Simulation and analysis of energy consumption in the use of industrial building of wall panel

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Abstract. The energy consumption of industrial building wall panels in the use phase is simulated. The temperature variation and heat transfer of wallboard with different thickness of insulation layer in different climate zones were studied. The results show that the difference of daily average heat transfer is less than 0.01 MJ/M² for the wall panels with different thickness of insulation layer in the same city in summer. However, the daily average heat transfer among cities is quite different. The daily average heat transfer of Guangzhou wallboard is the largest, which is more than 1 MJ/m², followed by Beijing. The average daily heat transfer is maintained above 0.69 MJ/m², and Shanghai's wallboard has the least average daily heat transfer, only 0.32-0.33 MJ/m². It can be known from the above data that Beijing needs to choose a composite wall board with a thermal insulation layer thickness of 6 cm in winter, Shanghai uses a composite wall board with a thermal insulation layer thickness of 4 cm, and Harbin chooses a composite wall board with a thermal insulation layer thickness of 6 cm or more to meet the insulation requirements.

1. Introduction
With the development of society, the energy consumption of building industry will continue to increase substantially[1], and research on the thermal performance of envelope structure has become the focus of many countries to reduce energy consumption[2]. China's building energy consumption accounts for about 27% of the total energy consumption, domestic energy consumption per unit of Gross leasable area is 2-3 times that of developed countries, more than 80% of new buildings are high-energy buildings[3]. The energy consumption of industrialized residential building wallboard is mainly in four stages: production, transportation, construction and use. The related literature shows that the proportion of wallboard in building materials is about 70%, so it is important to reduce the energy consumption of industrial building wallboard. For China's industrial buildings, the first thing is to find a more accurate method of measuring energy consumption, conduct systematic and accurate quantitative analysis of building energy consumption and put forward relevant Suggestions for building energy conservation and consumption reduction.

2. Research methods of mathematical simulation
2.1. Mathematical model of wall
A two-dimensional unsteady wall heat transfer model is established by using gambit software. Both the indoor and outdoor sides of the wall are set to the third type of boundary conditions. The convective heat transfer coefficient of the inner surface of the wall is 8.74 w/(m²·k), and the heat
transfer coefficient of the outer surface of the wall is 23.26 w/(m²·k). Indoor air temperature $t_n$ is set at 26 °C in summer and 18 °C in winter[4]. For a more comprehensive analysis of heat transfer using stage wall panels, three kinds of wallboard models with different insulation thickness were simulated. The dimension parameters are as follows (the simplified model ignores the steel bar material in the Wallboard) : The face1 and face 2 shown below represent the main wall layer of the composite exterior wall panel, the main material is fly ash concrete, the surface area between face 1 and face 2 is the grouting connecting layer, the main material is reinforced concrete; Face 3 represents the outer protective layer of the composite exterior wall board, the material is the same as the main body layer, the middle face area is the insulation layer of the wall board, its thickness “a” is 2 cm, 4 cm and 6 cm respectively, the insulation material is polystyrene foam plastic insulation board.

Fig. 1 Simplified model of insulation wall thickness δ external wall panel

2.2. Slection of meteorological parameters for typical cities
Harbin is selected as a typical city for simulation in cold regions; Beijing is selected for cold regions; Shanghai is selected for hot summers and cold winters; and Guangzhou is selected for hot summers and warm winters. The heating season in Harbin is from October 15 to April 8. The heating season in Beijing is from November 14 to March 15 in a typical meteorological year, and the cooling season is June, July, and August. The heating season in Shanghai is from November 14 to March 15 in a typical meteorological year.

3. Result analysis

3.1. Analysis of heat transfer in winter
Because of the difference between the grouting material and the wallboard material in the wallboard grouting joint during the construction, the wallboard heat bridge will be formed.
Figure 2 shows the temperature field in the wallboard during heat transfer in winter in Beijing. According to the cloud diagram of the temperature field at each heat transfer moment, the heat transfer of the wallboard is affected by the connection of the wallboard to the heat bridge. At the beginning of heat transfer, the temperature in the Thermal bridge area is lower than that in the wallboard area. Due to the difference in temperature, the heat will spread from the wallboard to the heat bridge. After 3 hours, the heat will transfer to the wallboard insulation layer. As the heat transfer in the Thermal bridge area is relatively rapid, there is a high temperature in the wallboard area and a slightly lower temperature in the Thermal bridge area. It is proved that the existence of wallboard heat bridge will increase the heat transfer of wallboard in winter. The influence of wallboard heat bridge should be considered in the analysis of wallboard heat transfer[5].

