Engineering Sustainable Cement-Free Construction Blocks From Desert Dune Sand and Recycled Glass

Alatawi, Noor (School: Tabuk International Schools)

The production of Portland cement accounts for approximately 7–8% of global CO2 emissions due to energy-intensive calcination processes, underscoring the urgent need for sustainable alternatives to construction materials. This study investigates the feasibility of producing cement-free construction blocks using locally available dune sand stabilized with geopolymer binders derived from natural pozzolan and Ground Granulated Blast Furnace Slag (GGBFS). Recycled glass was used as a reinforcement material. Geopolymer mixtures were prepared using alkaline activation with sodium hydroxide (NaOH) and sodium silicate (Na2SiO3). Crushed recycled glass was introduced at replacement levels of 0%, 25%, and 50% as a partial replacement of dune sand to evaluate its influence on structural performance. Specimens were evaluated for compressive and flexural strengths and water absorption per ASTM and SASO standards. Thermal durability was assessed through cyclic heating and cooling, and SEM was used to analyze the geopolymer matrix microstructure. Results showed that slag-based geopolymer blocks exhibited significantly higher compressive strength (21 MPa) than pozzolan-based mixtures. The incorporation of recycled glass improved matrix densification, and the 50% replacement mixture produced the most favorable mechanical performance, with a thermal strength loss of 3.2%. Microstructural observations confirmed a denser geopolymer network and improved particle bonding, with SEM imaging revealing developed gel formation and cohesive matrix structure in slag-based mixtures. This material system has potential as a sustainable, cost-effective construction solution leveraging local resources and recycled materials, suitable for infrastructure development in arid environments.

Awards Won:

Aramco: Third Place Prize Chemistry (CHEM) / Materials Science (MATS)