Planted Circumstances and Wind-break Techniques in the Isles of the East China sea

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ABSTRACT. In this paper the authors describe in detail the planted circumstanceswith wind-break effects,developed in the isles of Tonaki and Aguni, tens of kilometers off the mainisland of Okinawa in the East China Sea; both these isles are abundunt in *Fukugi*, an evergreen, tall and sturdy tree of tropic origin; and the time-honored Fukugi groves have played an all-important role in protecting thepeople and their properties against the year-round strong winds, and casual but frequent typhoons.

The Fukugi trees have been planted around each of house premises on three or four sides, arranged in different ways; in Tonaki the village street crossings were so arranged as to be out of alignment in one direction, with a distinct intention of making such irregular arrangement resist any possible wind acceleration.

In Tonaki, almost all houses would be built on sunken grounds, besides the Fukugi windbreaks, to avoid being hit direct by the fierce wind, while in Aguni no such artificial house-sites are found.

These devices are fairly efficeent, from the bioclimatic point of view, because they are to mitigate the cooling-off effect on the entire house envelopes in the windy winter season of Okinawa area.

1. INTRODUCTION

At the sight of rural landscapes in the hamlets of Okinawa, especially in isles remote from the mainisland of Okinawa, one would notice the green, conglomerate tree leaves surrounding house premises, and those trees are fukugi almost without exception; they stand defiantly firm against furious winds typical of that region, stretching their roots deep into the earth.

Fukugi is an evergreen, tall tree of tropic origin, called Garcinia Subelliptica Merr., and very familiar to Okinawan people.

Here the authors should make a brief comment on the old Okinawan legislative standard of forestation set by Sai On, a member of the supreme council of the Ryukyu kingdom, in the first half of the eighteenth century.

Okinawa is indebted to Sai On for much of its time-honored frorest conservation techniques.

In 1952, just two decades before its reversion from the U.S. administration to Japan, his essays on the subject were translated, published, and distributed abroad by the Forestry Division of the United States Civil Administration in the Ryukyu Isalnds.

Thus Sai On's thoughts of forest conservation and consequent land protection from the typhoon disaster had been embodied throughout the kingdom and were handed down to present-day Okinawa.

Both Aguni and Tonaki are among those isles which have been protecting themselves against wind disasters.

Okinawa is the southernmost prefecture of Japan, located in the East China Sea,about 1,700 km distant from Tokyo. and consists of many small islands forming partly the Ryukyu archipelago, iust off the great Asian land-mass.

Climatically the region including the isles of Aguni and Tonaki is often referred to as subtropical; there blow incessantly strong winds during its shorter winter seasons (i.e. January to March) besides frequent typhoons in longer summer seasons.

2. PROFILES OF THE TWO ISLES

Aguni and tonaki are similar to each other in many respects because they have long followed almost the same economic. social, and cultural ways of living: however the difference of natural topography between both isles and its resulting overall wind patterns seem to have played an impotant role in changing ways of protection of the people's houses and their communities.

Aguni Is. has an area of 7.62 Sq.km, more than twice as large as Tonaki Is. and hardly undulated as a whole; there are two small communities, one in the center of the isle and the other in the east open to the sea; none of hilliside forestry is found.; its soil is of coral limestone origin.

Aguni had lost houses,properties and Fukugi trees due to the warfare of 1945; as of 1995, the number of houses were 373 with a population of 859 pepole.

Mountainous Tonaki Is.is abundant of hillside forestry mainly in the south and north and has a sole community between those two hills in the form of a low saddle; its sandy soil measures as deep as 10m,Tonaki had not suffered any war damage in the World War II; and its population is 519 people with 209 inhabited houses.

It leaves something to be questioned: why the people had chosen to populate that part of the land; and it might be the only probable answer that they had found the place most convenient in having easiest access to the seashore.

3. WINDBREAK TECHNIQUES : SURVEY RESULTS AND ANALYSIS

3.1 Different types of fukugi arrangement

A distinct differnce in the fukugi groves of the two isles is characterized by their fukugi arrangements ; Aguni grows fukugi in one row around a house-site while Tonaki does in two rows in almost all cases;thus tonaki developed a more voluminous screen against the wind than Aguni.

