Thermal Performance Analysis of Concrete Small Hollow Block

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Abstract: In this paper, the thermal insulation coefficient and thermal inertia index of small hollow concrete blocks with different hole types are calculated by theoretical method and numerical method, and the block structure with the best thermal insulation property and heat-shielding performance is respectively determined. The relationships between thermal insulation property and heat-shielding performance and block structure parameters are analyzed. The conclusion obtained provides a good reference value for the manufacturer of the block.

Keywords: concrete hollow block; hole type; hole ratio; thermal insulation property; heat-shielding performance

1. Introduction

The concrete small hollow block has the advantages of wide source of raw materials, avoiding destruction of land and fired bricks, low production energy consumption, less environmental pollution, and consumption of some industrial waste, etc. It is one of the new wall materials promoted by China's wall reform. In recent years, it has been widely used in residential and other buildings. In this paper, measures to improve the thermal insulation performance and thermal insulation performance of small hollow blocks are studied.

At present, the main specification of concrete small hollow block is 390mm×190mm×190mm, presented in fig.1. The density of the concrete material used in the concrete hollow block studied in the paper is 1400kg/m³ and the thermal conductivity is 0.53W/m·°C. Since the minimum outer wall thickness of ordinary concrete hollow blocks should not be less than 30mm, the minimum rib thickness should not be less than 25mm, and the hole rate should not be less than 25%[1]. Under the above conditions, the thermal insulation performance and heat-shielding performance of small hollow blocks were analyzed.

![Figure 1. The schematic diagram of small concrete hollow block](image)

2. Analysis of block thermal insulation property
The thermal insulation coefficient is an important parameter reflecting the heat insulation performance of the envelope structure. The higher the thermal insulation coefficient is, the better the insulation performance is. The heat insulation coefficient of the block is obtained when the hole shape is rectangular and the hole rate is 25%, 30%, 35%, 40%, and 45% respectively, according to the calculation method of the average thermal insulation coefficient of non-homogeneous building envelopes. The calculation results are shown in Table 1.

Table 1. The heat insulation coefficient of the block (the hole rate is 25%)

| Number | Block configurations | Hole rows | Max. | Max. a×b | Min. | Min. a×b |
|--------|----------------------|-----------|------|----------|------|----------|
| 1      | [Block1]             | One       | 0.5466 | 330.0×56.1 | 0.4653 | 142.5×130.0 |
| 2      | [Block2]             | One       | 0.5374 | 152.5×60.5 | 0.4654 | 71.0×130.0 |
| 3      | [Block3]             | One       | 0.5273 | 93.0×66.5  | 0.4653 | 47.5×130.0 |
| 4      | [Block4]             | Two       | 0.6273 | 330.0×28.0 | 0.5511 | 176.5×52.5 |
| 5      | [Block5]             | Three     | 0.7134 | 330.0×18.7 | 0.6292 | 247.0×25.0 |
| 6      | [Block6]             | Two       | 0.6192 | 152.5×30.4 | 0.5431 | 88.2×52.5 |
| 7      | [Block7]             | Two       | 0.5820 | 93.0×40.5  | 0.5449 | 117.5×52.5 |
| 8      | [Block8]             | Two       | 0.5503 | 93.3×49.6  | 0.5473 | 88.2×52.5 |
| 9      | [Block9]             | Four      | 0.7778 | 330.0×14.0 | nonexistent | nonexistent |

In Table 1, when the hole rate is constant, by comparing all the data horizontally, the thermal insulation coefficient of each type of block increases with the increase of a and the decrease of b. If the a and b of the air layer in the block are constant, changing the thickness of the ribs and the outer wall does not affect the thermal insulation coefficient of the block, and staggering the air layers does not change the value of the thermal insulation coefficient. After exchanging the upper hole and the lower hole of the 7th and 8th blocks in Table 1, it is found that the value of the thermal insulation coefficient did not change.

When the hole rate is fixed, the thermal insulation coefficient of the block with four rows of holes is the largest, which is obtained by longitudinal comparison of all the data. If a is the same, the thermal insulation coefficient decreases as b increases. If b is the same and the total length of the air layer of the blocks is equal, then the thermal insulation coefficient is also equal. For example, b is 130mm in Table 1, the minimum of the thermal insulation coefficient of the 1st, 2nd, and 3rd blocks is equal. If a is the same, dividing an air layer into multiple layers can increase the thermal insulation coefficient of the block by comparing the maximum values of the 1st, 4th, 5th, and 9th block in Table 1. The variation law of the calculated results is the same as the above law when the hole rate is 30% ~ 45%. For the same structure, with the increase of the hole rate, the change law of the thermal insulation coefficient is shown in Table 2 for the 4th, 5th, and 9th blocks in Table 1. In the table 2, a is 330mm, and the value in parentheses is the b value at the corresponding hole rate.

Table 2. Maximum value of thermal insulation coefficient (m²·K) and corresponding b (mm) value

| Hole rows | Hole rate (%) | 25 | 30 | 35 | 40 | 45 |
|-----------|---------------|----|----|----|----|----|
| Two       |               | 0.6228 | 0.6234 | 0.6247 | 0.6052 | 0.5892 |
|           |               | (28.0) | (33.7) | (39.3) | (44.9) | (50.5) |
| Three     |               | 0.7134 | 0.7044 | 0.6902 | 0.6926 | 0.6840 |
|           |               | (18.7) | (22.5) | (26.2) | (29.9) | (33.7) |
| Four      |               | 0.7778 | 0.7784 | 0.7793 | 0.7678 | 0.7688 |
|           |               | (14.0) | (16.8) | (19.7) | (22.5) | (25.3) |
Observing the data in Table 2, it can be seen that with the increase of the hole rate, the variation law of the thermal insulation coefficient is not fixed, and the two rows and the four rows of holes increase first and then decrease, and the three rows of holes decrease continuously. For the block in this paper, in order to obtain a better thermal insulation effect, b of the two rows of holes should be about 40 mm, b of the three rows of holes should be about 19 mm, and b of the four rows of holes should be about 20 mm. This is because the thermal conductivity of air is smaller than the thermal conductivity of other materials constituting the envelope structure, so the air layer can play a role in blocking heat transfer within a certain thickness. When the air layer reaches a certain thickness, if its thickness is further increased, the thermal insulation coefficient of the air layer hardly increases due to the increase in the heat transfer space. At this time, the total thermal conductivity of the air layer is closer to the thermal conductivity of other materials constituting the envelope structure. This not only does not hinder the heat transfer effect, but also promotes heat transfer.

