Research on Green Building Design Strategy of Large Space Building —Taking Taiyuan South Railway Station as a Case

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Abstract. As a city's landmark building, railway passenger stations are often large in space, crowded and extremely comfortable, which resulted in high energy consumption. Taking Taiyuan south railway station as a case, this paper introduced the green energy-saving design of the adaptable climate through natural ventilation, palisade structure, shading and natural lighting, ventilation and heating,and so on. Meanwhile, design effects were verified by simulation and experimental test.

Introduction

In recent years, with the rapid development of social economy and urbanization in China, the high-speed railway entered a fast development period. As a type of public buildings, railway passenger stations are always seen as the landmark of the city and people here are relatively concentrated. They have stringent specification of construct and high demand of comfort. Therefore, ~~in~~ the priority issue for architecture to consider is how to deal with its' construction and regional climate and design in a ~~for~~ green and effective way to construct high-comfort, low-energy buildings. Taking Taiyuan south railway station as a case, this paper discussed the green energy-saving design of the adaptable climate and provided some measures for it.

Project Survey and Design Ideas

Taiyuan south railway station is located in Xiaodian zone, the southeast of Taiyuan city of Shanxi province in China. This station has three layers, the elevated waiting hall, platform layer and underground outbound,which is more than 60,000m^2. With reasonable traffic guide design, it provides a convenient entering and leaving route (Fig.1).

Fig. 1 Architectural appearance

As a place that large number of people concentrated, railway passengers stations often have a higher demand of comfort, so the energy consumption is huge. The Taiyuan south railway station adopts the green building passive design strategy, designing from the aspects of the natural ventilation, palisade structure, natural lighting and sunshade, HVAC and building control management and so on to carry on the design, and effect of passive design was demonstrated by simulation and test.

Green Design Idea and Analysis

Natural Ventilation Design. Taiyuan station ventilation tower was designed on the roof, and electric shutters and awning window were set to form the natural ventilation.

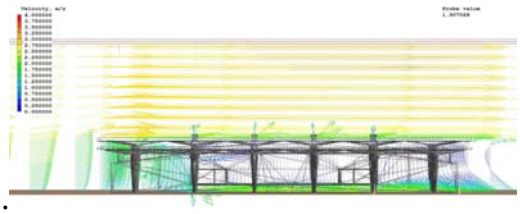

Fig.2 Natural ventilation analysis of the station

At the same time, the simulation CFD software PHOENICS was applied to analyze the effect of passive design. Taking the situation of summer noon at 12:00 as an example, it always braves west winds whose speed is 1.9m/s. From the Fig.2, the wind speed can be seen to reach 2.0m/s, but the air flow in the inlet and outlet is attenuated rapidly. The effect of pulling out the wind of roof hood is relatively obvious, which makes the area that wind speed approaching 0.5m/s in passenger station increase significantly.

In order to verify the effect of natural ventilation design further, combined with the ventilation simulation, five test points near the vertical direction of the space station and cowl were selected (Fig.3) to analyze the ventilation effect of roof hood. The test was taken from 8:00 to 18:00 on August 5th.

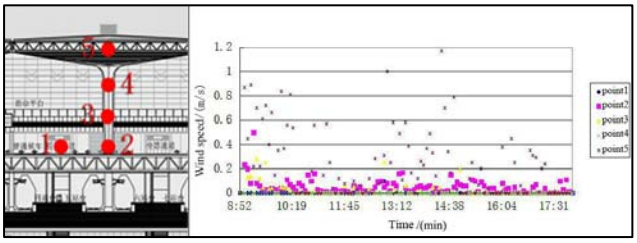

Fig. 3 Test point position and analysis of wind speed

The change of the wind speed at point 5 that close to the cowl is extremely obvious, and the maximum wind speed within the test period reaches 1.1m/s while the average wind speed is 0.22m/s . According to the Fig.4, combining with the temperature stratification of the whole waiting room space, the hood has a certain effect in guiding the air exhausted to the outside through the roof . At the same time, the test speed of the entrance door is about 1.5m/s, and the wind speed of the north and south wall is 0.46m/s. The test data indicates that window and door's openings and the hood play a certain role for outdoor airflow into, which is helpful to realize natural ventilation effect in the interior of the station.

