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Study on Building Energy Consumption Performance of Composite Polystyrene Granule Thermal Insulation Mortar

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In order to solve the problem of building energy consumption, the hygroscopicity, thermal conductivity and transfer properties of composite polystyrene particle thermal insulation mortar are analyzed. According to the commonly used external thermal insulation structure and its thermophysical characteristics in hot summer and cold winter zone, the test is carried out. The thermal conductivity function is applied to the simplified model of DeST thermal environment simulation. The variation of heat and moisture transfer to building energy consumption is analyzed. The results show that the energy consumption of simulated buildings can reach 13.25% of the annual electricity consumption of building heating. Therefore, the heat and moisture transfer characteristics of materials affect the thermal conductivity and thermal insulation performance of building envelope. It is an effective way to decrease the building energy consumption by using the thermal conductivity coefficient of various materials as a measure.

1. Introduction

According to statistics, China's per capita share of coal resources is 1/2 of the world average, and per capita oil occupancy is only 1/10 of the world average (Braiek et al., 2017). However, the total consumption of coal resources accounted for more than 40% of the world total’s, and oil consumption is also located in the world second (Boumhaout et al., 2017). China's dependence on overseas energy is up to 50%. Energy shortage is the short slab that restricts the development of social economy, and the rational and effective use of energy is the principle of sustainable development (Fu et al., 2017). In the context of rapid economic development in China, the primary energy consumption has increased dramatically, while the building energy consumption accounts for about 30% of the total social energy consumption, and this proportion has a rising trend (Ferrándiz-Mas et al., 2014). Therefore, the energy saving potential of the construction industry is very big, which is of great significance to further accelerate the construction of a resource-saving and environment-friendly society and to ensure the energy security of our country (Duan et al., 2017). With the promotion of energy saving work in the country, more and more attention has been paid to the development and application of building thermal insulation materials, and new thermal insulation materials are emerging constantly (Triantafillou et al., 2017). From the material and variety of building thermal insulation material, unshaped slurry insulation material is an important part of building thermal insulation material. Polystyrene, as the main raw material of thermal insulation material, is widely studied both at home and abroad (Wu et al., 2017). Because of the increasing demand for the quality of building environment, building simulation is becoming one of the most important tools in the design, analysis and evaluation of building environment. After years of continuous development, building simulation technology has been widely used in the whole life cycle of architectural design. It includes design, construction, operation, maintenance and management of various stages (Zhang et al., 2014). Building energy simulation is related to the heat and moisture transfer properties of wall materials. Therefore, many scholars begin to pay attention to the study of heat and mass transfer in building wall.

The composite polystyrene granule thermal insulation mortar has the advantages of good thermal insulation, good technical performance, convenient construction and low cost, so it has been widely promoted in recent years. Composite polystyrene grain insulation mortar is generally used in the exterior of exterior wall insulation. Like other wall building materials, it has porous properties. Due to the construction of the link or climate conditions, the humidity is easy to change, resulting in changes in the thermal conductivity of the material. In the process of use, due to the influence of climate conditions, thermal conductivity of thermal insulation mortar and design parameters have a certain gap. Therefore, in the specific engineering practice, its performance is difficult to truly get the hair, resulting in the uneconomical use of energy, and it cannot guarantee to achieve the desired energy-saving effect. Under the environment of building energy saving material, the composite polystyrene granule thermal deformation mortar as a new wall insulation material, which is widely used in cold region and the hot summer and cold winter area, it meets the needs of energy-saving reform, and has broad market prospects. A series of studies in this paper provide experimental basis for the extensive application of composite polystyrene particles in buildings. The study of composite polystyrene granule thermal deformation mortar has great academic value, engineering significance and economic benefit.

