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Study on Influencing Zone of Thermal Bridge of Corner Column in Self-insulation System

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Abstract: The two-dimensional steady heat transfer of corner column is analyzed using ANSYS, moreover, influencing zone of thermal bridge and heat loss in influencing zone is analyzed quantitatively. Research shows that when the thickness of insulation layer is more than 20mm, influencing zone of thermal bridge is about 160mm, and additional heat flow in influencing zone accounts for more than 20% of additional heat flow in thermal bridge.

Keywords: Corner column, heat flow, ınfluencing zone of thermal bridge.

1. INTRODUCTION

Exterior wall is an important part of building structure, and the heat loss from exterior wall is about 30% - 45% of building energy consumption [1-2]. In order to promote the heat insulation performance of wall, the heat conductivity coefficient of wall material is lower and lower, leading to the effect of thermal bridge more notable. The existence of thermal bridge leads to the average heat conductivity coefficient of exterior wall increasing. According to the research, the energy consumption from thermal bridge can reach 20% [3]. Therefore, the heat transfer analysis of thermal bridge has significant meaning.

At present, one-dimensional weighting method is still used to calculate the thermal bridge in energy-efficiency design in China. However, the nearby zone of thermal bridge is affected by the heat transfer, which is called influencing zone of thermal bridge [4]. Using steady or unsteady heat transfer method, there were already some researches about thermal bridge [5-9], but few about influencing zone of thermal bridge [10]. Moreover, the research on influencing zone of thermal bridge was only focused on the condition of none heat insulation in thermal bridge. Furthermore, the quantitative analysis of it was still blank. According to this phenomenon, influencing zone of thermal bridge and heat loss in influencing zone was comprehensively analyzed in this paper.

2. MATHEMATICAL MODEL

The two-dimensional steady heat transfer model for thermal bridge is used:

$$\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} = 0 \tag{1}$$

The third boundary condition is used:

Inner surface of wall:

$$-\lambda \frac{\partial t}{\partial y}\Big|_{y=\delta} = \alpha_1 (t_{f1} - t_{w1}) \tag{2}$$

Outer surface of wall:

$$-\lambda \frac{\partial t}{\partial y}\Big|_{y=0} = \alpha_2 (t_{w2} - t_{f2}) \tag{3}$$

In the equation, α_1 is the convective heat transfer coefficient of inner surface, which is 8.7 W/ (m2·K), α_2 is the convective heat transfer coefficient of outer surface, which is 23.0W/ (m2·K). Heating condition in winter in Wuhan is analyzed as an example, and t_{f1} is the indoor air temperature, which is $18\,^oC$, t_{f2} is outdoor air temperature, which is $-2\,^oC$.

3. CALCULATION MODEL

The typical thermal bridge of corner column is selected as the research object. Calculation model is shown in Fig. (**1**). The column material is reinforced concrete, the thermal insulation material is inorganic thermal insulation mortar, and the exterior wall is ultra-light aerated concrete block. By changing the insulation layer thickness of thermal bridge, influencing zone of thermal bridge and heat loss in this zone is analyzed quantitatively.

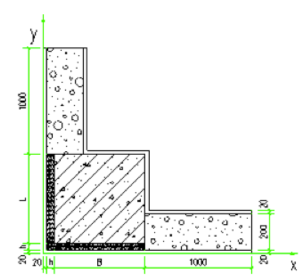

Fig. (1). Calculation model.

4. ANALYSIS OF RESULTS

According to Fig. (**1**), temperature and heat flow of outer surface can be obtained, which can determine the influencing zone of thermal bridge and heat loss in this zone using ANSYS.

4.1. Influencing Zone of Thermal Bridge

The ratio of temperature difference at point P can be defined as:

$$\xi = \frac{t_{f1} - t_p}{t_{f1} - t_{f2}} \tag{4}$$

In the equation, t_p is the temperature of any point (^oC).

The ratio of temperature difference in general place of outer surface:

$$\xi^{'} = \frac{t_{f1} - t_2}{t_{f1} - t_{f2}} \tag{5}$$

In the equation, t_2 is the temperature in general place of outer surface (^oC).

Influencing zone of thermal bridge is the point which can meet the requirement:

$$\frac{1\text{-}\xi^{'}}{1\text{-}\xi} < 0.95 \tag{6}$$

The temperature distribution of corner column is shown in Fig. (**2**) (take h=50mm for example). The temperature of different models is shown in Fig. (**3**).

As is shown on Fig. (**3**), when h=0 (none heat insulation for thermal bridge), the influencing zone of thermal bridge is 0.08m, and with the thickness of insulation layer increasing, the influencing zone of thermal bridge is increasing obviously, and when h≥20mm, the growing trend is slow.

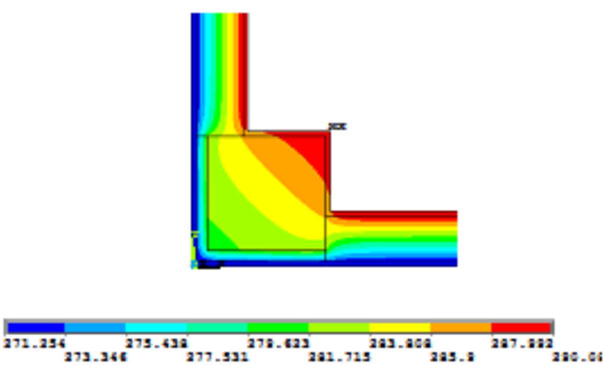

Fig. (2). Temperature distribution (h=50mm).

