A Study on the Indoor Environmental Factors of Granite Dome Models with Different Envelop Materials during the Summer Season

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Key words : Environmental element, Relative humidity, Envelop structure, Miniature model, Dry bulb temperature, Air velocity

Abstract

During the summer season, it is very hot and humid in Korea. So the humidity is an important factor regarding the environmental control function of building envelops. The purpose of this research is to measure and analyze the characteristics of such environmental factors as relative humidity, dry bulb temperature and air velocity varies both in the clay and cement envelop structures using granite dome models during the summer time. The interior relative humidity of the clay model is constant regardless of exterior humidity although a little range of variation is shown in comparison to the cement model.

Nomenclature

r^2	: Determination coefficient
RH	: Relative humidity [%]
T	: Time [h]
Ta	: Dry bulb temperature [℃]
v	: Air velocity [m/s]
Wt	: Weight of vaporized water [g]

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1. Introduction

Summer climate conditions in Korea feature high temperature and humidity with frequent typhoon and rainfall. Therefore, one should look out for moisture in designing building envelope during the summer season. The moisture transfer in building envelopes is very complicated as is heat transfer.

Studies on moisture transfer in porous structures have been conducted in the field of fiber and construction engineering. However studies are insufficient on moisture absorbing, emitting, and transfering in the wall structure under the real environmental conditions, which fluctuates widely both in temperature and humidity.[1]

This experiment is to measure and analyze the characteristics of variation in indoor environment factors (relative humidity, dry bulb temperature, air velocity, etc) in different envelop structures (clay+granite, cement+graynite) under the natural atmospheric conditions during the summer.

2. The Scope and Method of Study

2.1 Experiment Model

For the experiment, stone model domes were constructed with granite and equipped with evaporating dishes inside the model dome. Variations in relative humidity, dry bulb temperature, air velocity, and weight of evaporated water was measured and analyzed in each structure in the underground laboratory under natural atmospheric conditions during the summer season.[2]

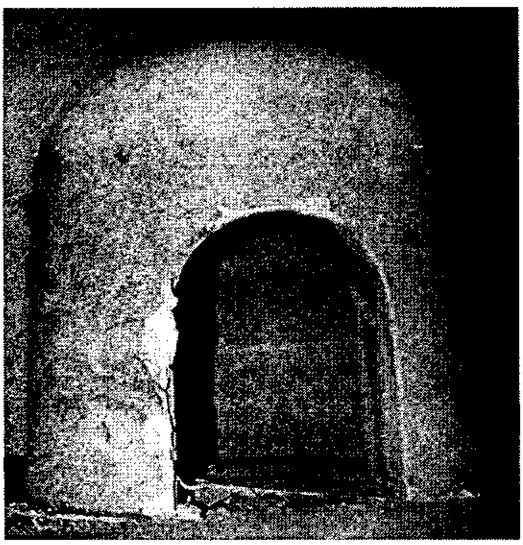

Fig. 1 Dome Model.

The models used in this experiment consist of average 9.5cm thick granite covering with either clay or cement. One of the envelop materials is 3-4cm thick clay and the other is 3-4 cm thick cement. The inside of the models is cylindrical in shape and the outside is 40cm in diameter and 48cm high.

For simulating the ventilation effect, 14 holes were bored, each hole is 1cm in diameter. An evaporating dish was equipped inside each model.

Cracks on the clay structure caused during the drying process required several times of clay plastering. Then, the structure was dried for about a month under the atmospheric conditions. On the other hand, cement structure did not show any crack after the model construction, it took two months to cure and dry the cement structure.

After confirming that the clay and cement are sufficiently dried by observing and touching the surface of models, main experiment was conducted (See Fig. 1, 2).

