A Study on the Characteristics of Environmental Factors of Granite Dome Models with Different Materials during Winter Season

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Key words : Environmental factor, Relative humidity, Envelop material, Miniature model, Dry bulb temperature, Air velocity

Abstract

Factors governing the rate of heat exchange comprise temperature, air velocity, relative humidity, and relation indoors. Recently, there are many researches on the transient analysis of indoor environmental factors such as dry bulb temperature, relative humidity and air velocity in miniature models. The purpose of this study is to measure the environmental factors and to analyze and evaluate the characteristics of indoor environment in different envelop structures using granite dome models. The interior relative humidity 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

Modern people, who have got used to envelop materials of cement and concrete, increasingly favor clay-finished envelop material. The environmental factors inside and outside the clay and cement envelop structures include temperature, humidity, smell, air veloc ity, and organic or inorganic compounds. This phenomenon of variation is very complicated.

Although studies on water movement in porous materials have been conducted in the field of construction engineering, studies in the architectural environment, which fluctuates widely in temperature and humidity condition, leave much to be desired.[2]

Previous studies have mainly focused on the analysis of dry bulb temperature. But in effect, air movement, temperature, and humidity are closely connected with one another.

This paper is to analyze the characteristics of variation in interior and exterior environmental factors (dry bulb temperature, relative humidity, air velocity, etc) in different envelop structures (clay+granite, cement+granite) under the natural atmospheric conditions during the winter.

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 winter season.[1]

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

For simulating the ventilation effect, 14 holes were bored, each of 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.

After confirming that the clay and cement are sufficiently dried by observing and touching the surface of models, main experiment

Fig. 1 Dome Model.

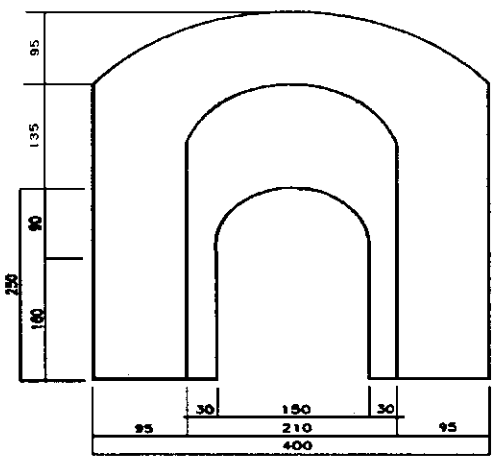

Fig. 2 Dimensions of a Dome Model (Unit : mm).

was conducted (See Fig. 1, 2).

2.2 Experiment Method

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, and it was restricted to open and close the windows adjoining outside.

Measurement of varying environmental factors inside and outside the structures was processed by sending electric signals remitted by Multichannel Anemomaster to 9-channel Data logger. It was then connected with a personal computer to be stored and analyzed by s-6242 software (See Fig. 3).

The period of the experiment and measurement including preliminary test was February, 12 - 15, 1998 (4 days) and February, 18 - 23, 1998 (6 days).

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 61.5-83.6% (average 70.9%) outside the model (in the laboratory), 90.7-95.8% (average 94.3%) inside the clay structure, and 91.5-98.3% (average 95.7%) inside the cement structure. It reveals that the relative humidity of the cement structure is average 1.4% higher than that of the clay structure. Apparently that is because clay is superior to cement in the capacity for retaining water.

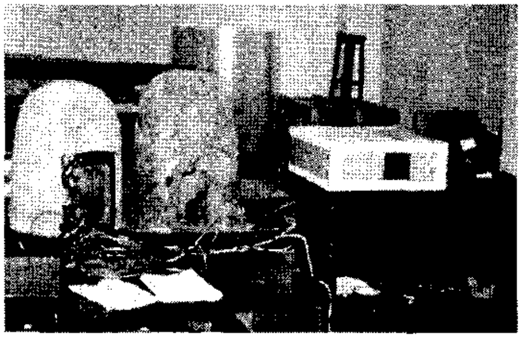

Fig. 3 Dome Models and Measuring Instruments.