Energy Saving Design of Building Envelope. The envelope design of Taiyuan station is mainly embodied in two aspects, roof system and unique curtain wall system. In order to adapt to the local cold regions climate and energy saving design requirements, Taiyuan south station adopts the roofing composed of unique unit body, which covers about 73,000 m^2. The material and function of each unit roof is different, which can be divided into the skylight, the ventilation tower and the metal roof (Fig.4). Transparent roof is made of high strength, good impact resistance, high transmittance, flame retardant polycarbonate and high strength plate; ventilation tower for natural ventilation and fire smoke exhausting device waiting hall; metal roof formed by aluminum alloy roofing system. The roof unit has double-layer structure and insulating mineral wool. Its' average thickness is about 3m.

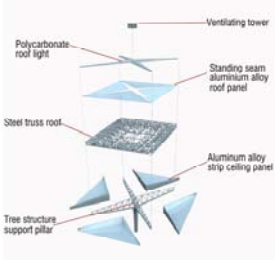

Fig. 4 Organigram of roof

The curtain system has two forms, full glass curtain wall and compound curtain wall. Full glass curtain wall adopts 8+15A+8 double hollow Low-E glasses, and the integrated heat transfer coefficient can reach 1.5W/ (m^2· K). The composite curtain wall is made of double layer imitation

stone panels, low radiation glass and glass windows (Fig. 5). The combination form of the stone panels and glass curtain wall can effectively block the solar radiation, and reduce the impact of the building to the sun and the load of summer cooling system. In addition, the form of stone wall is double layer masonry , and 600mm-air-layer is remained. As a good thermal buffer, the closed air layer is conducive to reduce the outdoor temperature changes to the indoor temperature in the cold region, thereby maintaining the indoor temperature stability, and reducing the energy consumption of the building.

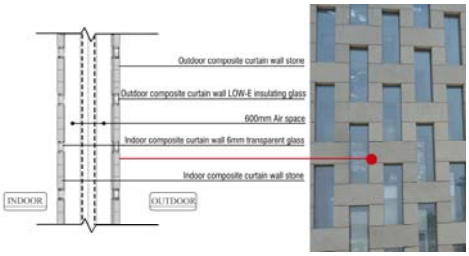

Fig. 5 Organigram of envelop enclosure

Natural Lighting Design of Roof. As we all known, it is difficult for natural lighting of large space building to meet the needs. The X type polycarbonate panel sunroof in Taiyuan station was designed and translucent material can go through and gentle the sunlight, so that natural light evenly illuminate the inside of the building. In addition, designed as a glass floor, the elevated layer perfuse the platform with radiance . These measures can meet the basic demand of lighting and reduce the energy consumption during the daytime in the building. After testing and analysis, summer daily average illuminance of station building can reach 350lx in the test period, while it goes to 220lx in winter. During the day without special circumstances, it can basically meet the construction needs of the natural lighting (Fig.6).

Fig. 6 Natural lighting of roof

Building Shading Design. In the passive design, reasonable shading avoid the sunlight direct into the indoor, which can cut down the thermal radiation and reduce the indoor temperature in summer, but also save energy consumption of air conditioning to achieve the goal of energy saving. The design of Taiyuan Station used the construction of shading mode combining the architectural modeling. The architect designed the large roof , which formed the inclusive transition space that the public space needs (Fig.7).

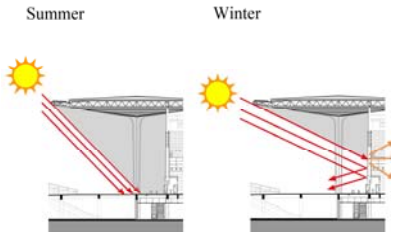

Fig. 7 Organigram of building shading

According to the analysis of the data, the building outdoor solar radiation, which is bigger in summer, up to 950 W/m^2. However, there is an obvious lower data when the building is on the west facade over the roof whose radiation could reach 100W/m^2.The analysis confirmed that the shading effect of revealing eaves is obvious in summer. And the sunlight can face the building facade directly, which is helpful to maintain indoor temperature and save the energy consumption of HVAC (Fig.8).

