

Research on phase-change material building mass applied in the air-conditioning field*

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Abstract: Phase-change material building mass contains phase-change materials. It can decrease air-conditioning load and indoor temperature fluctuations, and improve comfort degree in summer because of thermal storage property of phase-change material. Thereby, the scale, initial investment and operational cost of air-conditioning system decrease effectively. The indoor surroundings improve. In this paper, suitable phase-change material used in architecture and combination mode between phase change material and architectural material were studied. By considering the properties of materials, such as phase-change temperature, phase-change latent heat, thermal conductivity and expansion coefficient, phase-change materials were selected and evaluated. Combination mode between phase-change material and architectural material were provided. The influence of phase-change material structure on thermal performance in room and energy-saving effect were analyzed and compared with traditional structure without phase-change material. It is proved that phase-change material structure is feasible in the practical engineering. These provide the basis for developing phase-change material building mass.

Keywords: Phase-change materials, building mass, energy-saving effect

1. Introduction

With the increasing of living standard, people require more comfortable environment. Energy consumption of architecture (include air-conditioning and heating) and environmental pollution increase and quicken. It has become the subject in the field of architectural design and energy saving how finds suitable balance among comfort degree, energy consumption and environment. Application of phase-change materials provides a measurement to raise comfort degree and decrease energy consumption and negative influence on environment. It is a focus research that phase change materials are added into building mass by different forms[1]. The application of phase change material in the architectural field has been regarded as a main research direction by International Energy Association (IEA) [2].

Research in America is in a lead position in the field of energy storage with phase change material. Compounding of phase change material, improvement on performance of phase change material, heat transfer in phase change and design of energy storage system were studied deeply[3]. In 1978, research institute of Delaware college in America developed phase change material wall, which was super to general brick wall in thermal storage effect[4].

Research in Japan is inferior to America. Sanlin electronic company had made the study of phase

change material used in heating and refrigerating systems in 1970s.

In Germany, Krichel made the study of phase change material that phase change temperature is less than 100 °C

Researchers in France built experimental house to study effect of phase change material. It is proved that phase change material wall decrease temperature fluctuation in room. Y.Hirayama studied the influence of heat capacity of building mass on thermal performance in room. It is proved that phase change material structure can decrease temperature fluctuation and increase comfort degree[5].

S.Hokoi studied phase-change material floor that store energy by absorbing solar energy[6]. J.Ohishi thought that phase change wall not only use solar energy, but also store electrical energy at night to use in the day[7]. Some researchers also studied thermal storage in-phase change applied in the air-conditioning system.

Less research in this field was found in China. Research on phase change conduction and physical properties of phase change material had been reported, but research on thermal storage system and building mass with phase change material have not found.

At present, lightweight structure is used in order to decrease energy consumption in architecture, such as porous brick, hollow brick etc, but lightweight materials have less ability to store heat and poor sound

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insulating effect. Ability of thermal storage within building mass can improve indoor environment. As ability of thermal storage within building mass increases, indoor temperature fluctuation decreases, comfort degree rises, and energy consumption in heating or air-conditioning decreases, thus initial investment and operational cost of air-conditioning or heating system will decrease.

Phase change material is added into traditional building mass to form phase change material building mass. It increases ability of thermal storage, decreases heat transferred and temperature fluctuation and saves energy.

In this paper, composition and energy-saving effect of phase change material building mass and phase change material were studied. The results provide the basis for developing and applying phase change material in practice building mass in the future.

2. Selection and evaluation of phase change material

Phase change materials used in the building mass should satisfy the conditions listed below: (1) Suitable phase change temperature. (2) Larger phase change latent heat. (3) Suitable thermal conductivity. (4) No separation and super-cooling in the phase change process. (5) Lower coefficient of volume expansion. (6) Non-poisonous unburnable and cheap. The phase change materials most in use include paraffin wax, ester acid, polybasic alcohol, crystal hydrate salt etc.

Paraffin wax is the mixture of alkenes. It can be expressed by the formula of C_nH_{2n+2} . The melting temperature varies with the length of carbon chain. Paraffin wax with different melting temperatures (20-60 °C) can be gained from by product of oil. It has some advantages, such as cheap, wider phase change temperature range, larger phase change latent heat, non-poisonous, steady and no separation and super-cooling.

Ester acid can be formulated by $C_nH_{2n+2}O_2$. Its characteristics are similar with paraffin wax. Phase change temperature range is from 10 to 50 °C.

Polybasic alcohol is solid-to-solid phase change material. It has higher transformation heat, lower volume variation and no corrosion. It doesn't produce liquid. Polybasic alcohol with different transformation temperature (from tens to hundreds °C) can be gained by changing the ingredient of mixture.