The verage height of fukugi measures 5,6 m in Aguni against 3.9m in Tonaki while the number of fukugi per house averages 125 in Tonaki against 22 in Aguni; in terms of wind protection, the shorter height of fukugi in Tonaki is substantially compensated by more crowded growing in addition to the customary sunken house-site.

Fig.1 shows the two types of arrangement found in Aguni and Tonaki; the double-lined planting of fukugi is also found at some other places in the main island of Okinawa.

3-2 House-site excavation

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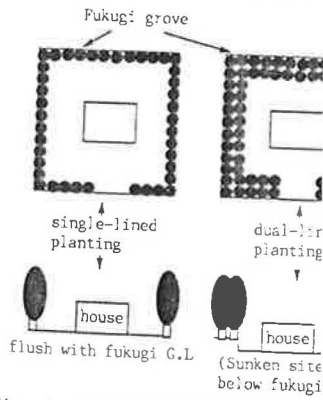


Fig. 1. Two types of Fukugi arr

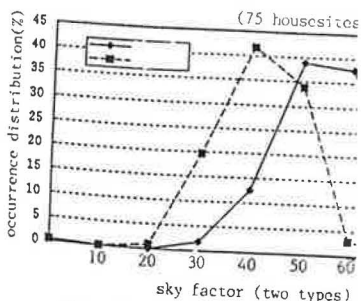


Fig. 2. Sky factor occurrenc

island of Okinawa.

3-2 House-site excavation practice in tonaki

As described, the difference of soil types in both isles seems to have brought them different approaches when constructing houses; the idea of lowering house-sites below any road surface level practiced in Tonaki must be the outcome of the inherent sand soil through which the rainwater seeps gradually; the sand layer is said to be deep enough to allow the rainwater to escape;for this reason Tonaki people could keep a less damp living environment despite of the practice.

Fig.3 shows a survey resultt of depth-variation percentages; two-thirdof sunken-site residents live in houses below more than 40cm of road surface level.

3-3 Decentered street crossings

In the sole community of Tonaki are found various decentered street crossings whose configurations are seemingly very curious; however they were originated from experiences of Tonaki people in former days.

Centerlines of any village streets would not meet at the centerpoint of a crossing; the practice was reasonably with the intention of hindering the wind from speeding up through narrow village streets as it blows.

Fig.3 shows two examples of the decentered streets.

In fig.4 , the solid line denotes values of the sky factor based on normal projection area ratio which is considered as a physical index of natural lighting at a specific point, while the dotted line is based on solid angle area ratio as an index of surrounding openness (if low, it may cause an oppressive feeling); both curves have their peak at some 40% occurrences.

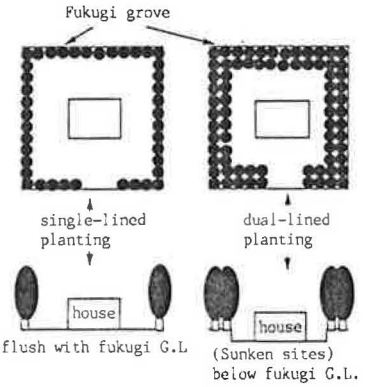


Fig. 1. Two types of Fukugi arrangement

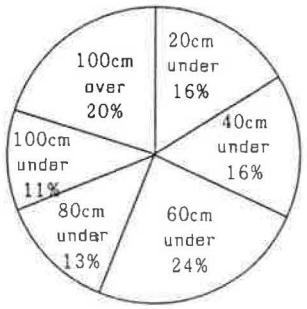
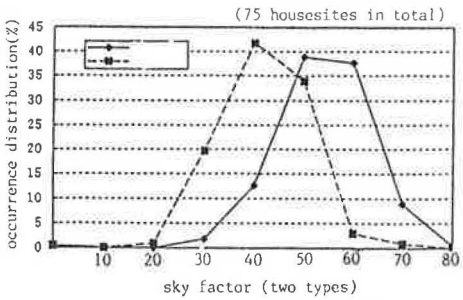


Fig. 3. Site excavation depth



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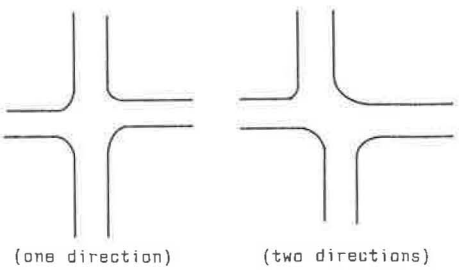

Fig. 4. Decentered Street crossing

4. CONCLUSIONS

In many countries of the world, there has existed a variety of time-honored styles of the vernacular architecture.

