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PROPOSAL OF CLIMATIC MITIGATION RATIO FOR EVALUATION OF THERMAL COMFORT INSIDE SEMI-OUTDOOR SPACE ATTACHED TO BUILDINGS CORRESPONDING TO GEOGRAPHICAL CHARACTERISTICS

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ABSTRACT

A new index “climatic mitigation ratio” was proposed to express the effect of climatic mitigation in semi-outdoor spaces attached to buildings corresponding to geographical characteristics in the world.

First, to evaluate thermal comfort, thermal environments in several semi-outdoor spaces were investigated on field observations; the enclosed arcade located under moderate climate in Japan both in summer 1995 and in winter 1996, the continuous covered walkways located in Southeast Asia under tropical climate in summer 1996 and the covered malls located in West Europe under cold climate in winter 1996. These field observations included measurements on air temperature, surface temperature, air velocity, solar radiation, etc.

Second, based on these investigations, taking geographical characteristics into account, the index "climatic mitigation ratio " was proposed considering geographical characteristics. In the index, semi-outdoor spaces are expressed as heating mitigation in hot season and as cooling mitigation in cold season.

Finally, the climatic mitigation ratio was applied to evaluate the climate in some semi-outdoor spaces at Imabari, Japan, and in Southeast Asia and West Europe. By compared with some semi-outdoor spaces in several areas, the characteristics of the climate in semi-outdoor space could be evident.

INTRODUCTION

A semi-outdoor space attached to buildings locates between indoor and outdoor. A function of a semi-outdoor space is mitigating outdoor climate without mechanical air-conditioning units and providing comfortable public space in urban area. For example, there are arcades which are seen in Japan, “gangi” arcades and “komise” arcades in North Japan, continuous covered walkways in South China and Southeast Asia (called “five foot way” in Malaysia and Singapore and “xiãng-zai-jiáo” in Taiwan), and covered malls in West Europe and North America (called “arcade”, “passage”, “galleria”, etc.).

An inside of atrium designed in a building is similar to a semi-outdoor space, but almost all of atria have air-conditioning units or other mechanical thermal controlling sysytem. Many researchers have investigated thermal comfort of the inside of atrium. However, that in semi-outdoor spaces attached to buildings has been indifferent. It is needed to evaluate it corresponding to geographical characteristics and to apply to design semi-outdoor spaces.

Therefore, first, it is essential to investigate the actual conditions of the thermal comfort in semi-outdoor space located in Japan. Then, to compare with them, other semi-outdoor spaces in Southeast Asia and West Europe under harsher climate were investigated. Finally, some methods were proposed to evaluate the thermal comfort in semi-outdoor space corresponding to geographical characteristics, whivh were needed to compare various semi-outdoor spaces and to design semi-outdoor spaces.

METHODS

The thermal environments in the following semi-outdoor spaces were investigated on field observations.

(1) Enclosed arcade located in moderate climate area in Japan

- Imabari (Summer) : August 10 (fair) and 11 (fair and rainy for a while), 1995
- Imabari (Winter) : January 11 (fair), 1996

(2) Continuous covered walkways located in Southeast Asia under tropical climate

- Taipei (Taiwan) : August 20 (fair) and 21 (fair), 1996
- Singapore : August 25 (fair) and 26 (cloudy and fair for a while to rainy), 1996
- Georgetown (Penang Is., Malaysia) : August 29 (cloudy to fair and rainy) and 30 (cloudy to fair), 1996

(3) Covered malls located in West Europe under cold climate in winter

- Hamburg (Germany) : December 10 (cloudy) and 11 (cloudy), 1996
- Milan (Italy) : December 17 (cloudy sometimes fair) and 18 (cloudy sometimes fair), 1996
- Paris (France) : December 21 (cloudy to rainy) and 22 (cloudy to rainy), 1996

The field observations include measurements on air temperature (measured with a T-type thermocouple (0.08 mm in diameter)), relative humidity (ETO humidity probe THP2119A), surface temperature (MINOLTA surface thermometer TA-0510), wind velocity (RION anemometer AM-03) and solar radiation (EKO albedometer MR-22). The field observations were made both in the semi-outdoor spaces and out, every two hours (9:00 to 21:00, seven times a day) , for comparing each other.

