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EXPERIMENTS ON PASSIVE SOLAR SYSTEM WITH FULL SACLE TEST HOUSES

Air circulation technique for heating rooms using solar heat gain taken at south windows.

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ABSTRACT

Main purpose in this investigation is the development of the technique for conveying the solar heat gain taken through south-facing window to north side rooms. The air circulation due to natural convection, which is caused by the temperature difference, is utilized as the technique for conveying the solar heat gain. Air circulation due to natural convection proved to be fairly good in our experiment: North side room air temperature in the test house could be maintained 4°C higher by providing this system. It may be concluded that "Air Circulation Type" is useful to convey the heat gain and that combining with some small fan or with some air collector for increasing heat gain, practical applications of this system are expected.

KEYWORD

Passive; air circulation; natural convection; north side room air temperature; tandem-type test house.

INTRODUCTION

In a house facing to the south, it is usual that solar radiation during daytime especially winter causes large temperature difference between rooms located at the south side and the north side. In the Northern Hemisphere, north side rooms are often out of use because of their low temperature while south side rooms are at moderate temperature or overheated. Main purpose in this investigation is the development of the technique for conveying the solar heat gain taken through south-facing windows to north side rooms. If it is sufficiently effective, it may be expected that the temperature difference between the south side and the north side is decreased and that the thermal environment in north side rooms is remarkably improved.
It is studied here by comparative experiments using a tandem-type test house under the same climatic conditions, how the air circulation contributes to the increase of the air temperature in the north side rooms and what is the most suitable sectional area of the air duct for the air circulation.

TEST HOUSES AND THEIR PERFORMANCE

Two test houses which were all the same concerning the floor space and the thickness of insulation, were constructed to be adjoining as shown in Fig. 1, in the campus of Tokyo Institute of Polytechnics. One of the test houses called "Air Circulation Type" (ACT) was equipped with the circulation system, while the other one called "Ordinary Type" (OT) was not. Air temperature in the north side rooms of both house were measured parallely, and compared. The air circulation system comprises of the sunroom space, the ceiling duct, the north side duct and crawlspace as shown in Fig. 2.

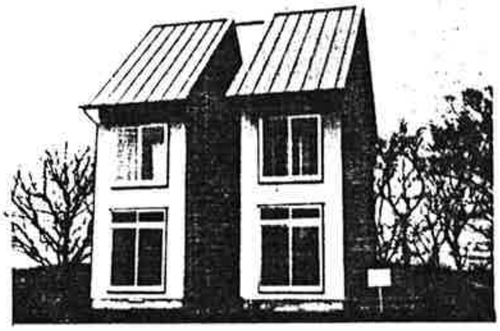

Fig. 1. Tandem-type test house.

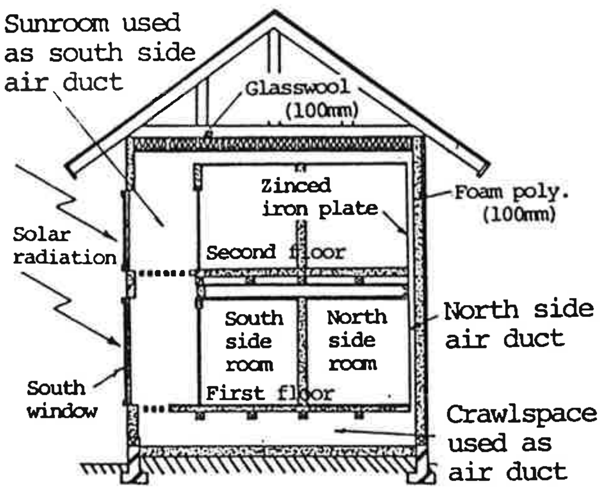

Fig. 2. Air circulation system in the ACT test house.

To evaluate the effects of the air circulation, it must be confirmed before the experiments that the two test houses have the same air-tightness and the same thermal performance. Air leakage characteristics of the test houses were measured separately by depressurization. Total air flow per unit floor area of the houses with 10(Pa) pressure difference were 0.053 and 0.062 (m^3/min.m^2) respectively, and therefore the two test houses can be considered to have almost the same air-tightness. After blocking the air duct completely by the shutter, the room air temperatures of the two test houses were measured. The difference between the thermal insulation of the ACT and the OT test houses is that the

