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Heat Transfer Analysis of Hollow Block Ventilated Wall Based on CFD Modeling

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Abstract

In china, the building energy consumption accounts for about 30% of the national terminal energy consumption, and the energy used for heating, ventilation and air conditioning has been about 65% of the building energy consumption [1]. The heat transfer through the building envelope is a big part of the building energy consumption. Reducing the heat transfer through the wall and enhancing thermal insulation performance will play an important role in reducing building energy consumption. At the present time, the hollow block wall that is proposed in this study is widely used as the building facade for saving energy, which makes the cold air in summer and hot air in winter flow through the cavity of hollow block in order to carry away the cooling and heat stored in walls. Based on the CFD simulation, the thermal performance of the hollow block ventilated wall is analyzed in this paper, and the effect of cavity size on the heat transfer performance is also studied.

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Keywords: Hollow block ventilated wall; Dynamic thermal performance; Numerical simulation; Human comfort; Building energy efficiency

Hollow block ventilated wall and the heat transfer model

Currently, there are a number of hollow blocks on the market, and the hollow area proportion is generally 25%~50%. In this paper, the single-perforated hollow block is studied, and the size of the hollow block is: 390×190×190(mm). The structure of the hollow block wall is shown as Fig. 1. The envelope structure in the dashed box in Fig. 1(a) is selected as the studied object.

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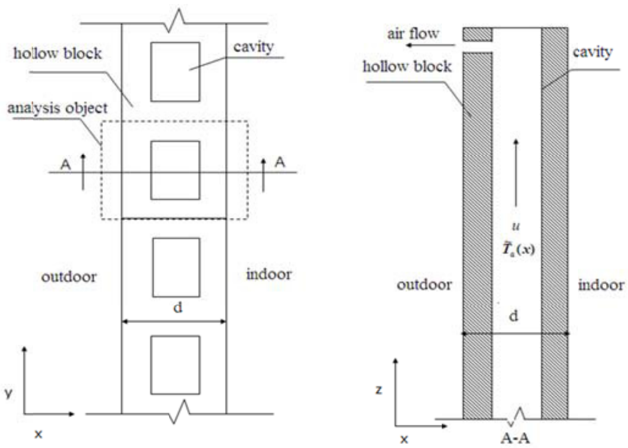

Fig. 1. The structure of the hollow block ventilated wall.

The upper and lower boundaries are adiabatic, and left boundary is affected by the outdoor air synthetic temperature, and right boundary is affected by the indoor temperature, and the inner cavity is influenced by the air through the cavity. A short wall in the height direction (z direction) is selected, and the air temperature change in the cavity along the height direction can be ignored. In this condition, only the cross-section along the length direction (y direction) and thickness direction (x direction) in Fig. 1 (b) need to be considered, and three dimensional heat transfer is simplified to the two dimension heat transfer.

In this paper, only the thermal performance of hollow block wall is considered, regardless of internal and external plastering. The thermal physical parameters of the wall are shown in Table 1.

Table 1. The thermal physical parameters of the wall

	Density/(kg/m^3)	Heat conductivity coefficient/(w/(m·k))	Heat capacity /(J/(kg·℃))
Hollow block	2500	1.74	920

A south wall of a building (the size is 3×8×10 m) in Wuhan city in summer is studied. According to the actual size, the length of cavity is 250mm, and the width of cavity along the thickness of the wall is 80mm, 100mm and 120mm. The air in cavity is considered to be the exhaust air from the air conditioning system, and the temperature equal to indoor temperature. The outdoor air synthetic temperature is calculated based on the outdoor air dry-bulb temperature and solar radiation on the design day of summer in Wuhan city. The outdoor air synthetic temperature [2] is shown as Fig. 2.

When the air conditioning system is working, the indoor temperature is assumed to be 26℃, and the temperature of the air flowing through the cavity is also 26 ℃. In this paper, the CFD software is used to simulate the heat transfer process. The outer surface and the inner surface are the third kind boundary condition, and convection heat transfer coefficient are 18.3 W/(m^2•K) and 8.6W/(m^2•K) respectively [3]. The surface of cavity is a mixed boundary condition, both air convection heat transfer with the cavity surface and radiation heat transfer between the inner surface of the cavity. The convection coefficient between the air in the cavity and the cavity surface is decided by the formula followed.

$$\begin{cases} h = 4.8 + 3.4u & u \le 5m/s \\ h = 6.12u^{0.78} & u > 5m/s \end{cases} \tag{1}$$

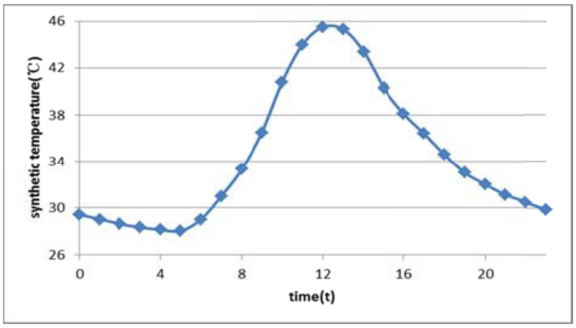

Fig. 2. The outdoor air synthetic temperature.

