Application of new green building materials in civil engineering

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Abstract. About 50% of the world's energy consumption comes from the construction industry. At the same time, more than 60% of the raw materials that humans obtain from nature, such as wood, stone, sand, etc., are used to build various buildings. During the construction process, the processing of these materials can cause a large amount of pollution. For example, the production of concrete can cause an increase in greenhouse gas emissions. These phenomena urge us to improve and upgrade building materials to ensure that the basic functions of the building are achieved and its safety is guaranteed on the basis of minimum pollution. Therefore, green buildings have emerged and gradually received attention. This paper mainly introduces two new concrete materials (one is the concrete material produced by Carbicrete Company that can realize the negative emission of carbon in production and use, and the other is high-performance concrete material), photovoltaic power generation system that can be installed on various structures of buildings and new SiO_2 aerogel building materials (mainly used in thermal insulation felt and concrete, which can ensure the heat resistance of materials while reducing the thermal conductivity).

Keywords: green building materials, improved high-performance concrete, BIPV photovoltaic power generation system, SiO_2 aerogel building materials.

1. Introduction

With the development of industrialization in the world, the energy problem has become one of the main problems that all countries need to face and face up [1]. Various building materials such as concrete, steel, wood, metal, ceramics, synthetic polymer materials, asphalt, etc. are the foundation for building a good building. The various properties of materials directly determine the safety of the entire project and its impact on the environment [2]. In the field of civil engineering, new environmental protection materials that are harmless to the environment, beneficial to the environment, and have good energy conservation effects have gradually occupied the main position of various building engineering application materials [3]. And new energy conservation and environmental protection functional materials are still being developed and applied, becoming the new direction and trend of material development in building engineering [1]. Taking the new thermal insulation building materials such as thermal insulation glass material and thermal insulation board as an example, through the secondary processing and utilization of waste, it can reduce waste and have good economic benefits. That is, after the end of the service period, the new building materials can be transformed and reused as new energy-saving and environmental protection materials or other functions through effective recovery means to achieve zero pollution in the three links of production, construction and waste [3].

2. Development prospects of green building materials

The construction industry around the world produces approximately millions of tons of solid waste each year. These wastes include but are not limited to: waste concrete, bricks, clay bricks, asphalt blocks, waste steel, worn tires, waste polyethylene terephthalate (PET), fly ash, slag, waste metals, etc. used for building houses. A large portion of these wastes have not undergone any treatment and are treated in simple stacking methods. Therefore, a large amount of them can be used in parks, schools, or other land occupied by landfills. Random stacking can cause pollution to the soil, water, and air in the area [4]. Green building materials are a relatively common new type of materials in the construction of wood engineering. At present, green building materials on the market generally have the following characteristics: (1) The demand for energy resources of green building materials is relatively low, which will not cause serious waste of resources, but also has the characteristics of high technology content. (2) In the process of construction, green building materials can not only play the role of conventional building materials, but their performance can even far exceed that of conventional building materials. For example, many green building materials have the performance of high strength, waterproof and light weight, which can reduce the cost of the use and construction of wood engineering to a certain extent. (3) The performance of green building materials is relatively considerable, which can fundamentally improve the quality of civil engineering. This has been confirmed in practical applications. For example, the commonly used lightweight high-strength concrete has more significant bearing capacity and lower dead weight than conventional concrete, and its application value is very prominent. (4) Green building materials can guarantee the life experience of civil engineering users. Compared with conventional building materials, green building materials have more outstanding environmental protection performance, and will not cause damage to users' health. (5) The raw materials of green building materials are mainly recyclable wastes, which enables the resources that should be discarded to continue to play a role and avoids the secondary pollution of waste building materials to the environment. To some extent, the emergence and use of green building materials have changed the pollution problem of building waste from the source"[5]. It can be seen that new building materials, including new concrete materials and new environmental protection materials, play a great role in saving engineering costs and environmental protection. This paper will explore the application of new materials in civil engineering the application of concrete and photovoltaic power generation system is still deficient, so this paper mainly supplemented from the two levels of new concrete materials, concrete, BIPV system and Building insulation materials required for green buildings