Then, for evaluating thermal comfort, SET* (Standard Effective Temperature, one of the most common indices for thermal comfort) was calculated on the field observations, according to Gagge et al. (1) and Gagge et al. (2).

RESULTS

Some examples of calculated SET* are showed in Fig. 1 to 8. In these figures, “IN”, “Temp” and “OUT” mean “inside semi-outdoor space”, “air temperature” and “outdoor space”, respectively.

The following can be seen from Fig. 1 and 2:

In the daytime of summer at Imabari, SET* of the inside of the arcade were lower than that of the outside, but in the nighttime the situation became opposite. However, according to ASHRAE HANDBOOK (3), SET* of the inside showed that the thermal environment was “warm” and “uncomfortable”. In the nighttime of winter, SET* of the inside were higher than that of the outside, but in the daytime the situation became opposite and the outside was more comfortable than the inside from a viewpoint of the thermal comfort.

The following can be seen from Fig. 3 to 5:

In the daytime in Southeast Asia under tropical climate, SET* of the inside of continuous covered walkways were lower than that of the outside, however the evaluation for SET* showed that the environment of the inside was not comfortable, but in the nighttime the situation became opposite. When direct solar radiation was observed in the continuous covered walkways in Singapore and Georgetown, the thermal environments were similar to that of the outside, but in Taipei direct solar radiation could not be observed in the continuous covered walkways.

The following can be seen from Fig. 6 to 8:

In the daytime in West Europe under cold climate in winter, SET* of the inside of covered malls were higher than that of the outside, but in the nighttime the situation became opposite. However, when solar radiation was observed in Milan, SET* of the inside was lower than that of the outside and the thermal environment of the outside was more comfortable than that of the inside from a viewpoint of the thermal comfort. And especially in Hamburg, the thermal environment of the inside of the covered mall was much different from that of the outside.

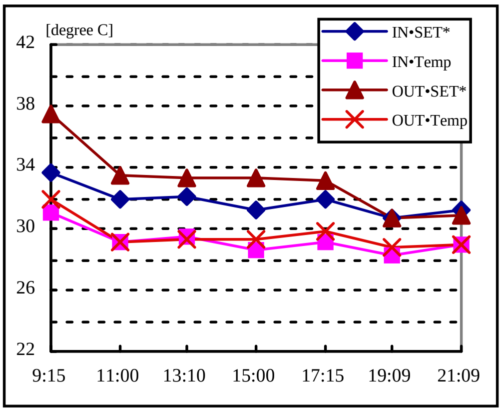

Fig. 1: Air temperature and SET* at Imabari (Aug. 10)

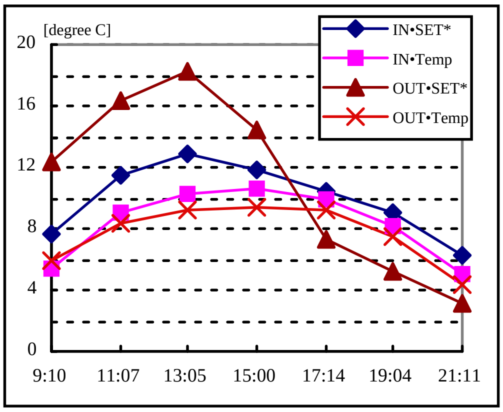

Fig. 2: Air temperature and SET* at Imabari (Jan. 11)

