# THE PASSIVE COOLING EFFECTS OF THE NATURAL VENTILATION SYSTEM FROM UNDER-FLOOR PIT TO WIND-TOWER

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**ABSTRACT** With the awareness of enviornmental problems as the starting-point, various investigations and trials aimed towards a sustainable society have been commenced; in recent years, the architectural field too has seen such research and development of passive methods. These methods are based upon traditional and previously practiced passive architectural techniques, but are inseparable from the latest technology.

One such project, of profound importance to the nation, is the promotion of and research towards "SYMBIOTIC HOUSING", which is to be friendly and symbiotic with both the environment and human-beings from the ecological and economical viewpoints. With this objective in mind, in 1994, a timber-frame building was designed by the author in the city of Iwaki for the public promotion of such a movement.

This project has been followed by a year long data measurement and analysis, in order to evaluate the passive cooling effects of the natural ventilation system from under-floor pit to wind-tower.

## 1. Introduction

The subject timber frame building, together with the surrounding landscape and garden as biotope, was designed to create a comprehensive living space which is symbiotic with the environment. Therefore, a number of passive techniques are applied in both the building (see Fig.1) and the landscape.

Among those, this report describes the passive ventilation methods applied within this building, and details the local climatic conditions upon which they are based. In addition, reported below are the results of an investigation carried out from the summer to winter of the last year, and an analysis of the verifications concerning the summer season this investigation yielded.

## 2. Outlines of the subject building

The building here surveyed stands on approximately flat ground, in the city of Iwaki, of Fukushima prefecture. To the East, South East, and South of this building, within 10km distance from it, lies the seacoast. The building is a wooden structure of two floors (200m²) with a curved grass roof. The plan of the first floor, and the cross section of the entire structure, are shown in Fig.2.

A simple passive technique is applied to this building in the combined use of an under-floor pit, and a roof-top wind-tower, for supplying cool air from the under-floor. Excluding the western room of the first floor, the whole building is a unified space (see Fig.1). In the eastern room of the first floor, air-inlets have been created in two locations of the floor surface, to allow cool air to enter from the under-floor pit. In addition, in order to allow the expulsion of air from indoors, the apex of the ceiling is fitted with a wind-tower and an air outlets which can be opened and closed manually by means of operators on the ground floor.

## 3. Outlines of the measurement

Because Iwaki is a coastal city, the sea winds appear characteristically strong during the investigative period. According to our measurements taken over the summer season, the highest outdoor atmospheric temperature occurs, on average, at 10 o'clock in the morning. Therefore, it is in principle possible to prevent outside air, during this high-temperature period, from circulating indoors, and instead allowing the cool air of the under-floor pit to preserve the comfort of the building's interior.

With such aims, measurements were carried out in order to ascertain the effects of the wind-tower ventilation outlet in putting the cool air of the under-floor pit into circulation, and the success of this cool air in lowering the room temperature. During the experiment, the air-inlets on the floor surface, and the air-outlet of the wind-tower were open, while from morning till noon all the windows were closed.

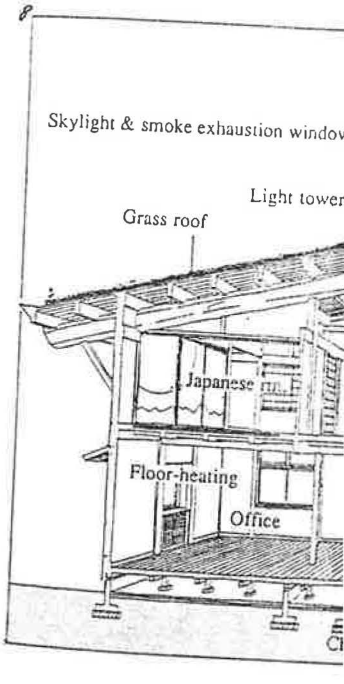
The room temperature distribution, and any changes in wind-speed at all air in-and outlets were also measured. The points at which this data was collected are indicated in Fig.2 by circles; squares indicate the outdoor points of data collection.

In addition, data for the experimental control was taken on a separate day, under the same temporal conditions, but with the wind tower outlets shut and the windows closed.

## 4. The cooling effects, through the combined use of rooftop wind-tower ventilation and the low-temperature air of the under-floor pit.