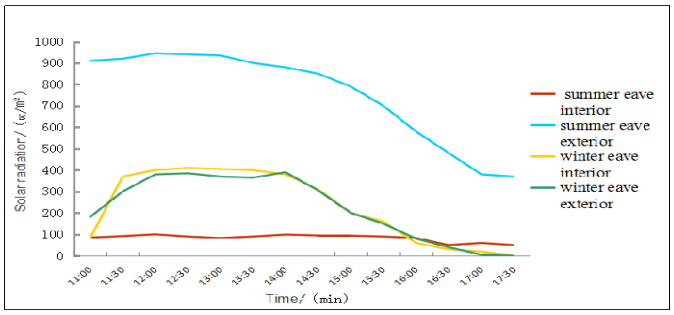

Fig.8 Winter and summer solar variations

Heating and Ventilation Design. Taiyuan located in a cold region, and the temperature is very low in winter. In order to maintain the thermal comfort in winter, the station needs to take heating to improve the indoor temperature in winter. The traditional form of heating in northern area mostly is floor radiation heating which combines ground source heat pump and city heat supply network (composite ground source heat pump system) as heat source.

The single action of traditional floor radiation heating is not able to make the space temperature to reach a comfortable standard. In addition, city heat supply network transmits for remote distance and require higher power. What's more, the construction of city heat supply network is not complete when the building was just built, and the ground source heat pump cannot meet long-term requirements. Therefore, simply relying on floor radiation heating is infeasible, so the HVAC design combining the floor radiant heating system and ventilation heating is used to solve the problem. In winter testing, except for the four air conditioning outlets of western entrance, heaters, which in the rest of regions are all turned on, are combined with floor heating to warm the indoor temperature in order to suitable level for human activities.

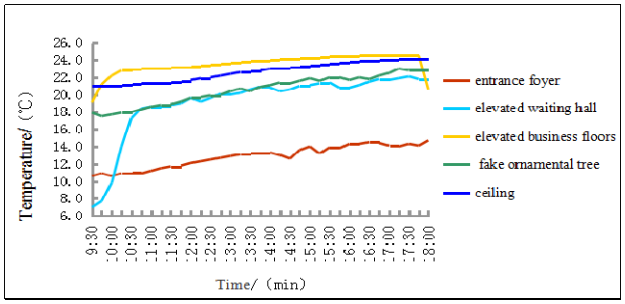

Fig. 9 Winter indoor temperature variation

In winter experiment, five measure points were chosen at universal hall, waiting storey, commercial storey, the top of the building and over the waiting storey to measure indoor temperature variation. From Fig. 9, we can see that the indoor temperature which fully meets the requirements of winter indoor thermal comfort is maintained at 18℃~ 20℃ in the waiting hall and two commercial storeys. But in the entrance hall, the temperature is relatively low, maintaining at 14℃. However, the temperature is apparently higher in the top of the building space, which can reach 24℃. It also create conditions for recovering some of the hot air in winter, realize the secondary use of heat and promote building energy efficiency.

Intelligent Control and Regulation

In Taiyuan station, intelligent control was designed to enhance energy saving effect, such as efficient lighting system, the self-starting of escalator, intelligent building property management system and so on. In this building, the artificial lighting uses energy saving lamps and lanterns, which can not only provide high photosynthetic efficiency lighting but also make it easily to maintain and clean. Accordingly, the Taiyuan station adopts the variable frequency starting escalator which is able to realize the self-starting function through the detection to passengers from the detectors. After the passengers enter the detection area, the escalator start operation or operate from low speed to specified speed. If nobody enters the detection area during the specified time interval, the escalator will return to original setting. What's more, the following systems are planned to be set up within the

station building: production office automatic telephone system, passenger wireless communication system, passenger and complex radio system, CATV system, alarm and linkage control system and the operation management information system. These intelligent systems are able to enhance the quality of property management service and save operational energy consumption of the station.

Conclusion

This paper takes Taiyuan South railway station as an example, through software simulation and field test, the efficiency of its green construction design has been fully detected. Based on the energy-saving and passive design, a series of green design strategies of the large space railway station have been put forward, such as natural ventilation, natural lighting, and intelligent control and so on. In the design of the large space railway station, this kind of construction's concrete demands should be highly considered. We should combine with the local climate and culture, adjust to the local conditions and make an active exploration to keep the sustainable development of green building design strategy.

Acknowledgement

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