Editorial

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Welcome to this themed issue on nanomaterials in construction. The manipulation of matter at the nanoscale has revolutionised medicine, electronics and biosciences, and is likely to have a similar impact on construction. Indeed, there is evidence that use of nanomaterials can improve strength and durability and may lead to the creation of smart construction materials. This themed issue of *Construction Materials* has brought together the experience of engineers and scientists utilising nanomaterials in lime-, cement- and asphalt-based construction materials.

My original intention when drafting this Editorial was to provide the reader with a brief overview of the use of nanomaterials in construction. However, as it happens the first paper (Jones *et al.*, 2019) covers all the information I wished to consider and more. Therefore, I feel no need for duplication and invite the reader to enjoy this excellent introduction to nanomaterials in construction.

An aspect that Jones *et al.* (2019) cover is the surprising difficulty in being able to pinpoint exactly what nanomaterials are. A commonly accepted definition is that nanomaterials are materials that have at least one dimension (or length in one plane) between 1–100 nm. However, this in itself leads to a large range in size of potential materials. Furthermore, some so-called nanomaterials do not actually meet the definition above. This leads to complications in considering the effect of nanomaterials on our construction materials.

Following this excellent introduction, the next four papers in this themed issue demonstrate the use of nanomaterials to improve the mechanical properties of cementitious composites. The first two of these papers deal with multi-walled carbon nanotubes (MWCNT) which are effectively strips of graphene rolled into multiple layers. The thickness of these tubes is in the order of 5–20 nm and the length can be many magnitudes higher.

Barbhuiya and Chow (2019) used 0.3% by mass of MWCNT in cement pastes. Improvements in performance of the cement paste were measured using nanoscale tests. In particular, they demonstrated an increase in the elastic modulus, resulting in a paste that more closely resembles one containing a greater proportion of high density calcium-silicate-hydrate (C-S-H). They argue that the MWCNT has, in effect, modified the hydration products. The precise chemical reactions and mechanisms are not explained, which suggests further work is needed. Perhaps some evidence that the increase in elastic modulus is not due to a mechanical contribution of MWCNTs is needed in light of our next paper.

The paper by de Medeiros *et al.* (2019) has utilised MWCNTs in repair mortars. Here they clearly show a mechanical contribution of the MWCNTs, which manifests itself in an increase in strength. While higher performance gains are perhaps theoretically possible, they show that with current technology, the quantities of MWCNTs that can be added to mortars is limited by their high water demand and the need to ensure good consistency of the mortar.

A popular nanomaterial for improving the performance of cementitious composites is nanosilica. The addition of very reactive fine particles of silica to cement has profound effects on the kinetics of C-S-H hydration and the resulting nano- and micro-structure. In the work of Varghese *et al.* (2019), nanosilica with a mean particle diameter of 40–50 nm was used to create high-performance concrete. The authors clearly showed that the use of nanosilica increased the rate of hydration of the cement and improved early-age strengths. However, as a consequence of the modification of the hydrate structure, the authors noticed a negative effect on some of the deformation properties, particularly creep. This shows that use of nanomaterials in cement composites is not without its caveats.

Our final paper on cementitious composites used magnetite nanoparticles (Mansouri *et al.*, 2019). When used at 2% by mass of cement, it was shown that the resulting concrete had higher strength and improved water transport properties (lower absorption and less chloride ion permeation). Hopefully, in further work, the authors will be able to explain if these attributes are due to chemical reactions, in which these iron-based nanoparticles perhaps modify the AFm or AFt phases, or whether there is a nucleation effect.

Of course cementitious composites are not the only construction material in which nanomaterials can improve performance. The next paper is a preliminary study on the use of nano charcoal ash as a component of bitumen for use in asphalt (Jeffrey *et al.*, 2019). Unfortunately, the process that they used to turn waste coconut shell into nano charcoal ash failed to produce particles with a size in the range of 1–100 nm. However, their particles (100–1000 nm in size) were shown to harden the bitumen, leading to lower penetration test values and higher softening points. Consequently, they demonstrated better rutting resistance of the asphalt, which could be ascribed to improved bond and rheology. Their work is at an early stage and it will be interesting to see whether further research could yield true nano charcoal ash and even greater changes to bitumen.

The final paper (Barbhuiya and Caracciolo, 2019) does not cover a nanomaterial, but focusses on nanoscale mechanical properties of asphalt when hydrated lime is added.

The use of nanomaterials in construction materials is becoming increasingly widespread and this themed issue only scratches the surface of the potential possibilities. I am certain that over the next 10 years we will see not just an acceleration

in research on nanomaterials in construction, but much more extensive adoption and admittance of their use in industry. I hope that you enjoy this themed issue on nanomaterials in construction.

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