2D Nanotechnology for Sustainable, Strong, and Frost-Resistant Concrete

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The urgent need to reduce the carbon footprint of the construction sector requires new materials that combine strength, durability, and sustainability. This research explores the integration of 2D nanomaterials, specifically graphene-based additives, into cementitious systems to enhance mechanical performance and frost resistance while lowering CO_2 emissions. By combining graphene with microadditive technologies, concrete can maintain strength despite the introduction of hollow microspheres for frost durability. Pilot-scale trials demonstrate that low-volume fraction Expancel microspheres (~40 µm) ensure reliable freeze-thaw performance. At the same time, graphene compensates for the associated reduction in strength and therefore avoids using traditional air entrainment technology, which significantly reduces strength.

Field evaluations, conducted in collaboration with Swedish concrete and cement producers and the traffic authority, include guardrails, speed bumps, bus stops, and other urban infrastructure elements in Sweden. Early results indicate that optimized low-carbon concrete mixes can reduce cement use by up to 80%, saving over 1.2 million tons of cement annually in Sweden, equivalent to more than 700,000 tons of CO_2 emissions, or approximately 2–3 times the pre-COVID carbon footprint of the national aviation industry.

This work highlights the potential of 2D nanotechnology and its integration with freeze-thaw additives, enabling the development of sustainable, high-performance, frost-resistant concrete and providing a scalable pathway toward ultra-low CO_2 infrastructure materials.

References

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Figures

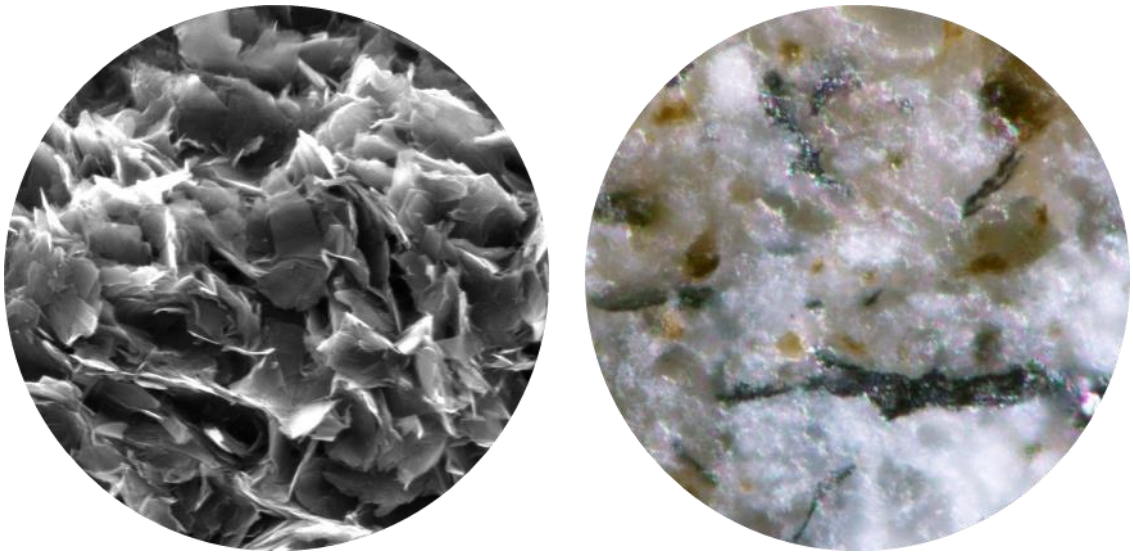

Figure 1: left is a micrograph of graphene, and right is a micrograph of graphene in cement.