A Brief Introduction on the Research Status and Future Prospects on Geopolymer Concrete

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Abstract. With the development of science and technology and the improvement of people's living standards, air pollution as the main environmental problem has become increasingly prominent. Promoted by economy and technology, architecture is not only to satisfy people's living needs, but also to integrate building functions and user experience. This leads to building energy consumption increasing, which is in line with industry and transportation, becoming the world's major energy consumers. In the tide of sustainable development and green building, energy saving, consumption reduction, green and health have become the common pursuit of architecture. However, in the process of production and construction, the formation and release of CO2 during the calcination of ordinary Portland cement raw materials has resulted in an increase in carbon emissions. Therefore, the traditional cement materials have gradually failed to meet the concept of green building because of its high pollution and energy consumption in production. With more and more stringent restrictions on pollutant emission in various countries, the environmental cost of cement production will be higher and higher. Continuously increasing environmental costs have forced major enterprises to invest a large amount of cost in energy saving and environmental protection of products. Geopolymer concrete has also developed rapidly. With the unremitting efforts of scholars at home and abroad, after nearly 40 years of development, as a new type of green building material, geopolymer concrete has undergone a transformation from metakaolin to industrial solid waste as raw materials, with low energy consumption, low carbon emissions, easy preparation, and excellent compressive and flexural strength, acid-alkali corrosion resistance, shrinkage and expansion rate, quick drying, quick hardening and durability. In contrast, it is one of the best substitutes for ordinary Portland cement-based materials. It has broad application prospects in the fields of construction, materials, military, nuclear and other fields, and has been preliminarily applied. This paper reviews the research progress of geopolymer concrete at home and abroad, summarizes the development of raw material composition, manufacturing technology, performance and application prospects, and puts forward the problems faced by geopolymer concrete technology.

1. Introduction
Traditionally, concrete can be divided into organic gelling materials and inorganic gelling materials according to different gelling materials. Geopolymer concrete, as an inorganic gelling material, is prepared for its excellent properties. Attention. Traditional geopolymer is a kind of high-strength, fire-resistant and high-temperature-resistant hydraulic cementitious material. It is a non-metallic material.
Geopolymer was originally discovered by Frenchman Davidovits in 1978 to study the network contained in ancient buildings. It is a kind of silicoalumino-oxygen compound, and the concept of geopolymer and its corresponding mechanism model are proposed. Geopolymer is an inorganic polymer with a three-dimensional network structure composed of tetrahedral tetraoxide tetrahedron structural unit, which has organic matter, cement, ceramics, etc. Features. In the past 40 years, many scholars have carried out a lot of research on geological polymers in organization structure, properties, and production processes. At present, geopolymer materials have been initially used in civil engineering, hydraulic engineering, transportation, material engineering and other fields. It has huge potential in terms of facilities reinforcement, garbage storage, and rapid construction.

Since the 1990s, Britain, the United States, China, and Canada have successively introduced green building standards, committed to sustainable development, and vigorously promoted green buildings. Under the advocacy of the green building concept and sustainable development concept, many new concrete materials have gone from laboratory to practice, including many new polymer materials, such as geopolymer concrete (as shown in Figure 1). Geopolymer concrete has high strength, high temperature resistance, corrosion resistance, and hardening compared to ordinary portland cement. With the advantages of quickness, the team of Eddie Koenders from Daimler University of Technology proposed the use of geopolymer concrete as an alternative to cement, and studied its performance, reaction mechanism and durability. The Van Jaarsveld team from the University of Melbourne is committed to Research on the preparation of geopolymers from industrial solid wastes such as fly ash and their applications [1]. At present, many geopolymer products have appeared, such as PYRAMENT brand cement in the United States, TOLIIT brand binder in Germany and GEOPOLYMER in France Brand ceramics etc. [2]. In this research, geopolymer concrete is the core, grasping green building and sustainableThe exhibition concept, study its basic components analysis, manufacturing processes, reaction mechanism, strength indicators, prospects and other aspects.

![Geopolymer structure](image)

