SURABAYA ECO-HOUSE
AN EXPERIMENT ON PASSIVE DESIGN IN A TROPICAL CLIMATE
PART 2: EVALUATION AND SIMULATION OF THE EFFECTS ON THERMAL PERFORMANCE

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1 The mode of monitoring

After the completion of a building, preparatory monitoring was conducted from July 27 to August 7, 1998. On the basis of the results, positions and time of observation were changed, and observation modes were determined.*[1]

In order to verify the effects of the installed passive cooling system and the influence of living styles, operation of a water circulation system was combined with that of openings to determine five modes. The observation modes and their periods were shown in Table 1 and Fig.1.

- Under observation mode I, openings remained open all day long with the water circulation system operating
- mode II, openings remained closed with the water circulation system operating
- mode IIIA, openings were open in the daytime with the water circulation system operating
- mode IIIB, openings were open with the water circulation system suspended: a condition similar to a general lifestyle in Indonesia).
- mode IV, ventilation was on at night with ventilation and a water circulation system operating in the daytime. This is the mode under which the passive cooling system was expected to operate most efficiently when the experimental building was designed. The pump for water circulation was powered by solar cells in the daytime as long as solar radiation was available.

Table 1 Observation mode

Observation mode	On Opening	Operation of Water Circulation
I	Open all day	Operated
II	Closed all day	Operated
IIIA	8:00-17:00 open	Operated
IIIB	8:00-17:00 open	Suspended
IV	8:00-17:00 closed	Operated

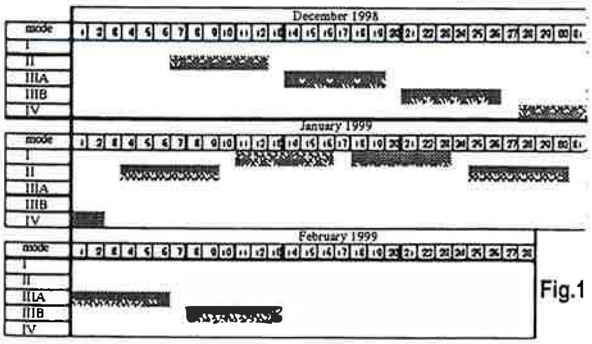


Fig.1 Observation period depending on modes

2 Effects of passive cooling

The latest experiment was conducted from December 7, 1998 to February 13, 1999, later than the initial schedule due partly to a lag in preparation of materials. Following are the results of the observation.

1-a) Thermal insulation of roof as shown below is the temperature of roof surface subject to solar radiation and temperatures of respective parts of a roof. The temperature of the roof tile surface rose to 53°C in the daytime, whereas the temperature inside did not go up greatly, displaying significant effects of the ventilation layer and heat insulation materials. The thermal resistivity of coconut fibers is estimated at 0.07 W/m.K, testifying to high heat insulation performance (Fig.2).