3. Cement-free concrete

Portland cement is the most widely used type of cement in various construction sites worldwide. It is produced by grinding a mixture of Portland cement clinker, crushed limestone or slag, and a small amount of gypsum to bake to 1450 to 1650 degrees Celsius. Reactions at such high temperatures are usually accomplished by burning fossil fuels such as coal. When limestone is heated, the calcium carbonate in it will also be heated and decomposed, releasing a large amount of carbon dioxide. Therefore, the production process of cement is also a process of greenhouse gas emissions, which is one of the reasons for global warming; According to a 2014 study by the Netherlands Environmental Assessment Agency, this represents 10% of the total global CO_2 emissions. Today, with the recovery of the global economy after the pandemic and the development of the construction industry, CO_2 emissions may account for a higher proportion. CarbiCrete has provided us with a new type of concrete material that can minimize the pollution caused by the concrete production process. It has produced a cement free concrete that achieves negative carbon emissions from the process. The process uses an industrial by-product - slag from steel plants - as a bonding component in precast concrete products, replacing cement, the main ingredient in traditional concrete. This process injects carbon dioxide into fresh

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concrete to provide strength, while permanently retaining the absorbed carbon dioxide in the final concrete product.

3.1. Process

The process of producing concrete by CarbiCrete is the same as that of traditional processes, but there are some differences in some production steps. For cement based concrete, the first step is to mix cement with aggregate and water. In the concrete produced by CarbiCrete, the main cement is replaced by steel slag to achieve mixing of steel slag with other materials. The mixture is then poured into a traditional block making machine, where a CMU is formed. In order to solidify concrete and enhance its strength, it is necessary to place the blocks in a dedicated absorption chamber, into which carbon dioxide is injected. The concrete can achieve the required strength in just 24 hours.

3.2. CO_2 curing and concrete properties

The patented curing process includes injecting carbon dioxide into an absorption chamber where it reacts with freshly mixed concrete. During the carbonation process. CO_2 is combined with concrete and converted into calcium carbonate. Fill the voids in the concrete matrix to form a dense structure and enhance the strength of the concrete.

Compared to cement based CMUs, CMUs produced by CarbiCrete have better durability and strength. CMUs produced by CarbiCrete have the same water absorption as concrete blocks produced by traditional processes, but their compressive strength is improved by nearly 30% compared to traditional concrete, and they have better freeze-thaw resistance

4. BIPV system

In essence, BIPV refers to the application of photovoltaic materials to building envelopes. During the building construction stage, the combination of traditional building materials and photovoltaic materials will better integrate photovoltaic materials into building envelopes, including roofs, windows, balconies, or skylights. Therefore, BIPV technology is very suitable for application to various new buildings, whether traditional concrete buildings or green buildings in this article. In addition, adding photovoltaic modules to the envelope structure of existing buildings is also one of the applications of BIPV. This combination of photovoltaic modules and building structures is referred to as building application photovoltaic (BAPV) systems, which can be easily installed on old buildings, resulting in years of application, BIPV has become a green and clean building energy technology, which can bring many improvements to various aspects of buildings, and is widely used in many traditional and new green buildings. First, photovoltaic materials can directly convert solar energy into electrical energy. Assembling photovoltaic elements into the building curtain or exterior walls and various building envelopes of a building can enable the building to generate its own electricity. The electricity generated can be partially or entirely used for indoor energy systems, such as air conditioners and electronic equipment, thereby saving the demand for installing power grids in cities, greatly reducing the losses generated in the transmission of electricity, easing the pressure on power supply, and further reducing fossil fuel consumption and greenhouse gas CO_2 emissions. The most important thing is that BIPV, as a green building technology that can be integrated with buildings, can provide assistance for the development of green buildings in the future. Compared to traditional building materials, another significant advantage of BIPV is that it can beautify buildings. So far, BIPV has always been a perfect combination of building energy technology and architectural aesthetics. Various types of photovoltaic modules can be assembled into the building envelope, which provides inspiration and assistance for designers to create novel architectural designs and can make future buildings more aesthetic. Although photovoltaic modules are a material accessory that can produce electricity, they can be used not only as roofs/sunshades for some large buildings, but also as sun visors for cars, as well as patios between large companies or hotel buildings [6].

