Economic and Environmental Assessment of Low-Carbon Concrete Using Rice Husk Ash and Steel Industry By-Products: Toward Sustainable and Circular Construction Finance

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Abstract

The cement sector accounts for approximately 7–8% of global anthropogenic CO_2 emissions (Andrew, 2019), posing both environmental and financial challenges to achieving carbon-neutral construction. This study evaluates the techno-economic and environmental feasibility of low-carbon concrete incorporating rice husk ash (RHA) and steel industry by-products—ground-granulated blast-furnace slag (GGBFS) and steel slag (SS)—as partial substitutes for ordinary Portland cement (OPC). Experimental mixes with 10–30% binder substitution were tested for compressive strength, durability, and microstructural performance, while a cradle-to-gate life-cycle assessment (LCA) quantified the environmental and cost impacts in accordance with ISO 14040/44 standards. The optimal blend (10% RHA + 15% GGBFS + 5% SS) achieved ≈46 MPa 28-day compressive strength—~8% higher than OPC—and exhibited enhanced chloride resistance. LCA results revealed ~30% lower global-warming potential (GWP), ~20% lower acidification potential (AP), and an estimated ~15% reduction in production cost per cubic meter of concrete. These improvements strengthen the financial case for low-carbon materials by reducing carbon liabilities, improving resource efficiency, and aligning with sustainable investment frameworks under the UN SDG 12 and EU Taxonomy for sustainable activities. The findings provide evidence-based insights for policymakers, investors, and construction firms seeking to integrate material innovation into green finance and circular economy strategies.

Keywords: Low-carbon concrete, Rice husk ash (RHA), Ground-granulated blast-furnace, Steel slag, Life-cycle assessment, Sustainable investment, Circular economy, Carbon reduction.