**Figure 1. Geopolymer structure**

2. Synthetic Raw Material for Geopolymer Concrete

Geopolymer concrete is mainly composed of cementitious materials, chemical activators, and additives. It is composed of geopolymers (as shown in Figure 2), chemical activators are widely used due to different types of activators, and admixtures are mainly composed of retarders and water reducing agents. Geopolymer concrete is a new type of green building material with a wide range of sources and easy preparation, it is the first choice for future building materials. This study summarizes the research results of scholars at home and abroad and summarizes the main raw materials and development trends of geopolymer concrete.
2.1. Cementitious Materials
Geopolymer concrete is mainly composed of cement material and chemical activator mixture composition. Among them, geopolymer is a cementing material for geopolymer concrete, which is mainly composed of aluminosilicate minerals rich in silicon and aluminum, which has potential volcanic ash characteristics. With the increasing popularity of green buildings and sustainable development concepts, scholars at home and abroad have conducted a lot of research on geopolymer raw materials and achieved rich results. At present, the raw materials of geopolymers mainly come from industrial waste, of which certain mineral industry wastes are rich in aluminosilicates such as blast furnace slag, steel slag, fly ash, waste brick dust, pyrogenic coal, stone and waste glass. Blast furnace slag and various slags used as coal-based fuels become geopolymers. The main raw materials (as shown in Figure 3) [3]. Various raw material sources, so the study of the influence of different physical and chemical properties of geopolymer concrete properties is of great significance. A lot of research is in related fields.

2.2. Chemical Stimulants
As a basic component of GPC, chemical activators can promote the conversion of their potential pozzolanic activity. Bases and anions or anionic groups react with ca$_2^+$ to form insoluble or insoluble substances are defined as chemical activators. According to the type of chemical activator, the products of geopolymers will be poor. Generally speaking, chemical activators can be divided into three types of acid salts, which is further classified by a large number of researchers. Foreign scholars have induced caustic, non-weak acid salts, silicates, and aluminum. There are six categories of acid salts, aluminosilicates, and non-strong silicates.
At this stage, the preparation of geopolymer concrete is mainly based on alkaline activators, which are mainly composed of a mixture of NaOH or KOH solution and sodium silicate or potassium silicate solution [4]. The preparation principle is shown in Figure 4. Sodium silicate and sodium hydroxide, It is widely used as a basic activator. On the one hand, water glass solutions are prone to self-polymerization under alkaline conditions, which leads to an increase in the viscosity of geopolymer concrete and poor workability. On the other hand, water glass solutions are used as polyciliate. The chemical composition of composite solutions is prone to change over time in practice, difficult to predict, and inconvenient for large-scale use.[5]

**Figure 4.** Schematic diagram of the reaction principle of the alkaline chemical excitation activator [20]

2.3. Retarder and Water Reducing Agent
Concrete admixtures, cement-based materials, stones, sand, and water are the basic components of modern concrete. Compared with modern concrete, geopolymer concrete's unique cementing materials and excitation methods have poor working performance and condensation. Fast time and other issues, so the use of admixtures as performance modifiers is very critical. At present, geopolymer concrete admixtures are mainly composed of retarders and water reducing agents.

At this stage of geopolymer concrete, a fly ash-slag powder composite gelling system is usually used. However, the composite gelling system has the disadvantage of short setting time. Therefore, the addition of a retarder can not only improve the setting time of geopolymer concrete and can increase its strength[6].

The use of water-reducing agents can reduce the amount of mixed water and increase the strength of the concrete when the amount of concrete is constant. Polycarboxylic acid-based water-reducing agents, water-reducing agents, lignosulfonate and naphthalene sulfonic acid as surfactants It has been widely used and has been fully utilized in the concrete industry. However, there is a lot of controversy in the use and application of geopolymers, and a unified opinion has not yet been formed.

3. Synthetic Method of Geopolymer Concrete
In the 1970s, the French scientist Davidovits first proposed the concept of geopolymers and the corresponding mechanism model: under the action of chemical activators, a new three-dimensional network glue was prepared using minerals rich in inorganic aluminosilicates and industrial waste. After 40 years of development, domestic and foreign scholars have conducted a lot of research on geopolymers, and have made great achievements in terms of raw material composition, reaction mechanism, and preparation process (see Figure 5). The status of geopolymer concrete at home and abroad, and the main methods for synthesizing mineral polymer concrete outlined a comprehensive study.[7]
Figure 5. Process of making geopolymer concrete

3.1. Pouring Method
The pouring method is the most commonly used GPC synthesis method, and its water consumption is large. For every 10 tons of geopolymer concrete production, 2 to 4 tons of water are consumed. Therefore, the slurry prepared by the pouring method has strong fluidity and can be prepared according to different needs. Into different shapes. The compressive strength of GPC made by this method is generally lower than 100MPa. [8]

3.2. Press Forming Method
Press molding method, also known as molding method, the main process is to mix the inorganic aluminosilicate solid composition with alkaline solution such as sodium hydroxide solution or potassium hydroxide, sodium silicate mixed solution, etc., and press molding 5 ~ 10MPa After that, the gel was obtained, and the fluidity of the sample was very poor. The compressive strength of the sample was 74 MPa. In addition, there were also geopolymers prepared by dry pressing with a compressive strength of 180 ~ 200 MPa. [9]