### 1) Changes in temperature with the floor air-inlets and the ceiling air-outlet open.

Changes in temperature over time, both in the room and in the under-floor pit, while the floor air-inlets and ceiling air-outlet were open, are shown in Fig.3. The windows were closed at 7:15, and opened at 11:47. It may be remarked, in observing the changes in room and under-floor pit temperatures during this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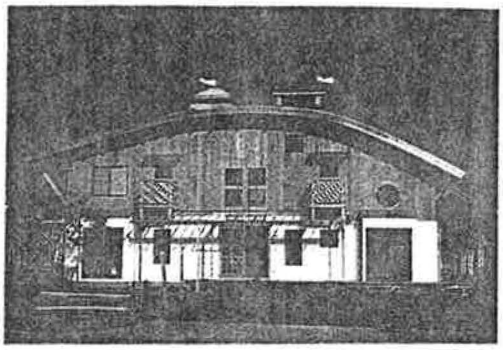


Photo.1: South elevation
with the main entrance

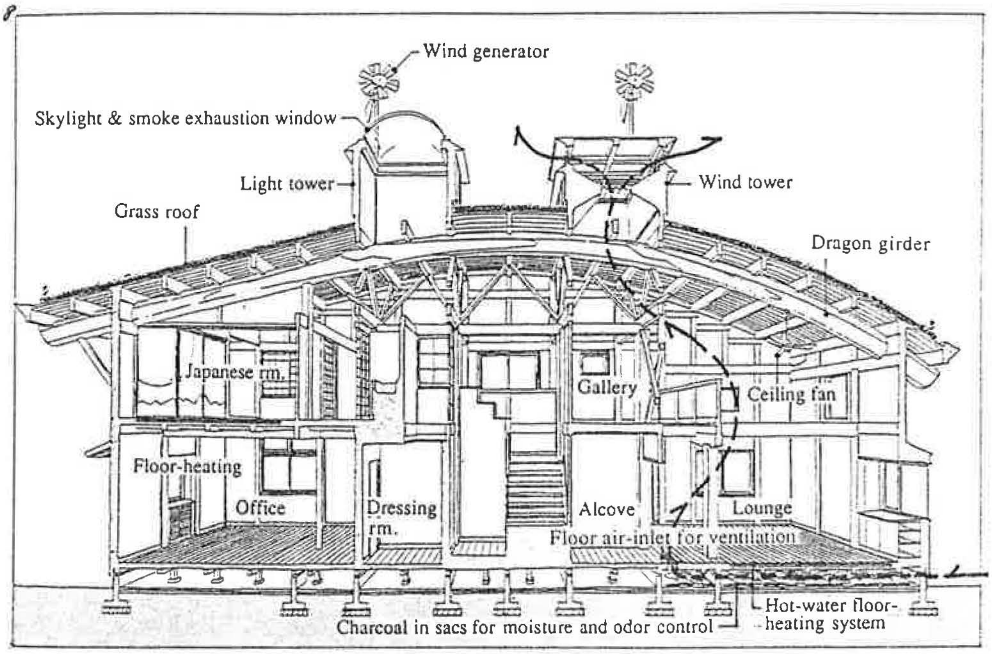



Fig.1: Sectional perspective

Photo.2: North elevation
beyond the biotope garden

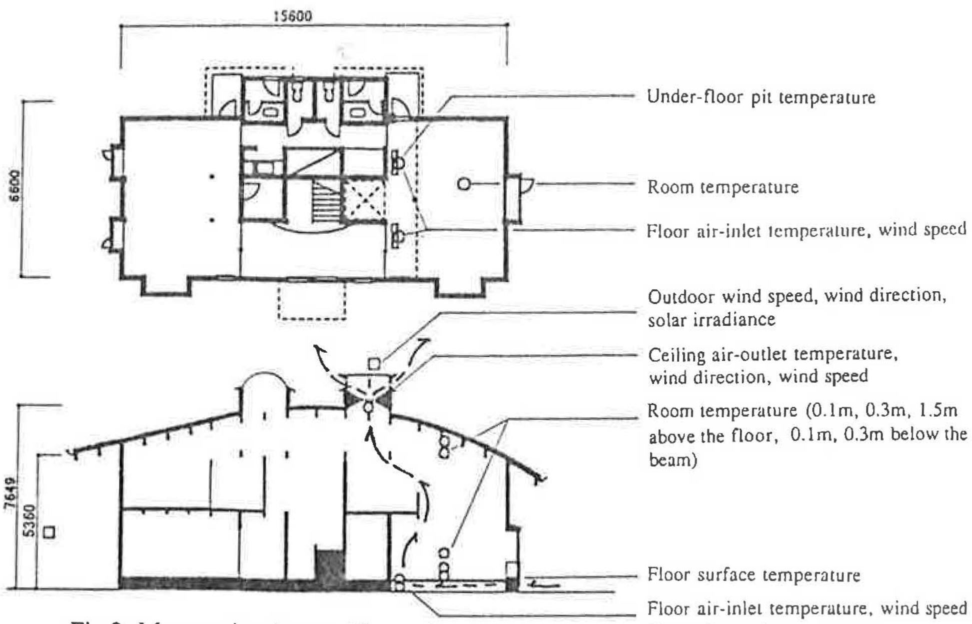



Fig.2: Measured points on Floor plan, and in cross section

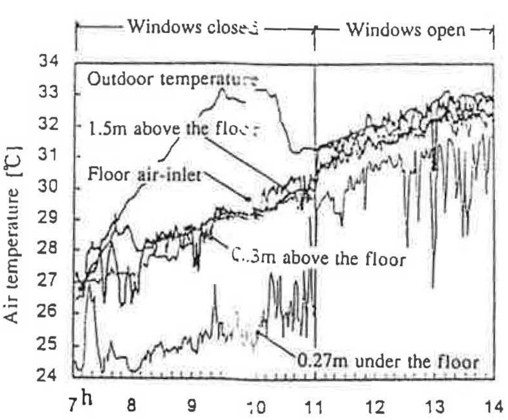



Fig.3-1: Change in temperature with ceiling air-outlet closed

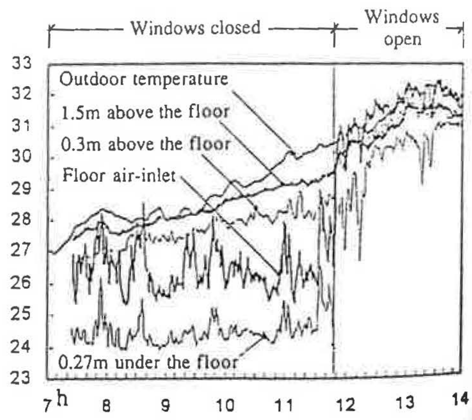



Fig.3-2: Change in temperature with ceiling air-outlet open.

interval, that the temperatures of the under-floor pit and of the floor air-inlets are approximately 4˚C and 2˚C lower, respectively, than the outdoor temperature.

