ENHANCING UHPC PERFORMANCE USING CARBON NANOMATERIALS

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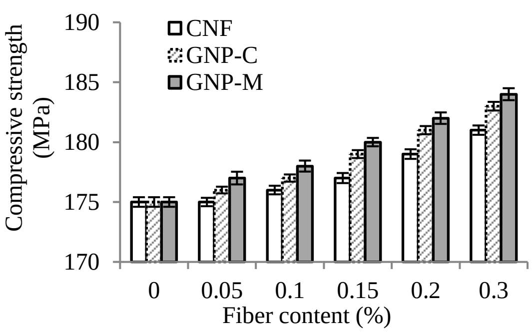
PRESENTATION ABSTRACT

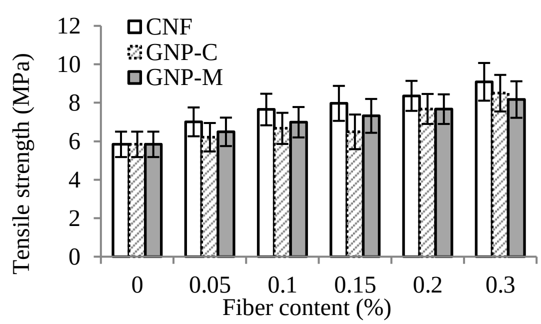
In this study, the effect of incorporating two types of graphene nanoplatelet (GNP) and one type of carbon nanofibers (CNF) on rheological properties, mechanical properties, and pores structure of ultra high performance concrete (UHPC) containing 0.5% steel fibers, by volume, is investigated. In consideration of the cost, the volume of steel fibers used in UHPC is low. The content of the nanomaterials is increased from 0 to 0.3% by mass of binders. The evaluated mechanical properties of UHPC include compressive strength and tensile properties. The microstructures of the UHPC mixtures containing nanomaterials were also examined.

The variations of compressive strength of UHPC mixtures with different nanomaterials content at 28 d. It can be seen that the compressive strength of the UHPC increased slightly (5 to 8 MPa) with the content of nanomaterials. Such increase can be attributed to the "bridging effect" of the CNFs and GNPs of microcracks as well as the "filler effect" for increasing the cement degree of hydration. Compared with UHPC made with CNF or GNP-M, the mixture made with GNP-C exhibited slightly higher compressive strength. The results of direct tensile responses are summarized in Figures 1(b) and (c). Figure 1(d) shows a representative load-deflection curve under bending. The area under the load-displacement curve and the horizontal axis represents the energy absorption capacity in tension. As the content of CNF was increased from 0 to 0.30%, the tensile strength increased by 55%, and the energy absorption capacity increased by 110%. As the content of GNP-C increased from 0 to 0.30%, the tensile strength and energy absorption capacity of UHPC increased by 40% and 190%, respectively. The increase in GNP-M content from 0 to 0.30% resulted in an increase of tensile strength by 45% and energy absorption capacity by 150%.