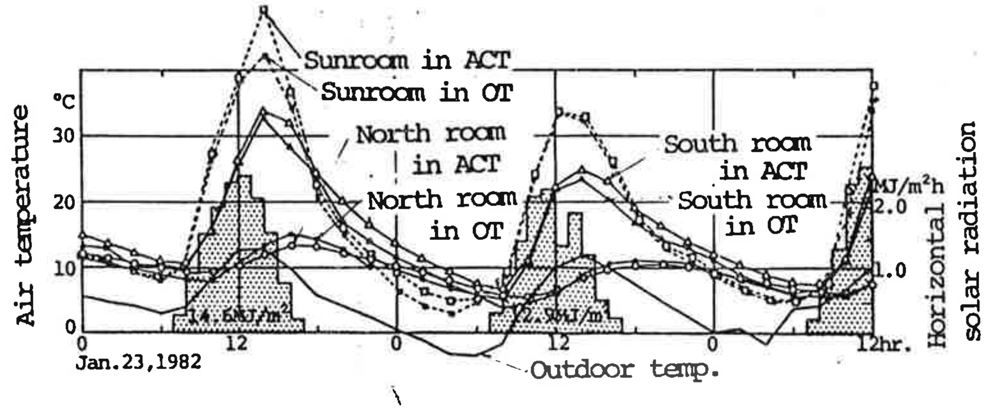

Fig. 3. Comparison of room air temperature between the ACT and the OT test house, when the air ducts in the ACT test house were blocked completely.

former one has the air layers produced by blocking the air duct, in the north wall and at the ceiling. Daily change of air temperature in different rooms are shown in Fig. 3. Temperature curves for the ACT and the OT test houses may be seen to run close to each other. Therefore, if the air ducts are opened, the effectiveness of the air circulation can be evaluated precisely.

SLOT SIZE OF NORTH SIDE AIR DUCT FOR AIR CIRCULATION

The slot size of the north side air duct was changed from 10 to 20, and finally to 50mm. These latter results obtained for the first floor rooms are shown in Fig. 4. As the purpose of the air circulation is conveying the heat gain to the north side room, the increase of the air temperature in the north side room is our interest. The north side room air temperatures of both types show similar temperature variation but the north side room air temperature of the ACT test house was always higher than that of the OT test house. For example, the north room air temperature of the ACT test house is about 4.0°C higher than that of the OT test house in the case of slot size 50mm.
It can be considered that these temperature increase of the north side room is due to the effects of the air circulation. The largest temperature increase was measured in the case of slot size 50mm.

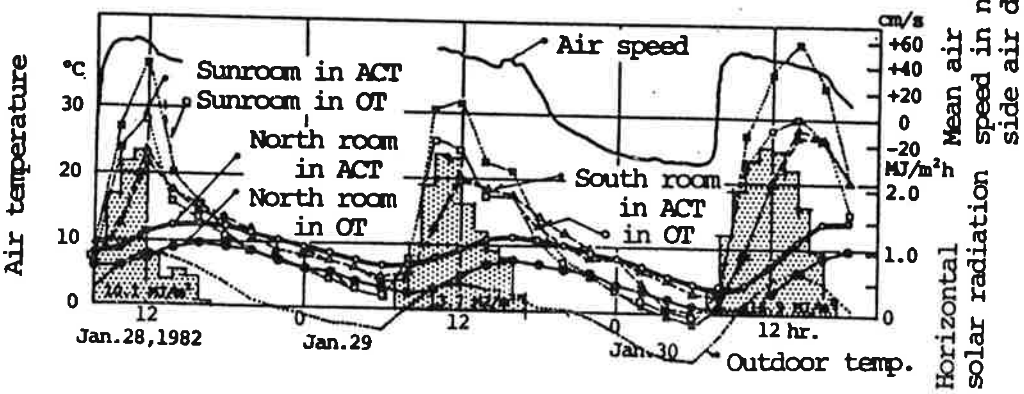

Fig. 4. Comparison of room air temperature between the ACT with air circulation and the OT test house, in the case of slot size 50mm of north side air duct.

AIR SPEED IN NORTH SIDE AIR DUCT

The variations of the air speed in the north side air duct are also shown in Fig. 5. The direction of the air flow in the north side air duct was always downward in daytime regardless of the slot size of the air duct. The air speed decreases gradually from the noon, and the direction of the air flow changes upward during the night. The direction and the speed of the air flow were observed visually and measured by thermistor anemometers, respectively.
It is considered that this inversion of the air flow direction is caused by the fact that the air temperature in sunroom is lower than that in the north side air duct in the night. Because the sliding shutters of the south windows are not used in these experiments even during the night.
In the case of slot size 10mm, 20mm and 50mm, the air speed in daytime were about 20cm/s, 50~65cm/s and 40cm/s respectively. In the night, the air speed hardly changed with the slot size of the air duct and their speeds were almost the same, about 20cm/s. If the sectional area of the north side

air duct is taken into consideration, the circulating air volume in the case of slot size 50mm was the largest among several slot size.