If the shape of the air layer is circular, it can be converted into a square shape with the same area, and then calculated according to the above method. From the above analysis, it can be seen that the thermal insulation coefficient of the block with a circular hole shape is at between the maximum and minimum values. When the shape of the air layer is elliptical, parallelogram, and triangular, the related literature does not describe how to determine the heat insulation coefficient. In this paper, the thermal insulation coefficients of all the blocks in Table 1 are calculated by numerical calculation method. The error between numerical calculation results and theoretical calculation results does not exceed 5%. Therefore, the numerical calculation method is used to calculate the thermal insulation coefficient of a block whose shape is elliptical and other shape. Take 1 of them as shown in Table 3, the shape of the block is shown in Fig. 1. In this case, a and b are 330 and 56.1 mm, respectively, and the hole rate is 25%.

Table 3. Comparison of thermal insulation coefficient of the block (the hole rate is 25%)

| Block configurations | axb     | Rectangle | circular fillet1 | circular fillet2 | oval       | Triangle | parallelogram | circle   |
|----------------------|---------|-----------|-----------------|-----------------|------------|-----------|----------------|----------|
|                      | 330×56.1| 0.5523    | 0.5522          | 0.5517          | 0.5403     | 0.5208    | 0.5151         | 0.4710   |

When the hole type in Table 3 is rectangular, the calculated thermal insulation coefficient of the block is 0.5523 m²·K/W, the theoretical calculated value is 0.5456 m²·K/W, the error between the two values is 1.20%. The four corners of the rectangular hole are changed to rounded corners, the calculated values at the corner radius of 10 and 20 mm are 0.5522 m²·K/W and 0.5517 m²·K/W, respectively, which are slightly reduced when compared with the rectangular hole. The calculated thermal insulation coefficient of the circular hole block is 0.4710 m²·K/W, the theoretical calculation is 0.4608 m²·K/W, and the error between the two values is 2.17%. The other hole patterns have smaller values than the rectangular hole patterns. The data in table 3 is the data when the hole rate is 25%. When the hole rate is other values, the law is same.

In summary, the hole-type rectangular four-hole block d has the best insulation performance when the hole rate is 35%, a is 330mm and b=19.7mm.

3. Analysis of block heat shielding performance
The thermal insulation coefficient is one of the performance parameters describing the heat transfer capacity of the envelope, and is the evaluation index of the building envelope under steady-state heat transfer conditions. Under non-steady-state heat transfer conditions, the thermal performance of the envelope structure should also be evaluated using the thermal inertia index D. According to the calculation method of D given in the literature[2], the blocks in the paper are calculated. The analysis of the calculation results reveals that if both the a and b values change, that is, if a increases, b decreases or a decreases, b increases, and finally the average thermal inertia index D of the mixed layer decreases when the hole rate is constant. Because a increases, the average heat storage coefficient and the average thermal insulation coefficient of the mixed layer composed of the air space and the concrete will be reduced, while the decrease of b will increase the thermal insulation coefficient of the pure concrete layer, and finally increase the thermal inertia index D of the pure concrete layer. How the thermal inertia index D changes depends on the algebraic sum of the above two parts.

D value is smaller than the D value when the shape of the air gap is rectangular. When the shape of the air layer is ellipse, circle, parallelogram and triangle, respectively. For each type of block in Table 1, because the air heat storage coefficient is 0, the thermal inertia index D of the block decreases as the hole rate increases. Based on the above conclusions, the D value of the 5th block in Table 1 is the largest (2.41), when the hole type is rectangular, when the hole rate is 25%, a=10, b=20mm. That is, the heat shielding performance is best, and the thermal insulation coefficient at this time is 0.6184 m²·K/W.

4. Conclusions

The impact of the hole types on the thermal insulation property and heat shielding performance of small hollow concrete block was analyzed in this paper. It can be concluded that:

(1) With a certain hole rate, increasing hole rows of the air layer can improve the thermal insulation property of the block.

(2) When the hole rate is fixed, the thermal insulation property when the hole type is rectangular is better than the insulation performance when the hole type is elliptical, circular, parallelogram and triangle.

(3) Reducing the hollow ratio can enhance thermal insulation performance. When the hole rate is constant. When the hole rate is constant, the three-hole or four-row hole block has the best heat shielding performance.

(4) The best thermal insulation performance and the best heat shielding performance of the hollow blocks do not occur at the same time. The maximum thermal insulation coefficient of 0.7793 m²·K/W appears in: the hole shape is rectangular, the hole rate is 35%, a=330mm, b=19.7mm, at this time D=2.13; the maximum value of thermal inertia coefficient 2.41 appears when the hole type is rectangular, the hole rate is 25%, a=231.3mm, and b=26.7mm, the thermal insulation coefficient at this time is 0.6184 m²·K/W.

Besides, If combined with the mechanical properties of hollow blocks such as compressive and shear resistance, the choice of block structure will be more comprehensive. The mechanical properties of hollow blocks are the direction of future research.

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