EFFECT OF COMPOSITE POLYSTYRENE GRANULAR THERMAL INSULATION MORTAR ON THERMAL ENERGY STORAGE OF BUILDING ENERGY CONSUMPTION

by

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In order to save energy and reduce building energy consumption, the author proposed a study on the impact of composite polystyrene particle thermal insulation mortar on building energy consumption and thermal energy storage, take the ETIRS-C residence as the research object, through simulation calculation under different insulation mortar thickness, analyze the relationship between insulation thickness and energy consumption and thermal environment. According to the simulation calculation of room temperature, horizontally, the thickness of thermal insulation mortar in air conditioning season is not sensitive to the natural room temperature, there is a certain sensitivity to the natural room temperature in the heating season, in the longitudinal direction, the 30 mm thick insulation mortar is the jumping point, and the increase of the thickness of insulation mortar has no obvious effect on the natural room temperature. According to the simulation calculation of room energy consumption, the thickness of thermal insulation mortar is about 20 mm, and both heat and cold consumption have achieved good thermal insulation and energy saving effect, further increasing the thickness of thermal insulation mortar will have limited impact on energy consumption, which may be uneconomical and increase the cost and construction difficulty. Therefore, based on the aforementioned results, it can be considered that the thickness of thermal insulation mortar should preferably be controlled within 20-30 mm.

Key words*: composite polystyrene, thermal insulation mortar, heat energy, building energy consumption*

Introduction

Energy is one of the pillars of contemporary national economic development, with the rapid development of industrial civilization, the oil, coal and other resources that can be used by human beings on the earth are being exhausted day by day, and the energy problem is a problem that all countries in the world attach great importance to at present. Since the world energy crisis occurred in the 1970's, human beings have gradually realized the unrestrained use of energy, it will inevitably aggravate the energy crisis and eventually destroy the human survival environment. Due to the restriction of the development level of science and technology, it will take time for human beings to develop new energy that can fundamentally solve the energy crisis, so how to save energy efficiently has become the key to solve the problem at present. Statistics show that about one-third of the world's energy is consumed by buildings, and the unnecessary

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energy consumption of buildings is also one of the main reasons for the global greenhouse effect, ozone hole and other environmental problems. With the development of air conditioning and lighting technology, building energy conservation has become an unavoidable problem. In the past 30 years, building energy conservation has flourished all over the world and become a hot issue concerned by all countries [1]. At present, in many developed countries, new buildings are required to meet certain energy-saving standards, and existing buildings have been or are being transformed into energy-saving buildings. Building energy conservation has become a worldwide trend. Energy consumption in the area of people's livelihood is huge, among which building energy consumption accounts for a large proportion in the total energy consumption, moreover, compared with developed countries with similar climate conditions, the heating energy consumption per unit area of residential buildings is significantly higher, about three times that of them [2]. With the increasingly widespread use of winter heating and summer air conditioning in high energy consumption buildings, energy waste will be more serious. Therefore, facing a series of serious problems such as resource depletion, environmental degradation, ecological destruction, and climate warming, we must take energy conservation as a long-term task of economic work, energy conservation is listed as the strategic focus of China's economic construction, and in accordance with the requirements of sustainable development, in-depth and detailed research on building energy conservation is carried out. The building envelope bears the main role of heat exchange between the building and the outside, the heat lost by the building through the envelope accounts for more than one third of the heat loss of the whole system, the heat consumption of the building envelope is related to the heat supply and the heat transfer coefficient of the building envelope, and the heat transfer coefficient directly depends on the thermal resistance of each component of the building envelope, that is, depending on the thermal conductivity and material thickness, the heat transfer of the thermal bridge (Lingqiao) is obtained by using the area weighted average of the average heat transfer coefficient, in fact, it is calculated by the thermal conductivity of the material in the design state. Therefore, the thermal conductivity of wall materials is an important parameter affecting building energy consumption [3]. The thermal conductivity of the material is not a constant value, but is related to the moisture content inside the material, different moisture content corresponds to different thermal conductivity, with the increase of moisture content, the thermal conductivity may increase a lot. This is because most of the building materials of the enclosure structure are porous media, porous media is literally the media with holes in it, in the dry state, only air is contained in the pores. When the material is damp, part of the space occupied by air in the pores is replaced by water, because the thermal conductivity of water is far greater than that of air, therefore, in the actual use process, the thermal conductivity of building walls, as a porous material, varies with the region, season and orientation due to the influence of moisture content change [4]. If the actual test data is evaluated, if there is a deviation between the test conditions and the thermal conductivity of the materials and the design value, the test results will lead to the deviation between the calculated energy consumption value and the energy consumption value of the design conditions, in this way, in order to conduct more accurate design and evaluation of building energy conservation, it is bound to require the study of the moisture thermal conductivity of wall materials [5]. Many researchers have conducted a lot of experiments on the thermal conductivity of unsaturated wet porous media, in view of the complexity of the research on moisture migration in multilayer porous structures, many contents are far from perfect, as far as the thermal and wet physical parameters of porous materials are concerned, thermal conductivity, density, specific heat, mass diffusion coefficient, thermal and mass diffusion coefficient, etc. are all functions of moisture content [6]. Therefore, the aforementioned parameters change non-linearly in the whole range from zero moisture content to saturation, and such data are very limited at present. The research on the influence of moisture content on the thermal conductivity of porous media has certain theoretical significance and practical value. Figure 1 shows the process flow chart of preparing adhesive from waste polystyrene foam [7].