2. The experimental procedure

2.1 Test equipment

The Laboratory has the equipment that the experiment is required, they are BES-C, SM1210B temperature and humidity data acquisition module, SLHT4 temperature and humidity sensors, heat sinks and so on (Lakrafli et al., 2017).
(1) Temperature and humidity acquisition module
SM1210B temperature and humidity data acquisition module supports 1-12 temperature and humidity sensors, and it can achieve low-cost temperature and humidity monitoring of the practical integration module.
This module can be used to: SMT industry temperature and humidity data monitoring; electronic equipment long temperature and humidity data monitoring; cold storage temperature and humidity monitoring; warehouse temperature and humidity monitoring; pharmaceutical GMP monitoring system; environmental temperature and humidity monitoring; telecommunications room temperature and humidity monitoring; and other various occasions that need to monitor the temperature and humidity.
Technical parameters and features: display temperature range: -40°C~123.8°C; sensor nominal temperature accuracy ± 0.5 °C; display humidity range: 0-100RH; power consumption 2W; storage temperature -40°C ~ 85°C
(2) The temperature and humidity sensor
The sensor consists of a capacitive polymer hygrometer and a temperature-sensitive element made of a gap-gap material, and on the same chip, it is seamlessly connected to the 14-bit A / D converter and the serial interface circuit. Therefore, the product has excellent quality, ultra-fast response, anti-interference ability and so on. The temperature measurement accuracy is ± 0.4 ℃, and the humidity measurement accuracy is ± 3%.
(3) BES-C portable microcomputer multi-channel data acquisition instrument
The instrument is mainly used for energy-saving building wall surface temperature, indoor and outdoor temperature, heat flux and other parameters of the field test. It integrates measurement, display, communication and other functions in one and has the characteristic of high precision measurement, full-featured, easy to use and so on. It is suitable for energy-saving building envelope thermal resistance, heat transfer coefficient of the field test, thermal testing of building materials and environmental monitoring and other occasions.
The technical parameters: Heat flow measurement channel: 16 road; range: 0 ~ ± 20mV; the measurement accuracy: ≤0.03mV; and the heat flow sensor uses a plate heat flow meter. It is mainly used for wall heat flux measurement. The sampling period: 10 seconds to 24 hours (optional). Data storage capacity: 128,000 data can be stored.

2.2 Experiment scheme

The test is divided into two parts: winter test and summer test. In the composite polystyrene granule thermal deformation mortar pilot house layout two temperature and humidity collection point that is 1 #, 2 # collection points, each collection point from the ground is about 70 cm, and not directly affected by the indoor heat source. In the outdoor layout of a temperature and humidity collection point that is 3 # collection point, which is not exposed to direct sunlight, and use equipment every 10 minutes to record the three-collection device to collect the temperature and humidity.
In the winter test, we use the heater to the composite polystyrene granule thermal deformation mortar pilot housing for heating. In the summer test, we use the air conditioning on the composite polystyrene granule thermal deformation mortar pilot housing for refrigeration. The power consumption of the heaters and air conditioners is recorded using a meter, and it continuously measured more than 7 days.

2.3 Experimental procedure

From February to March, the winter experiment is carried out in the composite polystyrene granule thermal deformation mortar building. In the pilot housing, use two rated power of 2500W heaters on the housing for winter heating. The first stage is constant power heating, and the second stage is constant temperature heating, set the temperature is 18 °C. With the meter to collect heating power consumption during heating, and install the collection device of the temperature and humidity inside and outside, and then record the indoor and outdoor temperature and humidity changes during the test.
The summer experiment is carried out in August, in the pilot house, use the air conditioning for the summer cooling of the house, and the cooling temperature is set at 26 degrees. We use the meter to record the power consumption during air conditioning and cooling, and use the temperature and humidity data acquisition instrument to record the indoor and outdoor temperature and humidity during the test.

2.4 DeST software

DeST software structure is composed of a number of separate modules connection, and it implements the concept of phased simulation (Sanz-Pont et al., 2016). The software structure diagram is shown in Figure 1.

