Temperature Field Analysis of Building Walls

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Abstract

Theoretical analysis of temperature field is carried out firstly to determine the method of heat transfer of building walls. Moreover, numerical analysis of temperature field is carried out. The results show the property of outer insulation system is the best due to the reason that the thermal bridge is effectively solved.

Keywords

Temperature field, heat transfer, hot summer and cold winter zone, moisture condensation.

1. Introduction

As climate modifiers, buildings are usually designed to shelter occupants and achieve thermal comfort in the occupied space backed up by mechanical heating and air-conditioning systems as necessary.[1-4]Significant energy savings could be realized in buildings if they are properly designed and operated. Therefore, the heat transfer properties are important for energy savings.[5-6]Theoretical analysis and numerical analysis of temperature field with different insulation systems are carried out in this paper.

2. Theoretical analysis of temperature field

Considering three-dimensional stable temperature field, the issue is presented as:

$$\frac{\lambda}{c\rho}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)=0$$

According to the variational principle, the issue is equivalent to the solution to the extreme value of function. If $T=T_h$, the issue can be presented as:

$$I(T)=\frac{1}{2}\iiint_R\left[\left(\frac{\partial T}{\partial x}\right)^2+\left(\frac{\partial T}{\partial y}\right)^2+\left(\frac{\partial T}{\partial z}\right)^2\right]dxdydz$$

According to Euler equation, if *T(x,y,z)* meet the boundary conditions, *T(x,y,z)* is the solution required. If solution domain is divided into some finite elements, node temperature can be presented as:

$$T^e(x,y,z)=[N]\{T\}^e$$

$$[N]=[N_i,N_j,N_m,\cdots N_p]$$

$$\{T\}^e=[T_i,T_j,T_m,\cdots T_p]$$

In the equation, *[N]* is the matrix of shape function, which is the function of coordinate, and $\{T\}^e$ is the matrix of node temperature. The function in the subdomain is:

$$I^e(T)=\frac{1}{2}\iiint_{\Delta R}\left[\left(\frac{\partial T}{\partial x}\right)^2+\left(\frac{\partial T}{\partial y}\right)^2+\left(\frac{\partial T}{\partial z}\right)^2\right]dxdydz$$

And the differential of the equation is:

$$\frac{\partial I^e(T)}{\partial T_i}=\iiint_{\Delta R}\left[\frac{\partial T}{\partial x}\frac{\partial}{\partial T_i}\left(\frac{\partial T}{\partial x}\right)+\frac{\partial T}{\partial y}\frac{\partial}{\partial T_i}\left(\frac{\partial T}{\partial y}\right)+\frac{\partial T}{\partial z}\frac{\partial}{\partial T_i}\left(\frac{\partial T}{\partial z}\right)\right]dxdydz$$

$$\frac{\partial T}{\partial x}=[\frac{\partial N_i}{\partial x},\frac{\partial N_j}{\partial x},\frac{\partial N_m}{\partial x},\cdots\frac{\partial N_p}{\partial x}]\{T\}^e$$

$$\frac{\partial I^e}{\partial \{T\}^e}=[h^e]\{T\}^e=0$$

Finally, the equation can be presented as:

$$h_{ij}^e=\iiint[\frac{\partial N_i}{\partial x}\frac{\partial N_j}{\partial x}+\frac{\partial N_i}{\partial y}\frac{\partial N_j}{\partial y}+\frac{\partial N_i}{\partial z}\frac{\partial N_j}{\partial z}]dxdydz$$

Simultaneously, if the element is aggregated, the equation is:

$$\frac{\partial I}{\partial \{T\}}=[H]\{T\}=0$$

3. Numerical analysis of temperature field of walls

3.1 Model of analysis

According to "Design standard for residential buildings of low energy consumption", the outdoor convective heat transfer coefficient is 19W/ (m^2 ·℃), and the indoor convective heat transfer coefficient is 8.7W/ (m^2 ·℃); the outdoor temperature is assumed as 18℃, and the indoor temperature is assumed as -5℃.

3.2 Results of analysis

Heat insulation system is outer insulation system, inner insulation system, self insulation system without dealing thermal bridge, and self insulation system, respectively. The analysis of temperature field is presented in Fig, 1 to Fig, 4 respectively.

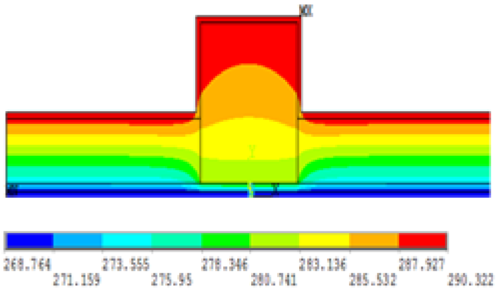

Fig. 1 Temperature of outer insulation

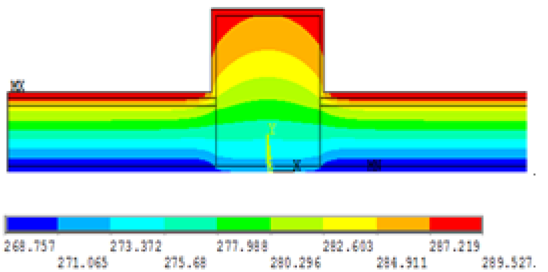

Fig. 2 Temperature of inner insulation

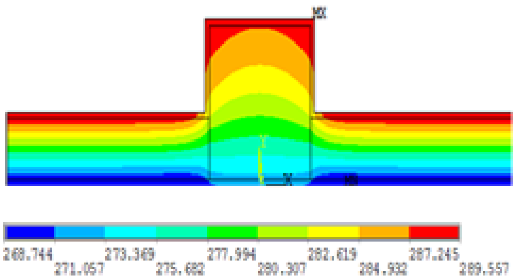

Fig. 3 Temperature of self insulation without dealing

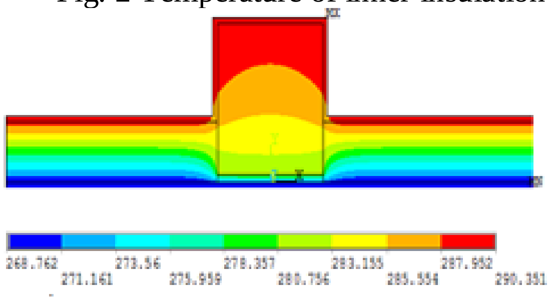

Fig. 4 Temperature of self insulation

Total heat, additional heat of thermal bridge and average heat transfer coefficient are listed in Table 1 respectively.

Table 1 Thermal property of different insulation systems

Insulation system	Inner surface temperature (℃)	Total heat (W)	Additional heat of thermal bridge (W)	Average heat transfer coefficient (W/m^2 ·K)

1	14.670	45.534	10.321	0.792
2	12.150	62.638	27.425	1.089
3	11.860	63.527	28.314	1.105
4	14.490	46.513	11.301	0.809

It can be seen from Table 1 that average heat transfer coefficient of outer insulation system is the lowest. The property of outer insulation system is the best due to the reason that the thermal bridge is effectively solved. And Table 1 also shows that inner surface temperature is all higher than the dew-point temperature, which shows that moisture condensation cannot be occurred in hot summer and cold winter zone no matter what insulation system.

4. Conclusions

The property of outer insulation system is the best comparing with other insulation systems. Moreover, moisture condensation cannot be occurred in hot summer and cold winter zone.

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