Nanomortar – Performance Evaluation of Self-Compacting Mortars with Nanomaterials (nano silica, nano titanium and graphene oxide)

Summary

The aim of this project was to evaluate the feasibility of producing self-compacting mortars (SCMortars) using nanomaterials (NM), namely nano silica (SiO_2), nano titanium (TiO_2) and graphene oxide (GO). The performance of various mortars was evaluated in which the traditional binder (Portland cement (C), composed of fly ash from thermoelectric power plants (FA) and silica fume (FS)) was reinforced by the mentioned and established NM.

Currently, the repair and rehabilitation of concrete structures plays a prominent role in the construction industry and SCMortars plays a vital role in this work. Due to their numerous advantages, SCMortars are currently the most used for repair and rehabilitation purposes, especially in reinforced concrete structures. The fluidity of the SCMortars can be an advantage in situations of inaccessibility of the areas to be repaired, such as in the case of densely reinforced elements, narrow cracks or fissures. The cement, as well as the other constituents of these SCMortars, must be carefully selected to obtain a suitable composition with a granular mixture as compact as possible and with good performance both in the fresh and in the hardened state. NM are very reactive, essentially due to their high specific surface and have a high potential for improving the properties of these SCMortars, both in terms of their mechanical behavior and durability.

In addition to the above, it is also worth noting that, the use of nanomaterials (NM) to improve the performance of cement and concrete matrixes nowadays appears as a potential alternative to the exclusive use of Portland cement (PC). Similarly, there is currently no doubt in the construction industry (CI) about the pressing need to reduce consumption of PC. The CI represents the world's third-largest industrial energy consumer, and the component related to the production of PC alone represents 7% of the carbon dioxide (CO_2) emissions globally. PC is undoubtedly the most used material in construction in terms of its relative volume. Raw materials for PC production are generally plentiful and are available throughout the world. It is possible to state that there is, at this moment, no other material, with the same availability as the PC, that can fulfil the construction's technical requirements as the concrete's main component. In this sense, it is imperative that the cement industry obtains viable technical solutions that allow the reduction of PC consumption. That reduction can be achieved either by its direct replacement with another material (as for example with the use of fly ash), or by improving the cement and concrete matrix performance with the addition of new materials such as NM. This second option is quite interesting since it allows, for example, to maintain the cement and concrete matrix properties/characteristics, reducing PC consumption by adding a tiny amount of a NM. The NM evolution has allowed the production of new cement-based nanocomposites with previously unimaginable properties. In general, NM can be grouped into three main types: the zero-dimensional (0D) nanoparticles, such as nanosilica; the one-dimensional (1D) nanofibres, such as carbon nanotubes and lastly the most recent two-dimensional (2D) nanosheet, ie, graphene oxide (GO). These materials, especially the 1D and 2D NM, have the ability to, in very small dosages, strengthen the cement and concrete matrix through the reinforcement and pore refinement. This allows for conventional cement composites to achieve higher performance levels or to maintain the same performance levels with decreasing PC consumption.

In the particular case of GO, we are in the presence of one of the most recent advances in materials science, with enormous potential to be used as nano-sized additive for cementitious materials. The GO shows a number of unusual properties, namely: super-high specific surface area, ultra-high strength and elastic modulus; excellent thermal, electrical and optical conductivity; easily forms composites with polymer and ceramic materials and contains a large concentration of hydroxyl, epoxide, carboxyl and carbonyl functional groups that are compatible with water and, for this reason, is highly dispersible in polar liquids. Its introduction in the production of cement and concrete implies a substantial improvement in the performance of these cementitious nanocomposites. There are reports that the 3 and 7 days compressive strengths of cementitious nanocomposites with 0.2 % of GO were increased by ≈36% and ≈42%, respectively when compared to the control mix. Analogously, other authors report that the microstructure morphology observed shows that GO can significantly reshape the microstructure of the cement paste. However, mainly associated to its high specific surface area, the GO can cause a significant loss of the workability of the cement and concrete matrixes due essentially to the increase of its viscosity.

The need for cement mixes with increasingly higher performances and on the other hand the need to reduce the impact of the CI, through cutting of PC consumption, require industry and researchers to look for new solutions and new materials. The use of GO in the development of a new cemetitious matrix can lead to a significant improvement in the performance of the mortars and concretes used in the CI.

Project Reference

IPL/2018/Nanomortar/ISEL

Leading Institution

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Funding

IPL – Instituto Politécnico de Lisboa

Period

2018-2019

Total

5 000.00€

CERIS

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Project Website

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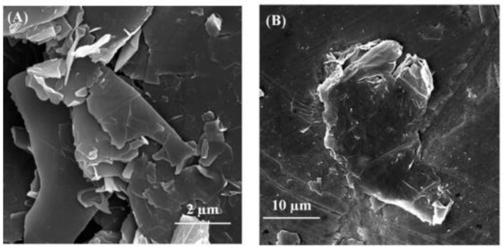

Figure 1. A) SEM micrograph of graphene B) SEM micrograph of GO.

Thus, the main objective of this project was to evaluate the performance of SCMortars produced, both in the fresh state (self-compactability) and in the hardened state (mechanical and durability behavior), in binary and ternary mixtures of C, FA, SF and the referred NM. Regarding graphene oxide, nine mortar mixes were produced, namely: Cement + 0%, 0,02% and 0,06% GO; Cement + FA + 0%, 0,02% and 0,06% GO and finally Cement + SF + 0%, 0,02% and 0,06% GO. In order to carry out a comparative analysis of the results, a reference mixture without graphene oxide was produced in all combinations.

In the particular case of GO, we are witnessing one of the most recent advances in materials science, with enormous potential to be used as an additive in cement-based materials. GO has a number of unusual properties, namely: high specific surface, high strength and modulus of elasticity; excellent thermal, electrical and optical conductivity; It easily forms composites with polymers and ceramic materials and contains a high concentration of hydroxyl, epoxide, carboxyl and carbonyl functional groups that are compatible with water. Its introduction in cement and concrete production implies a substantial improvement in the performance of these cement-based nano-composites.