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A Review: To Investigate the Properties of Geopolymer Concrete with Fly Ash in Place of Cement

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Abstract: A novel type of concrete called geopolymer concrete is created by reacting sodium silicate containing minerals with sodium aluminate and a caustic activator, such as fly ash or slag from the production of iron and metal. It can serve as a viable replacement for regular portland cement. In addition to having outstanding mechanical qualities, geopolymer concrete also possesses a number of extremely high-end qualities, including corrosion and fire resistance. The majority of industrial solid waste and bottom ash from waste incineration are stacked up at random, which not only uses up land resources but also negatively affects the ecosystem. They can be recycled and utilised as raw materials to make geopolymer concrete. Geopolymer concrete has the ability to absorb pollutants like heavy metals and other radioactive chemicals, so that its stability, elasticity, and thermal qualities are unaffected. However, geopolymer concrete's use goes beyond that because of its superior qualities. The geopolymerization of concrete, the origin of the raw materials, the numerous categories of activators, the development processes, and the diverse applications of geopolymer concrete in various fields are all covered in this paper. In this section, the factors that affect the mechanical and abrasion resistance of geopolymer concrete. In order to establish a hypothesis that will be used to develop geopolymer concrete for future development, the disadvantages and application quantification of geopolymer concrete, as well as its mix design, will be summarised in this paper.
Keywords: Geopolymer Concrete, Ordinary Portland Cement, Fly Ash, Workability, Sustainability, Mix Design

I. INTRODUCTION

Alkali-activated materials is another term for geopolymers (AAMs). Natural resources and waste products can be used as the main raw materials in the alkali or acid activation procedure to create geopolymers. The benefits of geopolymers include their outstanding longevity, high mechanical strength, and resistance to chemical corrosion and fire. Geopolymer materials have been viewed as alternatives to Ordinary Portland Cement (OPC) since the early 1980s, primarily because of their superior performance and minimal carbon dioxide emissions. Researchers have successfully developed a geopolymer coating that has outstanding qualities that make it suitable for coating lightweight polystyrene boards used for walls, roofing, and partitions. These properties include high strength, artificial ageing resistance, high-temperature resistance, and good processing performance. In Australia, mainline railway sleepers and commercial airports have both made use of geopolymers. These materials can also be utilised to restore stiff pavement on military sites that has damaged concrete. Geopolymers have been employed recently to immobilise dangerous metals. Studies have demonstrated that the alkali-activated municipal solid waste incinerator fly ash (MSWIFA) successfully reduced the leaching behaviour of numerous dangerous metals, and the leaching rate was well within the limits. Geopolymers are therefore both environmentally beneficial and able to turn waste into treasure. The world has recently pushed for sustainable development, which calls for us to use as few natural resources as possible. As modernization has advanced, people's worries about the release of industrial hazardous solid wastes like fly ash (FA), slags, and red mud (RM), as well as the pollution of heavy metals, dyes, and medicines, have increased. Between 71 million tonnes and 1 billion tonnes of FA are thought to be produced annually on a global scale. FA that is disposed of in large quantities in landfills or ash ponds, as well as the airborne entrainment of particles and the leaching of hazardous components into the soil or water, pose a serious threat to the environment. The aforementioned issues can be resolved successfully through the use of geopolymer materials. Geopolymers with mixed bases are the subject of numerous studies at the moment. All types of raw materials complement one another on the one hand, but they can also successfully cut down on the use of natural resources. Scholars domestically and abroad have discussed several geopolymer features and uses, but the discussion is not yet sufficiently thorough.

The purpose of this study is to cover geopolymer synthesis and preparation, characteristics of geopolymer materials, and multifunctional uses of geopolymers. Also addressed is the state of geopolymer materials' development. The progress of the solution is presented based on the present shortcomings and application limitations of geopolymers in order to lay a theoretical foundation for the long-term development of geopolymers.