In this paper, the value of u is 2m/s. The surface convection heat transfer coefficient is 11.6 W/(m^2•K), and the emissivity of cavity is 0.89.

In this paper, the conventional CFD numerical simulation cannot transform periodic boundary condition, a CFD interface program that can change the temperature periodically is imported. Performing the 72-hour simulation of heat transfer process based on the cycle of 24 hours until it reaches a steady state.

Three cases are studied in this paper. In case 1, the air conditioning system works 24h in a day, and the cavity is ventilated by the exhaust air of the air conditioning system for 24h in a day. In case 2, the inlet and outlet of cavity are closed and at this time, the air in the cavity is quiescent. And in case 3, the air conditioning system works from 8:00am to 22:00pm and exhaust air flows through the cavity of ventilated wall during this period, at the rest time in a day, the air conditioning system stops working and the air in the cavity is quiescent.

2. Comparative results analysis

2.1 Case 1

In this case, the air in the cavity is in motion all the day. Fig. 3 shows the comparison of inner surface heat flux density of the two walls. When the heat flux density is positive, it means inner wall surface temperature is higher than the indoor air temperature and the heat flux flows to indoor room from wall. According to Fig. 3, the heat flux of the common wall that flows to indoor through the building envelop continuously increases the indoor cooling load. The minimum value of the heat flux density is 15 W/m^2, the maximum value is 44 W/m^2, and the total heat transfer in 24 hours is 2.5 MJ/m^2. But the indoor cooling load decreases significantly when the envelope is hollow block ventilated wall. The heat flux density from outdoor to indoor is 0.42 MJ/m^2 in 24 hours. The cooling load can be greatly reduced and the energy-saving effect is remarkable.

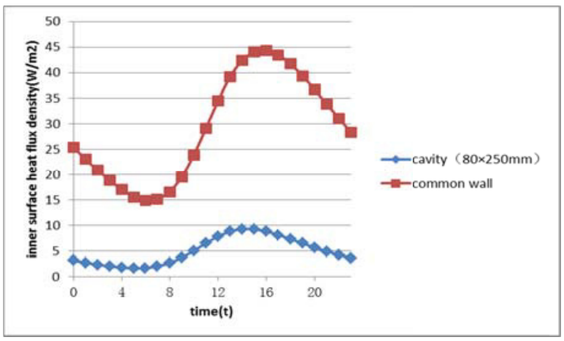

Fig. 3. Comparison of inner surface heat flux density of hollow block wall and common wall.

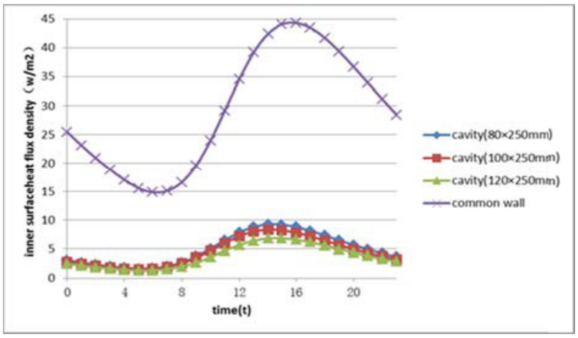

Fig. 4. Comparison of inner surface heat flux density of hollow block wall and common wall.

Changing the size of cavity to 100×250mm and 120×250mm separately, then a comparison and analysis of the heat transfer performance of different walls is made. Fig. 4 shows the comparison of inner surface heat flux density of different walls. According to the figure, the inner wall surface heat flux decreases with the increase of the cavity width when the air flows in the cavity, also, a little changes are revealed. At this time, compared to the common wall, the energy-saving of three kinds of hollow block wall is 83%, 85% and 87% respectively.

2.2 Case 2

In this case, the inlet and outlet of cavity are closed and at this time, the air in the cavity is quiescent. Fig. 5 shows the inner surface heat flux density of different hollow block walls. According to the figure, the inner wall surface heat flux decreases with the increase of the cavity width.Take the cavity with the size of 80×250mm for example, the total heat transfer in 24 hours is 1.6 MJ/m2. Compared with the common wall, the energy-saving of this kind of hollow block wall is 37%. Accordingly, the energy-saving of the other two kinds of hollow block wall is 41% and 44%.

