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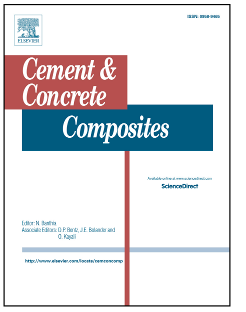

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The Use of Microfine Cement to Enhance the Efficacy of Carbon Nanofibers with Respect to Drying Shrinkage Crack Resistance of Portland Cement Mortars

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Abstract: Significant research has recently been aimed at quantifying the effects of carbon nanofibers and carbon nanotubes in portland cement pastes and mortars. Such efforts have shown that mechanical properties can increase with low concentrations of carbon nanofibers but have marginal improvement or are negatively affected with high concentrations. The objective of this paper is to evaluate the use of a microfine cement to enhance the efficacy of carbon nanofibers in portland cement mortar with respect to cracking resistance via enabling higher nanofiber concentrations. Experiments are performed with concentrations of carbon nanofibers up to 3% by weight of cement using either Type I/II or microfine cement. The primary test implemented was a restrained ring drying shrinkage test; unrestrained drying shrinkage tests, elastic modulus tests, and scanning electron microscopy imaging were performed to provide supplemental data to explain the observations from the restrained ring drying shrinkage tests. It was found that Type I/II cement mortars either lost performance or had insignificant gains with respect to cracking resistance, and all Type I/II mortar mixtures had losses in stiffness with the addition of high concentrations of carbon nanofibers. In contrast, microfine cement mortars had increased shrinkage cracking resistance and no loss in stiffness with increasing amounts of carbon nanofibers (up to the 3% by weight of cement tested in this research). The microfine cement mortar with 3% carbon nanofibers by weight of cement delayed the experimentally measured time of cracking in the ring test by a factor of up to 3.89. The delay in visible cracking time was attributed to microcrack bridging by the carbon nanofibers as imaged by scanning electron microscopy.

Keywords: Carbon nanofibers; crack resistance; drying shrinkage; restrained ring test; microfine cement;

1 Introduction

Significant research has focused on the effects of carbon nanofibers (CNFs) and carbon nanotubes (CNTs) in portland cement paste and mortar. Portland cement based materials (PCBM) are quasi-brittle materials that have the tendency to form cracks during structural loading, foundation settlement, when exposed to fatigue, and when exposed to harsh environments. These cracks allow water and deleterious chemicals such as deicing salts to penetrate and subsequently degrade the material and the reinforcing steel commonly used in concrete. One of the best ways to mitigate this material degradation is to limit the amount of water that can penetrate through the outermost layer of material by minimizing the size of the cracks that form. Crack size minimization is often achieved using macro fibers such as steel, polyvinyl alcohol, polypropylene, or a plethora of others to bridge the cracks after formation [1-5]. Aveston and Kelly proposed that the spacing between cracks (and, therefore, the size of the cracks themselves) is directly proportional to the diameter of the fiber used in the PCBM, i.e. fibers with smaller diameters produce more numerous but smaller cracks in the material [6]. Thus, the use of CNFs or CNTs in PCBMs may yield multitudinous microcracks that are too small to be seen with the naked eye. Since transport properties through a cracked material scale with the cube of crack width [7], it is preferable from a durability perspective to have a material with many microcracks rather than a few larger cracks.

The aforementioned theoretical beneficial use of CNFs or CNTs has driven much of the research into their successful incorporation into PCBMs [8]. CNFs and CNTs have been shown to increase flexural strength, density, and hardness of PCBMs when used in low concentrations (e.g. 0.048-0.30% by weight