4.2. Heat Loss in Influencing Zone

Using two-dimensional steady result, the total heat flow Q is:

$$Q = \int_l q\, dx \tag{7}$$

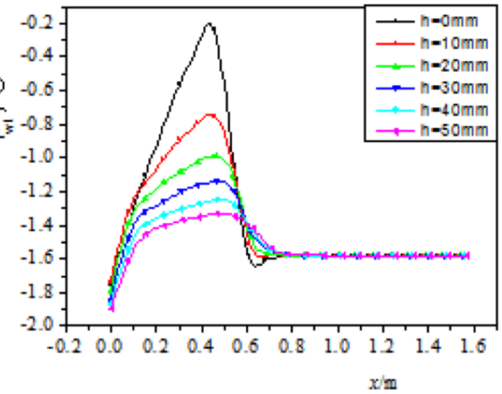

Fig. (3). Temperature of different models.

Additional heat flow ΔQ_B in thermal bridge is:

$$\Delta Q_B = Q - q_0 \cdot l \tag{8}$$

Additional heat flow ΔQ_{Bex} in influencing zone is:

$$\Delta Q_{Bex} = \int_D (q - q_0)\, dx \tag{9}$$

The degree of heat loss in influencing zone of thermal bridge can be represented:

$$\beta = \frac{\Delta Q_{Bex}}{\Delta Q_B} \times 100\% \tag{10}$$

In the equation, q_0 represents the density of heat flow in general place, l represents the length of outer surface. D represents the influencing zone of thermal bridge. The heat flow of corner column is shown in Fig. (**4**) (take h=50mm for example). The heat flow of different models is shown in Fig. (**5**).

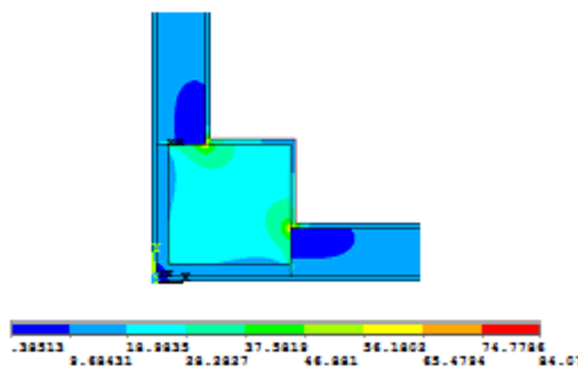

Fig. (4). Heat flow of corner (h=50mm).

Through the calculation, additional heat flow in influencing zone of thermal bridge, and the degree of heat loss in influencing zone of thermal bridge is shown in Table **1**.

As is shown in Table **1**, for corner column of self-insulation system, when the thickness of insulation layer is 0mm, the degree of heat loss in influencing zone of thermal bridge is 5.6%, when the thickness is 50mm, it is 20.4%. That is, with the thickness of insulation layer increasing, the degree of heat loss in influencing zone of thermal bridge is increasing, heat flow in influencing zone of thermal bridge is obvious.

Table 1. Degree of heat loss in influencing zone of thermal bridge.

Thickness of thermal bridge (mm)	h=0	h=10	h=20	h=30	h=40	h=50
Minimum inner surface temperature ($°C$)	11.19	12.34	13.10	13.66	14.11	14.47
Influencing zone of thermal bridge (m)	0.08	0.10	0.14	0.15	0.16	0.16
Heat flow in influencing zone q_0 (W /m^2)	9.74	9.74	9.74	9.74	9.74	9.74
Total heat flow Q (W)	50.07	44.78	41.37	38.85	36.95	35.34
Additional heat flow in thermal bridge ΔQ_B (W)	27.21	14.97	11.37	8.66	6.56	4.76
Additional heat flow in influencing zone ΔQ_{Bex} (W)	1.53	1.31	1.28	1.22	1.05	0.97
$\alpha = \Delta Q_B / Q$ (%)	54.3	33.4	27.5	22.3	17.8	13.5
$\beta = \Delta Q_{Bex} / \Delta Q_B$ (%)	5.6	8.8	11.3	14.1	16.0	20.4
Average heat conductivity coefficient $\overline{K_m}$ [W /(m^2·K)]	0.824	0.732	0.668	0.627	0.592	0.563

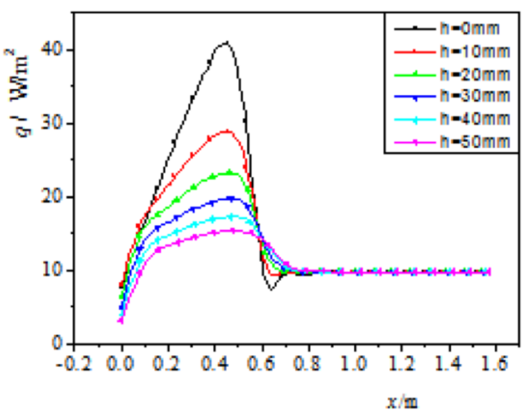

Fig. (5). Heat flow of different models.

CONCLUSION

The self-insulation system is taken as the research object, and the two-dimensional steady heat transfer of corner column is analyzed using ANSYS. The following conclusions are obtained:

When the thermal bridge is without thermal insulation treatment, influencing zone of thermal bridge is 80mm, and when the thickness of insulation layer is more than 20mm, it is about 160mm.

Additional heat flow in influencing zone accounts for more than 20% of additional heat flow in thermal bridge, heat flow in influencing zone of thermal bridge is obvious, so the problem of heat loss in influencing zone of thermal bridge should be brought to the forefront.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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