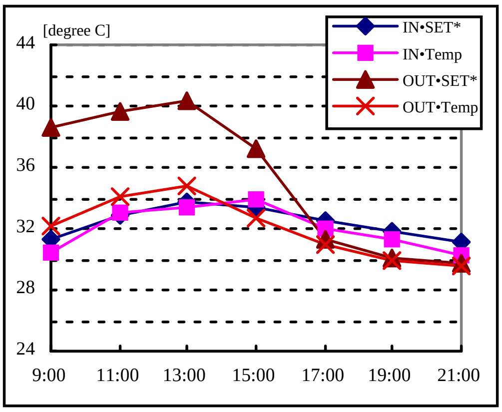

Fig. 3: Air temperature and SET* at Taipei (Aug. 17)

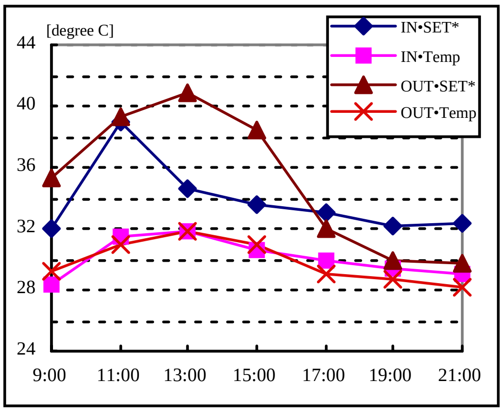

Fig. 4: Air temperature and SET* at Singapore (Aug. 25)

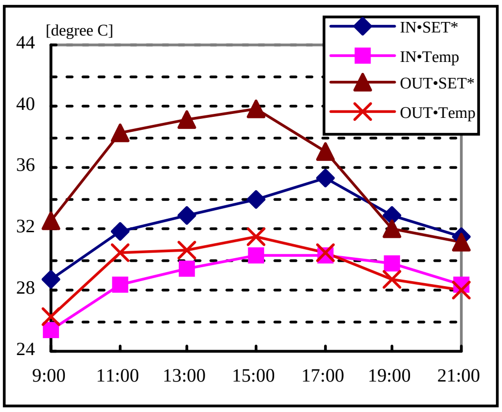

Fig. 5: Air temperature and SET* at Georgetown (Aug. 30)

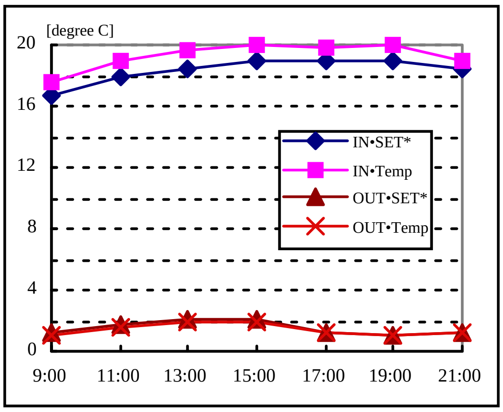

Fig. 6: Air temperature and SET* at Hamburg (Dec. 10)

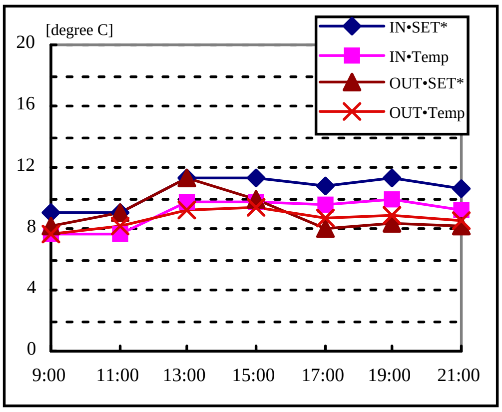

Fig. 7: Air temperature and SET* at Milan (Dec. 17)

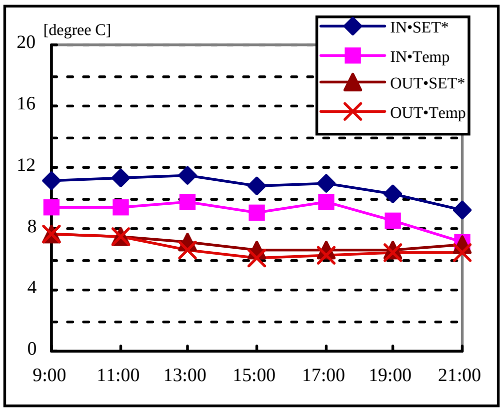

Fig. 8: Air temperature and SET* at Paris (Dec. 21)

