Research on the Application of Thermal Insulation Materials in Construction Engineering

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Abstract. As one of the most important supporting industries of urbanization, the construction industry has also caused environmental pollution and other problems in the process of rapid expansion. Therefore, promoting the development of green buildings and intelligent buildings and improving the quality of buildings is an inevitable trend in the current construction industry, which reflects the necessity of insulation materials in environmental protection and energy saving building materials. This paper classifies the application of thermal insulation materials in building engineering, and lists some common and new environmental protection and energy saving materials. On the basis of understanding the characteristics of environmental protection materials, their application value are also understood deeply. The research results show that insulation materials are developing in the direction of high performance, environmental protection, sustainable and intelligent, showing more diversified and efficient characteristics. The future of insulation is expected to showcase more innovative solutions to meet changing market demands and environmental demands.

Keywords: Thermal insulation materials; construction engineering; environmental protection; benefits and applications.

1. Introduction

In recent decades, the construction industry around the world has experienced rapid development. With the acceleration of urbanization, the construction industry is facing a huge market demand, and people have a strong demand for infrastructure and housing. However, in the process of construction, the consumption of traditional building materials is increasing. In addition, a large amount of pollution will be generated in the production and processing of materials, which poses a certain threat to the natural and ecological environment [1]. As a result, the introduction of the concept of green environmental protection in the construction industry, the vigorous promotion of the research and application of green building materials have become the mainstream trend. In the process of energy-saving design of construction engineering, the introduction of new energy-saving and environmentally friendly materials can optimize the overall function of the building, and provide people with a comfortable and environmentally friendly living environment. At the same time, it can also realize the recycling of industrial solid waste under the action of various new energy-saving materials. Compared with traditional building materials, environmentally friendly building materials have the characteristics of low pollution, recyclability, and low harm to human health. It can not only replace conventional building materials in many aspects, but also have a better use effect.

New environmentally friendly building materials are mainly divided into new-type wall materials, thermal insulation and environmental protection materials, new nano materials and new decorative materials [2]. As an important branch of building environmental protection and energy-saving materials, thermal insulation and environmental protection materials have the characteristics of cleanliness and environmental protection. It also pays more attention to the thermal insulation effect in the application effect, which plays a great role in the thermal insulation of the building structure and the reduction of indoor energy demand for electricity. Building materials with good thermal insulation will have a direct effect on the daily life of people in some areas with changing ambient temperature differences [3]. In addition, with the investment of relevant scientific research and technology, the thermal insulation effect of new building materials has achieved certain results and can meet the requirements of modern energy conservation and environmental protection. This paper

will introduce the types and properties of thermal insulation materials and practical application cases in real buildings.

2. Types and Properties of Thermal Insulation Materials

The use of insulation materials in buildings can effectively keep the indoor temperature stable, so that the indoor temperature will not rise rapidly in the hot summer, and the indoor temperature can also be kept relatively warm in the cold winter. In this way, users can reduce the use of indoor air conditioning, cooling and heating, save building power consumption, and achieve environmental protection and energy saving effects. In addition to some common thermal insulation materials, such as asbestos and diatom mud, new thermal insulation materials, such as aerogel and vacuum insulation panel, have also been widely used and studied.

2.1 Common Thermal Insulation Materials

The properties and application of common insulation materials are shown in Table 1. The following article mainly analyzes the performance and use of rock wool and diatom ooze.

Table 1. Properties and application of common insulation materials.

Material	Property	Application
Rock wool	Stable chemical properties, good thermal insulation performance, excellent thermal insulation performance	Building exterior wall insulation, roof and curtain wall insulation, fire isolation belt, elevator shaft, etc
Diatom ooze	Fireproof and flame retardant, thermal insulation	Reduce energy losses caused by indoor and outdoor temperature differences, and improve the energy efficiency of buildings.
Low-emissivity coated glass	Significantly reduces UV and NIR radiation	Building windows, doors and curtain walls
Composite membrane material	Low thermal conductivity and good thermal insulation energy	As a key component of external thermal insulation systems

2.1.1. Rock wool

Rock wool is a kind of lightweight fiber material obtained by centrifugation by using basalt or diabase as raw material, adding additives to melt into a liquid state under high temperature [4]. Because basalt has excellent compressive and bending resistance, fire resistance, and good wear resistance, low water absorption, rock wool is a very good building insulation material. The higher the basalt content of the exterior wall rock wool slab, the higher the acidity coefficient. The greater the acidity coefficient, the more stable the chemical properties, the better the weather resistance, the longer the anti-aging time, the stronger the ability to resist the erosion of natural wind and sun, and the longer the service life. The acidity coefficient of the rock wool board will affect the water resistance of the rock wool. When the acidity coefficient of rock wool is higher, its water resistance will be higher. The lower the acidity factor, the lower the water resistance [5].