3.3. Ultrasound-assisted Method
In recent years, there are many prominent domestic and foreign countries for the preparation of geopolymers. Among them, there are many new research breakthroughs in the use of ultrasonic methods. The ultrasonic-assisted method uses ultrasonic impact methods to prepare geopolymers. Studies have found that ultrasonic energy can accelerate and improve the dissolution of silicon and aluminum in calcined kaolin and fly ash activator, promote the process of soil aggregation, improve the combination of solid particle surface and geopolymer glue. Therefore, ultrasonic impact can make geopolymers have higher compressive strength. Compared with the traditional synthetic process, Feng et al. [10] prepared geopolymers with fly ash and calcined kaolin under ultrasonic vibration respectively. Compared with traditional synthetic samples, the compressive strength of the samples increased by more than 50%. Within a certain time range, the longer the impact time, the higher the compressive strength.

4. Performance Characteristics of Geopolymer Concrete
Due to the special structure of geopolymers, its performance is better than ordinary concrete, which is mainly reflected in compressive strength, flexural strength, durability, material source, shrinkage and expansion rate, easy to combine with metal ions, etc.

4.1. Mechanical Properties
Due to the geopolymer structure, the structural units can be covalently bonded to the main, which has good mechanical properties. According to the literature, the Mohs hardness of the geopolymer is 4 ~ 7, the compressive strength is ≥15M Pa, and the flexural strength ≥5 MPa, which can meet the requirements of building structural materials. Mineral polymeric materials prepared by improved processes can have
a compressive strength of 32 ~ 60 MPa, and the flexural strength of carbon fiber reinforced geopolymers can reach 245 MPa and tensile strength. Up to 327MPa [11], compared with ordinary concrete materials, when the pressure resistance
At the same time, GPC has high bending strength and a wide range of applications.

4.2. Durability
Mineral polymer has good durability because it can inhibit the alkali aggregate reaction caused by alkali metal ions of Portland cement. R. Malinouski Roy and J. Davidovits have worked on the ancient Roman arena, the ancient Greek Cister concrete wall, the Egyptian pyramid. After the inspection, it was found that these ancient building materials have a zeolite-like structure, which is believed to be the main reason for those ancient buildings to stand for thousands of years. [12]

4.3. Convenience
The raw materials for preparing geopolymers are from a wide range of sources and rich in reserves. At present, the main raw materials are geopolymer metakaolin and aluminosilicate minerals such as fly ash, blast furnace slag and other industrial wastes. These raw materials are readily available and cheap. Under alkaline conditions, geopolymer raw materials can undergo low-temperature polymerization and curing reactions through the polycondensation of oligomeric silicate precursors within a certain temperature range (50 ~ 250 °C). Therefore, the preparation process is as follows: Requires low energy consumption, low emissions of NOx, SOx, CO and CO2, and meets environmental protection requirements. [13]

4.4. Early-strength and Fast-hard
According to relevant literature, geopolymers can harden rapidly at room temperature. They can be adjusted to mortar with water and standard sand. After 4 hours at 20 °C, their strength can reach 20MPa, and their compressive strength can reach 70 ~ 100MPa after 28 days. It can reach 15MPa ~ 30MPa, and the strength can reach 30MPa ~ 60MPa at 28d. Usually within the first four hours of forming and hardening, the strength of the mineral polymer material can reach 70% of the final strength, which is similar to fast hard cement, but its physical properties are better than ordinary cement-based materials.

![Geopolymer in Airport runway](image)

**Figure 6.** Strength of geopolymer concrete in airport [21]

4.5. Low expansion and Contraction Rate
Compared with portland cement, geopolymers have lower shrinkage at high temperatures. Potassium aluminosilicate polymers have a shrinkage of 0.2% to 1.0% at 400 °C and 0.2% to 2.0% at 800 °C. Its line The expansion coefficient is (2.1 ~ 4.5) × 10-6 at 0 ~ 1000 °C.[14]

4.6. Excellent Isolation Performance
Geopolymers have excellent performance in preventing the dissolution of heavy metals. J.G.S.Van Jarsveld et al. Added 0.1% Pb to the geopolymers, and under certain conditions, performed leaching tests on them. Equilibrium is reached, and the concentration of Pb in the leachate is only 9 mg / L [15]. According to this characteristic, after industrial solid waste is made into geopolymers, toxic elements or compounds are solidified in the material, so geopolymers can be used to seal toxic metals and radioactive nuclear waste.

