in light of influence of stress as a driving force of moisture flow. Moisture volume was calculated using volumetric moisture content and unsaturated water potential (OZAKI, WATANABE et al. 2001).

NUMERICAL CALCULATION MODEL

Building model used for numerical calculation is shown in Figure 1. It was made on RC construction apartment. The model was on the middle floor. North, west, and south side walls contacted outside air. No insulation was provided to the external wall with single-paned windows. The door’s heat transmission coefficient was 6.5[W/(m2・K)]. Ventilation rate was always kept at 0.5 time/hour, and air was supplied from each room and ventilated from the rest room via hallway. Expanded AMeDAS (Automated

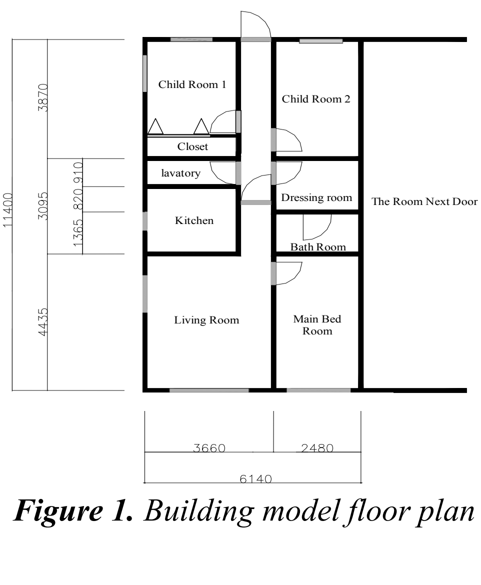

Figure 1. *Building model floor plan*

Meteorological Data Acquisition System) weather data (AIJ 2005) standard year of Tokyo was used as surrounding conditions.

LIVING SCHEDULE

Living schedule for calculating heating and cooling load was used to calculate calorific values and generated humidity of each room (IBEC 2009). Heating schedule is as shown in Table 1. Temperature for heating was set at 20 degreess C, and partial heating was implemented periodically.

Table 1. *Heating schedule (Temperature setting is 20degrees C.)*

	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Living Room		■	■	■	■			■	■			■	■	■	■	■	■	■	■
Child Room 1																■		■	■
Child Room 2														■			■	■	

PHYSICAL PROPERTY OF BUILDING MATERIALS TO REGULATE INDOOR HUMIDITY

Building materials to regulate indoor humidity were assumed to be applied to ceilings and walls. The physical property is shown in Table 2.

Table 2. *Physical property of building materials to regulate an indoor humidity*

	Moisture control ceiling material	Moisture control wall material
Tickness [mm]	12	6
Density [kg/m3]	340	630
Thermal conductivity [W/(m･K)]	0.051	0.077
Specific heat [J/(kg･K)]	1067	1067
Moisture conductivity [kg/(m･s･Pa)]	4.30×10^{-11}	2.24×10^{-11}

NUMERICAL CALCULATION STANDARD

Numerical calculation standard is shown in Table 3. Window's thermal insulation improvement using Low-E double window panes (air space is 12mm) was assumed. Thermal insulation improvement was provided to windows but not to the entrance door, and the amount of dew condensation on the entrance door changed was verified. For Case 1, window thermal insulation was implemented, and Case 2 to 5, window thermal insulation was improved and building materials to regulate indoor humidity was used. Calculation interval was 1200s. Preliminary calculations was 7 days. Output was between January 1 and 31.