PROPOSAL OF CLIMATIC MITIGATION RATIO

On the basis of these investigations, taking geographical characteristics into account, a new index "climatic mitigation ratio" was proposed. The climatic mitigation ratio is written as follows:

CMR = (SET*s – 25°C) / (SET*o – 25°C)

where

CMR: “climatic mitigation ratio”, non dimension

SET*s: SET* of the inside of semi-outdoor space, • C

SET*o: SET* at outdoor space, namely outside semi-outdoor space, °C

25°C: standard value of SET* inside indoor space, as neutral and comfortable sensation.

Thus, the climatic mitigation ratio (CMR) is the index that indicates a state of climate in semi-outdoor space between indoor and outdoor climate. When the value of CMR is 1.0, the climate in semi-outdoor space is equal to outdoor climate, which means the climate in semi-outdoor space isn’t mitigated. When the value of CMR is less than 1.0, the climate in semi-outdoor space is close to indoor climate, which means the climate in semi-outdoor space is mitigated. When the value of CMR is more than 1.0, the climate in semi-outdoor space is harder than outdoor climate.

In the climatic mitigation ratio (CMR), semi-outdoor spaces are expressed as heating mitigation in hot season and as cooling mitigation in cold season both in the daytime and evening as shown in Fig. 9.

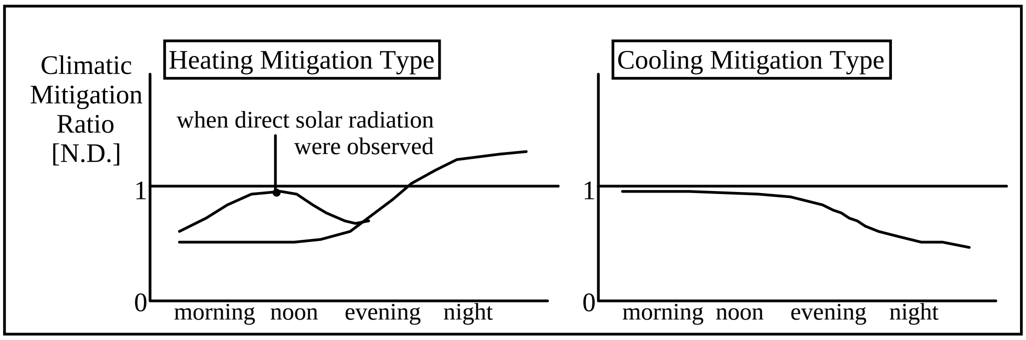

Fig. 9: The semi-outdoor spaces expressed as heating mitigation and that as cooling mitigation

DISCUSSION

The climatic mitigation ratio (CMR) was applied to evaluate the thermal environments in the semi-outdoor spaces at Imabari, Japan, and those in Southwest Asia and in West Europe. By compared some semi-outdoor spaces of various areas, the characteristics of thermal comfort of the inside of them could be made clear (See Fig. 10 and 11, in these figure, for example, “IMA0810”, “TPE”, “SIN”, “PEN”, “HAM”, “MIL” and “PAR” mean “Imabari at August 10”, “Taipei”, “Singapore”, “Georgetown (Penang)”, “Hamburg”, “Milan” and “Paris”, respectively.).

