BUILDING EXTERIOR WALL THERMAL ENERGY SAVING MODEL BASED ON GREEN ENERGY-SAVING NANOMATERIALS

by

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In order to reduce building energy consumption and make wall insulation materials meet fire protection requirements, the authors put forward a kind of energy saving model of building exterior wall under green and energy saving nanomaterials. Mainly using PBECA energy saving calculation software. By setting up multi-component, multi-material method. The energy consumption of building aggregate in light energy saving device modified by nanomaterials is simulated and analyzed, and the energy consumption of building agent area is compared. The energy saving effect of light energy saving system modified by nanomaterial fly ash in prefabricated buildings was verified. According to the calculation of PBECA energy-saving calculation software, the annual energy consumption of the building assembled by nanomaterials modified fly ash lightweight energy-saving units is 5981 kWh, and the energy consumption per unit area is 35.01 kWh/m^2. In the 1980's, the annual energy consumption of household agents was 86237 kWh, and the energy consumption per unit area was 50.42 kWh/m^2. Through the analysis of the calculation results, it is concluded that the energy saving efficiency of replacing the light-saving wall with nanomaterials fly ash in precast area A can reach 65% of the energy saving standard.

Key words: *building energy consumption, thermal insulation material, green and energy-saving nanomaterials, buildings, external wall heat energy saving*

Introduction

At present, the foam concrete board has become the leading product, but although the foam concrete board can reach a grade insulation material, but the main material is cement (the production process is high pollution and high energy consumption). Since autoclaved technology is used in production engineering, a large amount of energy is lost, which is not conducive to environmental protection [1]. Low strength (0.5-0.8 MPa) is not conducive to production and construction, in addition, due to unstable foaming time and low tensile strength, local cracking occurs during the production process, which makes the thermal insulation performance of foamed concrete not very ideal [2, 3]. In China, building energy consumption has been high, which makes China's building energy conservation is imminent.

In the planned economy era, China's economic development has been an extensive growth model with high consumption of resources and at the expense of the environment. Lack of research on building energy conservation and relevant building energy conservation standards, one-sided emphasis on reducing building cost, cause the building envelope is too

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thin, the door and window gap is too large, poor heat preservation, heat insulation and air tightness, poor residential thermal environment, low energy efficiency of building. China's energy efficiency development still lags behind that of Western countries. Household energy consumption refers to the energy consumed by buildings in the process of use. It mainly includes household energy consumption, heating energy consumption, heat energy consumption, cooking energy consumption, energy consumption and household energy consumption, *etc*. The energy consumption and energy consumption of buildings are analyzed. According to statistics, energy consumption accounted for 27.6% of China's total energy consumption, up from 10% in 1978. China has always attached great importance to the development of housing and residential areas. Especially since the reform and development, the construction industry has entered the road of rapid development, and its energy saving has become an important part of China's domestic energy saving. At the end of 2000, the national housing construction area, many cities have reached 10 billion m^2, but the heating building energy saving design standards only accounted for 0.6% of the total urban and rural construction area, accounting for 2.3% of the urban housing construction area. Among them, about 21 billion m^2 of residential buildings have problems such as poor thermal insulation and air tightness, and low efficiency of heating system [4]. The author put forward the hypothesis that the fly ash modified by nanomaterials can produce light energy-saving composite wallboard, and carried out heat transfer simulation on the light energy-saving composite wallboard modified by nanomaterials, in contrast, the main material used in this project is cheap thermal power generation waste – fly ash. Stacking wastes 424 million m^3 of land and causes huge pollution the environment. If this topic is realized, a large amount of fly ash can be consumed, which will play a huge role in improving the ecological environment, protecting land and rational utilization of land. Figure 1 shows the algorithm model of heat energy management and control [5, 6]. The author mainly carried out a simulation study on fly ash foam concrete insulation material modified by nanomaterials with high strength and low thermal conductivity. The PKPM PBECA energy saving calculation software is used. The thermal performance and energy-saving performance of lightweight energy-saving wall made of nanomaterial modified fly ash foam insulation in prefabricated buildings were observed. The energy consumption of nanomodified fly ash concrete wall panels in prefabricated buildings is simulated by using PKPM PBECA energy saving calculation software. The simulation results show that the energy consumption per unit area of the prefabricated building using nanomodified fly ash foam wall method is 35.01 kWh/m^2. Compared with the energy consumption per unit area of the 1980 model test (50.42 kWh/m^2), the energy saving rate is 65.28%, and the energy saving rate reaches increase in hot summer and cold winter areas.