Table 3. *Numerical Calculation Standard*

	Blank	Case1	Case2	Case3	Case4	Case5
Window	―	Insulation	Insulation	Insulation	Insulation	Insulation
Living room	―	―	―	―	Moisture control	Moisture control
Child room 1	―	―	―	―	Moisture control	Moisture control
Child room 1	―	―	―	―	Moisture control	Moisture control
Main bed room	―	―	―	―	Moisture control	Moisture control
Closet	―	―	―	Moisture control	―	Moisture control
Entrance	―	―	Moisture control	―	―	Moisture control

NUMERICAL CALCULATION RESULTS

TEMPERATURE AND HUMIDITY CHANGE OF EACH ROOM

Changes of temperature, absolute humidity, and relative humidity in the living room, child room 1, the closet, and the entrance are shown in Figure 2 to 5. As for Case 1, where window's thermal insulation was improved, the lowest temperature was higher by approximately 2 degrees C in rooms, and room temperature in the closet and the entrance without windows rose by approximately 1 degrees C. Absolute humidity of Case 1 in each room was higher than that of Blank. This was because the reduced volume of dew condensation on the window surface existed in the indoor space. There was no large differences in the entrance of Case 2 and 5, where building materials to regulate indoor humidity were applied to. There are some periods when absolute humidity of Case 1 was slightly higher than that of Blank, but they were almost equivalent. In the rooms, a peak cut of high humidity zone was made in Case 4, where building materials to regulate indoor humidity were applied to, and effectiveness of such materials can be confirmed. In comparison between Case 3, where building materials to regulate indoor humidity were applied to the closet, and Case 4, where such materials were applied to child room 1, each peak was almost the same but fluctuation is smaller in Case 4. As for Case 5, where such materials were applied to closet and child room 1, fluctuation of relative humidity was more repressed, and an area effect can be confirmed. In the entrance, Blank's relative humidity fluctuation was small, so effect by building materials to regulate indoor humidity was small.