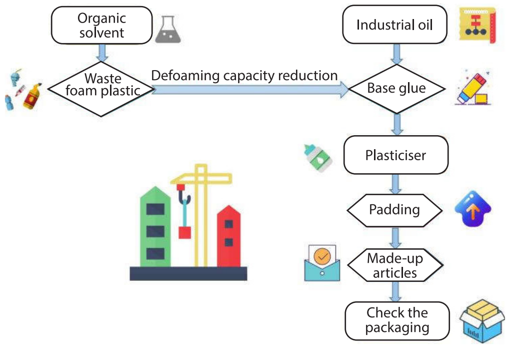

Figure 1. Process flow chart of adhesive preparation from waste polystyrene foam

Establish model

Select a typical multi-storey residential building in a community in City A, a 92 m^2 apartment building with three units and five floors, with a storey height of 2.8 m, households are divided into living room, master bedroom, secondary bedroom, study, kitchen and toilet according to their functions, see tab. 1 for types and components of building envelope [8]. Among them, the main and secondary bedrooms, study and living rooms are air-conditioned rooms, according to the fact that City A is located in a hot summer and cold winter area, the annual average temperature is 12.2-17.3 °C, the coldest month is January, and the average temperature is –0.4-5.5 °C, the hottest month is July, with an average temperature of 24.4-30.8 °C. In order to shorten the calculation time and be targeted and representative, the master bedroom in the air-conditioned room is selected as the simulation object. The set heating time in winter is from November 15 to March 15 of the next year, and the air conditioning time in summer is from June 1 to August 30. Thermal disturbance setting of master bedroom: the number of people is set as 2, the per capita heat output is 53W, the humidity output is 0.061 kg per hour, the light power is 10 W/m^2, and the equipment power is 10 W/m^2, the work and rest time of personnel, lights, equipment and curtains is the default value of the software. According to the specification, the indoor control temperature of air conditioning in summer is 26 °C, and the indoor control temperature of heating in winter is 18 °C, keep the room temperature at 18-26 °C when the air conditioner is running, and the upper and lower limits of tolerable indoor temperature are 29 °C and 16 °C, respectively, when the indoor temperature exceeds 16-29 °C, the air conditioner will be turned on. The ventilation mode is defined according to the energy saving standard, taking 1 time per hour. When studying the influence of the thickness change of the thermal insulation mortar for the exterior wall of the master bedroom on the room energy consumption and natural room temperature, keep the

Table 1. Enclosure of master bedroom

Category	Component name
Exterior wall	Porous brick masonry + interface mortar + polystyrene particle mortar + crack resistant mortar + finishing paint
Interior wall	Cement lime mortar + perforated brick masonry + cement lime mortar
Floor	Reinforced concrete + cement mortar
Exterior window	General inner sunshade curtain + steel plastic composite hollow glass (5 + 6A + 5) outer window
Inner door	Single layer wooden interior door

other set parameters of the master bedroom unchanged, and obtain the relevant data of natural room temperature, room heat consumption and cooling consumption corresponding to different thicknesses through dynamic simulation calculation [9].