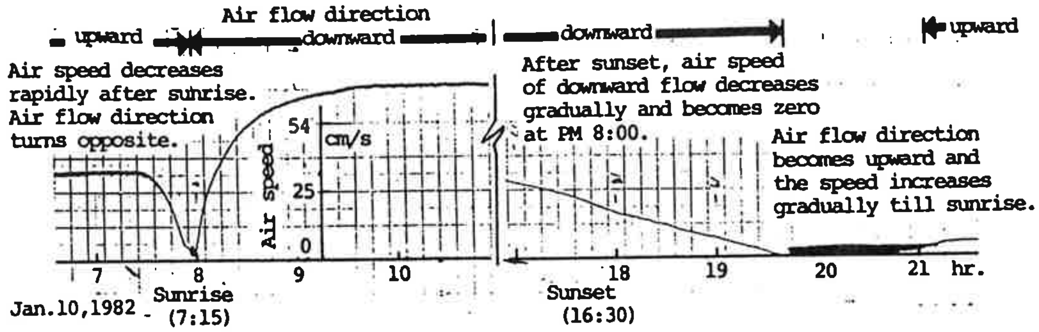

Fig. 5. Air speed in north side air duct measured by thermistor anemometer, in the case of slot size 50mm.

RELATION BETWEEN AIR SPEED AND TEMPERATURE DIFFERENCE

The relation between the air speed in the north side air duct and the air temperature difference of both side can be examined by simple model. Figure 6 shows the model with the air duct of same sectional area. As the force for air circulation is due to the temperature difference between the a temperature in the south side duct and that in the north side duct, the forc can be described as,

$$\text{Force} \propto g h\,(\rho_s - \rho_n) \qquad (1)$$

In the steady state condition, this force balances with the resistance of ai flow. Using the coefficient of the resistance C, the resistance of air flow is generally written by $C\,\rho_m V^2/2$. Therefore, Eq.(2) can be obtained,

$$g h\,(\rho_s - \rho_n) \propto C\,\rho_m V^2 \qquad (2)$$

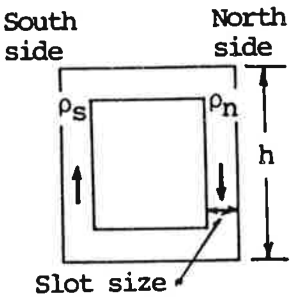

Fig. 6. Simple model of air circulation.

ρ_s = air density in south side duct
ρ_n = air density in north side duct
ρ_m = mean air density in air duct
h = hight of air duct
g = gravitational acceleration

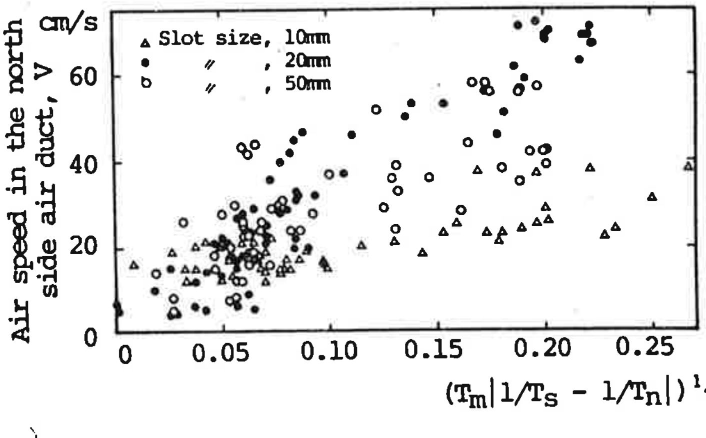

Fig. 7. Relation between air speed and temperature difference in air duct with different slot size.

By using the relation of $p/\rho = RT$, Eq.(2) can be described as,

$$V \propto (T_m |1/T_s - 1/T_n|)^{0.5} \quad (3)$$

Figure 7 shows the relation between the air speed and the value of right-hand term of Eq.(3) obtained by the experiments with the different slot size of the north side air duct. As we can not consider the condition of the measurement to be steady state in a strict sence, the experimental values are scattered. However, it can be seen that the air speed is in approximate proportion to the value concerning the temperature difference, at each different slot size of the air duct. In the case of slot size 10mm, the air speed is the smallest among several slot sizes.

CONCLUDING REMARKS

The possibility of the air circulation due to natural convection and the effectiveness of the air circulation to the room air temperature were studied by comparative experiment using tandem-type test house.
When rearranging the experimental results,

1. The air circulation due to natural convection occured fairly good and the air speed in the north side air duct of slot size 50mm was about 40cm/s in daytime with solar radiation. In the night, the flow direction in the north side duct turned opposite of that in daytime and the air speed was about 20cm/s.
2. The north side room air temperature in the ACT test house was maintained about 4°C higher than that of the OT test house all day. It may be concluded that this temperature difference between these rooms is due to the heat transport from the south side to the north side rooms by the air circulation.

It is concluded that the ACT test house is useful to convey the heat gain from the south side to the north side rooms and that combining with some small fan or with some air collector for increasing heat gain or with some rock bed, practical applications of this system can be expected.

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