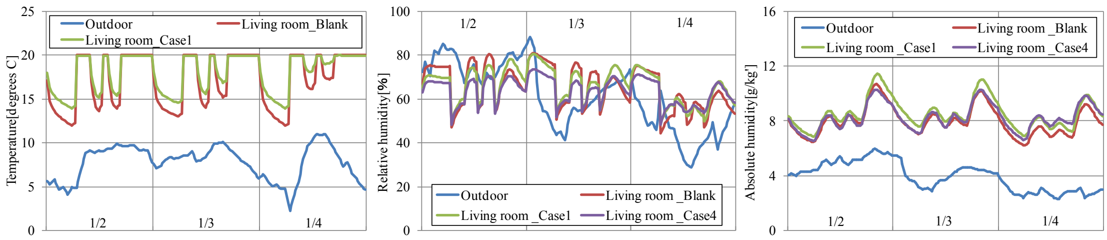

Figure 2. *Temperature and Humidity Fluctuation in Living Room (January 2 to 4)*

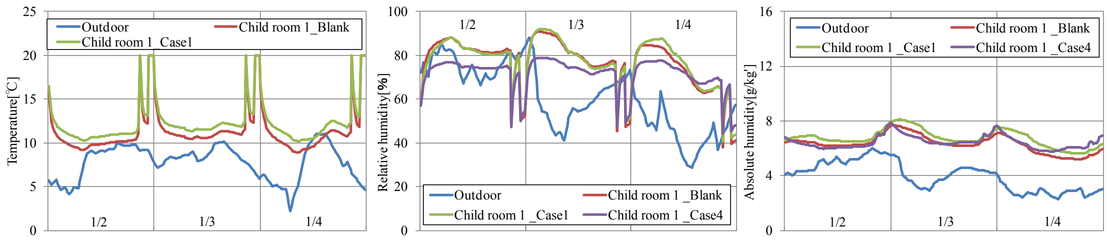

Figure 3. *Temperature and Humidity Fluctuation in Child Room1 (January 2 to 4)*

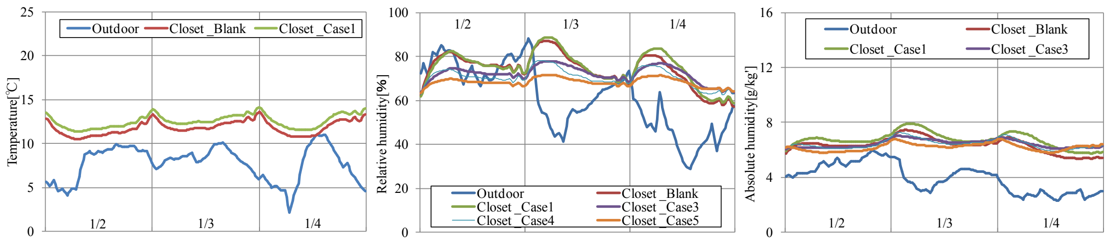

Figure 4. *Temperature and Humidity Fluctuation in Closet (January 2 to 4)*

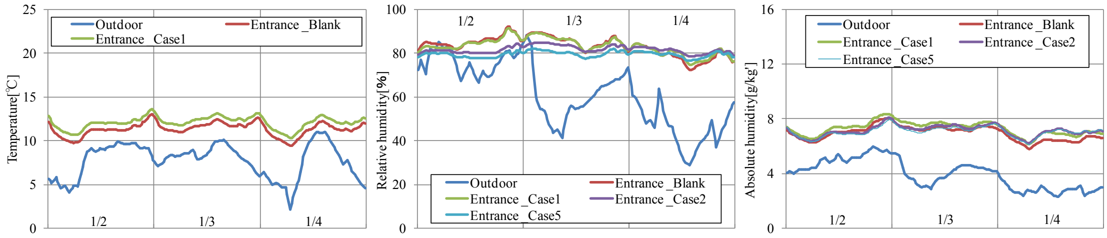

Figure 5. *Temperature and Humidity Fluctuation in Entrance(January 2 to 4)*

STATISTICS OF THE HUMIDITY ENVIRONMENT IN EACH ROOM

Maximum value, minimum value and an average of absolute humidity and relative humidity in each room in January are shown in Figure 6 and 7. Comparing Case 1 through 5, where window insulation was improved in each room, to Blank, absolute humidity average increased by approximately 0.3[g/kg']. There were no big changes in absolute humidity and relative humidity in the living room regardless of the presence or absence of building materials to regulate indoor humidity. It can be considered that humidity was not high and kept in the middle range. As for child room 1, humidity fluctuation range was small with Case 4 and Case 5, where effect of building materials to regulate indoor humidity could be confirmed. As for the closet, humidity fluctuation of Case 3 and that of Case 4 were almost equivalent. Case 4 is recommended to improve the humidity environment of a room that is next to a closet. Case 3 is recommended to improve humidity environment only in the closet while keeping cost low. Applying building materials to regulate indoor humidity to both spaces, the room and the closet, which is the case in Case 5, increases effect. As for the entrance, the humidity fluctuation range is small in Case 2 and Case 5. Applying building materials to regulate indoor humidity directly to the entrance and the hallway is effective in improving the humidity environment in the entrance.