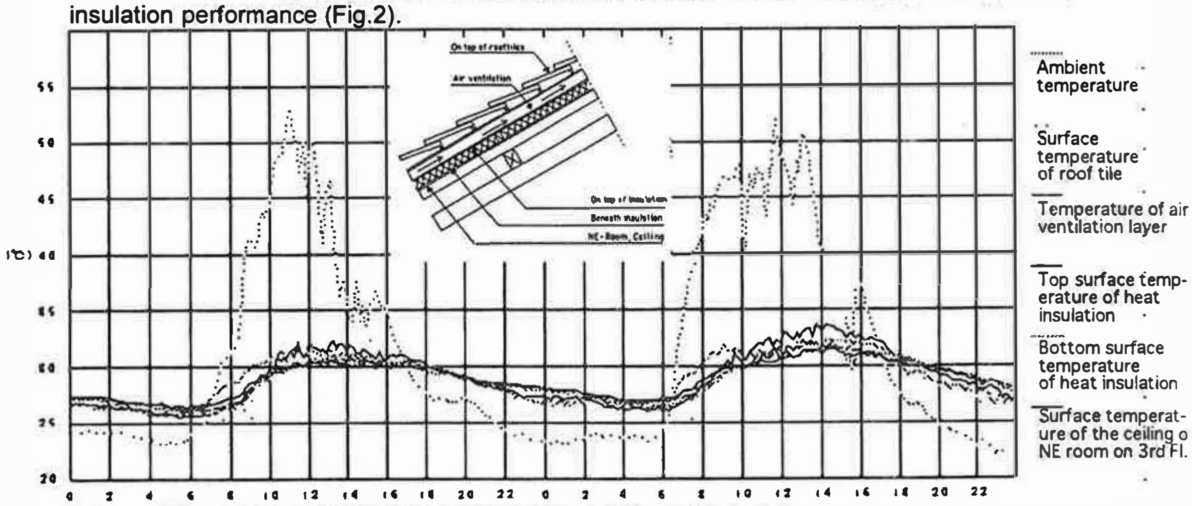


Fig.2 Effects of thermal insulation (December 7 – 8, 1998, under mode II)

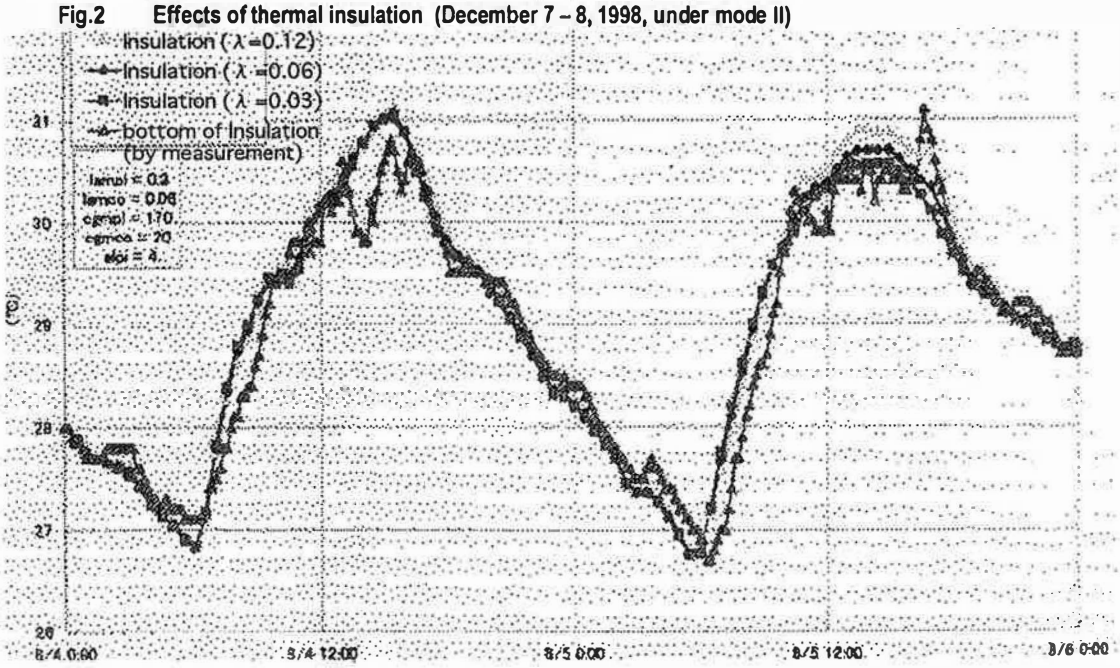


Fig.3 Temperature consequences of insulation simulated depending on conductivity

1-b) Fig.3 shows the temperature of insulation simulated depending on conductance as a variable in comparison with the actual data measured from 0.00 h 4th Aug. to 0.00 h 6th Aug.

1998. We can also estimate the thermal conductivity of coconut fiber as 0.07 W/m.K and the heat capacity is estimated at 23 Wh/m^{3}K. These are competitive with those of glass wool that is normally used.

1-c) We can also estimate the velocity of the air within the double roofing. It is estimated at 0.3m/s (4th Aug) and 0.25m/s (5th Aug). Fig.4 shows the comparison between simulation and actual measurement in case of 0.35m/s for 4th Aug and 0.22m/s for 5th Aug 1998.