Some are marked by their structural features or building materials peculiar to their respective locations, and others are characterized by particular environmental considerations given to a large group of buildings or whole of a community with the view to making most of the natural elements to better living advantages. In the current international climate for passive environments for architecture, the subject treated here is bioclimatic enough because such planted circumstances as seen in the isles are thermally advantageous.

The authors have been associated for years with the field research on fukugi groves principally in the mainisland of Okinawa, and found that fukugi groves seem to be in danger of decreasing steadily, with a few exceptions, for the reason that now the house structures (i.e. ferro-concrete) are sturdy enough, Fukugi trees have completed their historical role.

The the difference of natural topography between both isles and the resulting overall wind patterns seem to have played an important role in changing ways of protection of the people's houses and properties; thus Tonaki has developed more sheltered living environments than Aguni, besides the fact that Tonaki's sandy soil made the popular sunken house-sites to survive until today, otherwise subject to discomfort of persistent dampness due to the inflow of rainwater onto the grounds.

Finally, humans are more or less subject to the natural elements in their living environments and in this context, new bioclimatic approaches should be learned even through the ways by which people of old times adapted themselves to their inevitable circumstances.

ACKNOWLEDGMENTS

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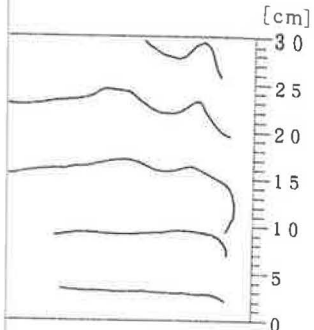

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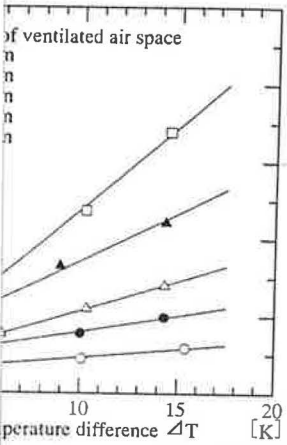

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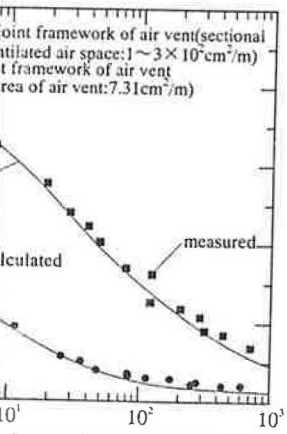

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STUDY ON SOLAR SHADING CONTROL FOR ATRIUM

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ABSTRACT A solar shading system for an atrium was proposed and its thermal performance was verified by field measurement and numerical simulation. For solar shading , the envelope of the atrium was designed to have double skins of glass with blinds in the cavity between the glass. Two types of ventilation (forced ventilation and natural ventilation) in the cavity could be selected according to conditions such as solar radiation, air temperature, etc. Field measurement of the thermal environment was carried out in the atrium in summer and autumn. The result showed that the indoor thermal environment was considerably improved by each solar shading control, and also suggested that in autumn, when the outdoor air temperature became relatively low, natural ventilation was more effective than forced ventilation. The thermal performance of the double skins was also evaluated by means of numerical simulation. A simulation model which describes the thermal behavior of each component was developed and proved the possibility of predicting the thermal performance of the double skins. By utilizing the simulation model, practical control methods of the shading system were developed and adopted.

1. INTRODUCTION

Because an atrium has a large glass area that comes in contact with the outside weather conditions, the concern is that a worsening of the thermal environment mainly due to solar radiation and an increase in cooling load would be caused. This paper reports an example where a double skin solar shading system was applied in the glassed envelope of the atrium in order to control solar radiation and to improve the thermal environment in the atrium.