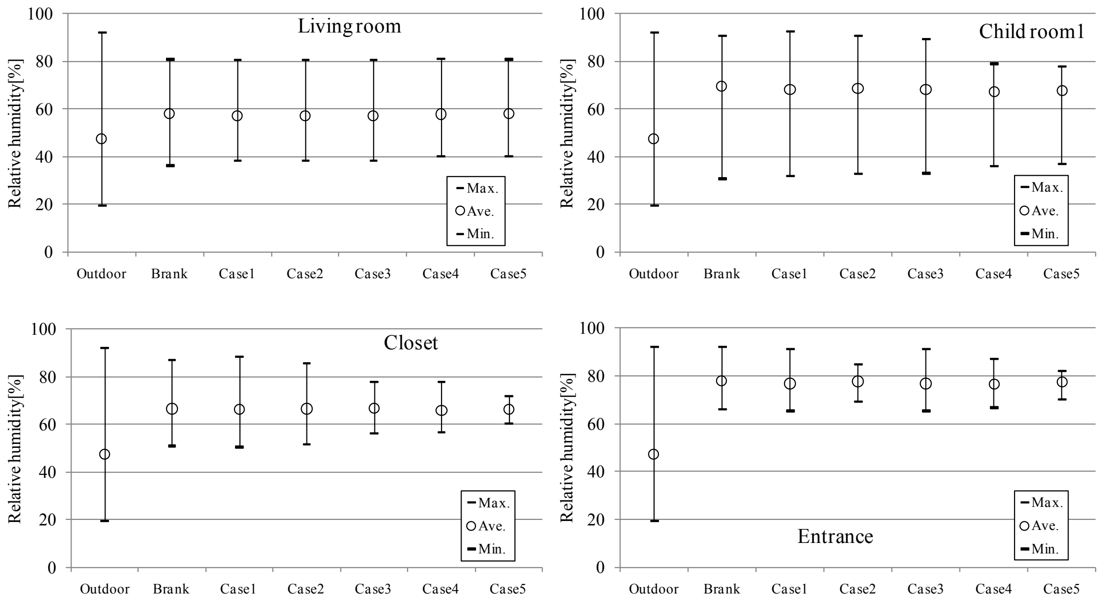

Figure 6. *Max., Min., Average of Absolute Humidity in Each Room (In January)*

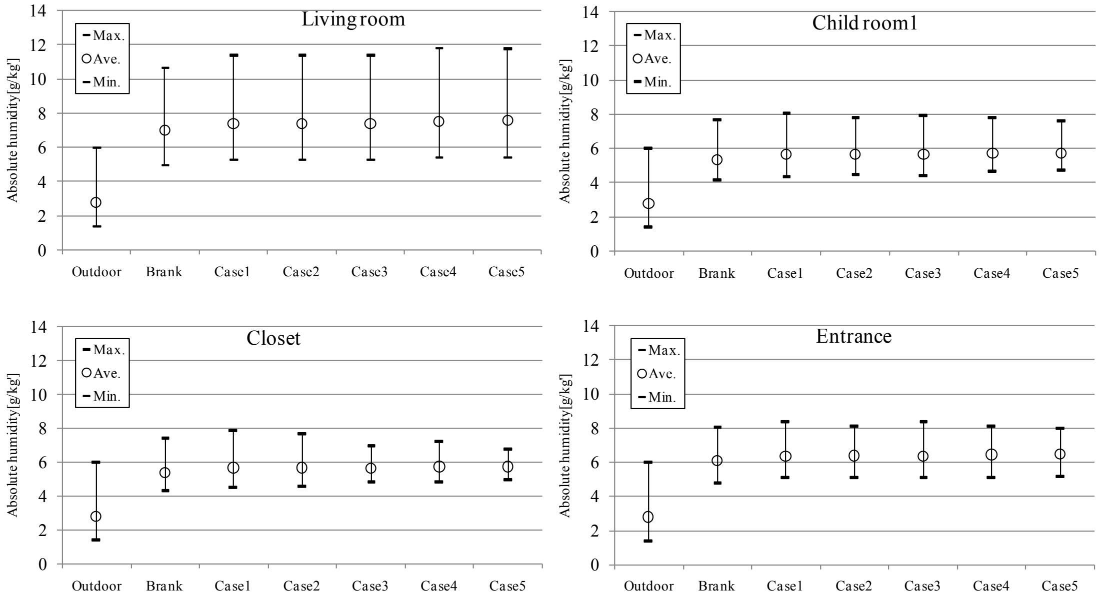

Figure 7. *Max., Min., and Average of Relative Humidity in Each Room (In January)*

FREQUENCY OF HIGH HUMIDITY RANGE APPEARANCE IN EACH ROOM

High humidity range (80RH% or more) appearance frequency in each room in January is shown in Figure 8. In the living room, a high humidity range hardly appeared. As for the closet, a high humidity range appeared more frequently in Case 1 compared to Blank, but the appearance frequency became zero after applying building materials to regulate indoor humidity to the closet, like in Case 3 through 5. As for child room 1, absolute humidity increased in Case 1, but the high humidity range appearance frequency decreased because temperature increase effect was larger. Appearance frequency became zero in Case 5. As for the entrance, frequency decreased in Case 1, which is same as child 1. Frequency decreased down to 10% or lower in Case 5.

