TO CHAPTER 6

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A CASE STUDY ON GLOBAL-CONSCIOUS AND LOCAL-ORIENTED HOUSING DESIGN IN A HOT AND HUMID CLIMATE

Part 2 Evaluation of the thermal environment in indoor and semi-outdoor spaces

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ABASTRACT In order to confirm the effectiveness of the indoor climate control system adopted in the experimental house, the indoor climate in summer was evaluated for the experimental house and two other buildings in Nanning city and a comparison was made. Two vernacular buildings which have natural indoor and semi-outdoor cooling systems were selected for the study. The majority of the measurements were taken using the spherical thermography system. The results showed that the quality of the indoor thermal environment of each building is approximately the same. However, the experimental house can also provide hot water and winter heating by using solar energy. This provides an argument for installing the technologies used in the experimental house in buildings in semi-tropic regions such as Nanning city.

1 Introduction

In part 1, a summary was given of the indoor climate control system of the experimental house. A number of parts of the indoor climate control system incorporate cooling functions which use natural energy. Of these, the two main cooling functions are the heat exhaust system which reduces the heat entering the room from the roof, and the nocturnal radiation cooling system which cools the precast hollow concrete slabs.

A number of other natural cooling systems are commonly adopted in the buildings in Nanning city. Therefore to evaluate the feasibility of the experimental house, we compare the indoor thermal environment of the experimental house with two other buildings in Nanning which use a vernacular natural cooling system.

2. Summary of observations

2.1. Summary of the buildings used for the comparison

In the present study, only buildings capable of housing a passive cooling system suitable for a semi-tropical area such as Nanning, were considered. Based on this, two buildings were selected for the comparison. Thus, the indoor thermal environment was evaluated for the following buildings:

Case 1: The new experimental house introduced in this study
Case 2: The top story of an apartment building
Case 3: A semi-outdoor space in a traditional vernacular house

Case 2 is a 6-story building in Nanning (Fig.1). At the top of the building, the building has eaves to control the receipt of solar radiation to the top story. The building is constructed of reinforced concrete with a double skin roof made of unglazed brick (Fig.2). The brick layer over the roof is believed to reduce the amount of solar heat coming into the rooms.

Fig.1 External view of case 2

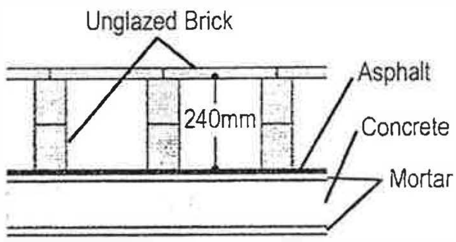


Fig.2 Cross-section of double skin roof

Case 3 is a vernacular house built approximately 300 years ago. The house is still used as provisional accommodation. In the present study, a semi-outdoor meeting and rest place called a "menching" was selected for the evaluation. Fig.3 is a complete birds-eye-view of the vernacular house and Fig.4 is an internal view of the menching. The walls are made of blue brick, and the floors are made of blue brick and stone. The floor of the menching is made of stone and performs a radiant cooling function.