2. SUMMARY OF ATRIUM AND SOLAR SHADING SYSTEM

The atrium was located in Tokyo, facing south, and was composed of a glassed envelope except the side that faced north (Photo 1, Fig. 1). In the cavity of the double skin (outside: heat reflective glass, inside: laminated glass sandwiching a white sheet) , a roll blind was installed. In addition, dampers and exhaust windows, etc., were provided around the double skin to allow ventilation in the cavity. As for the control of the ventilation, forced ventilation, in which room air is induced from inside the lower part of the double skin (Fig. 2: exhaust air volume was approximately 4,000m3/h in measured value), or natural ventilation in which outdoor air is induced from outside the lower part (Fig. 3) may be selected.

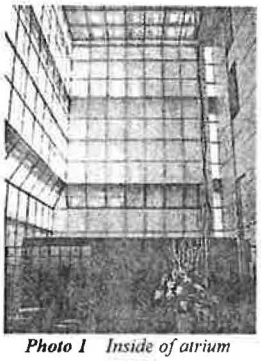

Photo 1 *Inside of atrium*

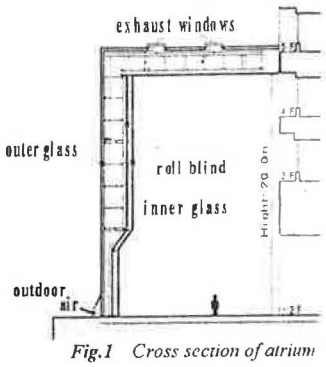

Fig.1 *Cross section of atrium*

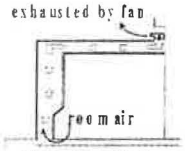

Fig.2 *Forced ventilation mode*

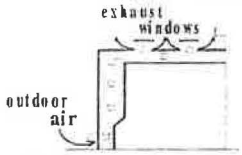

Fig.3 *Natural ventilation mode*

3. VERIFICATION OF EFFECTIVENESS BY MEASUREMENT

3.1 Summary of Measurement

The measurement was carried out throughout summer and the intermediate season. The occupied zone was air-conditioned at a set temperature of 24℃ and set humidity of 50%. In evaluating the atrium environment, the thermal environment of the double skin on days when solar radiation conditions were favourable in summer and the intermediate season was verified.

3.2 Results of Measurement and Considerations

(1) Effectiveness of Solar Shading by Roll Blinds

On the south side surface of the atrium, the blind in the cavity was fully opened on the west half and fully closed on the east half and a comparison was made. From the comparison of temperatures of inside glass surface (Fig. 4), it can be seen that after the start of measurement at 13:00hrs, the temperature of the whole of the glass surface rose gradually due to the effect of solar radiation and outdoor air temperature. At 15:00 hrs the maximum temperature on the side where the blind was fully opened had reached 44℃ and even on the side where the blind was fully closed, it had exceeded 42℃. On the other hand, however, in the lower part, which affects the occupied zone directly, while the maximum temperature had reached 38℃ on the side where the blind was fully opened, it had remained 34℃ on the side where the blind was fully closed. It was thus confirmed that at each level the temperature on the side where the blind was fully closed was shown to be 2~4℃ lower than on the side where the blind was fully opened. In other words, shading by blinds in the cavity can be expected to improve the long wave radiation environment in the occupied zone, as well be useful for the shading of short wave radiation.

(2) Thermal Environment without Ventilation

The thermal environment was examined in the case when the double skin was hermetically closed. Even though solar radiation fluctuated occasionally, solar radiation conditions were deemed to have been good on the whole. Looking at the temperature fluctuation of the cavity on the south surface of the double skin (Fig. 5), the temperature distribution was uniform without a temperature difference between the upper and lower parts during the night to early in the morning. However, the remarkable rise in temperature accompanied by the increase in solar radiation that resulted during the daytime, and at approximately 15:00 hrs, the upper part of the cavity had reached the maximum of nearly 50℃. Even near the floor surface, which

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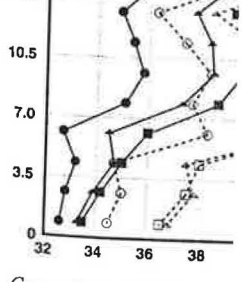

