Development of Ductile Cementitious Composites Using Carbon Nanotubes

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Abstract
Concrete is the primary construction material for civil infrastructures and generally consists of cement, coarse aggregates, sand, admixtures and water. Cementitious materials are characterized by quasi-brittle behaviour and susceptible to cracking [1]. The cracking process within concrete begins with isolated nano-cracks, which then conjoin to form micro-cracks and in turn macro-cracks. Formation and growth of cracks lead to loss of mechanical performance with time and also make concrete accessible to water and other degrading agents such as CO_2, chlorides, sulfates, etc. leading to strength loss and corrosion of steel rebars. To improve brittleness of concrete, reinforcements such as polymeric as well as glass and carbon fibers have been used and microfibers improved the mechanical properties significantly by delaying (but could not stop) the transformation of micro-cracks into macro forms [2]. This fact encouraged the use of nano-sized fillers in concrete to prevent the growth of nano-cracks transforming in to micro and macro forms. Nanoparticles like SiO_2, Fe_2O_3, and TiO_2 led to considerable improvement in mechanical performance and moreover, nano-TiO_2 helped to remove organic pollutants from concrete surfaces [3].

Nanomaterials with exceptional properties like carbon nanotube (CNT) [4] have been incorporated within cementitious matrix to improve mechanical performance and toughness and to introduce electrical conductivity and piezoresistivity [1]. Additionally, in nano-scale, CNTs exhibited the possibility to restrict the growth of nano-cracks through crack-bridging mechanism, thereby, enhancing the durability of concrete. However, the improvement of above properties was found strongly dependant on the dispersion of CNT within cementitious matrix and improper dispersion and agglomeration even resulted in deterioration of various properties. Therefore, there exists an enormous need for an efficient dispersion route to achieve homogeneous CNT dispersion and besides mechanical treatments (ultrasonication, stirring), various chemical dispersants (surfactants and polymers) have been suggested to prepare well dispersed CNT aqueous suspensions for mixing with cement [1].

The present paper reports the use of a novel dispersant (Pluronic F-127) to disperse CNTs in water and subsequently within cementitious matrix and the fracture behaviour of the resulting cementitious composites. CNT/water suspensions with different CNT concentrations were prepared using a short ultrasonication process (1 hr) with the help of Pluronic F-127 at optimum concentrations, and the suspensions were then mixed with cement/sand mixture to develop cementitious composites. The fracture behaviour was studied using single-end notched bending (SENB) specimens in the 3 point bend configuration and measuring the crack propagation parameters (such as crack length, crack-tip opening displacements, etc.) using digital image correlation technique (DIC). Fracture energy and toughness were then calculated using these parameters.

The load-displacement curves of plain mortar and CNT/mortar samples are presented in Figure 1. It is very clear from these graphs that the samples containing CNTs showed significantly higher breaking strain and ductility as compared to plain mortar specimens. The cementitious composites containing 0.1 wt. % single walled nanotubes (SWNTs) and 0.15 wt. % multi-walled nanotubes (MWNTs) resulted in 109% and 96% improvements in the fracture energy of plain mortar specimens, respectively. Fracture surface study using Scanning Electron Microscopy (SEM) suggested that CNTs were tightly inserted between the hydration products of cement and showed bridging of cracks to prevent quick propagation of cracks and opening of crack mouth, resulting in higher fracture energy and ductility.

References

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Figures

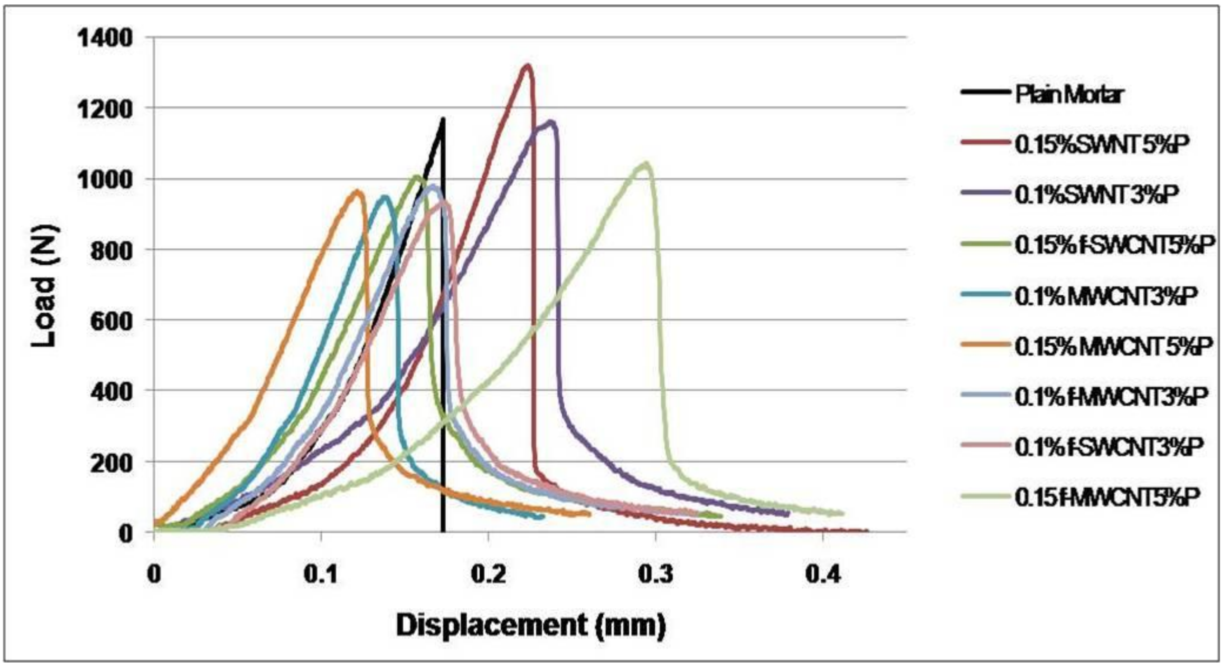

Figure1 Load-displacement curves of notched samples of plain mortar and CNT/mortar composites, tested at 3 point bending configuration