Geopolymer Composites: Contemporary Applications and Future Ahead

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Abstract

Cement production, a carbon-intensive process, alone contributes to approximately 5% of global CO2 emissions. Production of Portland cement at an unprecedented level, 4 billion tons/annum, with an annual growth of 4%, not only stresses raw material reserves, but also imposes huge energy consumption demand and, above all, emits substantial greenhouse gasses/ dust particulates. Switching to geopolymer-based composites, a carbon-neutral alternative, besides providing a technological advantage in terms of mechanical, durability, and thermo-acoustic properties helps in reducing carbon footprints, depletion of virgin materials, and stocking of by-product wastes. The polymerization of precursors, with an alkaline solution, forms molecular chains /networks which further hardens into solid mass at a very low heat of hydration. The C-A-S-H matrix chains in geopolymer composite being longer than C-S-H chains, present in OPC concrete, resulting in the denser microstructure. Fine-tuning of crucial parameters like liquid/solid ratio, SiO2/Al2O3 ratio, Na2O/Al2O3 ratio, water content, curing regime, and alkaline solution molarity aid in meeting the design objective. Recent years have witnessed considerable technological innovation in the development of geosynthetics and geopolymeric applications. New properties, procedures, and transforming ideas, with regards to geopolymerization, are providing diversified options in material engineering. Relatively better resistance towards the fire, with chloride permeability standing of 'low' to' very low', improved acid resistance, lesser corrosion susceptibility, lower bleeding, higher early-age strength, faster-curing speed confers notable versatility in geopolymers for usage in different construction domains. The geopolymer composite has been used for the construction of buildings, pavements, retaining walls, water storage tanks, marine members. Resistance towards chloride and sulfate salts makes it an ideal material for marine or coastal applications bridge beams, pavements, and building structures. Due to relatively lesser drying shrinkage, it is effectively used in thick and bulkier restrained structural concrete members. Remedification of toxic waste contaminated sites by encapsulation of hazardous/ toxic materials in structures like barriers, cappings, blocks, etc. The immobilization matrix of geopolymer concrete ensures safe chemical encapsulation of the contaminants as well as structural stability concerning adverse environmental conditions high temperature and humidity, microbial and chemical aggression, and mechanical stress. The possibility of using local wastes presents a strong economic advantage. The recent geopolymer based projects that have found their mention in the literature include, the University of Queensland's Global Change Institute (GCI), which is the world's first geopolymer structural building, Yarra river Melbourne road footpath, precast work at Salmon Street bridge, Melbourne, pavement work at Ceres environment park in Brunswick Australia, etc. The Brisbane West Wellcamp Airport, with geopolymeric concrete (E-Crete) utility of 40,000 m3, is the world's largest geopolymer concrete project and is estimated to have saved 6,600 tonnes of carbon emissions, as the greenhouse gas emission during the life cycle of E-Crete is estimated to reduce by approximately 62 to 66% than reference normal concrete. The geopolymeric precast products like the fire-resistant panels, temperature burning bricks, high-performance concrete, and 3D-printable mortars products, aerating agents to obtain blocks, panels, and tiles manufactured by companies like Renca

(Moscow, Russia), Agma (Italy) Geopolymer Solutions (Conroe, TX, USA), etc., have reported considerable demand, viability as well as acceptance. Due to rapid hardening and high early strength, large-scale precast geopolymer blocks and pavers can be produced at a higher pace and with minimal breakage. Refractory items, fire-resistant materials, thermal shock refractories, thermal insulators, low energy ceramic tiles, decorative stone artifacts, low-tech building materials, bio-technologies (materials for medicinal applications), foundry industry, geopolymer based mixes for 3D Printing fabrication technologies, composites for infrastructures repair, and strengthening, high-tech composites for aircraft interior and automobile, high-tech resin systems are some of the wide variety of prospective applications of geopolymer composites. The possibility of modification in geopolymer mixes with a new design approach and optimization provides an exciting opportunity for sustainable growth in a building–architectural fields. Future works must be done for the advancement of different material properties by way of incorporating fibers, micro, and nano-fillers and understand the possibility of using 3D Printing Fabrication Technologies to develop functional geopolymer-based applications.