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Analysis of heat transfer performance of precast concrete sandwich insulation wall

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Abstract. Based on the thermal performance test of precast concrete insulation sandwich wall, the finite element model of the wall is established to analyze the influence of insulation mortar layer thickness and insulation layer material on the insulation performance of the wall. The results show that with the increase of insulation layer thickness, the insulation performance of wall with insulation mortar and EPS as insulation layer can be improved to a certain extent. After EPS is used as insulation material, the insulation performance of the wall can be improved obviously.

1. Introduction

Precast concrete sandwich insulation wall is composed of reinforced concrete board, insulation board and connecting parts, which has good insulation, durability and fire resistance. Scholars have conducted relevant studies on the insulation performance of sandwich wall [1-3]. The thickness of insulation layer and the type of insulation material in the wall will affect the insulation performance of the wall to some extent. In order to further study the influence of these two factors on the thermal insulation performance of the wall, the finite element model of the wall is established based on the thermal performance test of the wall, and the influence of the thickness of insulation layer and the type of insulation material on the temperature field and heat flux of the wall is analyzed, providing a theoretical basis for the optimal design of the sandwich insulation wall.

2. Finite element model establishment of wall

2.1 Basic assumptions

(1) It is assumed that the thermal properties of all parts of the sandwich wall are stable and unchanged, ignoring the influence of changes in external conditions on the thermal conductivity of the wall materials, and assumed that the materials are homogeneous and isotropic.

(2) The effects of heat conduction and convection are mainly considered, while the effects of heat radiation are ignored.

(3) It is assumed that there is no gap between the layers of the sandwich wall and no contact thermal resistance occurs.

(4) It is assumed that the internal and external ambient temperature of the wall remains constant, and only steady-state heat transfer is considered

2.2 Finite element model

In this paper, the finite element model is established according to the experimental conditions in



reference ^[4]. The size parameters of prefabricated sandwich insulation wallboard are as follows: the length is 3200mm, the width is 2800mm, and the total thickness is 190mm (the thickness of both inner and outer blade concrete board is 60mm, and the thickness of intermediate insulation board is 70mm). The wall model is built and the model's grid is divided, as shown in figure 1. LINK33 (thermal analysis unit) is selected as the reinforcement unit. Eight nodal solid unit solid70 is selected for the concrete slab and insulation slab layer.

2.3 Model validation

According to the test of the wall under the stable state, internal and external surface temperature of the measured values, the wall model inside and outside environment temperatures are set to 35°C and 5 °C respectively. The surface temperatures measured inside and outside the wall in the test are 32.1 and 6.1 respectively, which is in good agreement with the simulation where the corresponding temperatures are 30.1 and 5.8.

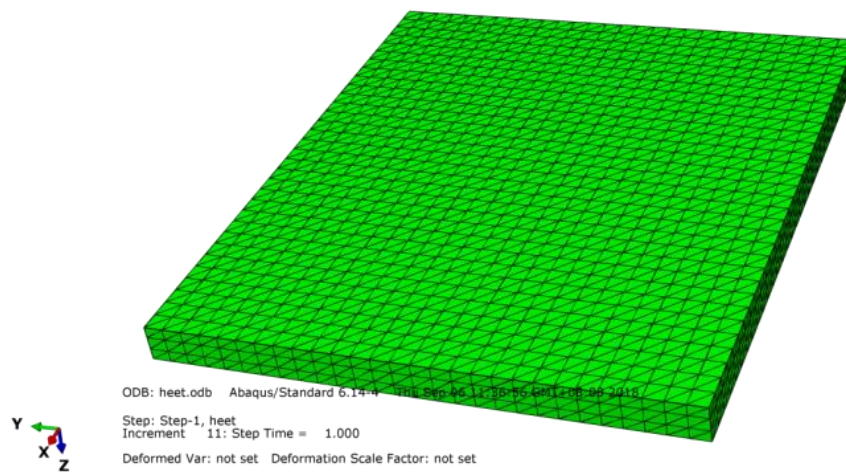


Figure 1. Wall mesh division.