The temperature at 0.3m above the floor is approximately 1˚C lower than the outdoor temperature, and since the changes in this temperature follow the temperature changes of the floor air-inlets closely, it may be surmised that the cool air of the under-floor pit has an effect upon the space up to 0.3m above the floor.

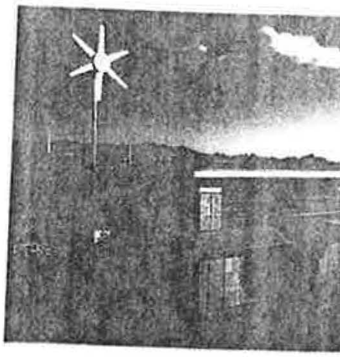


Photo.4:
West elevation
beyond the cor

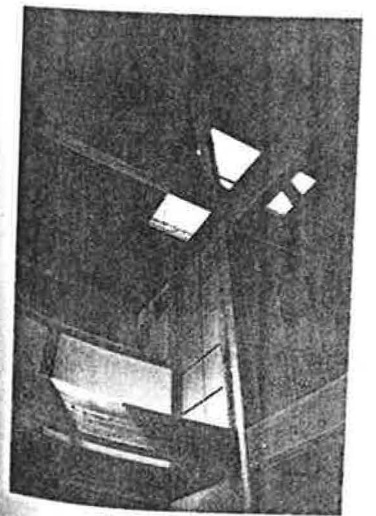


Photo.5:
Upward view towards the light tower

Under-floor pit temperature

Room temperature

Floor air-inlet temperature, wind speed

Outdoor wind speed, wind direction, solar irradiance

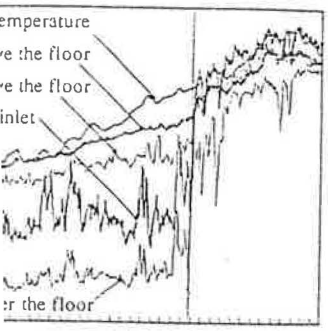
Ceiling air-outlet temperature, wind direction, wind speed

Room temperature (0.1m, 0.3m, 1.5m above the floor, 0.1m, 0.3m below the beam)

Floor surface temperature

Floor air-inlet temperature, wind speed

Under-floor pit temperature (0.2m, 0.27m,0.34m under the floor)




Change in temperature with ceiling air-outlet open.

