Preface

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During the past decade, scientific research worldwide has focused on the study of the behaviour of materials and structures at the atomic scale of matter. The proliferation of scientists and engineers studying matter at this length scale has led to the coining of the word, 'nanotechnology'. This term generally implies the investigation and technological utilisation of the properties of matter at the submicron length scale. With its ability to change basic material structure, nanotechnology today provides an excellent opportunity for the invention of new structural materials that exhibit some unprecedented characteristics. Structural materials are defined as load bearing and their design is mainly based on their mechanical properties. Examples where nanoscale materials can improve mechanical properties include polymer materials reinforced with carbon nanotubes or nanoparticles, cementitious composites reinforced with nanosilica or nanofibres and nanoscale thin films that increase the surface hardness of the materials.

The guest editors are pleased to introduce this special issue of the *International Journal of Materials and Structural Integrity* that focuses on current advances in 'nanotechnology for structural materials'. In this special issue, 11 articles present results of cutting edge research covering a wide spectrum of nanotechnology investigations in structural materials.

The 11 articles can be divided into three groups. The first group explores the use of nanomaterials (e.g. carbon nanotubes) for developing new structural composites, while the second group examines new simulation techniques that aim at realisation of structural materials at the nanoscale to account for multiscale complexities in structural materials. The third group focuses on nanocharacterisation of structural materials as a tool to understand structural material behaviour and how changes in the material's nanostructure influence its mechanical behaviour.

Four papers in this special issue examine the use of nanomaterials for developing new structural composites. The article by Sanchez examines the significance of pretreatment of carbon nanofibres (CNF) on their behaviour in cementitious composites. CNF are multi-walled high graphitic fibres with diameters ranging from 70 to 200 nm and lengths of a few hundred microns. Methods for enhancing dispersion of CNF in cement composites were examined and reported. The investigation showed a very limited enhancement in cementitious composite strength when CNF were used, however, some post-cracking enhancement was observed. Atwater et al. suggest a new method for producing and controlling CNF at low temperature in a fuel rich combustion environment. The new production technique enables good control on fibre diameter, aspect ratio, helicity and surface roughness which are key parameters for enhancing structural composites utilising CNF. Two articles examine the use of nanoparticles as possible ingredients for the fabrication of structural composites. Luhrs et al. suggest new synthesis of a novel class of ceramic nanoparticles manufactured via a plasma torch. This new technique, known as aerosol-through-plasma (A-T-P), is discussed and the synthesis process of three types of nanoceramics produced using A-T-P is explained. It is suggested that the new nanoparticles could achieve excellent mechanical properties making them a good alternative for new structural composites. Moreover, Jain and Neithalath suggest that nanosilica particles may have a beneficial durability influence in cementitious composites. It is shown that nanosilica may be able to control calcium ion leaching. The study points out such leaching control and the ability to enhance durability of cementitious composites may be attributed to the high pozzolanic reactivity of nanosilica.

Two interesting articles discuss simulation of nanostructure and how such simulations can be upscaled to predict macroscale properties of structural materials. Cranford and Buehler suggest the development of a new mechanomutable structural material via the use of an electromagnetic field in carbon nanotubes (CNT). An atomistic-based multiscale simulation using molecular dynamics of a magnetically active array of CNT is presented. The numerical investigation shows that contact stiffness of this new structural material can be enhanced by an order of magnitude under magnetic field enabling a new class of structural materials still to be realised by structural engineers. The article by Le Pape et al. discusses the simulation of concrete using homogenisation techniques. The proposed approach suggests integrating methods to account for the evolution of mechanical properties of cementitious composites with time. Moreover, a multiscale numerical simulation environment using a mixed finite element and microstructural homogenisation technique showed the ability to examine the significance of new materials on the short- and long-term behaviours of concrete.

The third group, on nanocharacterisation of structural materials, includes five papers. Garas et al. examine the use of nanoindentation to assess the behaviour of ultra high performance concrete (UHPC). The significance of thermal treatment on tensile creep of nano-engineered UHPC is examined. It is suggested that the difference between UHPC and steel fibres at the interface as quantified using nanoindentation may have a significant effect on tensile creep of UHPC. Trinkle and Al-Haik examine the tribological reliability of microelectromechanical systems (MEMS) using nanoscratch testing. It is shown that two deformation regimes can be identified: an elasto-plastic deformation at low loads and fully-plastic deformation at high loads. Porosities in tri films in MEMS can be detected by observation of abrupt changes in nanoscratch depth. Reinhardt et al. examine the nanoindentation behaviour of two phases of concrete; the cement paste (CP) phase and the interfacial transition zone (ITZ) phase. Using a new technique of nanopositioning, nanoindentation behaviours of both phases are determined. The constitutive models of these two phases of concrete are extracted via finite element simulation of the nanoindentation behaviour of the phases. Moreover, Shen and Tang present an article identifying the significance of structural materials heterogeneity on deformation evolution during nanoindentation. A composite multilayer heterogeneous material including aluminium and silicon carbide is examined. Unique deformation patterns are realised and the cracking observed during nanoindentation can be explained. The work by Shen and Tang reveals the complexity of the stress and deformation evolution in heterogeneous composites during the unloading stage of nanoindentation. Finally, Tehrani and Al-Haik realise the benefits of a moderate permanent magnetic field of 0.5 Tesla on mitigating the creep behaviour of structural epoxy. Nanoindentation experiments showed that magnetically processed structural epoxy has improved modulus, hardness and creep resistance. The ability of the moderate magnetic field to change the characteristic of epoxy through biaxial orientation of the epoxy cross-linking and main chain provides an opportunity to enhance the mechanical behaviour of a structural epoxy not attainable without the magnetic field. Such enhancement in structural material properties, using magnetic fields as discussed earlier by Cranford and Buehler, points to new frontiers in structural materials that would not be realised without nanotechnology.

The eleven papers presented in this special issue provide rich spectra of novel activities and advances in nanotechnology with special emphasis on structural materials. Nanotechnology research and field applications are growing, maturing and expanding in depth and breadth. Worldwide, nanotechnology is examining new ideas, developing new materials and modifying methods for material characterisation. The next decade will clearly enable nanoengineered structural materials with special characteristics beyond current capabilities.