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EFFECT OF ADDITIVES TO GEOPOLYMER CONCRETE

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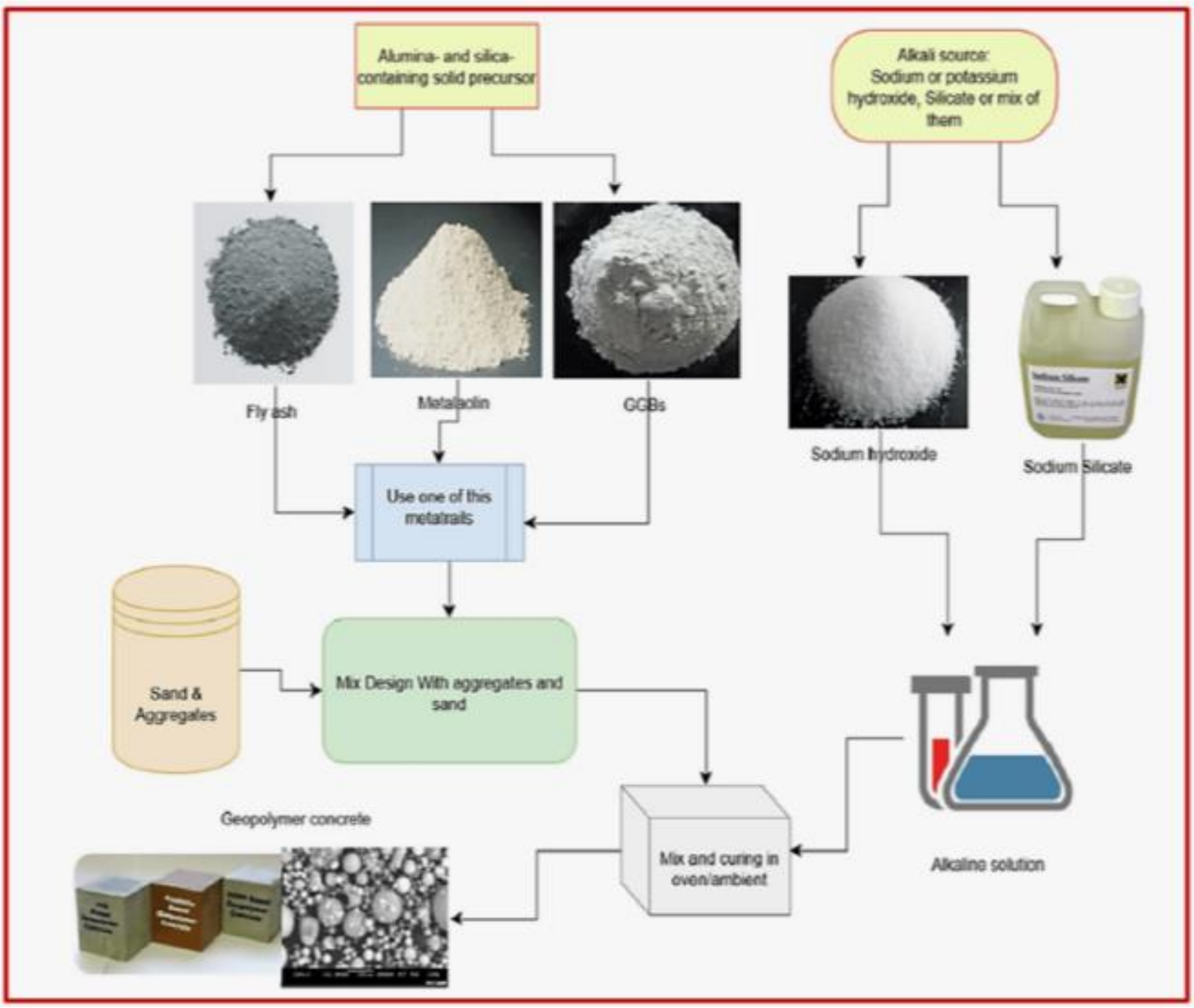
Abstract

Geopolymer concrete (GPC) is an eco-friendly alternative to traditional Portland cement concrete, primarily due to its lower carbon footprint. However, like any material, the properties of geopolymer concrete can be optimized by using additives. Additives can improve various mechanical and durability properties, enhancing the performance of geopolymer concrete in construction applications. This paper explores the effect of different additives on the properties of geopolymer concrete, including workability, strength, durability, and resistance to environmental conditions. The study highlights the types of additives commonly used in geopolymer concrete and their specific impact on the material's characteristics.

1. Introduction

Concrete is one of the most widely used construction materials, and its production is responsible for a significant portion of global CO_2 emissions due to the use of Portland cement. Geopolymer concrete has emerged as an eco-friendly alternative, where inorganic materials such as fly ash, metakaolin, or slag are activated using alkaline solutions, leading to a reduction in carbon emissions. Geopolymer concrete offers many benefits, such as high thermal stability, good resistance to acid and sulfate attacks, and high compressive strength.

The performance of geopolymer concrete can be significantly enhanced by the addition of various additives. These additives can be natural or synthetic substances that improve the concrete's properties by modifying its composition. This article aims to explore the role of additives in geopolymer concrete, focusing on how they affect properties such as workability, strength, setting time, and durability.