4.7. Acid and Alkali Resistance
The geopolymer has strong corrosion resistance in organic solutions, alkaline solutions and brines. Compared with ordinary cement and calcium silicate cement, mineral polymer materials have the lowest decomposition rate in 5% sulfuric acid and hydrochloric acid solutions. Compared with Portland cement, it has the effect of inhibiting alkali aggregate reaction, so it has good durability mineral polymer material. [16]

4.8. Strong Durability
Durability, as the resistance of concrete to chemical erosion, abrasion or other physical and chemical effects, has a significant degradation effect on concrete and plays a decisive role in the service life of the structure. At present, as a new building material, the durability of geopolymers is a major concern of scholars at home and abroad. The experimental results show that the geopolymeric concrete has excellent properties such as carbonization, freeze-thaw resistance, and alkali-aggregate reaction. Very strong durability. [17]

5. Application of geopolymers in the field of materials
Because of its unique structure and performance, GPC will play an important role in advocating the concept of green building in the future. After nearly 40 years of research, GPC has experienced a development process from scratch, from laboratory to commodity. Military, nuclear and other fields have huge development potential.

5.1. Geopolymer Sheet
At present, cement hydrates slowly at room temperature, and the streamlined production process of the board can not be maintained at room temperature or long-term steam.

Mud does not contribute to strength, causing waste and unstable performance. Geopolymer has the characteristics of fast hardening and early strength, and does not require wet curing to obtain high strength. In the production process, long-term normal temperature steaming can greatly reduce production costs and improve production efficiency. At the same time, as the main raw material cost of industrial waste geopolymers is only about Portland cement, and therefore can reduce the production cost of significant slabs.

5.2. Geopolymer Grouting
Generally speaking, grouting materials are mainly used for filling hollows such as underground caves and mined-out areas to ensure the safety of the above-mentioned buildings. Generally, cement is used in large quantities and requires high strength. Mineral polymer concrete has a wide range of raw materials and strength. Moderate and become the best choice. At the same time, geopolymer concrete can be used as raw materials such as yellow sand, fine sand, solid waste, which greatly saves costs. At the same time, due to the unique low porosity, high tightness and high specificity of geopolymer Corrosion resistance, so it has good corrosion resistance. [18]

5.3. Geopolymer Blocks
Building construction mainly refers to standard bricks, blocks of various sizes, and paving blocks with bulk materials. Because geopolymers have the characteristics of rapid hardening, early strength, and non-steam curing, and have good adhesion and plasticity, they are better than cement. It is more suitable
for the preparation of block materials. In particular, blocks made of aluminosilicate-containing solid waste as coarse and fine aggregates can also exert the activity of the solid waste itself, forming a chemical bond between the polymer and the aggregate and Gradient interface, which greatly reduces production costs and improves product quality.

![Geopolymer concrete samples](image)

**Figure 7. Sample of geopolymer concrete [22]**

5.4. Geopolymer Concrete Pavement
Because of its special purpose, concrete pavement requires good flexural strength and durability. Scholars who have studied in depth have concluded that when the same pressure is applied, the flexural strength and stiffness of geopolymer concrete are much greater than ordinary concrete. The elastic modulus of the geopolymer is much larger than the elastic modulus of the cement material, so the wear resistance of the geopolymer concrete is significantly higher than that of the cement concrete when the concrete aggregate is the same. The application of the geopolymer concrete in the future pavement has broad prospects.

5.5. Thermal Insulation Materials
Porous geopolymer concrete is based on a new type of green gelling material, geopolymer, and is expected to become a new generation of inorganic insulation materials through physical or chemical pore induction methods.

5.6. Nuclear Waste Solid Sealing Material
Geopolymers have the function of adsorbing toxic metal elements, which can be used to solidify various chemical wastes, toxic heavy gold ions, and nuclear and radioactive elements of effective gelling materials. Geopolymers have the unique function of reducing the dissolution of metal ions in solid waste. It makes geopolymers a better and cheaper consolidation material than cement for consolidation of high heavy metal solid waste and radioactive solid waste.

6. Summary
Geopolymer is an irregular trihedron composed of silicon-oxygen tetrahedron and aluminum-oxygen tetrahedron connected at the corner top.

Three-dimensional network structure, the solid material is filled with a network of voids formed by amorphous semi-crystalline alkali metal cations and alkaline earth metal cations. The geopolymer has a wide range of raw materials. Most aluminosilicate-containing solid wastes can be used to prepare geopolymers or geopolymer products. Compared with traditional cement, geopolymers do not need to burn cement clinker, and the energy consumption for production is very low, but in many applications, their performance is better than cement. Geopolymers are considered to have it is possible to replace a large amount of cement with green cementing materials. As the large-scale production technology of geopolymers continues to mature, its production costs will be greatly reduced, the application technology will be more mature, and various excellent properties will be further developed. The promotion of geopolymers The application will make a lot of changes in performance and cost of many new building materials. We firmly believe that geopolymer concrete will be the main force of green buildings in the future.
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