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Investigating the Effect of Using Multi-Walled Carbon Nanotubes on Increasing the Flexural Strength and Energy Absorption Capability of Cement Mortar

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ABSTRACT

This research investigates the effect of using multi-walled carbon nanotube (MWCNT) on flexural and compressive strengths, ultimate displacement and energy absorption capability of standard cement mortar. Different weight percentages of nanotubes as well as different dispersion methods were studied. The key issue of adding nanotubes to the composites is their proper dispersion, which was considered by comparing the results of two different dispersion methods. According to the test results and SEM images, the method using functionalized MWCNTs in combination with ultrasonication was pointed out as an appropriate dispersion method. Using nanotubes resulted in a significant increase in the flexural strength and energy absorption capability of cement mortar that represents the ability of properly dispersed nanotubes in bridging and closure of the micro cracks.

KEYWORDS:

Carbon Nanotube, Cement Mortar, Dispersion, Energy absorption capability, Flexural Strength.

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1- Introduction

Addition of fibers to concrete improves concrete properties such as tensile, flexural and impact strengths, energy absorption capability and fire resistance, and increases the lifetime of the concrete structures in comparison with those of conventional concrete.

As concrete is loaded, initially, short and discontinuous microcracks are created in a distributed manner. These microcracks coalesce to form large macroscopic cracks, known as macrocracks. Fibers are incorporated into cementitious matrices to control cracking by bridging the cracks during loading and transferring the load. The incorporation of carbon nanotubes (CNTs) will allow the control of the matrix cracks at the nano scale level. Effectively dispersed CNTs can improve the fracture properties of cement matrices by bridging the nano scale cracks and have a beneficial effect on the early strain capacity of the nano composites [1].

CNTs are well known for their extraordinary mechanical properties. Their high aspect ratio, high resistance to corrosion and low specific weight make them a very promising reinforcement material for modern building materials. So far, carbon nanotubes were incorporated into normal concretes, high and ultra-high performance concretes leading to improved mechanical properties [2].

The major challenge associated with the incorporation of CNTs in cement-based materials is poor dispersion. In some studies, effective dispersion of different length multiwall carbon nanotubes (MWCNTs) in water was achieved by applying ultrasonic energy and in combination with the use of a surfactant [3].

A variety of methods has been tested for dispersion of CNTs in cement-based materials. For example, the results of a research by Cwirzen et al. showed that stable and homogenous dispersions of MWCNTs in water could be obtained by using surface functionalization combined with decoration using polyacrylic acid polymers [4].

Metaxa et al. investigated the reinforcing effects of the well-dispersed multiwall carbon nanotubes (MWCNTs) in cementitious matrices. According to this study, increased fracture resistance properties represent excellent reinforcing capability of MWCNTs. The results show that incorporation of very low amounts of well-dispersed CNTs can significantly increase the strength and the stiffness of the cementitious matrix. Compared to plain cement matrix, the nano composites appear to have a higher amount of high stiffness C–S–H and reduced nano porosity [5].

2- Methodology, Discussion, Results

In this study, flexural strength and energy absorption capabilities of standard cement mortar containing MWCNTs in comparison with those of conventional cement mortar have been investigated. The effects of different weight percentages of nanotubes and their dispersion methods inside the mixture have also been considered.

For flexural strength evaluation, center point loading on cement mortar beams have been conducted. Specimens containing MWCNTs are obtained by adding 0.5 and 0.7 wt.% of cement nanotubes to the cement mortars.

For the proper dispersion of nanotubes inside the cement mortar and studying the effect of dispersion method, two methods of applying surfactant and functionalized nanotubes have been investigated. The MWCNTs are industrially functionalized with 3.7 wt.% hydroxyl (-OH) functional group. Polar covalent bonds of the hydroxyl functional group, could improve the solubility. In a series of specimens, aqueous solution containing functionalized nanotubes sonicated for 60 min without the use of surfactant. In the second series after the addition of SDS as a surfactant and functionalized nanotubes to water, the solution sonicated for the same time as first series of specimens.

Incorporating the surfactant led to producing foams during mixing of cement mortars. Foam formation can result in an increase in volume and porosity of the mortar and a decrease in compressive and flexural strengths. Furthermore, it caused inappropriate dispersion of nanotubes leading to formation of flocs, which disrupted the expected function of nanotubes. Another method of dispersion of CNTs is their functionalization, which seems to be more effective in the preparation of cement mortars and concrete mixes. In this method, functional groups on the nanotubes result in to better dispersion due to the repulsion of like charges. Scanning electron microscopy (SEM) images of the specimens confirmed efficiency of the dispersion method using combination of ultrasonication and functionalization of MWCNTs.

All specimens containing functionalized nanotubes showed higher flexural strength, ultimate displacement and toughness than those of conventional cement mortar.

The flexural strength and Energy absorption capability of specimens containing 0.7 wt.% well-dispersed MWCNTs in comparison with those of conventional cement mortar specimens showed increases of 45% and 83% respectively.

In the extent of this study, increasing the amount of nanotubes led to an increase of flexural strength, toughness and ultimate displacement, although the trend of this increase is not linear and the results can be affected by dispersion method.

3- Conclusions

Using different dispersion methods of MWCNTs in the cement mixture led to different results.

According to SEM images, the dispersion of nanotubes without surfactants and utilization of functional groups property besides ultrasonication led to appropriate dispersion and therefore an increase in the compressive and flexural strengths and energy absorption capability.

In the extent of this study, using MWCNTs can improve the mechanical properties of the cement mortar, which can be amplified with an increase in both the age of specimen and the percentage of incorporated nanotubes.

According to the results, the improving effect of MWCNTs on the toughness is more than that of the flexural strength.

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