5. Low carbon technology in China

Reducing the amount of concrete to reduce carbon dioxide emissions by achieving high-performance concrete. High-performance concrete refers to reducing the amount of cement concrete in the structure and carbon emissions by improving the mechanical properties of concrete, reducing the structural section and reducing the dead weight of the structure. The technical path is to control the microstructure of concrete paste, matrix and interface transition zone from the molecular and micro-nano level, and achieve the unity of high strength and high toughness while reducing the amount of cement.

First of all, in view of the dispersion of complex material components of ultra-high-performance concrete, Liu has developed hyper-dispersed polymers, with a water reduction rate of more than 50%, and then maintaining strength and fluidity under the condition of reducing the amount of cement. The direct emission of carbon dioxide can be reduced by more than 34% [7]. Secondly, ultra-high strength, high elastic modulus and low creep of ultra-high performance concrete under normal temperature curing process are realized through nano-hybrid materials, which provides a technical basis for the strength and stiffness matching of lightweight long-span concrete structures. At the same time, the tensile strength of ultra-high-performance concrete containing coarse aggregate has broken through 10 MPa and the tensile strain has been increased by 10 times by using chain-like polymer and micro-high strength steel fiber toughening technology, realizing the unity of ultra-high strength and ultra-high toughness. In the structural test, the bending deflection of the concrete slab in the midspan can exceed 20 cm, and the concrete beam has not cracked 12 million times, significantly improving the crack resistance and fatigue resistance of the lightweight long-span concrete structure.

At present, this technology has been successfully applied to the coarse aggregate ultra-high-performance concrete bridge deck of the Fifth Yangtze River Bridge in Nanjing, China. The Fifth Yangtze River Bridge in Nanjing, China is the world's first light steel-UHPC structure cable-stayed bridge. After the use of coarse aggregate ultra-high performance concrete deck, the steel consumption of composite beam is reduced by 20%, the dead weight is reduced by 30%, and the direct carbon dioxide emission is reduced by about 25000 tons meeting the development requirements of energy conservation and carbon reduction, and promoting the lightweight innovation of the bridge structure system.

6. Building insulation materials

The thermal performance of building exterior walls (such as floors, roofs, walls and other materials) is the main factor to control building energy consumption, so the common strategy to reduce building energy consumption is to add thermal insulation materials to walls and roofs [8-9]. In recent years, vacuum thermal insulation panels, low emissivity glass thermal insulation films Several new super insulating materials, such as porous foam perlite insulation materials and aerogel insulation materials, are widely used in building insulation materials because of their high thermal insulation performance [10-11].

6.1. Application of SiO_2 aerogel building materials

Among them, aerogel gel thermal insulation materials are the most widely used. Aerogel gel is not only used as aerogel glass and aerogel thermal insulation blanket in building exterior wall materials and thermal insulation materials, but also as support materials in building structural materials [12-13]. Easy production, high-cost efficiency and other characteristics. It is also widely used in building materials, such as glass panels, thermal insulation felt, thermal insulation board, concrete, thermal insulation coating and other thermal insulation materials. This paper summaries the thermal insulation characteristics and application of these materials [14].