Fig.3 Birds-eye view of vernacular buildings

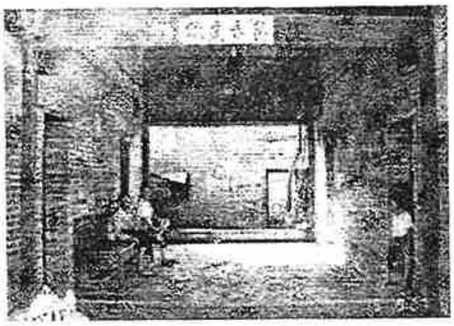
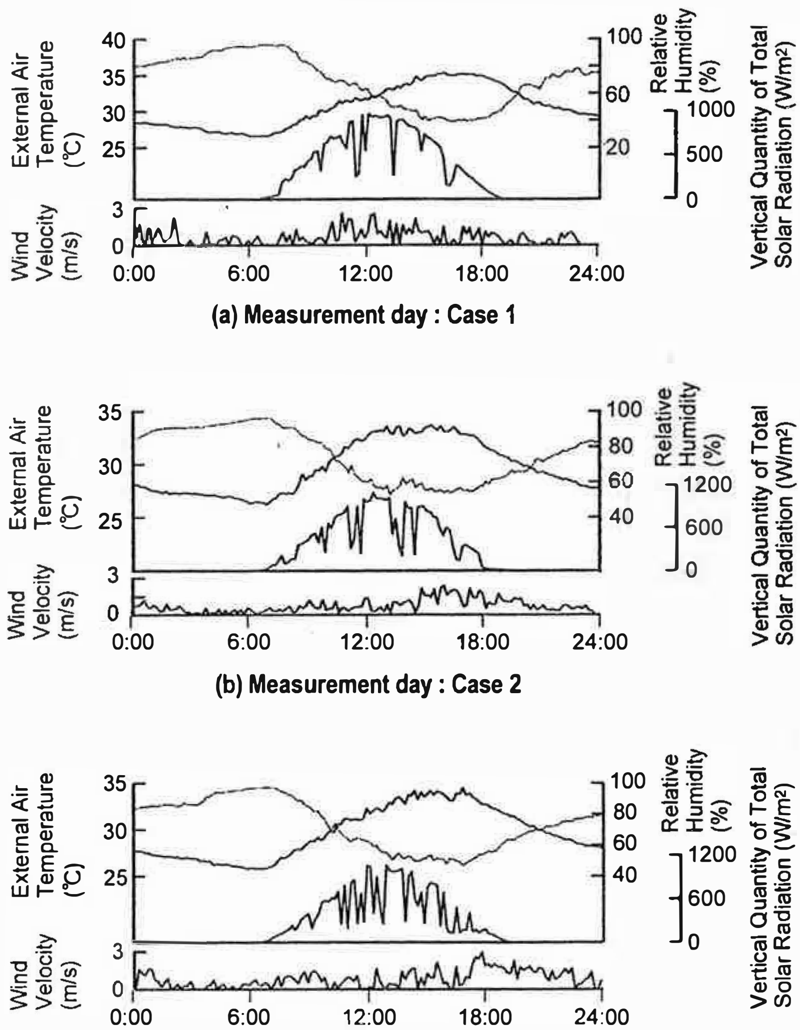


Fig.4 Internal view of *menching*

2.2. Measurement of the indoor thermal environment

The data measured on fine days was used for the evaluation. Fig.5 shows the weather conditions of the evaluation days. The measurements taken were spherical thermographs[1], ambient air temperature, relative humidity and wind velocity. Fig.6 shows the view and specification of the spherical thermograph detecting system. The data required to evaluate the thermal radiant field such as, mean radiant temperature (MRT) was calculated using the spherical thermography data.

Wind velocity was measured using a hot wire anemometer. For the evaluation, the data was measured for three minutes and the mean value was calculated. The position for capturing the spherical thermograph was set at a height of approximately 1.2 m which corresponds to the position of the average person's trunk. Fig.6 shows the location of each measurement point. Spherical thermographs were taken at different times throughout the day. The times were approximately, 7:00~8:00, 13:00~14:00 and 17:00~18:00 hours.