2.2 Experiment Method

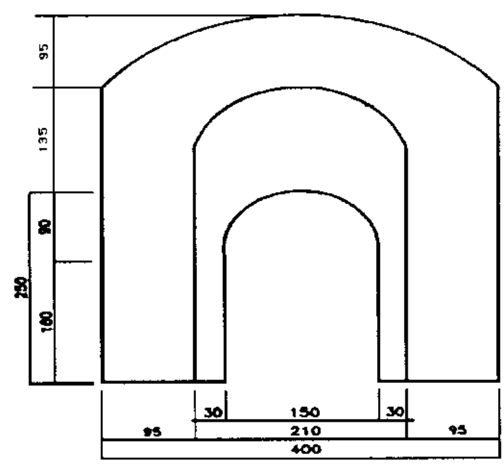

Fig. 2 Dimensions of a Dome Model (Unit : mm).

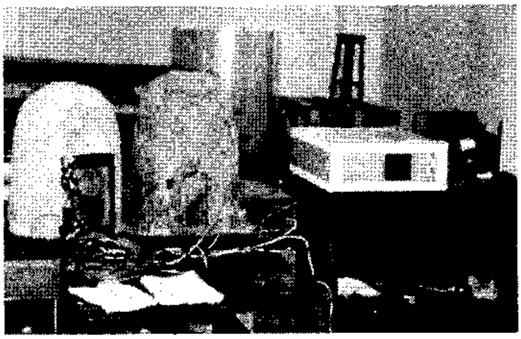

Fig. 3 Dome Models and Measuring Instruments.

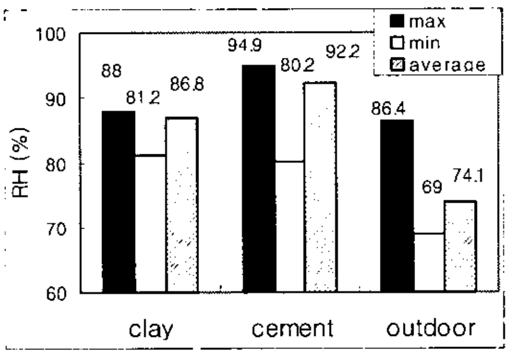

Fig. 5 Distribution of Relative Humidity.

The experiment was conducted in the underground environment laboratory. Environmental factors of dry bulb temperature, relative humidity, and air velocity were measured. Moisture evaporated under the natural conditions inside the models. During the experiment, only participants were given access to the laboratory because of maintaining the environmental condition.

The varying environmental factors inside and outside the structures were measured with Multi-channel Anemomaster (Kanomax), and the measurement was connected with a personal computer to be stored and analyzed by s-6242 software.

The experiment period was from August 8 to August 13, 1999 (6 days).

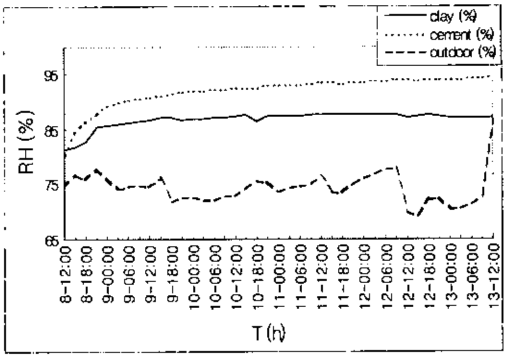

Fig. 4 Comparison of Relative Humidity between the Clay and Cement Model.

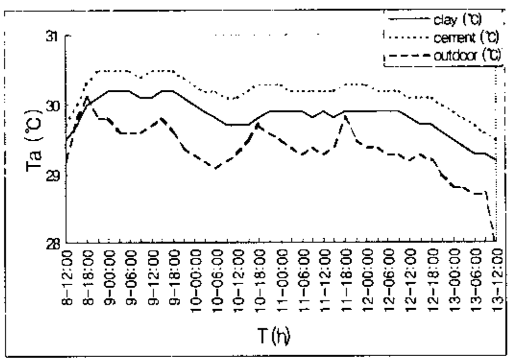

Fig. 6 Comparison of Dry Bulb Temperature between the Clay and Cement Model.