II. LITERATURE REVIEW

1) Priyanka Pradhan, Saswat Dwibedy, Monalin Pradhan, Soumyaranjan Panda, Saubhagya Kumar Panigrahi (2022) carried out the study on Durability characteristics of geopolymer concrete - Progress and perspectives. Ordinary Portland Cement (OPC) based concrete does not meet the requirement of green infrastructure development because the production process of OPC liberates enormous carbon dioxide gas which has a hazardous effect on the environment. Geopolymer concrete (GPC) on the other hand is potentially acceptable as they overcome such issues. Geopolymer concrete (GPC or Geocrete) though have been considered an emerging sustainable material and exhibits superior fresh and hardened properties, still it is not yet globally accepted as a construction material due to the lack of credible information about its long-term characteristics. To vanquish such weakness several studies have been put forth so far on a broad range of durability characteristics. Thus, the durability characteristics progress study of GPC conducted so far almost over the last three decades is summarized here. A set of twelve durability characteristics and twenty factors have been identified. Through a mapping between these factors and the characteristics, primary and secondary influencing factors for various durability characteristics have been identified. The production process of GPC is also provided. A thorough study on limitations in global acceptance along with the scope of further research in GPC is illustrated too. The elaborative discussion presented here about the durability characteristics of GPC can bring confidence among researchers to work on various aspects of it and can enhance its acceptability among implementers around the globe.
2) Hemn Unis Ahmed, Lavan J. Mahmood, Muhammad A. Muhammad, Rabar H. Faraj, Shaker M.A. Qaidi, Nadhim Hamah Sor, Ahmed S. Mohammed, Azad A. Mohammed (2022). Geopolymer concrete as a cleaner construction material: An overview on materials and structural performances, Cleaner Materials. The manufacture of ordinary Portland cement (OPC) produces a lot of CO_2 in the atmosphere. Researchers have recently focused on exploring the behaviour of geopolymer concrete (GPC) as an alternative to Portland cement concrete (PCC) in micro and macro dimensions. Geopolymers (GP) are innovative cement-based materials that could totally replace OPC composites. Geopolymer composites (GC) have a reduced carbon footprint and utilize less energy than OPC. The construction industry's main concerns are material characteristics and the performance of reinforced concrete (RC) structural components. Therefore, this review paper is going to look at some important material properties, like fresh characteristics, compressive strength, splitting tensile strength, flexural strength, and modulus of elasticity, as well as the evidence of the structural behaviour of GPC beams. According to the findings of this review, GPC offers similar or superior fresh and mechanical properties to conventional concrete composite. In addition, it was mentioned that GPC might be utilized to design GPC members securely in terms of their strength capabilities and standard codes of practice. Nevertheless, further study is suggested to include more detailed and cost-effective design methods for the potential use of GPC for large-scale field applications.
3) Peiliang Cong*, Yaqian Cheng (2021) carried out a study on Advances in geopolymer materials: A comprehensive review. Geopolymer is a new environment-friendly cementitious material, and the development of geopolymer can reduce the carbon dioxide emission caused by the development of cement industry. Geopolymer materials not only have excellent mechanical properties, but also have a series of excellent properties such as fire resistance and corrosion resistance. Most industrial solid waste and waste incineration bottom ash are piled up at will, which not only occupies land resources, but also has a bad impact on the environment. Recycling them can be used as raw materials for preparing geopolymers. Geopolymer materials can effectively adsorb heavy metals, dyes, and other radioactive pollution, which is very beneficial to society's future development. However, due to the excellent properties of geopolymer materials, its application goes beyond that. Some useful information about geopolymer materials was introduced in this paper. The paper included the geopolymerization, the source of raw materials, the types of activators, the preparation methods, and the different application fields of geopolymer materials. The factors affecting the fresh properties and mechanical properties of geopolymer materials were discussed. In this paper, the shortcomings and application limitations of geopolymer materials were summarized, and their progress was summarized to lay a theoretical foundation for the long-term development of geopolymer materials.