Simplification of dynamic thermal process model

Type of thermal disturbance included in the original mathematical model of DEST, the building physical model is very complex, due to space limitation, the author did not embed the moisture thermal conductivity function into the source program of DEST software for analysis, instead, after the DEST mathematical model is reasonably simplified, two thermal conductivity coefficients are substituted to calculate energy consumption, at the same time, in order to highlight the influence of the change of thermal conductivity in moisture content on the simulation of building energy consumption, the author will combine the influence characteristics of thermal conductivity on building energy consumption simplify the building physical model, the type and action mode of thermal disturbance, and the equation expression and calculation parameters of the mathematical model [10].

Model simplification principle

Since the author mainly discusses the influence of the thermal conductivity of the wall material in the moisture state on the simulation results of building energy consumption, in order to simplify the calculation, the author will mainly highlight the influence of the change of the thermal conductivity in the moisture state on the simulation of building energy consumption: Set an empty room with no ventilation in the adjacent room, small external window and good sealing as the physical model. Therefore, in the heat balance equation of the whole room, all items related to indoor furniture, window heat transfer and ventilation no longer exist, as the moisture content change of the partition wall (or floor) material between the adjacent room and the external wall is almost negligible, similarly, the impact of this slight change on the energy consumption of the room can be almost ignored compared with the external wall, therefore, the author omits the items related to the adjacent room [11].

Simplified energy consumption calculation formula

According to the previous simplification principle, the hourly heat expression of the air conditioner can be simplified:

$$q_{\text{havc}}(\tau) = \Phi_{\text{hvac}}^{-1}\left[t_a(\tau) - \sum_i e^{\lambda,\Delta\tau} t_{ai}(\tau - \Delta\tau)\right] \tag{1}$$

Among them:

$$t_{ai}(\tau - \Delta\tau) = \int_{-\infty}^{\Delta\tau} \sum_i \varphi_{i,k} e^{\Delta_i(\tau - \Delta\tau - \xi)} u_k(\xi) \mathrm{d}(\xi) \tag{2}$$

where φ is the reflects the response characteristics of the thermal disturbance on the building, and its value is determined by the thermal properties and output parameters of the system itself:

$$\varphi_{i,k} = \sum_l \sum_j d_l c_l^{-1/2} p_{l.i} p_{j,i} c_j^{-1/2} b_{j,k} \tag{3}$$

$$\Phi_{\text{hvac}} = \sum_i \varphi_i = \sum_i \int_{-\Delta\tau}^{+\infty} \varphi e^{\Delta_i(\tau - \xi)} \tau \mathrm{d}\xi \tag{4}$$

where d_l, c_l, p_l, and b_j are the vector in the matrix parameters D, C, P, and B.

Simplification of parameters in energy consumption calculation formula

Since the simplified model only considers three kinds of thermal disturbances, namely air conditioning heat, outdoor temperature and solar radiation, the air conditioning heat has been separated as the dependent variable, and the matrix u is simplified:

$$u = \left(u_{\text{the outside temperature}} u_{\text{radiation}}\right)^T \tag{5}$$

Within the calculation time range of the author, eq. (6) is applied to two kinds of thermal disturbance vectors $u_k(\xi)$ in eq. (5), which are treated as first-order linear changes. Namely:

$$u(\xi) = u(\tau)\frac{\xi - (\tau - \Delta\tau)}{\Delta\tau} - u(\tau - \Delta\tau)\frac{\xi - \tau}{\Delta\tau} \tag{6}$$

Under the simplified conditions set by the author, the previous matrix parameter C changes into the following form:

$$C = \begin{bmatrix} C_1 \\ \ldots \\ C_m \\ c_{p,a}\rho_a v_a \end{bmatrix} \tag{7}$$

Assume that the east, west, upper and lower parts of the room are adjacent rooms, and the south and north are exterior enclosures, because the author only studies the influence of the moisture thermal conductivity of the wall material of the exterior enclosure structure on the building energy consumption and the influence of the adjacent room thermal disturbance, $m = 2$. Since the wall model material of the author has three layers, C_1 and C_2 are calculated according to eq. (7) [12].

Energy consumption analysis

For the analysis of room energy consumption, the simulation software is used to calculate the cumulative heat consumption in heating season and the cumulative cooling consumption in air conditioning season under different insulation mortar thicknesses, the results are shown in tabs. 2 and 3, the area of the master bedroom is 16.72 m^2, in order to facilitate visual analysis, the thickness of thermal insulation mortar is taken as 0-100 mm [13].