The interior relative humidity of both clay and cement structures was average 23.4-24.8% 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

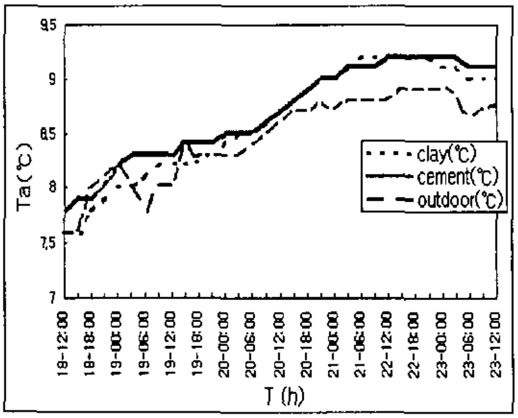

Fig. 4 Comparison of relative Humidity between the Clay and Cement Model.

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 (See Fig. 4).

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]

3.2 The Distribution of Dry Bulb Temperature Condition

Fig. 6 demonstrates the change in dry bulb temperature during the measurement period. The graph exhibits the change in interior and exterior dry bulb temperature of clay and cement structures.

The temperature was 7.6-8.9℃ (average 8.4℃) inside the under ground environment laboratory, 7.6-8.9℃ inside the clay structure, and 7.8-9.2℃ inside the cement structure, indicating mutually similar temperature.

Because of rare change in temperature in the basement, the range of temperature change was 1-1.5℃, showing little difference between day and night. It is expected that evaporation doesn't increase with change in temperature condition. Thermal conductivity of cement concrete is average 1.4kcal/mh℃ and that of clay is average 0.6kcal/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 can effect changes in temperature depending on envelops (clay and cement). In this experiment, however, the structures have thin finishing material of 3-5cm thick envelops. Therefore the thermal conductivity had little effect on change in interior and exterior dry bulb temperature (See Fig. 5).

3.3 The Evaporating Amount and Interior/Exterior Correlation Rate

The bar graphs in Fig. 6 indicate the amount of vaporized water in evaporating dishes, which were equipped in the clay and cement structures respectively during the whole measurement period. The net weight of vaporized water excluding the dish weight was measured with electronic balance.

The net weight of vaporized water was 4.2 g in the clay structure and 3.5 g in the cement structures. The amount of vaporized wa-

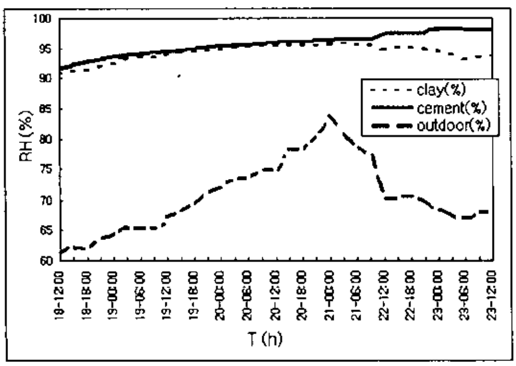

Fig. 5 Comparison of Dry Bulb Temperature between the Clay and Cement Model.

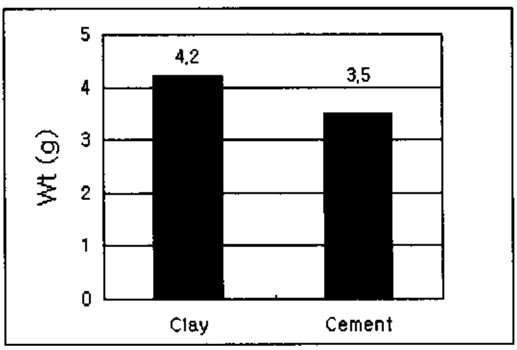

Fig. 6 Weight of Vaporized Water.

ter was larger inside the clay structure than inside the cement structure by 0.7g (See Fig. 6).

Fig. 7 and Fig. 8 illustrate the correlation rate of relative humidity between inside and outside the clay and cement structures. The correlation rate of relative humidity was $r^2 = 0.8$ between the interior and exterior clay model and $r^2 = 0.2$ between the interior and exterior cement model. The correlation rate was higher in the clay model than in the cement model.[4]

Fig. 9 and Fig. 10 demonstrates the correlation rate of dry bulb temperature between inside and outside the models of clay and cement. The correlation rate of dry bulb temperature was $r^2 = 0.92$ between the interior and exterior clay model, and $r^2 = 0.89$ between the interior and exterior cement model. The correlation rate of both the clay and cement models is high. That is because the finishing material of the envelop was not thick enough to have much influence on the correlation rate of dry bulb temperature of each material.