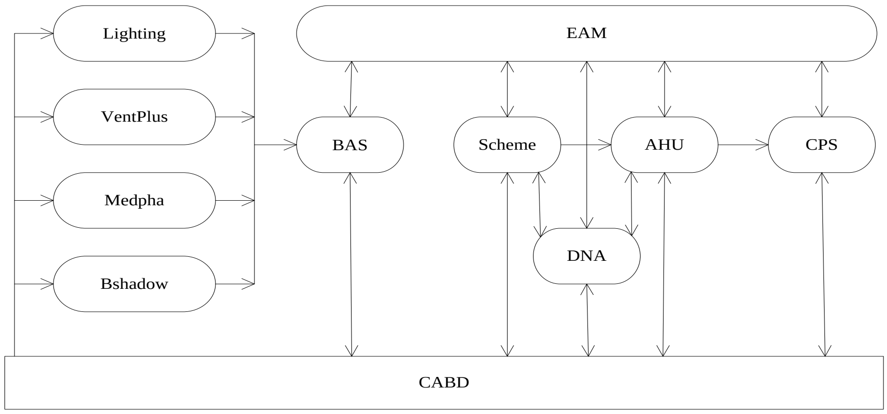


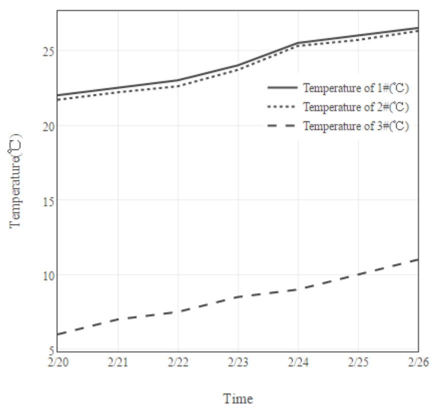
Figure 1: DeST simulation software structure

First, building shadow calculation module BShadow: use the geometric projection method to calculate the shadow details of the surface of the building at any time throughout the year.
Second, outdoor meteorological parameters module Medpha: according to the design needs, we provide year-round meteorological data for the simulation analysis with extremely high temperatures, extremely low temperatures, very high solar radiation, minimal solar radiation and extremely high enthalpy.
Third, natural lighting calculation module Lighting: responsible for indoor lighting calculation.
Fourth, natural ventilation simulation module VentPlus: use the multi-regional network model to form a fluid network, and use the Newton method to obtain the air flow of each branch.
Fifth, building thermal characteristics calculation module BAS: the core module of the building's thermal characteristics calculates the temperature and the load of the building.
Sixth, air conditioning system design module Scheme: by simulating the performance of buildings under different air conditioning options, designers can explicitly use different solutions to produce results.
Seventh, mechanical ventilation system analysis module DNA: mechanical ventilation system analysis module, which can complete the wind system design calculation and check the calculation.
Eighth, air handling equipment AHU: through the simulation means of the designer's air treatment program to carry out annual verification, and it provides a quantified basis for the designer's program.
Ninth, cold and heat source and water system simulation module CPS: after the designers determined the air treatment program, through the CPS simulation to analysis operating energy consumption of different cold and heat source system and water system, and provide designers with comparison data of different schemes.
Tenth, CABD: the graphical user interface, the designer can directly through the interface to carry out data design of various buildings (material, geometry, thermal interference).
Eleventh, economic evaluation module EAM: it can economically evaluate the life cycle costs of HVAC programs and provide economic basis of program options for HVAC designers and engineering construction departments.

3. Methods

3.1 The winter constant power test

In the constant power test phase, two heaters continue to run at constant power, and measured the average daily power consumption is 94 degrees. The indoor temperature increased with the increase of the outdoor temperature, and the daily average temperature in the test stage reached 26.64 ℃. At this point, the indoor temperature is too high, and the humidity is relatively low. This brings discomfort to people's work and life, and the heaters constant power work consume a lot of energy, which is detrimental to energy saving and environmental protection. The winter constant power temperature chart is shown in Figure 2, and the winter constant power humidity chart is shown in Figure 3.