3. Finite element analyses of heat transfer performance of wall

In order to investigate the influences of the thickness and material of prefabricated sandwich insulation walls' insulation layer on the whole thermal insulation performance, heat transfer analysis of the wall with varying parameters in the model is performed. The parameters are set as shown in Table 1, while the inside and outside temperatures of the wall are set to the indoor and outdoor temperatures in winter in Shenyang: 18°C and -25°C.

Table 1. Models and parameter Settings.

The model number	Thickness of insulation board	Insulation board material
1	70mm	Inorganic insulating mortar
2	80mm	Inorganic insulating mortar
3	90mm	Inorganic insulating mortar
4	70mm	EPS
5	80mm	EPS
6	90mm	EPS

The temperature field distributions of model 1 and model 4 are shown in figure 2 and figure 3.

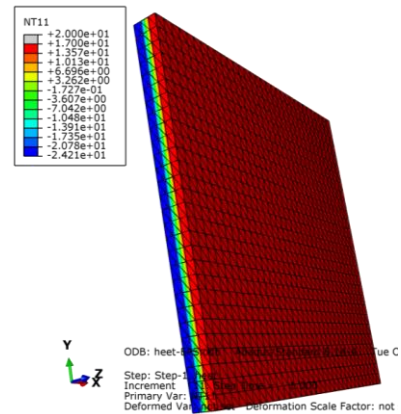
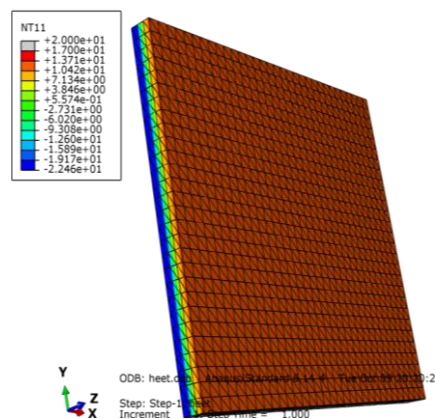


Figure 2. Temperature field distribution (model 1). Figure 3. Temperature field distribution (model 4).

The heat flux distributions of the two models are shown in figure 4 and figure 5.

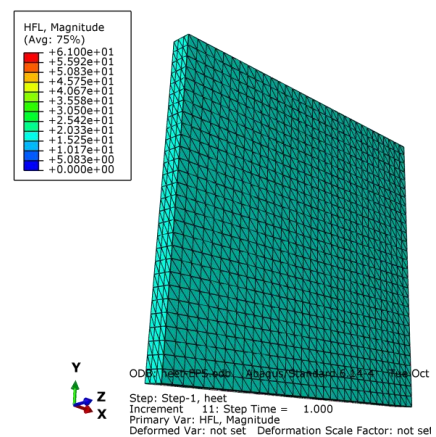
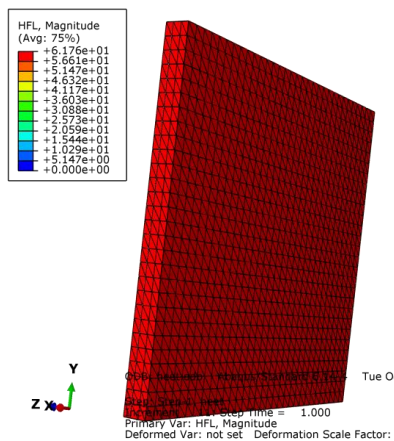


Figure 4. Heat flux distribution (model 1).

Figure 5. Heat flux distribution (model 4).

The wall is divided into four analysis surfaces from the indoor side to the outdoor side, namely the inner surface of the wall, the contact surface between the inner blade wall and the insulation layer, the contact surface between the outer blade wall and the insulation layer, and the outer surface of the wall, as shown in figure 6.

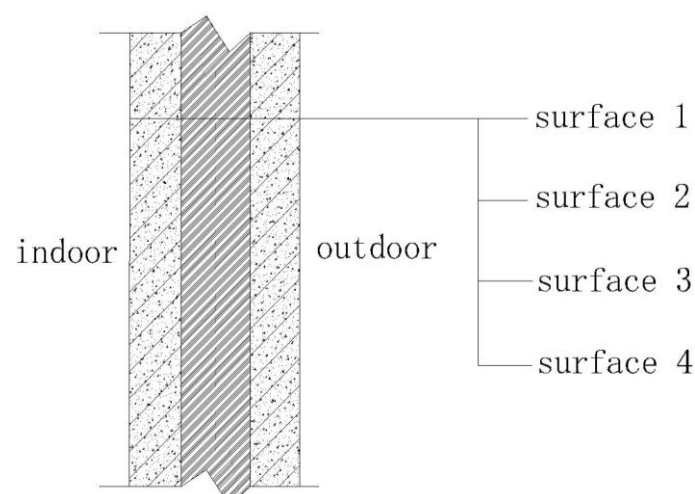


Figure 6. Schematic diagram of wall analysis surface.