Fig.4 *Comparison of temperature*

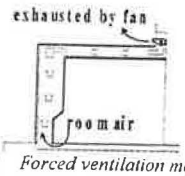

Fig.2 Forced ventilation mode

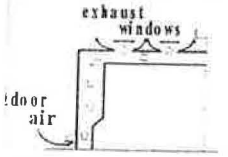

Fig.3 Natural ventilation mode

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(3) Effectiveness of Forced Ventilation

Figs. 6 and 7 show the results of measurement during the summer and the intermediate season, respectively. Inside the double skin solar radiation was shaded by roll blinds. Immediately after the start of the forced ventilation, although a lowering in temperature at the lower part of the cavity (below 7m) of 2~6℃ in the summer and 2~3℃ in the intermediate season was observed, an overall effectiveness including the upper part was not at all noticeable. However, in this atrium, as the occupied zone was limited to the lower part of the space, it may be an effective method of control from the point of view of lowering the effect of long wave radiation. By inducing in conditioned air (about 24℃) to the double skin, it may be considered to contribute to creating a stable radiation environment that would not be affected by the outdoor air temperature and solar radiation.

(4) Effectiveness of Natural Ventilation

Figs. 8 and 9 show the results of measurement during the summer and the intermediate season, respectively. During the summer season solar radiation was not shaded by the blind, while it was shaded during the intermediate season. Looking at the temperature fluctuation of the cavity on the south surface of the double skin in the summer and the intermediate season, respectively, it can be confirmed that the temperature rise in the double skin was larger in relation to the summer season or even in the intermediate season, as it was more strongly affected by the solar radiation amount than the outdoor air temperature. In both seasons, the temperature had reached a maximum of 45℃ before the start of the natural ventilation. From immediately after the start of the natural ventilation, an abrupt lowering in temperature was observed in the whole of the cavity, i.e. 3~5℃ in the summer season and 6~8℃ during the intermediate season. These indicate that the outside air is ventilated in the whole of the double skin. Also, comparing the summer season and the intermediate season, it can be seen that the range of lowering in temperature immediately after the start of ventilation is larger for the intermediate season. This may be considered to be due to the fact that the incident solar radiation amount on the vertical surface on the south side is larger during the intermediate season when solar altitude is lower than the summer season, while the air temperature introduced into the double skin, that is the outdoor air temperature, falls by a large margin compared with the summer season.

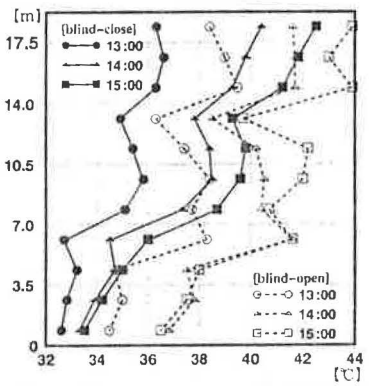

Fig.4 Comparison of temperature of inside glass surface

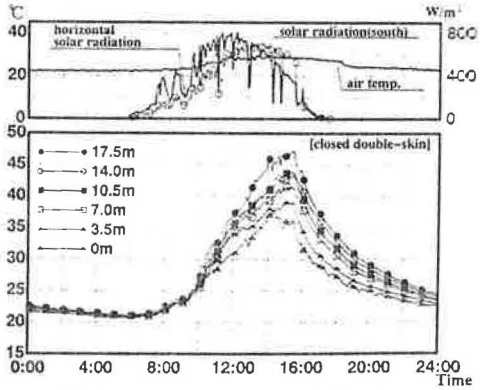

Fig.5 Air temperature in cavity(Sep.26)

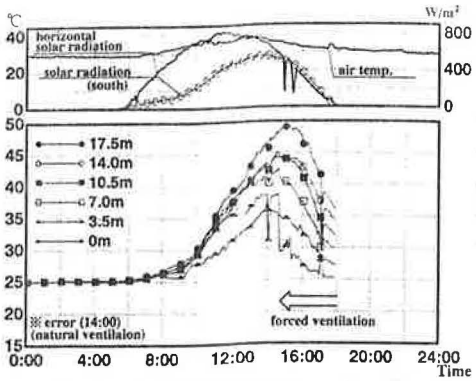

Fig.6 Air temperature in cavity(Aug.28)