3. Results and Discussion

3.1 The Distribution of Relative Humidity and Air Velocity

Fig.4 shows the change in relative humidity during the measurement. Interior and exterior relative humidity of clay and cement structures was measured.

The relative humidity was 69.0-86.4% (average 74.1%) outside the model, 81.2-88.0% (average 86.8%) inside the clay structure, and 80.2-94.9% (average 92.2%) inside the cement structure. It reveals that the relative humidity of the cement structure is average 5.4 % higher than that of the clay structure. Apparently that is because clay is superior to cement in the capacity for retaining water (See Fig. 5).

The interior relative humidity of both clay and cement structures was average 12.7-18.1 % higher than exterior relative humidity. It is due to the average moisture content of the materials and the moisture vaporized from the evaporating dish.

In terms of relative humidity, when there is any change in exterior humidity, the same pattern, even though the range is smaller, is observed in the clay structure and consistent high humidity in the cement structure.

In conclusion, the clay structure has some channels for ventilation while the cement structure holds the moisture in the material.

The air velocity in the underground laboratory was average 0.01m/s with rare and small change presumably because of the characteristics of the air in the basement. It is estimated that evaporation of surface water due to air current is consistent.

3.2 The Distribution of Dry Bulb Temperature Condition

Fig. 6 demonstrates the change in dry bulb temperature during the measurement period.

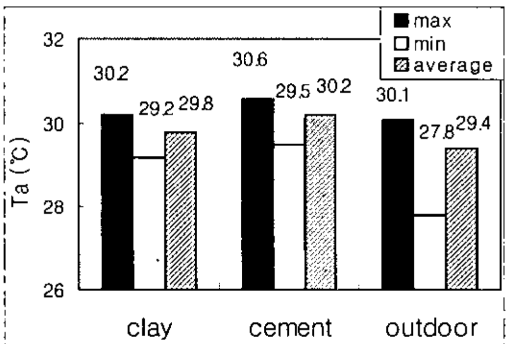

Fig. 7 Distribution of Dry Bulb Temperature.

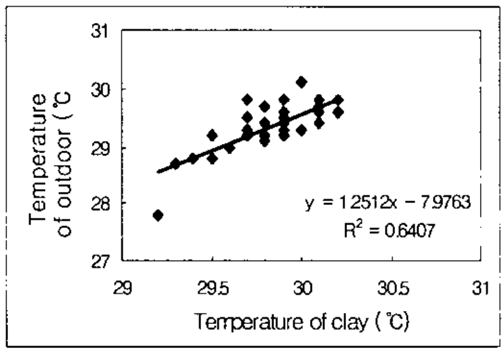

Fig. 8 Correlation between the Ambient and Indoor Temperat ure of the Clay Model.

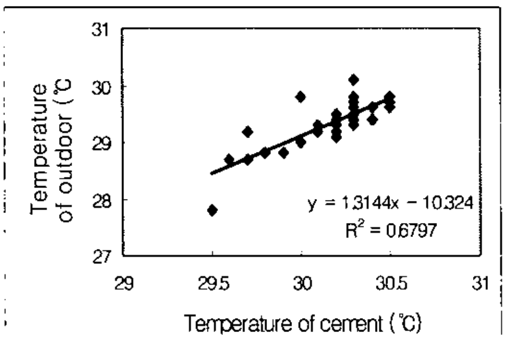

Fig. 9 Correlation between the Ambient and Indoor Tempera ture of the Cement Model.

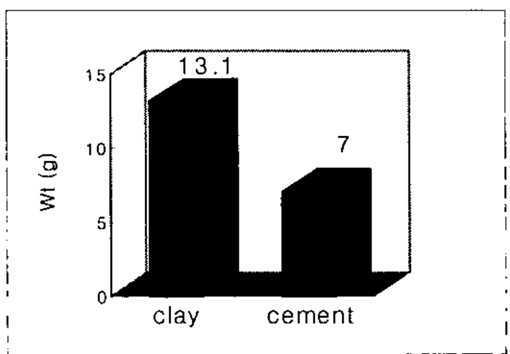

Fig. 10 Weight of Vaporized Water.