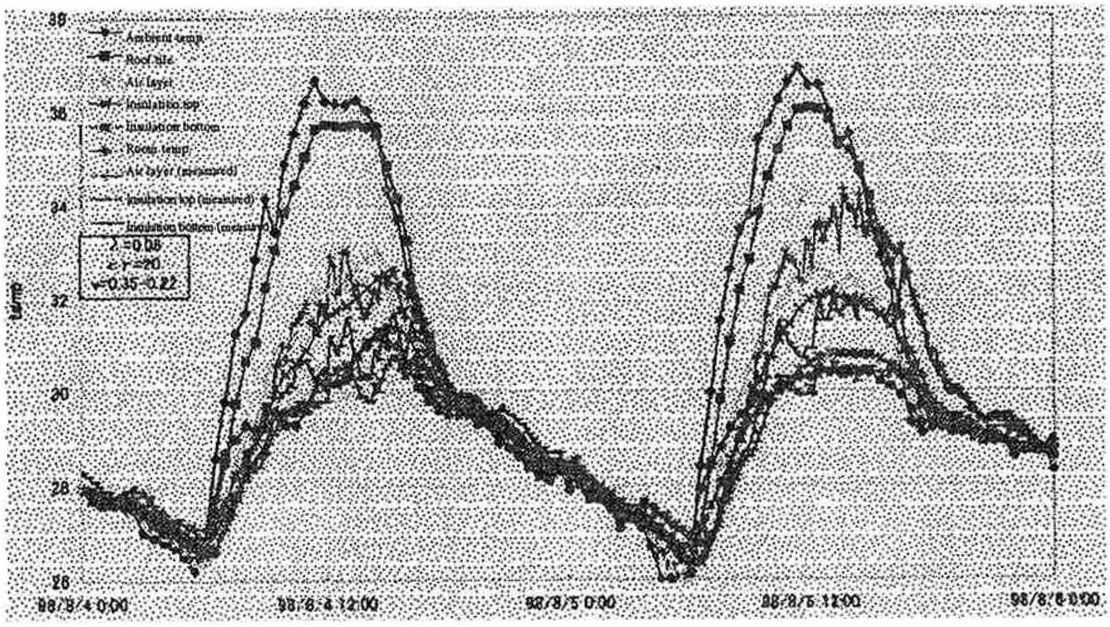


Fig.4 Comparison between simulation and measurement of temperatures of roof layers