In winter, the heat transfer process of composite exterior wall panels with insulation thickness of 2 cm, 4 cm and 6 cm in Harbin, Beijing and Shanghai was simulated. By means of integral method, the heat transfer at the junction of external wall panel and thermal bridge can be obtained under various working conditions.

Figure 3 shows a histogram of the total heat transfer of the external wall during the heating season. The heat transfer of wallboard varies greatly from city to city. Because of the difference of wall insulation thickness, the total heat transfer of wall insulation in winter is in the range of 280 ~ 430 MJ in Harbin, 100 ~ 200 MJ in Beijing and 29 ~ 55 MJ in Shanghai. Figure 4 shows a histogram of the daily average heat transfer of the exterior panel during the heating season. It can be found that the temperature conditions in Beijing in winter need to choose the composite wallboard with an insulating layer of 6 cm thick, and in Shanghai, the composite wallboard with an insulating layer of 4 cm thick,
in order to meet the requirement of heat preservation, the temperature conditions in Harbin need to choose a composite wall board with a thickness of 6 cm or more to meet the insulation requirements.

3.2. Analysis of working condition in summer

The heat transfer simulation of the wall panels in summer simulated the heat transfer of the wall panels at the ambient temperatures of Harbin, Beijing and Shanghai when the thickness of the insulation layer of the composite wall panels were 2 cm, 4 cm and 6 cm respectively, the heat flux through the wall surface and the Cross section of Thermal Bridge and the temperature change of the wall surface during the heat transfer process are obtained respectively, to analyze the heat distribution inside the wallboard.

Figure 5 shows the temperature field in the wallboard during summer heat transfer in Beijing. According to the cloud diagram of the temperature field change at each heat transfer moment, due to the large temperature difference between day and night in summer, the external environment will sometimes be higher than the internal design temperature and sometimes lower than the internal design temperature, that is, the direction of heat transfer changes with temperature. In the process of heat transfer of wallboard, the external temperature is slightly higher than the internal temperature at the first 2 h and the heat is transferred to the inside without passing through the insulation layer, and then the internal temperature is high at the second 24 h, and the heat is transferred to the outside, which results in the fast transfer of the heat bridge and then iterating so many times. In general, when heat is transferred inwards, it is not until it passes through the insulation that thermal bridge's influence on heat transfer becomes apparent. When heat is transferred indoors, it is also transferred to thermal bridge; when heat is transferred outwards, the heat flow direction is the same as the heat transfer of the thermal bridge in winter.

Different from the working conditions in winter, the temperature difference between day and night in summer varies greatly, the heat transfer direction of the wall panel is uncertain, and the phenomenon of heat transfer in the positive and negative directions will occur. After integrating the
heat transferred to the room and averaging it to the whole summer, the daily average heat transfer in summer of each city's thickness of insulation wall panels can be obtained. The calculation results are shown in Figure 6.

It should be noted that the summer simulation cycle is the same (3 months), so the total heat transfer value in summer under each operating condition is not analyzed.

It can be seen from the graph that the difference of the daily average heat transfer between the wall panels with different thickness of insulation layer in the same city is small under the summer working condition, and the difference of the daily average heat transfer between the wall panels with different thickness of insulation layer is less than 0.01 MJ/m², which can be ignored. However, the daily average heat transfer among cities is quite different. Among them, Guangzhou has the largest heat transfer per day, and the average heat transfer per day is more than 1 MJ/m², followed by Beijing. The average heat transfer per day is about 0.69 MJ/m², and Shanghai has the least heat transfer per day, only 0.32-0.33 MJ/m².

4. Summary
Fluent software was used to simulate and analyze the heat transfer of each working condition of the wall panel and the heat transfer of the thermal bridge at the wall panel connection. In winter, Beijing needs to choose a composite wall board with a thickness of 6 cm, Shanghai chooses a composite wall board with a thickness of 4 cm, and Harbin chooses a thermal insulation wall board with a thickness of 6 cm or more to meet the insulation thermal requirements. In addition to the different heating periods in cities in winter, the difference in external temperature is the main reason for the large differences in heat transfer between wall panels in winter. The relationship between the increase of the thickness of the wall insulation layer and the heat transfer of the wall plate is not linear. As the thickness of the wall insulation layer increases, the heat preservation capacity per unit thickness is decreasing.

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