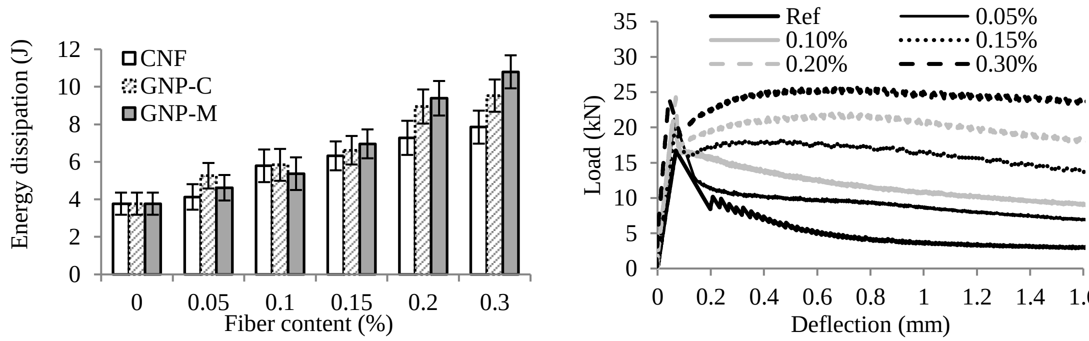
Overall, the incorporation of CNFs was more effective than the GNPs in bridging microcracks and enhancing the cracking stress/load due to the longer length. Thus, the UHPC mixtures containing CNFs demonstrated higher tensile strength than the UHPC mixtures mixed with GNPs. However, the CNFs have smaller rigidity/stiffness than the GNPs, and thus are less effective in the steel fiber pull-out process. The post-cracking behavior is mainly associated with fiber pull-out behavior. Therefore, the UHPC mixtures mixed with GNPs demonstrated higher load resistance in the post-cracking. Furthermore, the GNPs have the "surface effect", which leads to enormous interface area, thus ensuring intimate bond between the GNPs and the matrix due to Van der Waals forces. The platelet shapes of GNPs enable them to block and divert microcracks, thus slowing the crack propagation and formation of the crack network. The bridging effect of GNPs can delay the initiation and opening up of cracks. In addition, the GNPs can enhance the mechanical properties of nanocomposites via crack-arresting effect and improvement to the interfacial transition zone of composites.



(a)



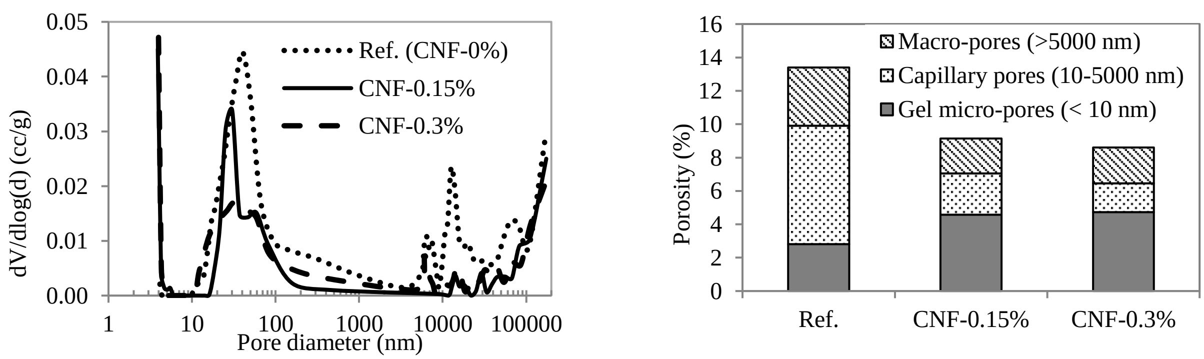
(b)



(c) (d)

FIGURE 1 Effect of nanomaterial content on 28-d: (a) compressive strength, (b) tensile strength, and (c) energy dissipation of UHPC. (N=3), (d) flexural behavior of UHPC mixtures with different GNP-C content

Figure 2(a) shows the pore size distribution of the UHPC mixtures covering pores with apparent diameter of 4 nm to 105 μm. Figure 2(b) plots the porosity results that indicatethat the total porosity was reduced by about 35% as the CNF increased from 0 to 0.3%. The porosity of macro-pores, which are mainly due to entrapment of air, ranged from 2.5% to 4.5%. The addition of CNF significantly decreased the volume fraction of capillary pores and increased the gel micro-pores porosity. As the CNF content was increased from 0 to 3%, the total porosity was reduced from 13.4% to 8.6%. The increase in CNF content from 0 to 0.3% decreased the porosity of capillary pores by 75% and increased the gel pores by 70%, which reflects a refinement of the pore structure. The increase in gel pores can be attributed to the enhanced degree of hydration of the binder in the presence of high-volume CNFs. The reduction in capillary pore volume may be due to the fact that CNFs can promote cement hydration and lead to a refined microstructure of the hydration products.



(a) (b)

FIGURE 2 Effect of CNF content on: (a) pore size distribution and (b) porosity of UHPC at 28 d.