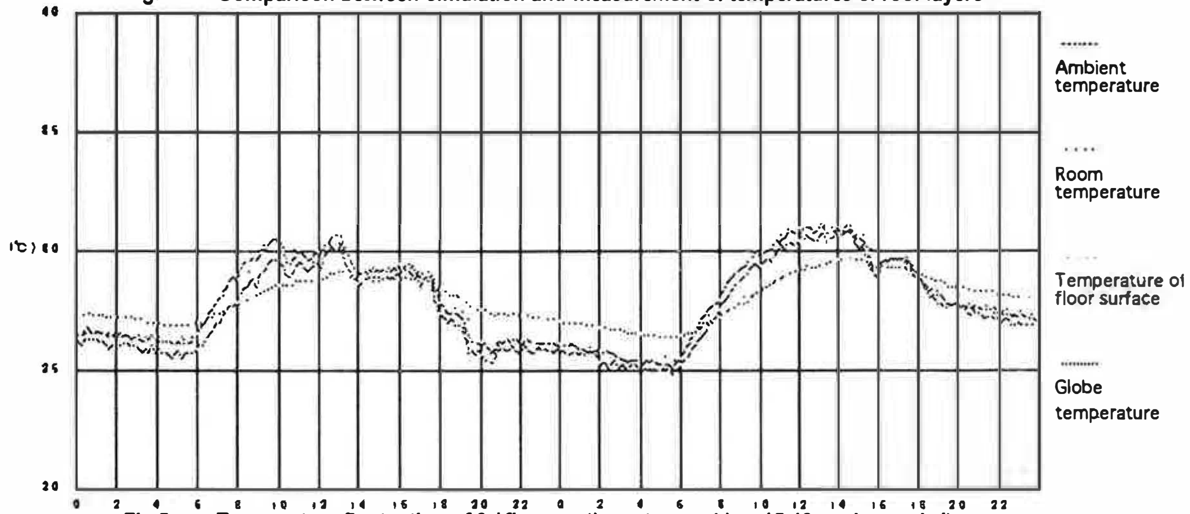


Fig.5 Temperature fluctuation of 3rd floor north-east room (Jan. 15-16, under mode I)

2) Effects of water circulation system (by measurement)

Effects of a water circulation system under mode I are studied on the basis of the results of the observation on January 15 and 16, 1999. As shown in Fig. 5, room temperature charts the course is similar to that of ambient temperature because an opening remains open. The temperature of floor surface displays milder changes, compared with room temperature, helping cool room temperature. This attests to cooling effects resulting from heat capacity of the concrete slab. Such effects are expected to become greater if combined with the water circulation system and nighttime ventilation.

3) Cooling effects of nighttime ventilation (by simulation)

Shown in Fig.6 are the results of a simulation study on effects of cooling concrete floor by massive ventilation at night when the temperature falls. Typical climatic conditions in Surabaya (8°south latitude, 112°east longitude) in December were used for simulation. The Figure shows changes in room and floor surface temperatures when ventilation is 3 ac/h in the daytime (6:00 to 19:00) and 30 ac/h at night. For comparison, changes are also displayed when ventilation is 3 ac/h during the day (with no nighttime ventilation). Room temperature during the day under the former case is two degrees lower than the latter case. Cooling effects from floor surface are also expected.