4) Paul Awoyera, Adeyemi Adesina, (2019) carried out a study on A critical review on application of alkali activated slag as a sustainable composite binder, Case Studies in Construction Materials. A state-of-the-art review of advances in alkali activated slag (AAS) with respect to its behaviour is presented. The need for sustainable development of AAS, and factors that affect the fresh and hardened properties of AAS based composites were discussed. The fresh properties of AAS reviewed include flow, setting times and heat of hydration. While the hardened properties considered were compressive strength, shrinkage, and microstructure. Major limitation of using AAS and possible solutions were also highlighted. Overall, various studies showed that large scale application and commercialization of AAS is imminent in the coming years, as AAS is capable of exhibiting similar/higher properties compared to that of Ordinary Portland Cement (OPC). In addition, the viewpoint of this review will be useful for contractors and researchers to have more understanding about AAS. Grey areas for possible research exploit were also identified.
5) K.M. Klima, K. Schollbach, H.J.H. Brouwers, Qingliang Yu (2022) carried out study on Thermal and fire resistance of Class F fly ash based geopolymers. In recent years, the construction industry has striven to promote environmentally friendly materials. A growing body of literature has recognised fly ash-based geopolymers as a promising alternative to Portland Cement. However, a detailed and in-depth review specifically concerning high-temperature exposure and fire resistance of fly ash-based geopolymers is still missing. This review provides a comprehensive summary on the recent research progress concerning mix design, curing and their effects on thermal and fire resistance of Class F fly ash geopolymers. Due to the wide variety of characteristics, the performance of class F fly ash is recommended to be assessed in terms of its reactive phases. The influence of different alkali sources and their effects on thermal resistance are discussed, showing that potassium-based activators contribute to better performances. By applying Factsage calculations, the role of minor elements in controlling melting temperature and phase formation as well as the mechanisms behind the initial strength increase of fly ash-based geopolymers during heating are discussed. Moreover, the evolution of material properties during high-temperature exposure and the key parameter pore interconnectivity to avoid damage such as spalling is reviewed. Finally, recommendations for further investigations are provided.
6) Blessen Skariah Thomas, Jian Yang, A. Bahurudeen, S.N. Chinnu, Jamal A. Abdalla, Rami A. Hawileh, Hussein M. Hamada (2022) carried out a study on Geopolymer concrete incorporating recycled aggregates. Several industrial by-products are extensively used again as a supplementary cementitious material or aggregates in the interest to reduce environmental footprints in terms of energy depletion, pollution, waste disposition, resource depletion, and global warming related with conventional cement. A remarkable quantity of industrial scrap materials, primarily designated as construction and demolition waste from the construction industry, has transformed into crucial apprehension of governments. In the recent past, substantial explorations have been accomplished to appreciate the distinct characteristics of concrete, employing recycled aggregates from construction and demolition waste. Geopolymer composite is a new cementitious material, and it appears to be a potential replacement for conventional cement concrete. This paper summarises the previous research concerning the utilisation of recycled aggregate as a partial or complete supplants for conventional aggregates in geopolymer concrete. The influence of recycled aggregate addition on the fresh and hardened properties of geopolymer concrete is comprehensively reviewed in this paper. The studies suggest significant improvement in the workability on addition of recycled aggregates to geopolymer concrete. However, the addition results in increased water absorption and sorptivity.
7) Musab Alhawat, Ashraf Ashour, Gurkan Yildirim, Alper Aldemir, Mustafa Sahmaran, (2022) Properties of geopolymers sourced from construction and demolition waste. Geopolymers have been recognised as a viable replacement to ordinary Portland cement (OPC), providing a cleaner solution since it can significantly reduce greenhouse gas emissions as well as accomplishing effective waste recycling. Construction and demolition waste (CDW) has been recently identified as raw materials for geopolymers due to its availability and high contents of silica and alumina. This paper aimed at reviewing the current state-of-the-art on the geopolymer paste, mortar, and concrete production and their properties, with special attention paid to geopolymers incorporating CDWs. The review covers brief assessment of using CDWs in concrete, the mix design of geopolymer mixtures in addition to identification of the main factors influencing the performance of geopolymer containing CDW. The most recent data related to the mechanical and durability properties of CDW-based geopolymers are presented, while the cost and environmental impacts of using recycled materials in producing geopolymer concretes are also discussed. Geopolymer concretes have a vast range of possible applications, however, there are still several barriers facing commercialisation of geopolymers in construction industry. The review indicated that it is possible to produce geopolymer concretes from CDW-based materials with properties comparable to OPC-based ones; however, the selection of proper material composition should be carefully considered, especially under normal curing conditions.

8) Shoukat Alim Khan, Anıl Kul, Oğuzhan Şahin, Mustafa Şahmaran, Sami G. Al-Ghamdi, Muammer Koç, (2022) carried out research on Energy-environmental performance assessment and cleaner energy solutions for a novel Construction and Demolition Waste-based geopolymer binder production process. Construction and Demolition Waste (CDW)-based geopolymers are expected to lower the construction sector's environmental impacts by reducing the use of ordinary cement and reusing waste materials and are considered a substantial step toward a circular economy and environmental sustainability in the long run. However, due to the energy-intensive mechanical, thermal, and chemical processes involved in preparing the CDW-based geopolymers, it is essential to quantify their environmental implications in the early stages of development. The objective of the study is to analyze the environmental sustainability of newly developed geopolymers containing CDWs, i.e., roof tile (RT), hollow brick (HB), red clay brick (RCB), and glass waste (G) based geopolymer binder materials. The study aims to identify the environmental impact of their critical process parameters using Life Cycle Assessment (LCA) approach and evaluate their production feasibility at a location with completely different energy and water scenarios. According to the results of the study, compared to Ordinary Portland Cement (OPC), all the CDW-based geopolymers had lower environmental impacts. G-based geopolymer binder resulted in the lowest Global Warming Potential (GWP) with a 38% reduction, followed by RT and HB with 35.3% and 34.8%, respectively. However, due to the energy-intensive processes of crushing and grinding CDWs, electrical energy is identified as a hotspot with significant environmental impacts. The replacement of mix-grid energy with hydropower reduced GWP by 63.3%, Eutrophication (EP) by 52.5%, Acidification potential (AP) by 86.4%, and fossil fuel deposition (FFD) by 74%. The highest environmental performance is calculated for electricity produced from hydropower, wind, and photovoltaics, then geothermal and biomass resources.

III. CONCLUSION

The impact of use of geopolymer concrete helps in reducing in carbon emission and a sustainable step towards the environment. The GPC shows better durable properties, for all extreme environmental conditions i.e., acid attack, seawater conditions, sulphate attack, carbonation of concrete, chloride penetration, alkali-aggregate reactions and elevated temperature, OPC concrete. Setting time, workability and durability characteristics of Geopolymer concrete are better than that of Ordinary Portland Cement. There are still some limitations when overcame will increase in the growth of Geopolymer concrete. The Geopolymer concrete can be used in number of applications in infrastructure development and other various fields, and can become a material for the sustainable development in the construction industry.

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