The data in tabs. 2 and 3 are fitted into fig. 2, which shows that the accumulated heat consumption in heating season decreases with the increase of insulation mortar thickness, between 0 and 20 mm, the heat consumption drops sharply, indicating that the effect of polystyrene particle thermal insulation mortar in this section is quite obvious, the heat consumption decreases slowly with the thickness in the 20-50 mm section, the effect of the thermal insulation layer is average, and the heat consumption in the 50-100 mm section has not decreased significantly, which indicates that it may not be economical if it is more than 50 thick, but will increase the project cost, structural safety and construction difficulty [14].

The cumulative cooling consumption in the air conditioning season is different from that in the heating season through the fitting curve fig. 3, the curve has peaks and valleys, showing that the cooling consumption decreases first, then increases and then decreases with the increase of insulation mortar thickness, and the cooling consumption drops sharply from 0-20 mm, indicating that the thermal insulation in this section is very critical and the effect is very good, however, the thickness change between 20 mm and 75 mm has basically no change

Table 2. Relationship between thickness of insulation mortar and cooling and heat consumption

Thickness of insulation mortar [mm]	Annual accumulated heat consumption [kWh]	Annual accumulated cooling consumption [kWh]
0	304.38	129.38
5	161.04	105.26
10	145.6	98.14
15	133.79	90.09
20	123.77	88.13
25	114.25	88.17
30	108.04	85.59
35	104.4	85.39
40	99.19	85.46
45	96.68	85.37
50	91.24	83.52

Table 3. Relationship between thickness of thermal insulation mortar and cooling and heat consumption

Thickness of insulation mortar [mm]	Annual accumulated heat consumption [kWh]	Annual accumulated cooling consumption [kWh]
55	87.91	83.72
60	86.48	83.59
65	85.1	83.59
70	82.69	80.75
75	77.77	78.76
80	77.26	76.79
85	75.23	76.76
90	73.98	77.01
95	72.07	77.07
100	70.93	74.99

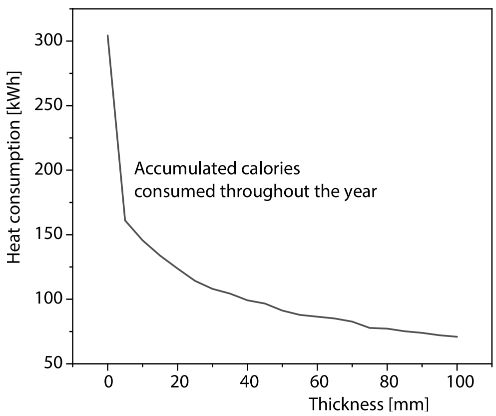

Figure 2. Relationship between annual cumulative heat consumption and insulation thickness

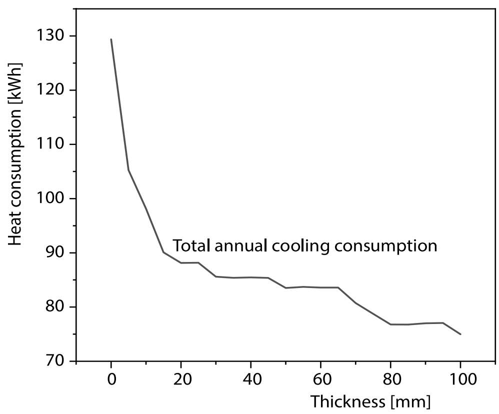

Figure 3. Relationship between annual cumulative cooling consumption and insulation thickness

to the cooling energy consumption, and it is meaningless to increase the thickness again, it can even be seen that increasing the thickness after 75 mm increases the energy consumption instead [15].

Conclusion

The author puts forward the influence of composite polystyrene particle thermal insulation mortar on building energy consumption and thermal energy storage, and will analyze the influence of thermal insulation mortar thickness on building energy consumption and indoor thermal environment, the analysis of building energy consumption includes the energy consumption in heating season and air conditioning season. The analysis method is to use DEST-h simulation software to calculate, taking the thickness of polystyrene particle mortar in the external wall thermal insulation system as a variable, the change of natural room temperature and building energy consumption under the climatic conditions in Huzhou. According to the simulation calculation of room temperature, horizontally, the thickness of thermal insulation mortar in air conditioning season is not sensitive to the natural room temperature, but is sensitive to the natural room temperature in heating season, in the longitudinal direction, 30 mm thick thermal insulation mortar is the jumping point, and increasing the thickness of thermal insulation mortar has no obvious effect on the natural room temperature.

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