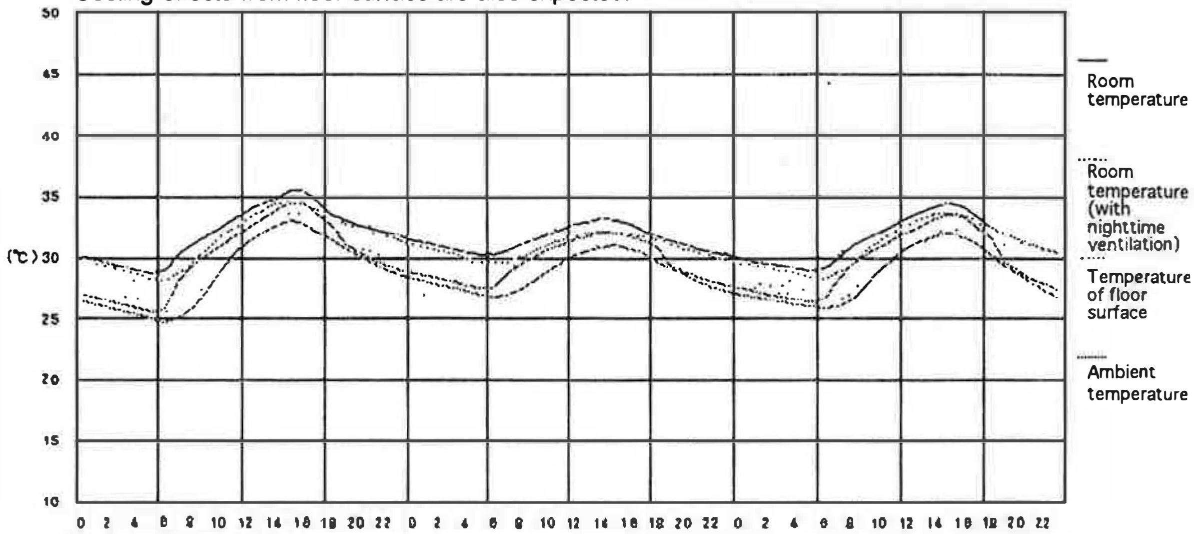


Fig.6 Cooling effects from night-time ventilation

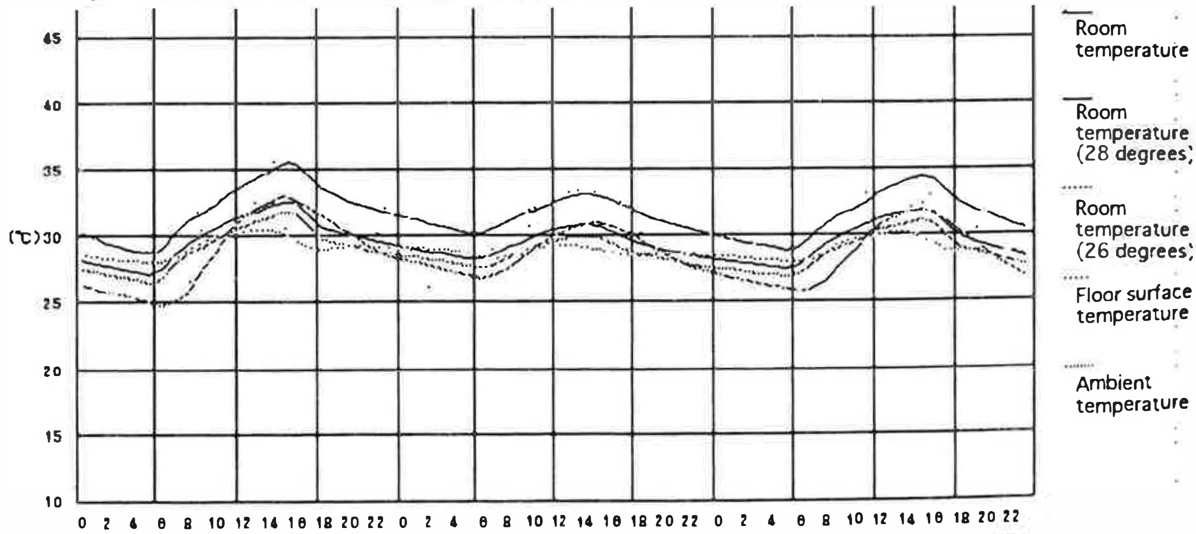


Fig.7 Effects of water circulation system (simulation)

4) Cooling effects from water circulation (study by simulation)

Fig. 7 shows the results of a simulation study on the cases where the temperatures of water to be circulated are 28 and 26°C. Pumps are operated when solar radiation is available. The lower the water temperature, the greater the cooling effects. Nevertheless, it is confirmed that 28°C water produces sufficient cooling effects.

5) Effects of combined use of water circulation system and nighttime ventilation (by simulation)

Fig.8 shows the results of a simulation study on combined use of nighttime ventilation and a water circulation system. Under the same climatic conditions as the case 3), water of 26°C is circulated. Floor surface temperature is even lower than the cases 3) and 4), where nighttime ventilation and a water circulation system is used respectively. Room temperature changes in the lowest range are due to effects from lower floor surface temperature.