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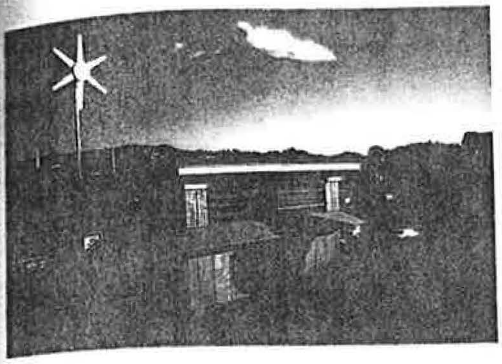

Photo.3:
Wind tower on the grass roof

Photo.4:
West elevation beyond the corner park

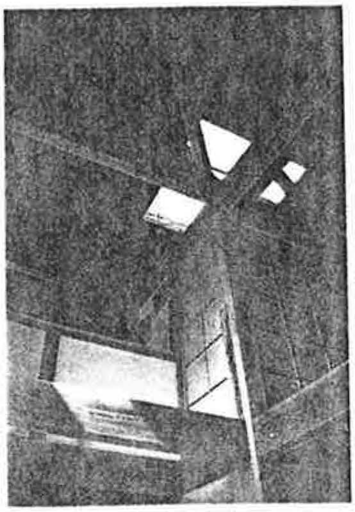

Photo.5:
Upward view towards the light tower

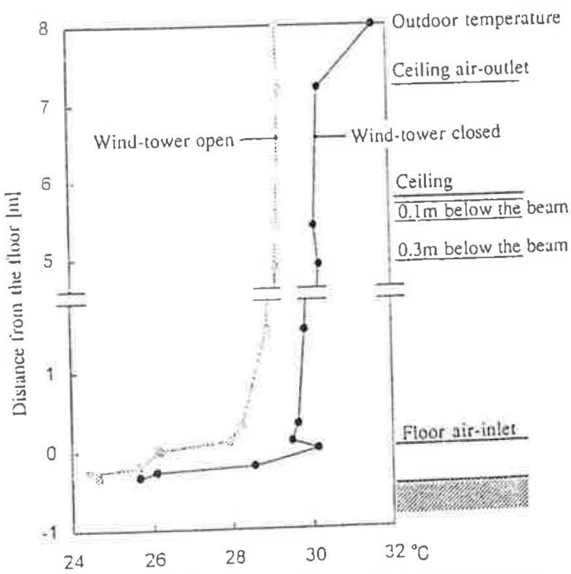


Fig.4: Difference in the vertical temperature distribution according to the open or closed state of the ceiling air-outlet (at 10:30 both days)

After the windows were opened, the respective temperatures 0.3m above the floor, 0.5m above the floor, and of the floor air-inlets ranged from the outdoor temperature, to 0.5°C lower than the outdoor temperature, and the room temperature was little different from that of outdoors.

This means that, when the windows allow direct aeration, it is impossible to cause the cool air of the under-floor pit to rise into the room.

**2) Difference in the vertical temperature distribution in the room and under-floor pit, according to the open or closed state of the ceiling air-outlet.**

The temperature distribution over time, in the case where the wind-tower and ceiling air-outlets are closed, is shown in Fig. 3. While cool air can be found in the under-floor pit, the room temperature shows no sign of being affected by this, and the cool air of the under-floor can not be guided into the room.

Looking at Fig.4— which shows in further detail the vertical temperature distribution for instances when the windows are closed, but when the ceiling air-outlet are either open or closed — the cooling effects or non-effects of the floor air-inlets appear, in both the difference of temperature of the floor air-inlets, and in the difference of gradients of the respective room temperature changes up to 1.5m above the floor level.

In addition, when the windows remain closed but the ceiling air-outlet open, the wind speed of the air-outlet is on average 0.69 [m/s], while the total wind volume from the two floor air-inlets on average 0.038 [$m^3$/s]. The amount of cooling capacity can be measured to be on average 146 [w], and when measured in terms of per unit volume of the room, is found to be 0.51 [w/$m^3$], and not of significant effect against the entire heat load.

## 5. Conclusions

The above survey has yielded these results:

1) With the windows closed, and the wind-tower air-outlet and the floor air-inlets open, it is possible to create a flow of cool air from the under-floor pit.

2) Although the cool air of the under-floor pit slightly lowers the temperature of the space directly above the floor, its effect upon the heat load of the entire interior is marginal.

3) However, the above result may be improved by enlarging the capacity of both wind-tower and under-floor pit. This may help in keeping the interior cooler, especially in the morning, when this region's summer outdoor temperature peaks.

## Acknowlegements

This survey was compounded with the cooperation of the Joban Branch of the Public Corporation for Regional Promotion and Development, and the Iwaki Newtown Center Co.,Ltd. We hereby express our deep thanks.