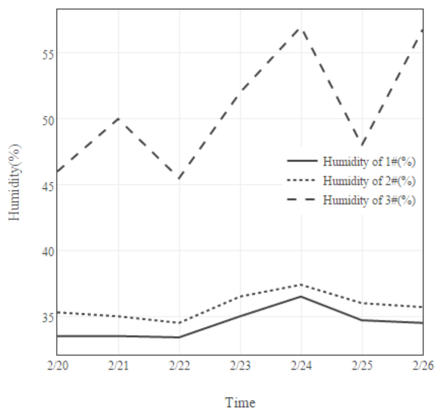
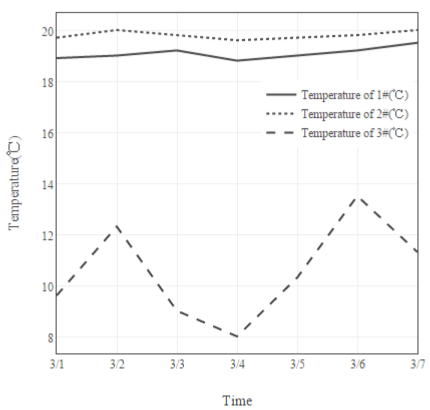


Figure 2: The winter constant power temperature chart *Figure 3: The winter constant power humidity chart*

In the constant power test stage, the indoor humidity is relatively stable, about 35%, and the change of outdoor humidity is great. The indoor humidity is less affected by the change of the outdoor humidity.

3.2 The winter constant temperature test

In the constant temperature test phase, we use the heater to continue heating pilot building, set the heating temperature is 18 ℃, and measured the average daily power consumption is 29 degrees. The indoor temperature is less affected by the change of the outdoor temperature, the temperature is constant, the people's comfort is high, and it is suitable for the working life. The winter constant temperature chart is shown in Figure 4, and the winter constant temperature and humidity chart is shown in Figure 5.



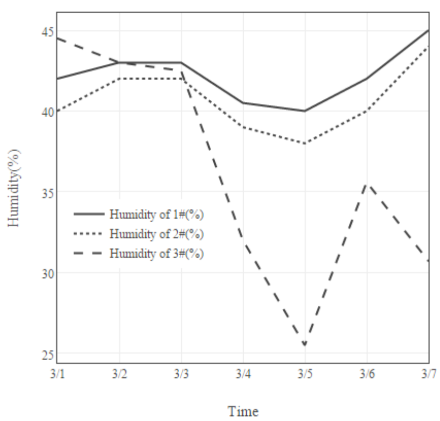


Figure 4: The winter constant temperature chart *Figure 5: The winter constant temperature and humidity chart*

The change of indoor humidity is small, and it has little correlation with the change of humidity. However, there is a certain impact between the two.

3.3 Summer test

The average power consumption of air conditioning in summer is 1.5 degrees per day. During the experiment, the indoor temperature and humidity trend is relatively stable, the temperature is maintained at about 26 ℃, and the average humidity is about 70%. The outdoor temperature and humidity changes greatly, and the correlation between indoor and outdoor humidity changes is small. The summer temperature chart is shown in Figure 6, and the summer humidity chart is shown in Figure 7.

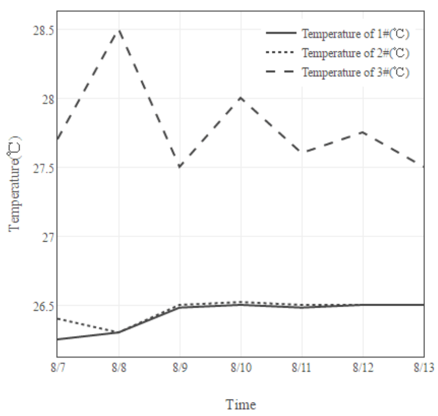


Figure 6: The summer temperature chart

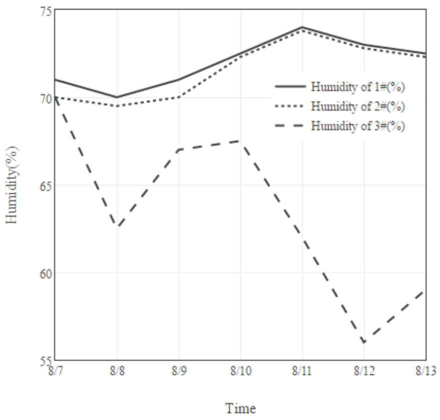


Figure 7: The summer humidity chart

4. Analysis of results

According to the analysis of the relative humidity of the pilot building during the test, the humidity changes in the outdoor environment of the composite polystyrene granule thermal deformation mortar house will have a certain impact on the humidity inside the house, but there is a certain lag time. In the short term, the indoor humidity environment is relatively stable. Under the influence of long-term outdoor environment, the indoor humidity will change with the change of outdoor humidity. The changing trend is basically the same.