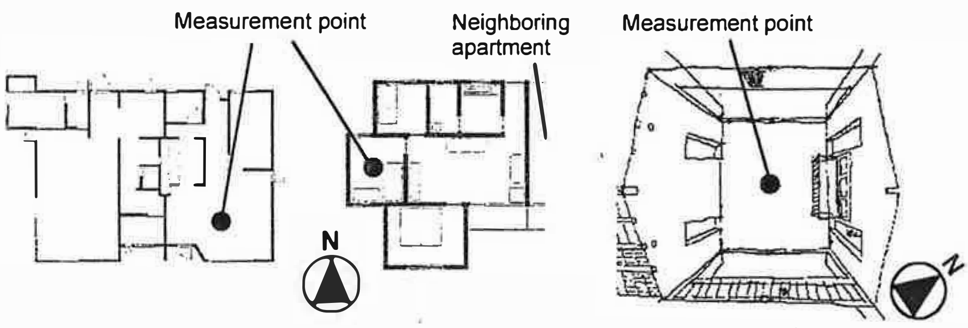


(a) Measurement day : Case 1

(b) Measurement day : Case 2

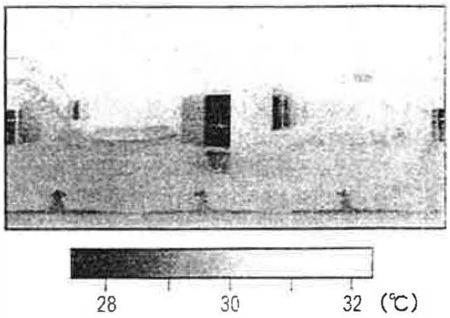
(c) Measurement day : Case 3

Fig.5 Weather conditions

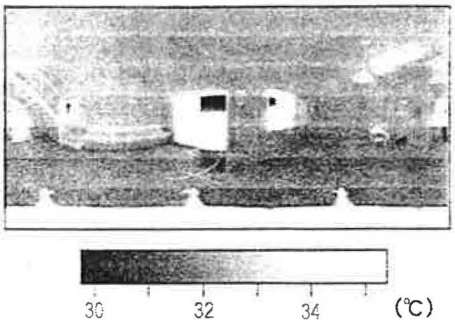


Case 1 Case 2 Case 3

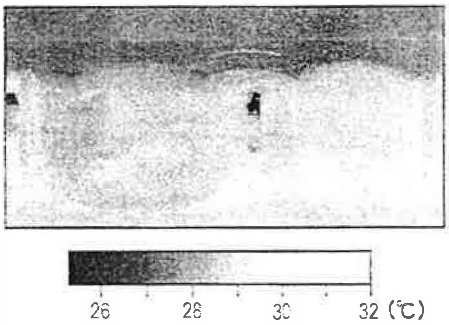
Fig.6 Location of measurement points



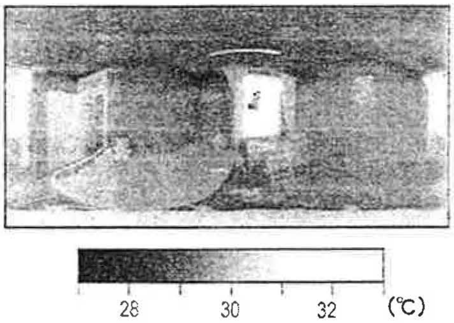
[Case 1] AM 6:35~37, Air Temperature 28.6°C
Relative Humidity 90%
MRT 29.8°C, Wind Velocity 0.1m/s



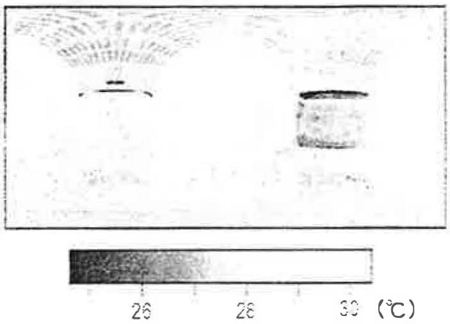
[Case 1] PM 2:28~30, Air Temperature 33.3°C
Relative Humidity 56%
MRT 32.6°C, Wind Velocity 0.3m/s



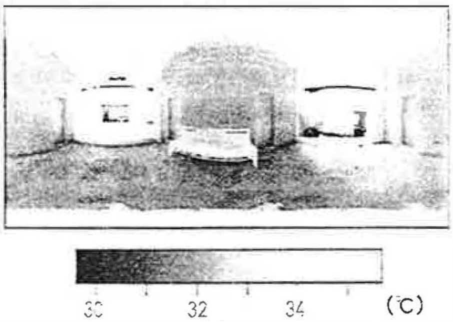
[Case 2] AM 7:39~41, Air Temperature 28.9°C
Relative Humidity 85%
MRT 28.6°C, Wind Velocity 0.2m/s