Crystal hydrate salt is inorganic compound. It can be formulated by $AB \cdot mH_2O$, such as $Na_2SO_4 \cdot 10H_2O$, $Na_2CO_3 \cdot 10H_2O$, $CaCl_2 \cdot 6H_2O$ etc. Phase change

temperature range is from 30 to 50 °C. It has some advantages, such as cheap, larger phase change latent heat, higher density etc. But it produces separation and super-cooling.

Paraffin wax and polybasic alcohol are ideal phase change materials used in the building mass according to the characteristic of phase change materials motioned above and the affection of phase change materials on building mass. In order to gain required phase change temperature, we can use polybasic alcohol with different component and paraffin wax with different length of carbon chain.

Phase change temperature should be considered firstly when selecting phase change materials. The suitable range of phase change temperature is the key factors to phase change material building mass. Phase change temperature should be more than the lowest temperature of air in summer. For a city, we should know the highest outdoor temperature and the lowest outdoor temperature in summer. The phase change temperature of phase change material should be two centigrade more than the lowest outdoor temperature. For example, the lowest temperature of air is 27 °C, thus phase change temperature can be 29 °C.

In Beijing, the lowest outdoor temperature in summer can be thought as 24.4 °C, so it is suitable that the phase change temperature of phase change material used in the building mass is 27 °C~30 °C. Paraffin wax and polybasic alcohol are ideal phase change materials.

3. Combined mode between phase change material and architectural material

It is one of the key questions to develop phase change material building mass how introduces phase change material to existing building mass. There are several methods to combine phase change material with architectural material. (1) Suck phase change material into porous architectural material. (2) Penetrate phase change material into polymer material. (3) Suck phase change material into special silicon to form soft and flowing powder, then mix it with architectural material. (4) Phase change material is sealed into the suitable container, and then put it into building mass. Container can be made by iron or plastic.

The first method is relatively suitable, its structure is simple and the character is well-distributed. It is easy to make architectural member with different shape and size. Architectural materials that can suck phase change materials include cement member, lime board, cement-sand-lime synthetic brick, and porous wall etc. put architectural members into phase change material

solution. They can be used after architectural members reach saturation and solvent evaporates. The good and bad and the effect of this method mainly depend on absorbing capacity and stability between architectural material and phase change material.

4. The effect of phase change material building mass on thermal performance and energy consumption

Compared with traditional building mass, phase change material building mass can decrease indoor temperature fluctuation, increase comfort degree and decrease energy consumption and operational cost of equipment. Figure 1 shows the variation law of indoor temperature with time in the building with and without phase change material. In the figure, real line represents building without phase change material and dotted line represents building with phase change material. From the figure, we can see that indoor temperature fluctuation of the phase change material building is lower than that of the traditional building. Comfort degree increases because of thermal storage property of phase change material.

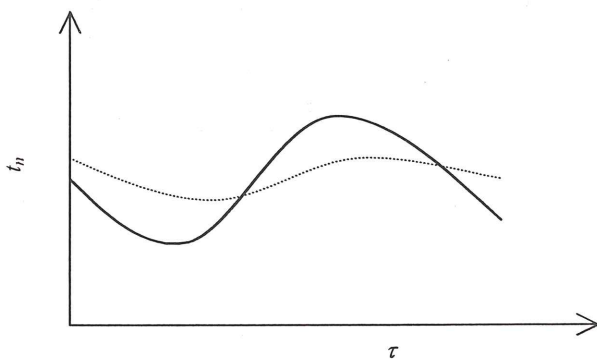


Fig.1. The variation law of indoor temperature with time

On the other hand, thermal current from outdoor to indoor through phase change material building mass is delayed and lower than that through building mass without phase change material. Moreover, thermal current fluctuation is lower, thus decrease heat and cool load of building.

5. Conclusions

Phase change material building mass plays a positive role in the development of air-conditioning. phase change material building mass can decrease transferred heat from indoor to outdoor by building mass and raise comfortable degree in the summer because of the property of thermal storage of phase change material. Phase change material building mass can store quantity of cool at night to bear peak load at day, thus decrease

energy consumption in the air-conditioning system. Load of the building with phase change material is much lower than the existing building, thereby decrease the scale of air-conditioning system and investment and operational cost.

Phase change material building mass is composed of phase change material and architectural material. Selection of phase change material and combined form between phase change material and architectural material are key to study and develop phase change material building mass.

Paraffin wax and polybasic alcohol are suitable to use in the building mass. Combination between phase change material and architectural material should use the method that phase change material is sucked into architectural material. In the building with phase change material, indoor temperature fluctuation is low and thermal current is delayed, so raise comfort degree in room and save energy.

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