The temperature of the pilot building during the test period is mainly affected by the summer refrigeration equipment and the winter heating equipment. The outdoor temperature has some influence on the indoor temperature, but the effect is far less than that of indoor heat preservation equipment. It can be seen that the composite polystyrene granule thermal deformation mortar pilot housing insulation effect is good.

(1) Winter insulation performance

According to the provisions of the region, the winter heat consumption index is 14.8W/m2. After the calculation, in 18 ℃ constant temperature heating conditions, the pilot building heat consumption index is 9.35W/m2. The comparison results are shown in Figure 8. It can be seen that the composite polystyrene granule thermal deformation mortar pilot housing winter insulation performance can meet the energy efficiency design standards.

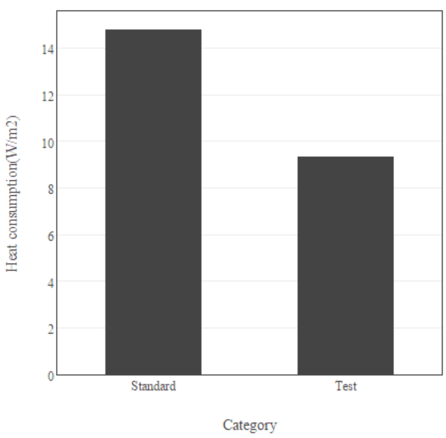


Figure 8: The comparison of winter heat energy

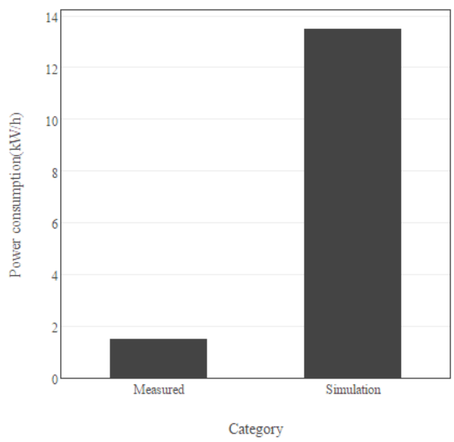


Figure 9: The comparison of summer power consumption

(2) Summer heat preservation performance

We use DeST to simulate the summer energy consumption of ordinary concrete building houses, and compare with the measured situation of composite polystyrene granule thermal deformation mortar building, as shown in Figure 9. The composite polystyrene granule thermal deformation mortar pilot building in the summer measured power consumption is 1.5 degrees per day, and the DeST simulation of ordinary concrete construction in the summer power consumption is 13.5 degrees per day. It can be seen that the pilot building summer heat insulation performance is good, and the energy consumption of buildings is greatly reduced.

The comparative analysis of energy consumption simulation results and heating annual electricity consumption is shown in Table 1.

Table 1: The comparative analysis of energy consumption simulation results and heating annual electricity consumption

Annual heating electricity consumption (kWh/m^2)	Simulated energy consumption difference value (kWh/m^2)	Simulation energy difference / annual electricity consumption (%)
12.5	2.69×10^3	13.25%

5. Conclusions

Based on the experimental study on the thermal insulation performance of the composite polystyrene particles, it is concluded that the calorific value measured in the winter test of the composite polystyrene particles is in accordance with the local regulations. The power consumption index of composite polystyrene particles pilot building measured in summer test, which has the advantages of good insulating property and distinctive effect of energy saving. In the short term, the change of outdoor humidity has little effect on the change of indoor humidity environment, and the humidity control performance of the straw compressed block is not significant. However, the overall humidity of indoor environment will change with the change of outdoor humidity environment, and the process is relatively slow.

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