The temperature of each analysis surface of the model is shown in table 2.

Table 2. Stratified temperature of each model.

The model number	surface 1 (°C)	surface 2 (°C)	surface 3 (°C)	surface 4 (°C)
1	11.2	9.2	-20.4	-22.5
2	11.8	9.9	-20.8	-22.7
3	12.3	10.6	-21.2	-22.9
4	15.9	15.3	-23.6	-24.2
5	16.1	15.6	-23.7	-24.3
6	16.3	15.8	-23.9	-24.4

The results of the temperature analysis of the wall model show that the temperature on each surface decreases gradually from the inside. The temperatures on surface 1 and 2 are below 18, while the temperatures on surface 3 and 4 are beyond -25, implying that the temperatures even on the surfaces that are in direct contact with indoor and outdoor environment are below or above ambient temperatures. With the increasing of the insulation thickness, from model 1 to 3, the temperature on surface 1 (indoor side) is increased by 5.4% and 10%, while the temperature on surface 4 (outdoor side) is decreased by 0.8% and 1.8%, indicating that with the increasing of the thickness, the temperatures on the inner surfaces would increase, while the temperatures on the outer surfaces decrease. Therefore, the increasing of the insulation thickness improves the insulation performance, making the temperatures of the inner and outer panel closer to ambient temperatures.

When the insulation material is changed into EPS, the insulation performance is significantly improved. The temperatures on surface 1 in model 4 is increased by 33% than in model 1, while the temperature on surface 4 is decreased by 8%. With the increasing of EPS thickness, from model 4 to model 6, the temperature on surface 1 is increased by 1.3% and 2.6%, while the temperature on surface 4 is decreased by 0.2% and 0.4%. Since the temperature on surface 1 is closer to ambient temperature, the change of temperature is decreased.

The heat flux on each analysis surface of the model is shown in table 3.

Table 3. Heat flux of each analytical surface.

The model number	surface 1 (J/m ² ·s)	surface 2 (J/m ² ·s)	surface 3 (J/m ² ·s)	surface 4 (J/m ² ·s)
1	59.2	59.5	59.3	59.2
2	53.9	54.2	54.0	53.9
3	49.4	48.6	49.5	49.4
4	18.3	18.0	18.4	18.3
5	16.2	16.0	16.3	16.2
6	14.6	14.3	14.4	14.6

The heat flux data shows that there is minor difference between the heat flow densities on each surface. With the increasing of the insulation thickness, the heat flux on each surface is decreased, and the speed of the decreasing is reduced along with the increasing of the thickness. From model 1 to 3, the heat flux on surface 1 is decreased by 9% and 17%, while the density is decreased by 11% and 20% from model 4 to 6. Replacing the insulation layer with EPS board which possesses better insulation performance leads to significant reduction in the heat flux of the wall, making the temperature on surface 1 in model 4 lower than in model 1 by 69%. Thus the increasing of insulation thickness and the utilization of material with better insulation performance increase the thermal resistance of the wall, reducing the heat flux in the wall and the heat dissipation of houses. Specifically, as an insulation material, EPS possesses great insulation performance and improves the insulation performance of the wall significantly.

4. Conclusion

In this paper, heat transfer analysis combined with the principles of thermal engineering was performed. The following conclusion are drawn:

- (1) With the increasing of insulation layer thickness, the insulation performance of the wall is

improved. The improvement is decreased with the increasing of the thickness.

(2) Replacing mortar with EPS as insulation material increases the temperature on the inner surface and decreases the temperature on the outer surface, reducing the heat flux in the wall. As an insulation material, EPS can improve the insulation performance of the wall significantly.

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