It has many advantages, including chemical stability, good sound absorption and thermal insulation properties, excellent thermal insulation performance, fire performance up to Class A, and non-toxic production materials [4]. Therefore, the insulation materials of the wall, rock wool boards, rock wool strips, rock wool composite integrated boards and other products with rock wool as the main material are widely used. Among these products, the more common is the rock wool insulation decorative integrated board. In the rock wool insulation decoration of the exterior wall of the prefabricated building, the rock wool insulation and decoration integrated board has outstanding advantages, such as good thermal insulation, aesthetics, safety and durability. Specifically, first, the decorative effect of the finish is good, and the coating is uniform under the automatic assembly line mode, and the color difference is very small, which enhances the integrity and uniformity of the finish of the construction project [6]. Second, the thermal insulation performance is good. As a rock wool material of thermal insulation layer, the thermal conductivity of the building design is 0.032W/(m·K)

~0.042W/(m·K), which has good thermal insulation performance [7]. Therefore, compared with the traditional insulation method, the insulation effect of the new material is at least 65% higher [7]. Third, the crack resistance is good.Traditional insulation systems shrink under the temperature difference between day and night, resulting in cracking of joints and affecting the overall insulation performance. However, the non-asbestos calcium silicate board in the rock wool insulation decorative integrated board has a very high density, and through waterproof treatment, the problem of board surface cracking can be solved, and the crack resistance is extremely high [7].

2.1.2. Diatom ooze

The main component of diatom mud is diatomaceous earth, and the main component of diatomaceous earth is diatomaceous. Its main ingredient is protein, which is rich in a variety of beneficial minerals, and the chemical composition is mainly SiO2, and the color of diatomaceous earth is divided into white, gray-white, gray and light gray-brown [8]. This shows that it is composed of pure natural inorganic materials and does not contain any harmful substances as well as harmful additives. The thermal conductivity of diatomaceous earth is very low, usually in the range of 0.008 ~ 0.02W/(m·K). The thermal conductivity of diatomaceous earth is comparable to that of gas, so diatom mud has good thermal insulation performance, and its thermal insulation effect is 5 ~ 7 times that of cement mortar of the same thickness [9]. In addition to this, diatom mud also has the property of absorbing moisture and purifying the air. However, it also has drawbacks. First of all, the price of diatom mud is high, and the price of diatom mud products is high due to the high cost of raw materials and complex construction. In addition, diatom mud has poor waterproofness, and diatom mud is very absorbent due to its own structure, and it is not waterproof. Excessive oil smoke and moisture will block the microporous structure of diatom mud and affect other functions of diatom mud [10]. Therefore, diatom mud is not suitable for wall coating in kitchens and bathrooms. It shows that diatom mud has great potential, and there are still shortcomings worthy of improvement.

2.2 New Type of Thermal Insulation Material

The properties and uses of the new insulation materials are shown in Table 2. The following article mainly analyzes the properties and uses of aerogels and vacuum insulation panel.

Table 2. The properties and application of the new insulation materials.

Material	Property	Application
Aerogel	Very low thermal conductivity, excellent thermal insulation properties	Used in many fields such as construction, aviation, aerospace, energy and so on
Vacuum insulation panel (VIP)	The gas inside the vessel is evacuated into a vacuum, and the thermal conductivity is reduced.	Suitable for construction and plumbing
Phase-change material (PCM)	It enables temperature control during phase transitions (e.g., between solid and liquid states) at specific temperatures.	Used in the field of building energy conservation and solar energy utilization
Nano-insulation material	Heat conduction is reduced by reflecting or scattering heat radiation.	Used in construction, clothing and electronics