In conclusion, the clay structure has some channels for ventilation. After they hold moisture they distribute it. On the other hand the cement structure continuously retains water in itself.

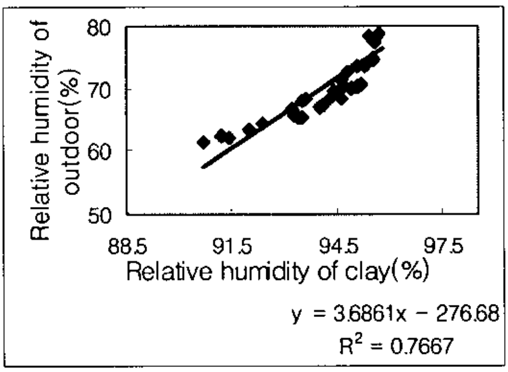

Fig. 7 Correlation between the Ambient and Indoor Humidity of the Clay Model.

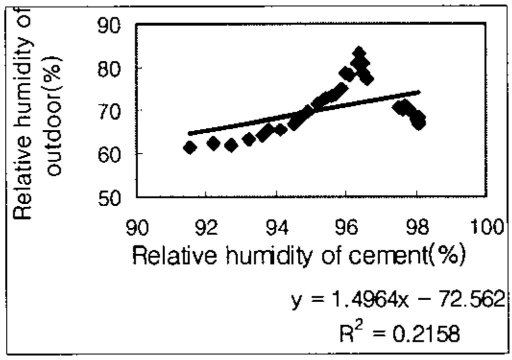

Fig. 8 Correlation between the Ambient and Indoor Humidity of the Cement Model.

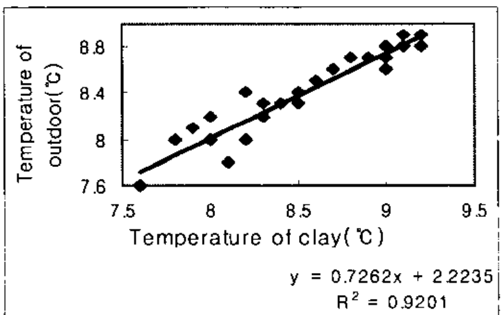

Fig. 9 Correlation between the Ambient and Indoor Temperature of the Clay Model.

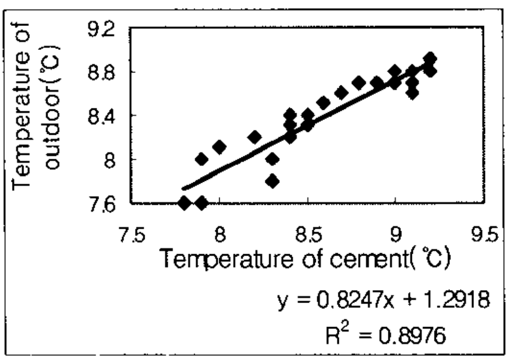

Fig. 10 Correlation between the Ambient and Indoor Temperature of the Clay Model.

4. Conclusion

The distinctive variation in environmental factors of inside and outside the envelop materials (clay+granite, cement+granite) was measured and analyzed in this experiment.

The summarized conclusion of the study is as follows.

(1) The net weight of vaporized water was 4.2g in the clay structure, 3.5g in the cement structures. The amount of vaporized water was larger inside the clay structure than inside the cement structure by 0.7g.

(2) The clay structure has some channels for ventilation while the cement structure continues to retain water.

(3) The distribution of dry bulb temperature during the measurement period was 7.6-9.2℃ with no significant difference between the models. It is estimated that the thermal conductivity was not much affected by the material. The air velocity was around 0.01m/s throughout the measurement period.

(4) The relative humidity was 61.5-83.6% (average 70.9%) outside the model (inside the basement), 90.7 -95.8% (average 94.3%) inside the clay structure, and 91.5-98.3% (average 95.7%) inside the cement structure. It reveals that the relative humidity of the cement structure is average 1.4% higher than that of the clay structure. That is because clay has more moisture content than cement.

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

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