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Aqueous Carbonation Treatment for Repurposing Post-consumer Glass into Supplementary Cementitious Materials

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As urbanization and population growth continue to drive construction demand, reducing the carbon footprint of cement-based materials has become a critical challenge for achieving a sustainable built environment, particularly as the future supply of conventional supplementary cementitious materials (SCMs), such as fly ash (FA) and blast furnace slag (BFS), is expected to decline with the decommissioning of coal-fired power plants and the decarbonization of iron and steel production. Post-consumer glass as a SCM offers a promising alternative for reducing cement demand and diverting waste from landfills, yet its broader deployment and scalability is constrained by its low intrinsic reactivity, particle re-agglomeration, and limited calcium content, which limits pozzolanic activity and early-age compressive strength development. To address these barriers, this study investigates aqueous carbonation as a strategy to enhance the reactivity of ground glass pozzolan (GGP) while simultaneously increasing its capacity for carbon sequestration. Controlled carbonation experiments were conducted under systematically varied pressure, temperature, exposure time, and liquid-to-solid ratios to promote the reaction of dissolved CO_2 with GGP's lime (CaO) content and the formation of stable carbonates. Carbonate formation and mineralogical transformations were quantified using a combination of Fourier-transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and thermogravimetric analysis (TGA). Despite its significantly lower calcium content, carbonated GGP achieved a CO_2 uptake up to 27% under optimized conditions, reaching levels comparable to carbonated low-calcium fly ash. These results demonstrate that aqueous carbonation of GGP not only enhances its functionality as an alternative SCM but also creates an additional pathway for carbon utilization and permanent mineralization. By integrating waste valorization with carbon sequestration, carbonation-treated GGP enables further reduction of the carbon footprint of cement-based materials while advancing circular economy objectives, contributing to both emissions mitigation and sustainable infrastructure development.