2.2.1. Aerogel

Aerogel is an amorphous and highly dispersed material composed of nanometer-sized ultrafine silica particles aggregated with each other to form a nanoporous network, and the pores are filled with gaseous dispersion medium. In the medium, there are three main ways of heat diffusion. The first method is heating conduction. The low density and high porosity of aerogel lead to the prolongation of the heat propagation path in the material, the decrease of heat propagation efficiency, and the low thermal conductivity of the solid state. The second method is convective heat transfer. Due to the small size of aerogel colloidal particles and the low free path of air molecules, there is no space for air molecules to move inside the aerogel material, and the convective thermal conductivity is low. The third method is radiative heat transfer. Aerogel thermal radiation is infrared thermal radiation,

infrared wavelength is about 14μm, can hedge infrared light radiation, coupled with the porous network structure to block thermal radiation, so it has high shielding efficiency for thermal radiation and low radiant thermal conductivity [11]. Aerogel integrates super heat insulation, high temperature resistance, non-combustible, flame burn-through resistance, super hydrophobicity, sound insulation and shock absorption, environmental protection, low density, insulation and other properties, which is very suitable for building energy-saving wall materials [12]. At present, SiO2 aerogel is widely used in thermal insulation materials. The application form of SiO2 aerogel in building thermal insulation is usually composite products, and has a variety of forms, including SiO2 aerogel glass, SiO2 aerogel cementitious composites, SiO2 aerogel fiber composites, SiO2 aerogel coatings and other new SiO2 aerogel composites [13].

2.2.2. Vacuum insulation panel

Vacuum Insulation Panel is a kind of vacuum insulation material, which is composed of a filling material and a vacuum protection surface, which can effectively avoid the heat transfer caused by air convection. Its thermal conductivity is generally less than 0.0035 W/(mK), which is only 1/10~1/5 of the thermal conductivity of commonly used insulation materials (such as rock wool, EPS, PU) [14]. There are three main insulation principles of vacuum thermal insulation board. First, it uses a high-vacuum double wall. Second, it uses a high-vacuum cavity. There are a certain number of intermediate polished sheets in it that act as emission screens to reflect light and thus prevent heat radiation transfer. Thirdly, cavities with powdered substances or light fibers are used. These powdered material fibers have low thermal conductivity in vacuum and at low temperatures [15]. The application of vacuum insulation panel in building insulation is still in its infancy. So far, there have been dozens of examples of vacuum thermal insulation boards applied to ground, roof, balcony, wall and other thermal insulation projects. Vacuum insulation panels, which are currently the most widely used flat roof insulation panels, can easily avoid significant temperature differences between the interior of the building and the terrace space. VIP panels have also become the insulation material for building exterior walls [16]. For example, in 2004, a commercial and residential building was built in Munich, Germany, at 23 Zützstrasse in the central area, using VIP as all materials. The building's energy consumption is only about 20 kW·h per square meter of living space per year [17]. It not only meets the German standard for low-energy housing, but also far below the annual energy consumption standard for commercial housing in Munich. It is estimated that in the European Union, the CO2 emissions of buildings could be reduced by 8% if VIP insulation is used for energy-efficient retrofitting of old buildings and for energy-saving implementation of new buildings [17]. It has a smaller insulation thickness than general insulation and can be recycled. This shows that the vacuum insulation board is not only efficient and energy-saving, but also saves a lot of resources. This is of great significance to promote the intensification and environmental protection of the construction industry.

3. Conclusion

This paper mainly studies the application of thermal insulation and environmental protection materials in construction engineering, and obtains the following conclusions.

(1) Common thermal insulation materials are mainly introduced with asbestos and diatom mud as examples. These materials have good fire resistance, high temperature resistance and sound absorption properties, and are commonly used in industrial equipment and building partitions. However, they absorb water when exposed to moisture for long periods of time, resulting in a decrease in thermal insulation.

(2) Aerogel and vacuum insulation board are mainly used as examples to introduce new thermal insulation materials. With ultra-low thermal conductivity and low density, aerogel is a highly efficient thermal insulation material suitable for thermal insulation in extreme environments. The core material of the vacuum insulation panel is pumped into a vacuum, which has a very low thermal conductivity. However, compared with other insulation materials, the manufacturing cost is higher.

(3) Insulation materials play a vital role in the construction industry. However, there are also some challenges and shortcomings in this field. Many traditional insulation materials may pollute the environment during the production process, while the cost of high-performance materials is relatively high. However, in addition to the challenges faced, insulation and environmental protection materials also have broad prospects for development. With the continuous innovation of technology, new insulation technology is expected to improve the efficiency of insulation, and carry out interdisciplinary cooperation in the fields of material science and architectural design to develop more comprehensive new materials.

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