Valorization of Red Mud Waste Into a Sustainable Geopolymer for Low-Carbon Oil-Well Cementing

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Approximately 2.7 billion tons of red mud waste from the aluminum industry are stockpiled worldwide, and nearly 1.5 million tons of glass-fiber waste are generated annually. In alignment with the U.N. Sustainable Development Goals (SDGs), this project addresses two urgent global challenges; high CO2 emissions from Portland cement production and the growing accumulation of industrial waste. The purpose of this research is to determine how these materials can be transformed into a high-performance, carbon-free geopolymer binder for oil-well cementing applications. Red mud and glass-fiber waste were characterized using XRD, XRF, SEM, TGA, and particle size analysis to assess their chemical composition and geopolymerization potential. Multiple formulations were synthesized by varying precursor ratios and alkali activator concentrations to optimize performance. Evaluation included slurry rheology, free water, thickening time, and compressive strength development under relevant conditions. The optimal formulation, 60% red mud, 40% glass-fiber waste, activated with 5 wt.% NaOH, exhibited negligible free water, stable rheology with a plastic viscosity ˜ 35 cP and a controlled thickening time exceeding 8 hours at 150°F, indicating good pumpability and field applicability. Compressive strength reached ~800 psi at 24 hours and ~2,465 psi at 28 days, surpassing early-strength benchmarks of conventional cement systems. Life-cycle analysis indicates 80–90% CO2 reduction relative to Portland cement by eliminating limestone calcination. By valorizing hazardous industrial by-products, this approach can reduce landfill burdens, support sustainable materials manufacturing, and demonstrate strong potential for commercialization in low-carbon oil-well cementing applications.

Awards Won:

Aramco: First Place Prize Environmental Engineering (ENEV)