1. **Figure 1. GPC manufacturing; reprinted with permission from (*"Handbook of Alkali-Activated Cements, Mortars and Concretes"*** *Fernando Pacheco-Torgal, Sérgio Jalali, João Labrincha, M. M. M. (Editors))*

2. Types of Additives in Geopolymer Concrete

- **Superplasticizers (Chemical Additives)**: Superplasticizers are commonly used in conventional concrete to increase workability without increasing the water content. In geopolymer concrete, superplasticizers help in reducing the viscosity of the paste, thus improving the flowability and ease of mixing. This is particularly important when using highly reactive materials like fly ash and metakaolin, which can make the mixture thick and difficult to work with.

- **Fibers (Physical Additives)**: Fibers, such as steel, glass, or synthetic fibers, are added to geopolymer concrete to improve its mechanical properties, particularly its tensile strength and crack resistance. Fibers help distribute the stresses more evenly throughout the concrete, reducing the formation of cracks and enhancing its overall durability.
- **Silica Fume and Fly Ash (Pozzolanic Additives)**: Silica fume and fly ash are two common pozzolanic materials used as additives in geopolymer concrete.

  These materials react with the alkaline solution to form additional binding phases, improving the strength and durability of the concrete. Silica fume, due to its high silica content, contributes to the production of a denser microstructure, while fly ash is often used to lower the overall cost of geopolymer concrete production.

- **Nano-materials (Nanotechnology Additives)**: Nano-materials such as nano-silica and nano-alumina have been used in geopolymer concrete to improve the material's properties at the microscopic level. These nano-materials significantly enhance the strength and durability of the geopolymer matrix, making the concrete more resistant to cracking, chemical degradation, and environmental stresses.
- **Activators (Chemical Additives)**: Alkali activators, such as sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3), play a crucial role in the geopolymerization process. The addition of these activators helps in the dissolution of alumino-silicate sources like fly ash or slag and the formation of a hardened geopolymer matrix. The choice and concentration of activators significantly impact the setting time, strength, and workability of the geopolymer concrete.

3. Effects of Additives on Geopolymer Concrete Properties

3.1 Workability

The workability of geopolymer concrete is crucial for its handling, transportation, and placement during construction. Superplasticizers and other chemical additives are often used to improve the flowability of geopolymer concrete, especially when high amounts of fine materials like fly ash or metakaolin are used. Superplasticizers reduce the need for excessive water content, which helps maintain the mix's consistency while preventing segregation.

Fibers also affect workability by altering the rheological properties of the concrete mix. While short fibers may increase the viscosity of the mix, their overall effect on workability depends on their type and dosage. In general, fibers help improve the structural integrity of the material rather than directly enhancing its workability.

3.2 Compressive Strength

Compressive strength is one of the most important properties of any concrete. Additives such as silica fume, fly ash, and nano-silica improve the compressive strength of geopolymer concrete by contributing to the formation of additional gel-like compounds that enhance the bonding between the geopolymer matrix and aggregates.

Fly ash, as a pozzolanic material, reacts with the alkaline activators to form calcium silicate hydrate (C-S-H) gel, which improves the strength of the concrete over time. Similarly, silica fume's high content of amorphous silica helps form a more compact and denser microstructure, which results in a significant increase in compressive strength.

Fibers also contribute to compressive strength by improving the post-cracking behavior of the concrete. Steel fibers, in particular, are known to improve both tensile and compressive strength by reinforcing the concrete matrix.

3.3 Durability

Durability is another key property of geopolymer concrete, particularly in aggressive environmental conditions. Geopolymer concrete is naturally resistant to acid and sulfate attacks due to its low calcium content and the dense structure of the geopolymer gel.

Additives such as nano-silica and silica fume significantly enhance the concrete's durability by improving the material's resistance to permeability, chloride ion penetration, and abrasion. These additives help to densify the concrete and reduce its porosity, thereby enhancing its resistance to environmental stresses.

Moreover, fibers help prevent the development of cracks, thus improving the long-term durability of the concrete by mitigating the risks associated with water ingress and chemical attack.

3.4 Setting Time and Shrinkage

The addition of chemical activators and retarders can influence the setting time of geopolymer concrete. Retarders help in controlling the rate of setting, allowing for longer workability time, especially in hot weather conditions.

Additives such as fly ash and silica fume can also influence the shrinkage properties of geopolymer concrete. Fly ash typically results in reduced shrinkage, while silica fume can sometimes increase shrinkage due to the high surface area of the particles. The use of fibers helps control shrinkage by reducing the tendency of the material to crack under stress.

4. Environmental Impact of Additives in Geopolymer Concrete

Geopolymer concrete is already recognized as an environmentally friendly alternative to traditional concrete, primarily due to the use of industrial by-products such as fly ash and slag. However, the use of certain additives, especially synthetic ones, can have environmental implications. The production of chemical additives like superplasticizers and retarders may involve energy-intensive processes, which could partially offset the environmental benefits of geopolymer concrete.

On the other hand, the use of natural fibers or locally available materials as additives can further reduce the carbon footprint of geopolymer concrete. Research into sustainable and green additives for geopolymer concrete continues to grow, with a focus on reducing the environmental impact of the entire concrete production process.

5. Conclusion

Additives play a significant role in enhancing the performance of geopolymer concrete, improving its workability, strength, durability, and resistance to environmental stresses. The choice of additives—ranging from superplasticizers to fibers and pozzolanic materials—has a substantial impact on the properties of the final concrete.

As research in this field continues, the development of more sustainable additives and optimization of existing materials will likely lead to even more efficient and eco-friendly geopolymer concrete solutions. The future of geopolymer concrete depends on balancing the benefits of additives with their environmental footprint, creating a truly sustainable construction material.

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