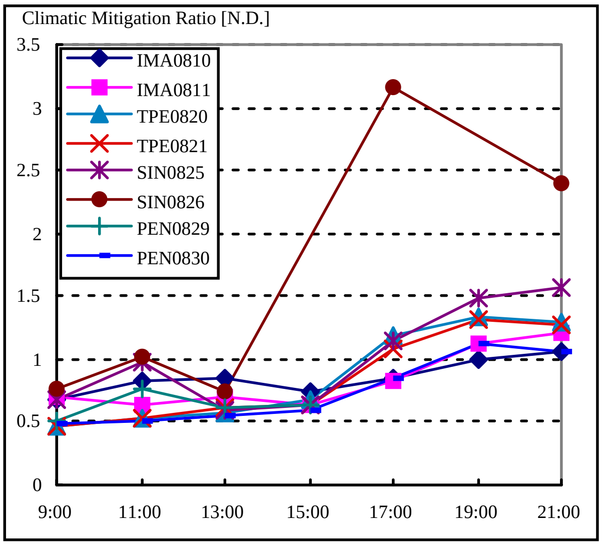

Fig. 10: Climatic Mitigation ratio (Summer)

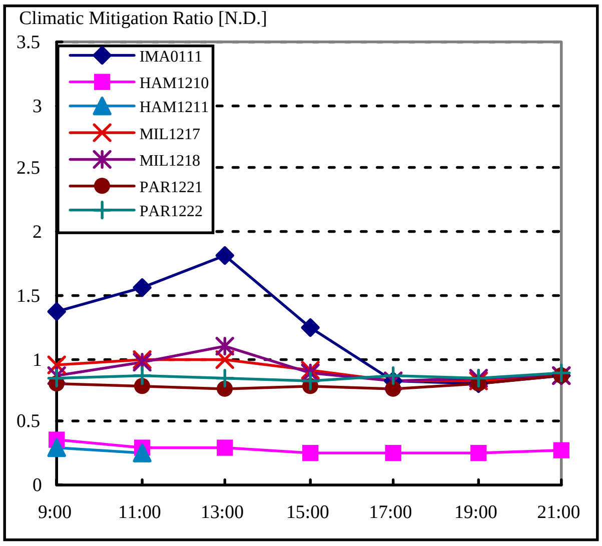

Fig. 11: Climatic Mitigation ratio (Winter)

From Fig. 10, the following can be suggested:
In the daytime of summer, because the value of CMR is less than 1.0, climates in the semi-outdoor spaces at every place were mitigated. However, at Singapore and Georgetown, the values of CMR are nearly equal 1.0, because solar radiation was observed in the semi-outdoor spaces. In the nighttime, because the values of CMR are more than 1.0, climates in the semi-outdoor spaces at every place weren’t mitigated.

The range of change in CMR at Imabari is smaller than at the others. It means that the climates in the semi-outdoor space at Imabari was better than those at the others, because it is more desirable that the daily difference in the thermal comfort is smaller. On the other hand, at Singapore and Georgetown located in the tropical zone, the ranges of change in CMR are bigger than at the others. It might be considered that the demand for semi-outdoor spaces is different between the Temperate Zone and the Ttropical Zone.

From Fig. 11, the following can be suggested:
In the daytime of winter, because the values of CMR are less than 1.0, climates in the semi-outdoor spaces at Hamburg and Paris were mitigated. However, at Imabari and Milan, the values of CMR are over 1.0, because solar radiation was observed at outdoor spaces. In the nighttime, because the values of CMR are more less 1.0, climates in the semi-outdoor spaces at every place weren’t mitigated.

Especially at Imabari, the range of change in CMR is bigger than at the others and the value of CMR in the daytime is over 1.0. Therefore, the climatic mitigation of the semi-outdoor space was worse than at the others. And at Hamburg the value of CMR is smaller than at the others. It is shown that climate in the semi-outdoor space at Hamburg was much near to indoor climate.

It might be considered that the demand for semi-outdoor spaces is different between in winter in the Temperate Zone and in the Frigid Zone, and the former located in middle latitude such as Japan takes more solar radiation than the latter located in high latitude.

In concluding, authors should note that it could be possible to compare various semi-outdoor spaces attached to buildings and to make the characteristics of them clear, using the climatic mitigation ratio (CMR).

ACKNOWLEDGMENTS

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