Engineering a Resilient Steel-Concrete Interface via Optimized g-C3N4 Nanosheet Dispersion: A Dual-Action Solid Corrosion Inhibitor

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Abstract

The deployment of 2D materials in cementitious matrices is frequently hindered by aggressive alkaline environments and the risk of promoting galvanic macro-cells. Graphitic carbon nitride (g-C_3N_4) offers a paradigm shift in this domain; its nitrogen-rich heterocyclic framework provides inherent chemical stability and a semi-conductive nature that mitigates the electrical connectivity risks associated with pristine graphene [1]. This work presents a holistic strategy for utilizing g-C_3N_4 as a multifunctional solid corrosion inhibitor, underpinned by a rigorous Design of Experiments (DOE) optimization of its interfacial chemistry. By modulating sonication energetics and sterical stabilization through Polycarboxylate Ether (PCE), we achieved high-fidelity aqueous dispersions that remain stable within the ionic complexity of cement pore solutions. Integrating these optimized nanosheets at a precise 0.1 wt.% dosage facilitates a "dual-action" protection mechanism. Firstly, a physical barrier effect is established; chloride uptake analysis demonstrates that the high-aspect-ratio nanosheets significantly enhance the tortuosity of the cementitious matrix, effectively obstructing ion diffusion pathways. Secondly, an electrochemical defense is activated at the steel-concrete interface. Electrochemical Impedance Spectroscopy (EIS) reveals a substantial elevation in charge transfer resistance and a corresponding suppression of double-layer capacitance, indicating the formation of a robust, passive layer [2]. These electrochemical signatures, corroborated by shifted Half-Cell Potential (HCP) values toward noble regions, confirm that g-C_3N_4 significantly extends the corrosion initiation threshold. Beyond durability, the material optimizes the rheological evolution of the fresh paste, ensuring that the structural integrity and workability are not compromised for the sake of protection. This research validates g-C_3N_4 as a scalable, high-performance additive for the next generation of resilient and low-maintenance civil infrastructure.

References

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