The graph exhibits the change in interior and exterior dry bulb temperature of clay and cement structures.

The distribution of dry bulb temperature during the measurement period was as follows: the temperature was 27.8-30.1℃ (average 29.4℃) inside the underground environment laboratory, 29.2-30.2℃ (average 29.8℃) inside the clay structure, and 29.5-30.6℃ (average 30.2℃) inside the cement structure, indicating mutually similar temperature.

The range of temperature change is 1-2℃ in the laboratory with little difference between day and night. It is expected that evaporation doesn't increase with change in temperature condition.[4]

3.3 The Evaporating Amount and Correlation Rate between Interior and Exterior Temperature

Fig. 8 and Fig. 9 illustrate the correlation rate of dry bulb temperature between inside and outside the clay and cement structures. The correlation rate of dry bulb temperature was $r^2 = 0.64$ between the interior and exterior clay model, and $r^2 = 0.68$ between the interior and exterior cement model.[3] The correlation rate was high in both the clay and cement model. Thermal conductivity of each material doesn't seem to make much difference in the correlation rate.

Thermal conductivity of cement concrete is average 1.4 kcal/mh℃ and that of clay is average 0.6 kcal/mh℃. Clay has greater thermal resistance than cement. This feature can create time lag effect when the envelop of the model structure is thick and effect change in temperature depending on envelops (clay and cement).

In this experiment, however, the structures have thin finishing material of 3-5 cm thick envelops. Therefore the thermal conductivity had little effect on change in interior and exterior dry bulb temperature (See Fig. 5).

The net weight of vaporized water was 13.1 g in the clay structure and 7.0 g in the cement structures. In the clay structure 0.7 g more water has evaporated. It is because clay has more moisture content than cement, and because of ventilation through hair cracks of clay and voids of gravel (See Fig. 10).

4. Conclusion

In this study the variation in environmental factors (relative humidity, dry bulb temperature, air velocity, the amount of vaporized water) of different envelop structures (clay+granite, cement+granite) was measured and analyzed under the natural atmospheric condition during the summer time.

The summarized conclusion of the study is as follows.

(1) The relative humidity of the cement structure is average 5.4 % higher than that of the clay structure. The amount of vaporized water was larger inside the clay structure than inside the cement structure by 6.1g.

(2) The distribution of dry bulb temperature during the measurement period was 27.8 - 30.6 ℃. The air velocity was 0.01 m/s and was constant throughout the measurement period.

The correlation rate of dry bulb temperature between inside and outside the structures was about $r^2 = 0.6$. The envelop material didn't make much difference in temperature because the finishing material was only 3-4 cm thick.

(3) The clay structure has some channels for ventilation while the cement structure con-

tinues to retain water.

More experiment under various conditions of temperature and humidity is expected. Besides result analysis using chamber, an equipment for artificial weather, and simulation will be necessary in the future.

Postscript

This study has been conducted with Bisa Research Funds of Keimyung University.

References

(1) ASHRAE. 1996. HAVC System and Equipment.

(2) K. H. Yim, S. U. Jeong, Y. G. Yim, S. H. Kong, et al. 1998. "A study on survey of indoor environment of Seokguram miniature model dome in winter." Air conditioning and refrigeration engineering society of Korea, 98 Summer Symposium, pp. 187-190.

(3) S.B Leigh, 2000, "A study for predicting building energy use with regression analysis", Korea journal of Air-conditioning and refrigerating engineering, Vol. 12, No. 12, pp.1090-1097.

(4) J. J. Yee, 2000, "The proposal of a guantitative evaluation method on mixing loss in the HVAC system design", Korean journal of Air-conditioning and refrigerating engineering, vol. 12, No. 10, pp.879-885