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Research Progress of Geopolymer based Porous Materials

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Abstract

Geopolymer is an amorphous cementitious material with the advantages of high strength, acid and alkali resistance, easy forming, high temperature resistance and low cost. Compared with dense materials, geological polymer-based porous materials have some interconnected or closed holes, and have different structural and functional characteristics from dense materials, such as low density, high specific strength, large porosity, light weight and low thermal conductivity. It has broad application prospects. This paper introduces the concept, structure, raw materials and preparation methods of geological polymer-based porous materials in detail, in order to provide reference for academic research and industrial application of geological polymer-based porous materials.

Keywords

Metakaolin; Particle Stacking; Solvent Volatilization; Direct Foaming.

1. Introduction

Geopolymer is an amorphous cementitious material with three-dimensional network structure composed of silica tetrahedron and alumina tetrahedron. In 1978, Davidovits reported that the geopolymer was a cementitious material prepared by the mixing of silicate aluminates such as dolomite, limestone and metakaolin with alkaline solution [1]. The raw materials for preparing geological polymers can be natural and synthetic aluminosilicate minerals or industrial aluminosilicate wastes, such as metakaolin, slag and fly ash. Geopolymer materials have received extensive attention in the past decades due to their excellent mechanical properties, chemical stability and high temperature resistance. Geopolymer production is contrary to traditional cement energy-intensive production, which consumes little natural resources. Raw materials are usually selected from landfills or natural minerals. The preparation process is carried out at ambient temperature or slightly higher temperature, which can reduce carbon dioxide emissions and natural resource consumption in the preparation process. Geopolymer-based porous materials have properties similar to those of porous glass or porous ceramics, but do not need to be produced at high temperatures higher than 900 °C, and are mostly prepared at temperatures lower than 100 °C, which is a very promising material [2].

Porous material is a new material developed in the 20th century. It is proposed relative to dense material. It is a material with network structure composed of interconnected or closed pores and skeletons, with special functions and structures. It has small density, small thermal conductivity, large specific surface area, high specific strength, large porosity, and light weight. Its porosity is based on the original material to play the uniqueness of porous structure, which

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makes it have great changes in mechanical properties, photoelectric properties, and chemical activity, and can play a major role in separation, noise elimination, shock absorption, and structure [3]. Therefore, it is widely used in chemical building materials, environmental protection, aerospace and other fields.

2. Structure of Geological Polymer

Geopolymers form a network structure by sharing bridged oxygen bonds between silica tetrahedron and alumina tetrahedron, and there are some positive ions (such as sodium ions, potassium ions and calcium ions) to balance the negative charge in AlO_4 tetrahedron. According to Loewenstein' s aluminum atom exclusion rule, two aluminum atoms cannot connect with one oxygen atom, so aluminum-oxygen tetrahedron can only connect with silicon-oxygen tetrahedron [4]. Take the structure of sodium base polymer for example. The magic angle rotation nuclear magnetic resonance test confirmed that silicon atoms could have multiple coordination situations, and silicon atoms could connect 0~4 oxygen atoms, which proved the long-range disordered structure of geological polymers.

3. Raw Material of Geopolymer-based Porous Material

Geopolymers have a wide range of raw materials, including a variety of natural aluminum silicate minerals and industrial wastes. The raw materials commonly used as geopolymer-based porous materials include metakaolin, fly ash, slag, biomass ash and other materials. Metakaolin is produced by calcined kaolin clay at 500~ 800°C and the calcination temperature is determined by the purity and crystallinity of kaolin [5]. Fly ash is the residue produced by coal combustion during the operation of thermal power plants. Its particle size ranges from less than 1μm to more than 100 μm and its specific surface area is usually 300~500 m^2/kg. Slag is a kind of glass-like granular material. The slag produced by the melting process of blast furnace ironmaking is quenched by water and then grinded to obtain gray-white powder. It is mainly characterized by gelling characteristics, but it also shows some volcanic ash characteristics. Biomass ash is the residual ash after biomass combustion, including rice husk ash, wood ash, coconut ash, palm oil fuel ash, etc. Other aluminosilicate raw materials include natural minerals such as clay, bentonite, tuff, diatomite, illite and montmorillonite, and industrial by-products such as red mud, waste glass, volcanic ash, bottom ash catalyst residue, mining tailings residue, etc. Appropriate raw materials have a very important impact on the performance. With the deepening of scientific research, the types of raw materials for preparing geopolymer-based porous materials will be more and more.

4. Preparation Method of Geopolymer-based Porous Materials

There are four main methods for preparing geological polymer-based porous materials, including particle stacking method, direct foaming method, solvent volatilization method and add porous filler method.

4.1. Particle Stacking Method

Geopolymers prepared by particle packing method cannot occupy all the space outside the filling aggregate. Geopolymer wrapped aggregate as a separate particle, particles accumulate and form pores. Filling aggregate can be large or small, can be a variety of aggregate size and size will affect the pore structure, aggregate particle size and pore size of porous materials generally larger, and can be directly observed [6]. Geopolymer-based porous materials prepared by this method generally have good permeability and mechanical properties, mainly used in sub-permeable concrete and porous pavement.

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4.2. Direct Foaming Method

Direct foaming method is to directly add foaming agent or surfactant or both, and generate or maintain foam inside it to produce porous structure. Porous materials prepared by this method have low density, small thermal conductivity, large porosity and poor mechanical properties, which are commonly used in building insulation materials, building lightweight materials and adsorption [7].

4.3. Solvent Volatilization Method

Due to the volatilization of solvent, there are certain gaps in it, thus forming the porous structure of geological polymer. It is difficult to directly observe the porous structure of the geopolymer-based porous material prepared by this method because of the small pore size. When observed by electron microscope, it can be seen that the material is composed of many regular or irregular particles [8]. Geopolymer-based porous materials prepared by this method are commonly used as adsorbents and membrane separation materials.

4.4. Add Porous Filler Method

The method of adding porous fillers is to make geological polymer materials have porous structures by adding porous fillers or fillers that can form porous structures. These materials include cork, saw shoulder, porous polystyrene, porous siliceous materials, recycled lightweight aggregate, oil palm shell, etc. This method can select fillers with excellent performance in different fields and mix them with geological polymers to improve their performance. Due to the different properties of the added fillers, the geopolymer-based porous materials prepared by this method have great performance shyness and are suitable for different fields.

5. Conclusion

Geopolymer is a kind of environmental friendly, wide source of raw materials, low preparation cost of inorganic materials, and has excellent high temperature resistance, chemical stability and mechanical properties. Compared with dense materials, geological polymer-based porous materials have some interconnected or closed holes, and have different structural and functional characteristics from dense materials, such as low density, high specific strength, large porosity, light weight and low thermal conductivity. Geopolymer-based porous materials prepared by different methods have their own characteristics, and their pore size and application fields are also different. Geopolymer-based porous materials prepared by different methods are used in many fields, such as building insulation materials, building lightweight materials, permeable concrete, adsorbents, membrane separation materials, porous ceramics, catalysts, pH regulators and so on.

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