[Case 2] PM 1:31~33, Air Temperature 30.1°C
Relative Humidity 68%
MRT 30.1°C, Wind Velocity 0.2m/s



[Case 3] AM 7:57~59, Air Temperature 28.3°C
Relative Humidity (No Data)
MRT 28.3°C, Wind Velocity 0.2m/s



[Case 3] PM 1:31~33, Air Temperature 34.3°C
Relative Humidity 54%
MRT 33.2°C, Wind Velocity 0.4m/s

(a) Morning

(b) Afternoon

Fig.7 Spherical thermographs

3 Measurement results and discussion

Fig. 7-(a) shows the spherical thermograph for each case in the morning. In case 1, the radiant temperature at the floor was relatively lower than the other parts of the room. In case 2, the radiant temperature at the ceiling was the lowest in the room. The value is a few degrees lower than the air temperature. However in both case 1 and case 2, the cooler area is the result of the nocturnal radiation cooling system in each case.

The spherical thermographs for each case in the afternoon are shown in Fig.7-(b). In case 1 and case 3, the radiant temperature at the floor, made of concrete and stone, was lower than the other parts of the room. This is because of the large heat capacity of the floor. The radiant temperature distribution in case 2 was uniform and the value was a few degrees lower than the air temperature. A wind was passing through the space of case 2 because of north and south facing windows. Thus, the thermal comfort of case 2 was excellent during this time of the day.

In order to evaluate the thermal radiant field, the PRT distribution at each measurement point was calculated (Fig.8). In case 1, the roof surface was subject to strong solar radiation with an irradiance of approximately 1000 W/m^2. However, the upper side PRT was almost equivalent to that of case 2 and case 3 indicating that the heat-exhaust function of the roof operates efficiently. The down side PRT was the lowest of the six directions and results from the floor cooled down during the night.

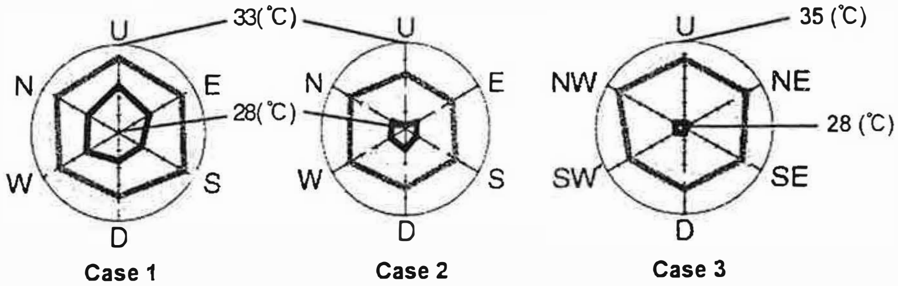


Fig.8 **PRT distribution at each measurement point**

In case 2, the upper side PRT was the lowest of the six directions and MRT was approximately equal to or lower than the air temperature. This suggests the heat reducing function of the double-skin roof, which is made of unglazed brick, was very efficient. The cooling phenomena might be caused by both evaporation and convection.

In case 3, similar to case 1, down side PRT was highest in the afternoon and evening. This results from the stone floor cooled down during the night. The highest PRT was the upper side PRT and this occurred in the afternoon. This was because the radiant temperature of the ceiling was raised by solar radiation. However, after a rainfall, evaporation from the unglazed roof tiles may reduce the surface temperature.

4 Conclusion

The indoor thermal environment of spaces in the experimental house and two vernacular buildings in Nanning were compared to each other. All of the selected buildings have cooling systems which use natural energy. The results showed that the quality of the indoor thermal environment of each house is approximately the same. However in addition, the experimental house can operate a hot water supply and provide heating in winter using solar energy. This is impossible for the other buildings. Therefore, these results can be used to argue that the technologies used in the experimental house should be implemented in semi-tropic regions such as Nanning city.

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5 References

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