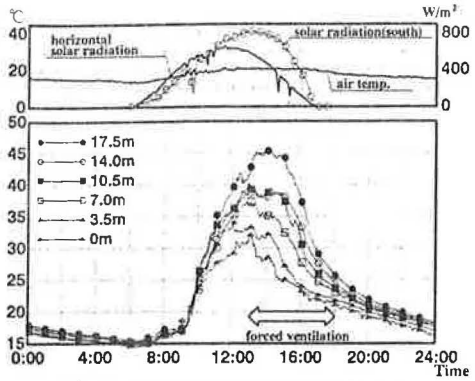

Fig.7 Air temperature in cavity(Oct.27)

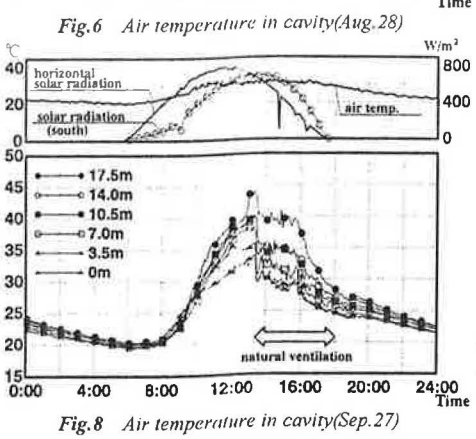

Fig.8 Air temperature in cavity(Sep.27)

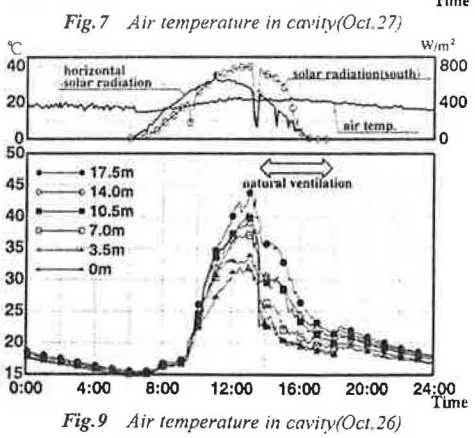

Fig.9 Air temperature in cavity(Oct.26)

4. EXAMINATION OF SIMULATION METHOD

4.1 Summary of Simulation

The simulation model was made based on the thermal equilibrium of each part that constitutes the double skin (exterior glass, the blind, interior glass) and the passing air in the cavity as shown in Fig. 10. In addition, the double skin was divided in a vertical direction in consideration of the vertical temperature distribution and sequence of calculation was made with the outlet temperature of the lower part being treated as the inlet temperature of the upper part.

