ARCHITECTURAL DESIGN OF PASSIVE SOLAR RESIDENTIAL BUILDING

by

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This paper studies thermal environment of closed balconies that commonly exist in residential buildings, and designs a passive solar residential building. The design optimizes the architectural details of the house and passive utilization of solar energy to provide auxiliary heating for house in winter and cooling in summer. This design might provide a more sufficient and reasonable modification for microclimate in the house.

Key words: *solar energy, thermal environment, passive, greenhouse, balcony*

Introduction

The functional layout of residential building is usually very compact which largely limits the degree of freedom in design, and therefore there are some inherent rules in residential design. For most residential buildings, especially for the unit residences, closed balconies are usually designed on the sunny side of the buildings arranging outside of the sunny rooms, such as living room, dining room or master bedroom, and across one or two or even more rooms. The window area in closed balconies is generally large which takes advantage of solar radiation creating the greenhouse effect. However the disadvantages of the thermal environment of closed balcony are also obvious. Firstly, in sunny winter weather, although the temperature is high in closed balcony due to the greenhouse effect, hot air is not easy to enter the room. Secondly, in hot summer weather without wind, strong solar radiation overheats the balcony as a result of the greenhouse effect in the daytime. However at night, because of no obvious convection wind, the cold outdoor air is difficult to enter the room, also leading to incredibly hot and muggy.

Because of the functional requirements of family life such as drying, planting and so on, the residential building, especially the unit residence, is difficult to avoid constructing closed balcony adjacent to the sunny facade of the building. Therefore, the defects of the thermal environment of closed balcony are inevitable problems in residential building design for a long time.

This study proposed the design of the passive solar residential building adjacent to greenhouse, to solve the above defects. The design optimized the architectural details of the house and passively utilized solar energy to provide auxiliary heating for the house in winter and cooling in summer by the adjacent greenhouse. This design overcame the defects of the thermal environment of closed balcony in the existing residential buildings and regulated the microclimate in the house more sufficiently and reasonably by making full use of solar energy.

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Architectural design

Figure 1 shows the architectural design of passive solar residential building adjacent to greenhouse. A greenhouse is built adjacent to the sunny facade of the building.

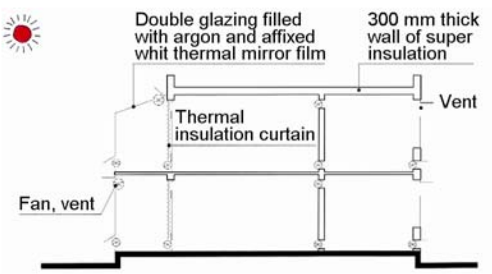

Figure 1. Architectural design

The proposed adjacent greenhouse is different from the closed balcony on the sunny side of the existing residential buildings, and their differences are as follows.

Compared to existing closed balcony with relatively limited window area, the outer surface of the greenhouse is completely composed by glass, which makes it easy to collect more solar energy in winter. The greenhouse adopts double glazing filled with argon and affixed with thermal mirror film. The combination of 10 mm thick argon gas layer and thermal mirror film which allows transmission of the short wavelength radiation and reflected the long wavelength radiation makes the thermal resistance up to around 0.4 m^2K/W, even larger than that of 32 cm thick brick wall. The thermal mirror film remarkably reduces the indoor radiation loss and maintains the sufficient transmission of solar radiation.

Moreover, additional adjustment is conducted on the architectural design of the passive solar residential building adjacent to greenhouse. Residential roofing and exterior walls are made of 300 mm thick wall of super insulation. All residential exterior windows and glass doors separating the greenhouse and interior are made of double glazing filled with argon and affixed with thermal mirror film. The vents which can be opened or closed by the remote control are designed at the upper and the lower ends of the glass doors separating the greenhouse and interior, on the indoor walls paralleling to the glass doors and on the shady exterior walls. A retractable thermal insulation curtain is added on the outside of the glass door separating the greenhouse and interior. Ventilating fans are installed in some vents to accelerate the air flow as shown in fig. 1 [1-3].

Operating mode analysis

Operating modes of the proposed residential design which utilizes solar energy to passively assist the house in heating and cooling in winter or summer, day or night are different and the detailed modes are as follows [4, 5].