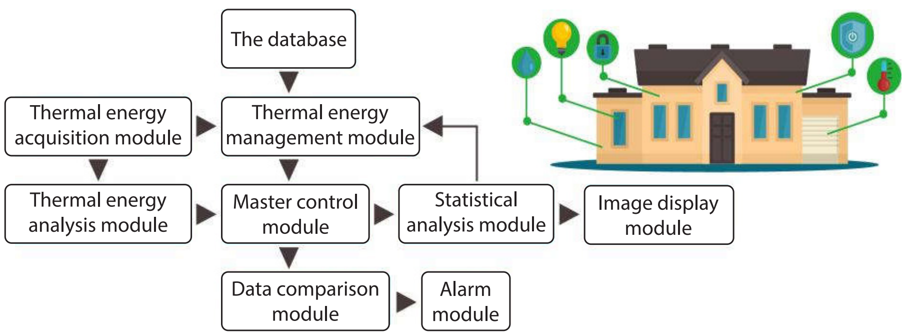

Figure 1. Thermal energy control algorithm model

Methods

Calculation method of energy consumption

At present, the calculation of building energy consumption mainly uses the steady-state heat transfer method and the dynamic heat transfer method, the difference between the two methods is that the temperature field of the steady-state heat transfer method does not change with time, which is a relatively simple calculation method of energy consumption, dynamic heat transfer method is a more accurate method to calculate energy consumption because the temperature field varies with time. Steady-state heat transfer method includes effective heat transfer coefficient method and degree-day method. The dynamic simulation of dynamic heat transfer method needs to be completed with the help of energy-saving calculation software [7]. The author will use dynamic heat transfer method for energy consumption simulation, that is, select appropriate energy saving calculation software for energy consumption simulation, so as to get more accurate simulation results.

Selecting energy-saving computing software

At present, the energy saving calculation software used in China mainly includes DOE-2, DEST, ANSYS*, etc.*, the author chooses the energy saving calculation software PBECA to carry out dynamic energy consumption simulation analysis for the research object [8]. The PBECA energy-saving computing software is built based on PKPM kernel, designed and developed by China Academy of Building Science and Technology, a major feature of this software is perfect compatibility with CAD, which can be directly imported into CAD for modelling and calculation. The software has strong functions, including energy consumption development, power generation and analysis, energy development and energy consumption evaluation, which can solve most of the problems of energy-saving building. The software interface is accurate and easy to understand, easy to operate, fast and accurate calculate results, and has a wide application prospect in energy-saving development. Therefore, the author selected this software for building energy consumption simulation analysis [9, 10].

Technical characteristics of prefabricated residential buildings

The author plans to select several prefabricated dwelling houses in District A as the research object. By controlling the cooling and heating of the building, the author makes an experiment on the energy consumption in residential area, and analyzes the energy consumption performance of the building using nanomaterial modified fly ash light saving energy wall [11]. The apartment building has a rectangular plan, as a frame structure building, the building layout faces south from the north, the specific residential parameters and thermal parameters are shown in tab. 1 [12].

Before energy saving simulation calculation, PBECA software needs to set the practices of each envelope structure, the outer wall is 150 mm thick nanomaterial modified fly ash light energy saving wallboard, 10 mm thick cement mortar is applied on both sides, and the connection between exterior wall and frame beam and frame column is also referenced to the aforementioned model.

Influencing factors of energy consumption of prefabricated buildings

Region A is located in a region with hot summer and cold winter, and its climate characteristics are very unique, in recent years, more and more people flock to City A, resulting in the increase of heat island effect in City A year by year, temperatures hit record highs during the

Table 1. Main parameters of multi-storey residential buildings

Parameters of the category	Multi-storey residential
Long [m]	27.91
Wide [m]	10.45
High [m]	19.20
The layer number	6
The height [m]	3.20
Frame beam dimensions [mm]	200×400
Frame column dimensions [mm]	400×400
Building base area [m^2]	291.61
Area of the building [m^2]	1710.39
Building volume [m^3]	5273.24
Building surface area [m]	1744.65
Window to wall area ratio	Northbound: 0.26, southbound 0.23

hot summer months, greatly affecting people's travel and increasing the risk of illnesses such as heat stroke. In winter, because there is no collective heating facility, the cold and wet climate in region A will also make people feel uncomfortable [13].