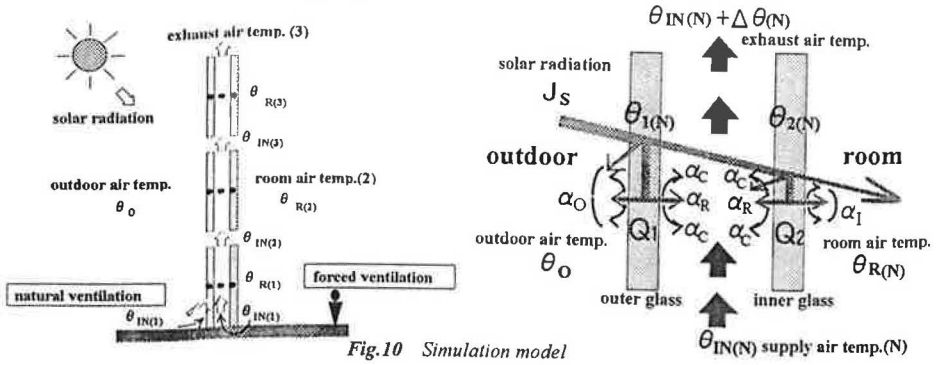

Fig.10 Simulation model

4.2 Results of Simulation

In order to examine the
between the calculated va
in the case of the forced v
fluctuation at each level
lag of phase of 1~2 hours
this may be considered at
the heat capacity of each
temperature that comes a
comparison between the
natural ventilation. The
interior glass agree appro
shows a higher measured
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As has been mentioned ab
temperature agree approxi
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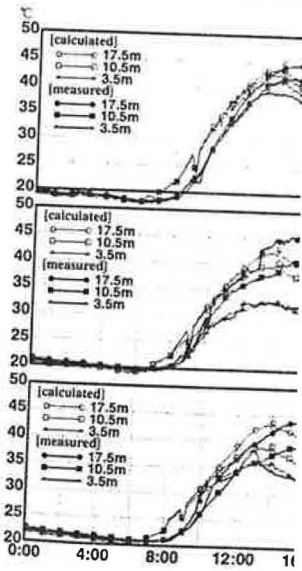
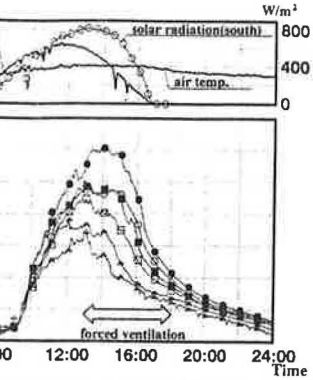


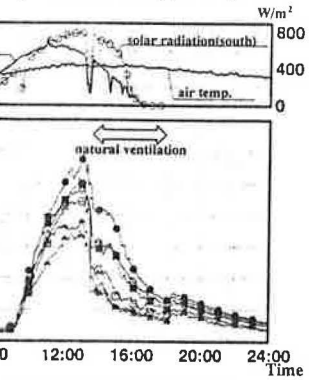
Fig.11 Comparison of calcula measured value in int

5. APPLICATION TO CC

In order to apply an appro
actual atrium environment,
method for the selection of v
(lower layer part) and outsid



emperature in cavity(Oct.27)



mperature in cavity(Oct.26)

uilibrium of each part that
r glass) and the passing air
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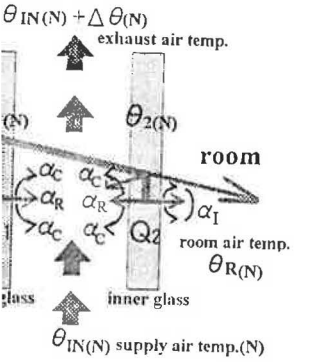
lower part being treated as



4.2 Results of Simulation and Considerations

In order to examine the accuracy of the simulation model, comparison was made between the calculated value and the measured value. Fig. 11 shows the comparison in the case of the forced ventilation. Close agreement was obtained in the temperature fluctuation at each level of exterior glass, cavity and interior glass. Although a time lag of phase of 1~2 hours exists in both the upper layer part and the middle layer part, this may be considered attributable to the fact that the model did not take into account the heat capacity of each part around the double skin and also was affected by the air temperature that comes around from other surfaces (west, east). Fig. 12 shows the comparison between the calculated value and the measured value in the case of the natural ventilation. The temperature fluctuation at each level of exterior glass and interior glass agree approximately, but the cavity temperature of the upper layer part shows a higher measured value than the calculated value. This may be due to the difference between the actual passing air volume and calculated air volume, since it was difficult to grasp the passing air volume in the double skin.

As has been mentioned above, from the fact that calculated results of the interior glass temperature agree approximately with measured results in both ventilation modes, the influence of long wave radiation from the interior glass on the workers near the double skin and evaluation for selection of ventilation mode may be considered to have been examined with practical accuracy.