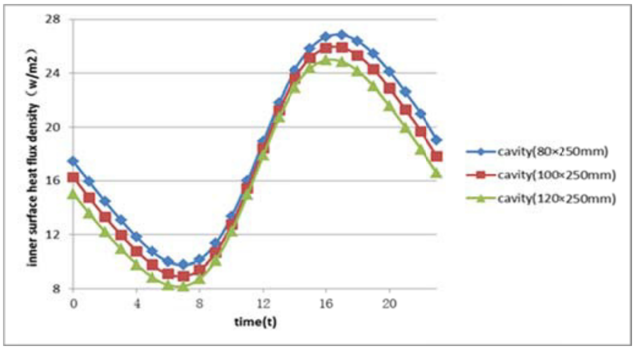

Fig. 5. The inner surface heat flux density of different hollow block walls.

2.3 Case 3

In this case, the air in the cavity is in motion sometimes and is quiescent sometimes. Fig. 6 shows the comparison of inner surface temperature of three kinds of hollow block wall. Fig. 7 shows the inner surface heat flux density of different hollow block walls. The case of the cavity with size of 80×250mm shows the highest inner surface heat flux density, the total heat transfer in 24 hours is 0.71 MJ/m2. Compared to the common wall, the energy-saving of this kind of hollow block wall is 72%. Accordingly, the energy-saving of the other two kinds of hollow block wall is 75% and 77%.

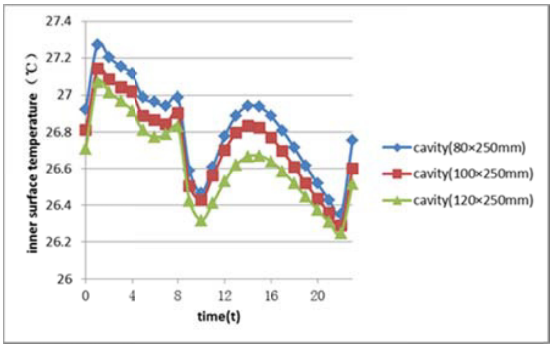

Fig. 6. Comparison of the inner surface temperature of hollow block walls

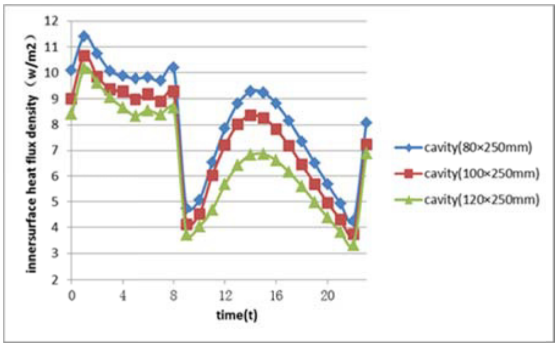

Fig. 7. Comparison of inner surface heat flux density of hollow block walls

3. Methods

The dynamic thermal performance of a hollow block ventilated wall and the conventional wall with the same configuration is numerically simulated by CFD program under typical hot summer and cold winter weather condition, and the effect of cavity size on the thermal performance of the ventilated wall is also studied.

4. Results

The results show that, compared with the conventional wall, the internal wall surface temperature is lowered and the heat transfer from the outdoor to the indoor is reduced significantly. With the increase of the thinness of the cavity, the inner surface temperature and the heat transfer from the outdoor to the indoor is decreased.

5. Discussion

The paper shows that the heat transfer from the outdoor to indoor of the hollow block wall is much fewer than that of the common wall. Moreover, when the thinness of the cavity increases, the inner surface temperature and the heat transfer from the outdoor to the indoor decreases greatly. This is beneficial for human comfort and the simulation results are reliable. Because the heat transfer area is bigger when the size of the cavity increases, it can strengthen the convective heat transfer between the air and the cavity.

6. Conclusions

In this paper, a heat transfer model of hollow block wall is established, and the heat transfer process is studied by using numerical simulation method. According to the result, the energy efficiency and human comfort of hollow block wall are much better than that of the common wall. Moreover, the thermal performance of hollow block ventilated wall becomes better with the increase of the cavity size. In the same conditions, the thermal performance of hollow block wall when the air in the cavity is in motion is better than the thermal performance of wall when the air in the cavity is quiescent.

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References

[1] R.M. Yao, B.Z. Li, K. Steemers, Energy policy and standard for built environment in China, Renew. Energ. 30 (2005) 1973-1988.
[2] Air conditioning design manual (second edition), the tenth design and Research Institute of Ministry of electronic industry, China Architecture and Building Press, Beijing, 1995. (In Chinese).
[3] Y.Q. Lu, Practical heating and air conditioning design manual, China Architecture and Building Press, Beijing, 1993. (In Chinese).