It is precisely because of the special climate conditions of A city, whether in public places or at home, with its unique advantages of cooling in summer and heating in winter, air conditioning has become the most widely used electrical equipment in region A. Therefore, the energy consumption analysis of buildings in area A should take into account not only the energy consumption of the envelope itself, but also the energy consumption of such electrical appliances as air conditioning in winter and cooling in summer. In addition, the factors affecting household energy consumption are as follows. The whole shape of the house has a great influence on household energy consumption. In general, the energy consumption of buildings with different shapes is higher than that of buildings with simple structure.

Therefore, the influence of building shape on building energy consumption should be considered in the process of building design. The graphic design of buildings should be integrated with the natural factors, and reasonable graphic design is also an important means of building energy conservation. For example, the monsoon flow direction of an investigation place is reasonable to adjust the building's orientation, through the position of reasonable setting doors and Windows guide, use natural air supply to reduce indoor heat, reduce the energy consumption of electrical appliances such as air conditioning. With the continuous popularity of low carbon and green concepts in recent years, batches of new, lightweight and energy-saving materials emerge as the times require, by upgrading the traditional envelope materials, the new materials can further improve users' quality of life with their excellent thermal performance of heat preservation in winter and heat insulation in summer [14].

The roof of a building is the weakest link in the maintenance structure, and the heat energy loss of the roof is the most serious in hot summer, therefore, the roof needs to do more thermal insulation treatment, for high rise residential buildings can be used as the top layer of equipment layer, reduce the impact of house heat on people.

Establishment of energy consumption model for prefabricated buildings

The interface settings of PBECA software are simple and easy to understand, building energy consumption simulation, divided into the following steps.

Enter the software to set parameters and fill in basic information such as province, city and building type, from the column of energy saving parameters, the examination standard and frame of Wuhan area is the building structure. The heating period in winter and cooling period in summer are set from the trade-off calculation parameters.

Import CAD plane graphics into PEBCA energy saving software, the components such as walls, doors and windows are extracted during the import to facilitate the modelling and analysis in the next step. The floor plan was converted into a standard floor, and the walls, doors and Windows, balconies, thermal bridge parts, room settings and other components were edited successively [15, 16].

After the component parameters are edited, the materials of each component are edited. The PBECA has a rich built-in material library, which can meet most material choices, for materials that are not in the material library, new materials can be created in a custom way. After editing the materials, the defects were analyzed, and the problems were found to be checked and filled, so as to further improve the simulated objects.

Before the calculation, the initial conditions of energy saving calculation should be set, in addition the energy consumption of the building envelope, indoor and outdoor air penetration and the use of electrical appliances are also energy consuming, therefore, all energy consumption factors should be taken into account when setting the initial conditions, and the outdoor meteorological calculation conditions are taken as the typical meteorological year of the whole year.

The final calculation and analysis will be carried out after all the preparations are completed. First, the specified index is calculated to verify whether the simulated object meets the final calculation requirements. After the calculation of specified indexes, the trade-off calculation is carried out. The trade-off calculation can accurately calculate the annual heating energy consumption, air conditioning energy consumption and total electricity consumption of the simulated object, it provides practical and effective data for analyzing and studying the effect of building energy conservation [17].

Analysis of energy consumption simulation results

The energy saving calculation and analysis of a multi-storey residential district in City A, the simulation calculation data as shown in tab. 2 is finally obtained.