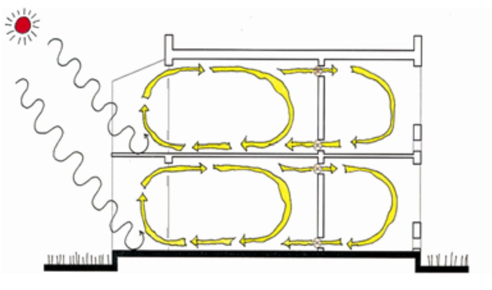

Figure 2. Operating mode in winter daytime

In sunny winter daytime, the opening and closing mode of the vents and the fans in the house is shown in fig. 2. The greenhouse absorbs abundant solar radiation, resulting in the greenhouse effect. The air temperature in the greenhouse subsequently rises, and then the chimney effect appears. As the hot air rises, it flows into the room through the vent at the upper end of the glass door and the indoor cold air enters the greenhouse from the vent at the lower end of the glass door, followed by heating by solar radiation and providing continuous heating for room. In order to enhance ventilation to interior space, the fans can be opened as shown in fig. 2.

At night, all vents are closed. Good heat insulation effect is achieved by the architectural insulation measure.

In summer daytime, the house seems to be packaged with a thick layer of electric blanket by the closed balcony because of the greenhouse effect. At night, if there is no convective wind along the main direction of the house's ventilation, the outdoor cold air is very difficult to enter the room, even if the doors and windows are wide opened. The passive solar residential building adjacent to greenhouse can overcome the defects of the thermal environment of closed balcony through its distinctive mode and assist in cooling the house efficiently.

In the summer daytime, the opening and closing mode of the vents is shown in fig. 3 and the thermal insulation curtain is hung. The solar radiation enters the greenhouse, but the thermal insulation curtain reflects the majority of this radiation, which leads to a sudden temperature increase in greenhouse. The hot air in greenhouse flows out from the upper vent, and the outdoor air with relatively low temperatures pours into the room through the lower vent. Strong solar radiation in summer maintains strong greenhouse effect and chimney effect inside the greenhouse, which generates continuous ventilation from indoors to outdoors, avoiding the hot air accumulation and temperature rise in the greenhouse. The thermal insulation curtain and the glass door prevent the heat transfer into the room to a great extent.

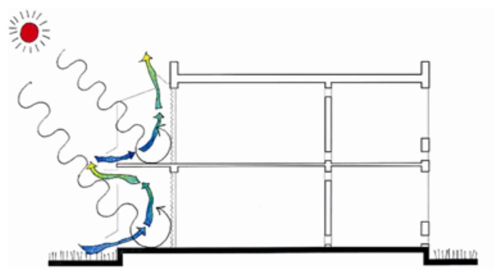

Figure 3. Operating mode in summer daytime

This operating mode successfully overcomes the "electric-blanket effect" of the closed balcony in summer daytime.

At night, if there is no convective wind along the main direction of the house's ventilation, the opening and closing mode of the vents and the fans in the house is shown in fig. 4. The air in the room and the greenhouse is heated due to the radiation from human, electric appliance, and so on, and then rises. Because the chimney effect is weak, the fans are opened as shown in fig. 4 to accelerate the air flow. The outdoor cool air is continuously drawn into the rooms from the lower vents of the greenhouse and the exterior wall, which flows outdoors from the upper vents after heating and rising.

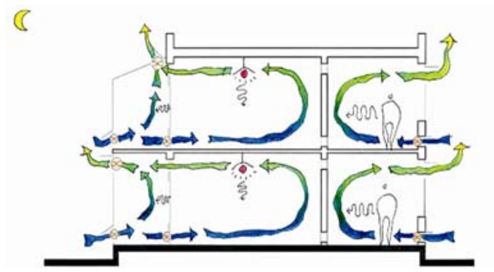

Figure 4. Operating mode in summer night

Conclusions

This work proposed the design of the passive solar residential building adjacent to greenhouse, which overcame the defects of the thermal environment of closed balconies that commonly exist in residential buildings. The design optimized the architectural details of the house and passively made use of solar energy to assist in heating the house in winter and cooling in summer by the adjacent greenhouse. This design provided a more sufficient and reasonable modification strategy for the microclimate of the house by using solar energy more effectively and optimally. This research is also valuable for the problems of glass-wall building in utilizing solar energy.

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