6.1.1. Insulation felt. The thermal insulation felt of SiO_2 aerogel material is relatively novel in the application of building materials, especially for special scenarios with space and weight constraints or application scenarios with thermal insulation requirements such as pipeline insulation. The heat insulation sweet made of SiO_2 has better mechanical properties than natural gas gel, and does not affect its excellent insulation performance. Compared with the traditional thermal insulation material, SiO_2

aerogel thermal insulation blanket has only the traditional thermal conductivity. 1/3~1/5 of thermal insulation material, and its thermal insulation capacity is 2~8 times that of traditional materials [13]. Liang et al. optimized SiO_2 by adjusting the density of aerogel and fiber content in their research work [15]. Thermal conductivity of aerogel composite fiber felt. Under the condition of keeping the working pressure at 1.0 Pa, the author explored the influence of different aerogel densities of 50~200 kg • m-3 on the thermal conductivity of composite fiber felt. From the experimental results, it can be seen that the effective thermal conductivity increases with the increase of density. In addition, it is necessary to change the thickness of aerogel (from 3.6 mm to 9.9 mm) in real-time during the experiment to keep the U value unchanged at 0.6 W • (m • K) – 1. In addition, when the fiber content is 6.6%, the best thermal conductivity is 4.3 W • (m • K) – 1 thermal conductivity and 5.6mm thickness. By controlling the density of aerogel and fiber content (the density is lower than 90kg / m -3 and the fiber content is between 6% - 16%, the service life of composite fiber felt can be effectively extended, and the maximum use expected by the experiment. The service life is 63a.

6.1.2. Concrete. Aerogel concrete is widely used in building materials because of its low thermal conductivity (0.07~0.16) W · (m • K) -1, light weight, heat insulation and fire resistance. However, due to the addition of exogenous materials, the mechanical strength of concrete will be reduced, so how to ensure the mechanical strength of concrete and improve its thermal insulation performance has become the main problem faced by scientific researchers at this stage. In view of this research situation, S Fickler et al. developed composite high-performance SiO_2 aerogel concrete [16]. By adjusting the content of SiO_2 and the proportion of aerogel, materials with different strengths and different thermal conductivity can be obtained. For example, when the volume proportion of aerogel in cement matrix reaches 60%, the density of composite SiO_2 aerogel concrete material is 860 kg/m -3, its compressive strength reaches 10MPa, and the best thermal conductivity coefficient of 0.17 W • (m • K) -1 is obtained. Liu et al. prepared a new type of composite foam concrete (FC-SA) reinforced by SiO_2 aerogel using three technologies, namely, sol-gel technology, vacuum impregnation method and supercritical rapid drying [17]. Compared with ordinary foam concrete, the thermal conductivity of composite material (FC-SA) is reduced by about 48%. At the same time, the mechanical properties of composite material (FC-SA) are even better than ordinary foam concrete, with its bending strength reaching 0.6 MPa and compressive strength reaching 1.1 MPa. In addition to testing the performance of the material, the author also conducted simulation experiments on the thermal insulation performance of the material, for example, in the winter of Chicago, using FC-SA materials can save 6.64% of energy.

7. Conclusion

The invention and application of green building materials have a significant impact on the development of green buildings. This article studies the new concrete materials of CarbiCrete Company, which can even achieve negative carbon emissions in the production process and application process. The high-performance concrete invented by Professor Liu's team can reduce the amount of concrete used in the construction production process, thereby reducing carbon dioxide emissions. The BIPV system is applied to the roofs, exterior walls, and balconies of buildings, The skylight and windows are used to replace traditional building materials, so as to realize the self-sufficiency of the house in electricity consumption as part of the building, reduce greenhouse gas emissions and the use of fossil fuels. The thermal insulation blanket made of SiO_2 aerogel building materials can improve the thermal insulation and fire resistance capacity of the building and reduce the thermal conductivity while ensuring the thermal insulation performance and insulation performance required by the building. The high-performance SiO_2 aerogel concrete invented by Fickle can improve its thermal insulation performance. At the same time, ensure the frost resistance, impermeability and corrosion resistance of concrete, thus reducing the energy consumption in the process of building use. What is insufficient is that the application of these new green building materials in civil engineering is still in its infancy. However, these new green building materials play a significant role in energy conservation and emission reduction, and are built within the entire life cycle of a building to maximize resource conservation, protect the environment, and reduce pollution, providing people with healthy, applicable, and efficient use space. Building in harmony with nature must be the development direction of future civil engineering. This paper will provide new inspiration to engineering practitioners.

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