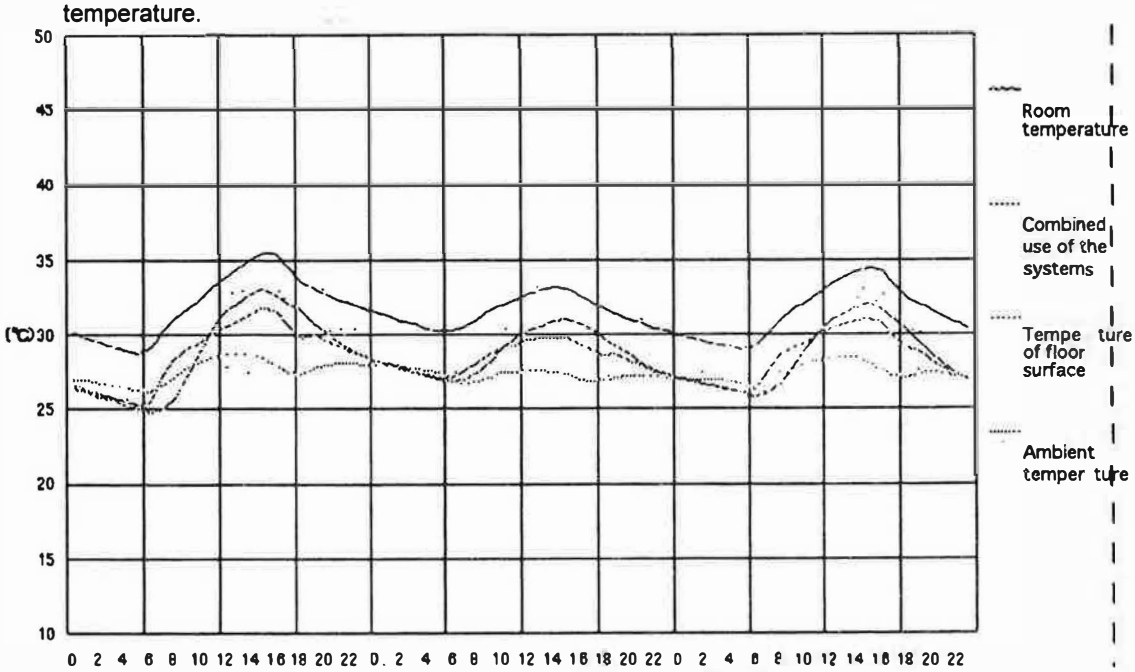
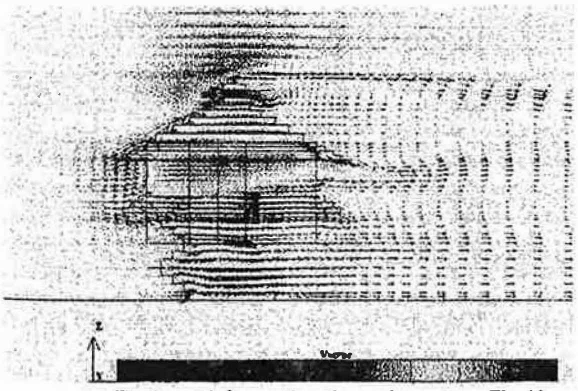


Fig.8 Effects of combined use of water circulation system and night-time ventilation (simulation)



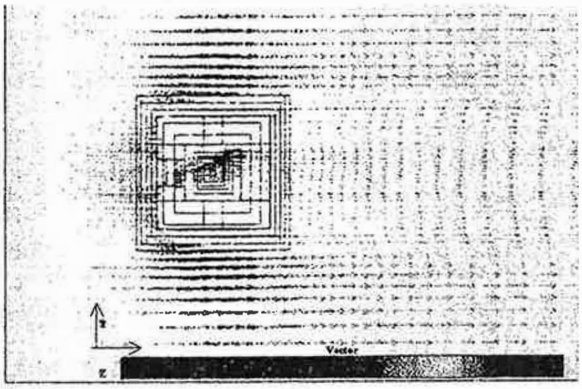


Fig.9 left: section through centre, Fig.10 right: plan at 0.4 m above second floor
Simulation usin STREAM., assuming east wind of 1.5 m/s

3 Effect of ventilation in common space

We use "Stream" as a simulation software. The hypothetical condition: East wind 1.5m/s

a. In case of All the windows (openings) open

Fig. 9 shows the section in the center. Fig. 10 shows the plan 0.4m above the level of 2nd floor. The velocity of the wind in the 2nd floor is estimated at 0.5m/s. The velocity of the wind in the 3rd floor is estimated at 1.8m/s

b. In case of East windows closed

Fig.11 shows the section in the center

Fig.12 shows the plan 0.4m above the level of 2nd floor

The wind flows toward the north and south balcony at the 2nd floor. The wind flows toward the high-side roof and 2nd floor vertically through the void of the floor at the 3rd floor. The velocity is estimated at 1.2m/s.