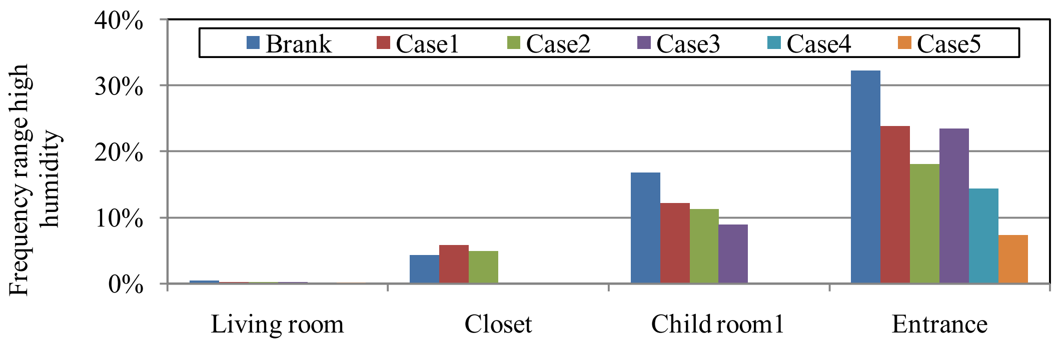

Figure 8. *High humidity range appearance frequency in Each Room (In January)*

DEW CONDENSATION VOLUME AT OPENING

Accumulated dew condensation volume of each room in January is shown in Figure 9. Dew condensation was zero in Case 1 through 5 of spaces except for the entrance, and window insulation improvement has an effect. However, the entrance door was not changed, so absolute humidity that was increased in each room condensed on the entrance door, resulting in increased dew condensation in Case 1. Also, dew condensation control effect on the entrance door by applying building materials to regulate indoor humidity could not be confirmed with this calculation.

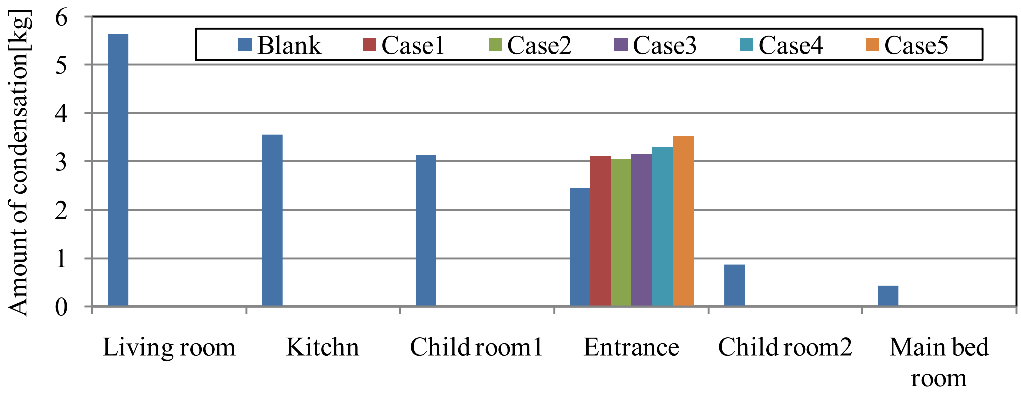

Figure 9. *Dew Condensation Volume at Opening in Each Room (In January)*

CONCLUSION

In this research, the following points were clarified concerning the humidity environment after window insulation improvement and dew condensation at opening sections of RC construction apartment buildings with no insulation in Tokyo.

1) Room temperature becomes higher by improving window insulation, and the amount of condensation on the window surface greatly decreases.
2) The amount of condensation on the window surface decreases by improving window insulation, but absolute room humidity increases.
3) In comparatively warm regions such as Tokyo, absolute humidity does not increase much when window insulation is improved.
4) Without improving entrance door insulation, the amount of dew condensation on entrance doors increases when window insulation has been improved.
5) Frequency of appearance of high humidity zones can be reduced by using building materials to regulate indoor humidity in the living room or closets.
6) Slight condensation on the window surface after improving window insulation can be reduced by using building materials to regulate indoor humidity.
7) Building materials to regulate indoor humidity are not overly effective in reducing condensation on entrance doors.

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