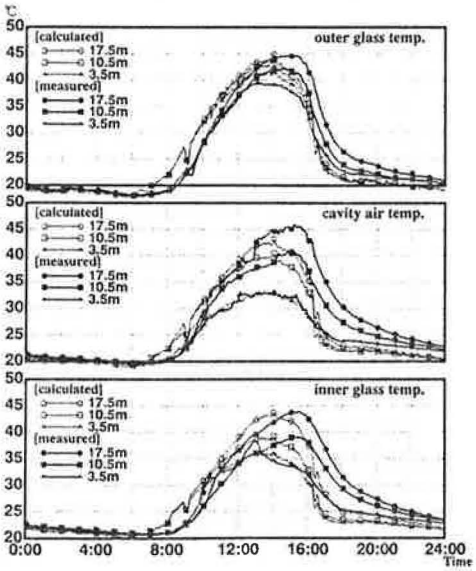


Fig.11 Comparison of calculated value and measured value in intermediate season

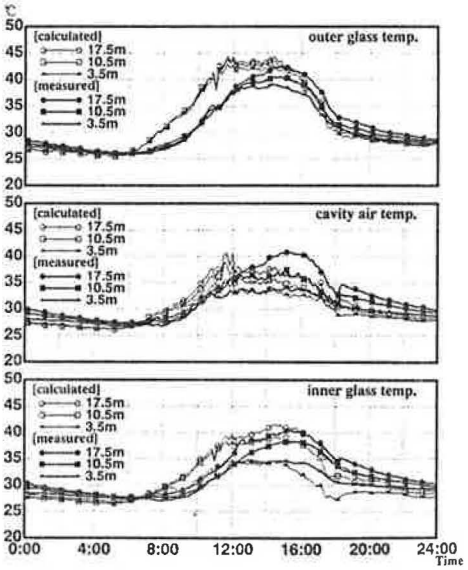


Fig.12 Comparison of calculated value and measured value in summer season

5. APPLICATION TO CONTROL OF ATRIUM THERMAL ENVIRONMENT

In order to apply an appropriate control of solar radiation in the double skin to the actual atrium environment, examinations were carried out concerning a practical method for the selection of ventilation mode. From the air temperature inside the cavity (lower layer part) and outside, the range of the lowering in temperature of the cavity at

the time of switching from the forced ventilation to natural ventilation was estimated. The reason for using the air temperature of the cavity was that the solar radiation had not been measured in this building and therefore it was estimated by paying attention to a high correlation of the cavity temperature with the solar radiation. The results of this were used for the prediction of the thermal environment around the double skin (Fig. 13).

The ventilation mode was changed when the lowering of the temperature by approximately 10℃ was estimated by switching from forced ventilation to natural ventilation under actual use conditions in the intermediate season (Nov/6-11,'95). As a result, the calculated value and the actually measured value agreed approximately (Fig. 14) and the effectiveness of improvement of the thermal environment by switching ventilation mode was able to be predicted with a practically sufficient accuracy.

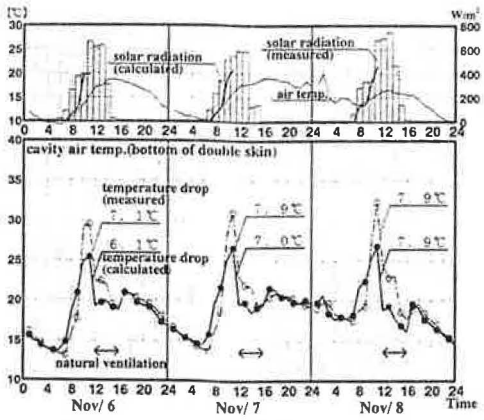


Fig.13 Comparison of calculated value and measured value of cavity air temp

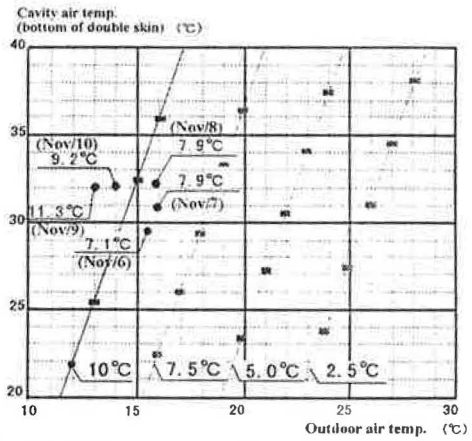


Fig.14 Estimated lowering of temp. and measured value

6. CONCLUSIONS

A solar shading system for an atrium was proposed and its thermal performance was verified by field measurement and numerical simulation. Furthermore, in order to apply an appropriate control to an actual atrium, thermal characteristics were ascertained and examinations concerning the practical measure used to select ventilation mode were carried out.

ACKNOWLEDGEMENTS

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