4 Heat transfer in case of heat generation from the human body

We use also 'Stream' as a simulation software. The heat generation is taken as 58 W/pers, x 4 persons on the 2nd floor

a. In case of no wind (Fig.13)

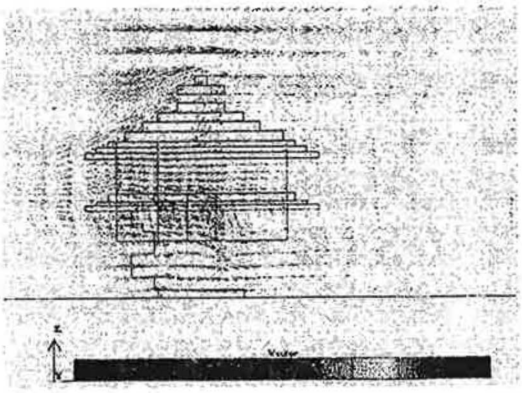
The vertical flow of the air is generated at a velocity of 0.7m/s The air flows outside through the void of the floor and high-side. The room temperature is estimated at 28°C

b. In case of east wind 0.3m/s (Fig.14),

Almost all the heat is let out through west window. A small fraction of it flows to 3rd floor through the void of floor. The heat is discharged vertically in case of no wind through the void. The heat is discharged in case of east wind through the windows.

Footnote

*1 Major change is that we decided to measure temperature of the circulating water that was not collected during preparatory monitoring.



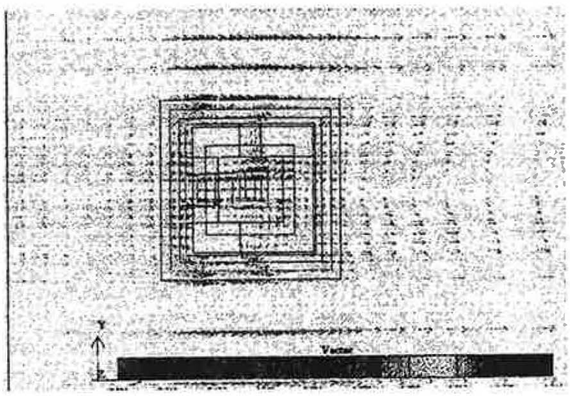
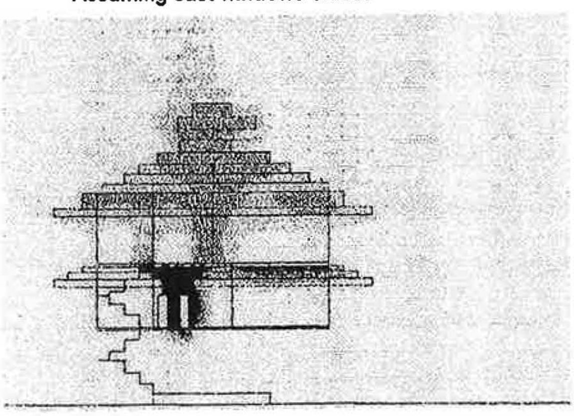


Fig.11 left: section through centre and Fig.12 right: plan at 0.4 m above 2nd floor
Assuming east windows closed



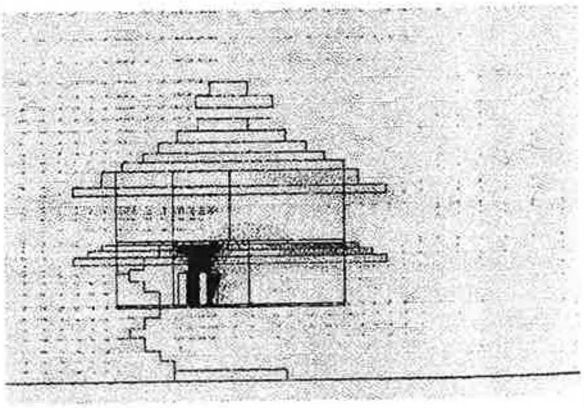


Fig.13 left: no wind Fig.14 right: easterly wind of 0.3 m/s – simulations using STREAM
Assumed 4 persons on the 2nd floor, at 58 W / pers