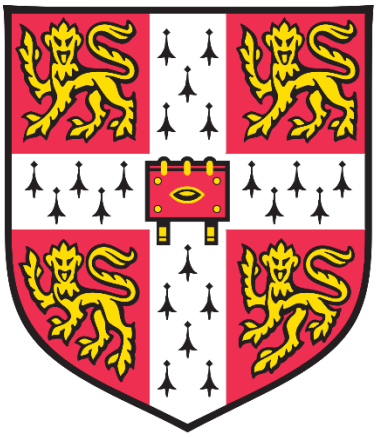
MULTI-FUNCTIONAL APPLICATIONS OF GRAPHENE RELATED MATERIALS IN CEMENTITIOUS COMPOSITES



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This dissertation is submitted for the degree of

Doctor of Philosophy

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September 2020

ABSTRACT

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Cementitious composites are the most widely used construction materials with 4.1 billion tonnes of cement being produced globally in 2017. However, cement production is associated with ~7% of the total global anthropogenic CO_2 emissions. Moreover, concrete structures suffer from poor durability, with a fifth of the total civil engineering output in the UK being spent on repair and maintenance. The poor durability of concrete structures necessitates frequent inspections and an enhanced structural monitoring regime. Despite the advancements in material science over the years, cementitious composites remain passive structural materials and do not possess any functionalities.

The motivation for this research was to take advantage of emerging graphene-related materials (GRMs) to solve the challenges associated with concrete infrastructure and to instigate additional functionalities that would make the material smarter. Initially, the homogenous dispersion of GRMs was experimentally investigated in detail, as this was recognised as a key challenge in the literature. The results showed that a combination of sonication and the use of a polycarboxylate superplasticiser, were effective in homogenously dispersing the main GRM material, graphene nanoplatelets (GNPs), in cementitious systems. Subsequently, the effect of the GRMs on the early age, mechanical and permeability performance of cement pastes and mortars was investigated. It was found that GNPs reduced the fluidity, delayed the hydration, and had a poor microstructural interaction with the cement hydration products. This consequently led to a reduction in the flexural and compressive strengths. An early age beneficial effect with GNPs was found for water, gas, and chloride permeability. The use of GRMs to improve the electrical conductivity performance was also investigated, with the aim to create electrically conductive networks in the composite that could then be used to monitor changes in loading or damage, by triggering a self-sensing response. Natural graphite and GNPs were found to be effective, however, their use in bulk applications would be challenging and instead, their use in coatings was proposed. Finally, an industry survey was carried out to understand the industry perceptions of this novel material and a Lifecycle Assessment (LCA) study was also undertaken to establish the sustainability performance of a novel GNP-cement composite. The results demonstrated the potential of GRMs to improve the permeability performance of cementitious composites and to instigate a functional behaviour.