Table 2. Calculation data of residential energy saving

Building load statistics	Energy consumption [kWh]	Energy consumption per unit area [kWhm^{-2}]
Winter heating energy consumption	32451	23..30
Cooling energy consumption in summer	29973	11.71
The total power consumption	62424	35.01

From the table data, it can be seen that the annual energy consumption for heating in winter, cooling in summer, and the total annual energy consumption of assembling multi-storey dwellings with nanomaterial modified fly ash light saving energy are 324551 kWh, 29973 kWh, and 6224 kWh, respectively. In order to ensure the energy saving efficiency of prefabricated multi-storey buildings using nanomaterial modified fly ash light energy saving wall, further energy saving measures are needed. If we want to verify the strength of assembling multi-storey buildings with light-weight energy-saving wall modified by nanomaterials, we should make further calculations of energy-saving. According to China Building Energy Management System, the designs of 30%, 50%, and 65% of building energy efficiency have been gradually used since 1986, and the local standards of 50% energy saving have been increased by 30% to reach the goal of 65% energy saving. The 65% energy conservation in the hot summer and cold winter areas refers to the annual energy consumption of the residential community representatives from 1980 to 1981, including the utilization of thermal energy in the winter and the utilization of cold energy in the summer. Based on the review process of PBECA software development, the basic structure of the building in 1980's is introduced in tab. 3.

Table 3. Main parameters of housing in the 1980's

Category	The material	Parameter
The wall	240 solid clay turning wall	Heat transfer coefficient 2.0 W/m^{2}K
Roof	Reinforced concrete with simple insulation material	Heat transfer coefficient 2.3 W/m^{2}K
Window	Single glazed steel WINDOWS	Heat transfer coefficient 6.5 W/m^{2}K
Shading coefficient	–	0.8
Number of air changes per day	–	1.0 times per hour
Power density of indoor electrical equipment	–	20 W/m^2

According to the main parameters of representative houses in the 1980's, the energy saving calculation and analysis are carried out, and the calculation data shown in tab. 4 are obtained [18, 19].

Table 4. Energy saving calculation data of representative residential buildings

Building load statistics	The energy consumption [kWh]	Energy consumption per unit area [kWhm^{-2}]
Winter heating energy consumption	61146	35.75
Cooling energy consumption in summer	25091	14.67
The total power consumption	86236	50.41

The comparison between design energy consumption and reference energy consumption is shown in fig. 2.

As can be seen from the data in the tab. 2, the annual total energy consumption of the representative house in the 1980's was 86236 kWh, and the energy consumption per unit area was 50.41 kWh/m^2. The total annual energy consumption of buildings assembled with nanomaterial modified fly ash light energy-saving unit is 5981 kWh, and the local energy consumption is 35.01 kWh/m^2. According to the calculation formula of energy conservation, energy conservation = 100 – (design energy/2 × energy consumption). That is, energy conservation = 100% – 35.01/2 × 50.42% = 65.28% meeting the requirements of 65% energy saving in the standard energy conservation for low energy buildings [20].

Conclusion

The author mainly carried out a simulation study on fly ash foam concrete insulation material modified by nanomaterials with high strength and low thermal conductivity, through the use of PKPM PBECA energy saving calculation software, the thermal and energy-saving properties of lightweight energy-saving wall of prefabricated building modified with fly ash foam insulation materials were studied. The energy consumption of nanomodified fly ash concrete wall panels in prefabricated buildings is simulated by using PKPM PBECA energy saving calculation software. The simulation results show that the energy consumption per unit area of the prefabricated building using the nanomodified fly ash foam wall method is 35.01 kWh/m^2. Compared with the energy consumption per unit area of the model test in 1980 (50.42 kWh/m^2), the energy saving rate is 65.28%, and energy saving can be achieved in hot summer and cold winter areas.

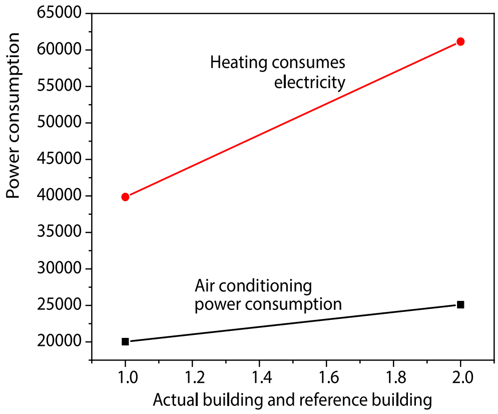

Figure 2. Residential energy consumption analysis chart

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