Sindh Univ. Res. Jour. (Sci. Ser.) Vol. 50 (3D) 10-13 (2018)

SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES)

Experimental investigation on the contribution of pristine multi-walled carbon nanotubes (MWCNTs) addition to the strength enhancement of cement composites

A NAQI*, N. ABBAS[++], N. ZAHRA**

Department of Civil & Environmental Engineering, Chung-Ang University Seoul 06974, South Korea

Received 10th June 2018 and Revised 15th September 2018

Abstract: This research discusses the different dosages of pristine carbon nanotubes added to the strength enhancement of cement composites. Carbon nanotubes (CNTs) dispersion in the cement composite was aided using silica fume particles. Dispersion of CNTs within the cement matrix is confirmed by FESEM analysis. Addition of silica fume was found to be helpful in strength increment by improving the bond between the nanotubes and cement matrix. The experimental results showed an increase in compressive strength up to 4.2% and 19% at 7 and 28 days testing for the MWCNTs dosage of 0.10% (by weight of binder) compared to the reference specimen. This strength increment is due to improved microstructure formed by the addition of nanotubes.

Keywords: Pristine multi-walled carbon nanotubes, silica fume, mortar, compressive strength

1. INTRODUCTION

The Carbon nanotubes (CNTs) possess high electrical and mechanical properties and their nano size enables them crack growth prevention at nano level (Coleman *et al.*, 2006). Carbon nanotubes (CNTs) also possess high mechanical strength, high surface area and strong adsorption affinity towards organic matters and microbes. The strength of carbon nanotubes comes from the C-C covalent bond between carbon atoms. Experimental results reported tensile strength of carbon nanotubes approximately 100gigapascals, Young's modulus of 1TP and yield strain of 12% (Patton *et al.*, 2002). Carbon nanotubes have strong tendency to agglomerate due to high attractive forces that make it a challenging task to ensure uniformity in the paste (Sanchez and Ince, 2009). The other motivational factors of using Multi walled carbon nanotubes (MWCNTs) are the high aspect ratio, specific surface area and stiffness by which these CNTs significantly improve the mechanical properties and electrical conductivity of different materials used in different sector and industries.

The present study discusses dry mixing technique and the possible dosages of pristine multi-walled carbon nanotubes that can added to the cementitious materials in order to improve their micro-structure, which ultimately leads to an increment in strength of mortar specimen.

2. BACKGROUND

Carbon nanotubes are considered to be the toughest materials found till now. They have been utilized in almost every field of science. Owing to their nano level size they possess very strong van der Waals attractive forces and proper dispersion of these nanotubes in high strength cementitious materials is a challenging task. Properly dispersed CNTs in matrix are desired to achieve the proper reinforcement. They can act as nano fillers and can reduce the porosity of the specimen resulting an improved microstructure. A common technique for the dispersion of nanotubes is a combination of chemical (surfactant) and physical (sonication) treatment (Konsta-Gdoutos *et al.*, 2010a).

Several attempts had been made by researchers on increasing the compressive strengths of cement composites by incorporating carbon nanotubes. Li *et al.* (Li *et al.*, 2006) showed an increment in compressive strength for specimen containing 1% CNTs by weight of cement. Mortar specimen containing untreated multi walled carbon nanotubes showed higher compressive strengths compared to reference specimen (Manzur and Yazdani, 2010). Agullo *et al.* (Vera-Agullo *et al.*, 2009) obtained early age higher strength values for the mortar specimens utilizing low concentration of CNTs. Researchers found that with an increase in concentration of CNTs in composites, the compressive strengths decreased (Lelusz, 2015).

3. MATERILAS AND METHODS

3.1 Materials

Portland cement (type 1) in accordance with ASTM C 150 was used. Pristine multiwall carbon nanotubes (MWCNTs~ K Nano series) with bundle diameter 3-15 micrometer, bundle length 10-50 micro meter were obtained from Kumho Petrochemicals Korea.

[++] Corresponding author: Naseem Abbas email: naseem.abbas@ucp.edu.pk naseem.engr@gmail.com
* Department of Mechanical Engineering, University of Central Punjab Lahore-54000, Pakistan.
**Department of Physics, Government College University, Faisalabad-38000, Pakistan

Specifications of CNTs are provided in **(Table-1)**. Silica fume, used as pozzolan, while chemical composition was in accordance with ASTM C 1240.

Table-I. Specifications of MWCNTs (K-Nanos 100P)

Property	Unit	bundle
Bundle diameter	µm	3~15
Bundle length	µm	10~50
diameter	nm	10~15
purity	>90	0.45
crystallinity	IG/ID	0.6~0.8

3.2 Mixture Preparation

Four mixes were prepared. Dosages of nanotubes added were 0%, 0.05%, 0.075% and 0.10% respectively. 10% silica fume by amount of cement was added. Water was added in amount of 25% by binder weight. Workability was ensured using a superplasticizer (SP) in amount of 1% by weight of binder. All materials were dry mixed in Hobart mixer for 5 minutes. Pre-conditioned water was added and mixed for 2 minutes and then superplasticizer was added and mixed at medium speed. Mixing was finished with 3 minutes mixing at high speed. Specimens were prepared in 50x50x50mm moulds. **(Fig-1)** shows cone filled with fresh mortar. Specimens were demoded after 1 day and water cured further till testing. Compressive strength testing was carried out at 7 and 28 days using a universal testing machine. **(Fig-2)** shows compressive strength test setup.

Fig. 1. Cone filled with fresh mortar.

Fig. 2. Compressive strength test setup

4. RESULTS AND DISCUSSION

4.1 Compressive Strength

(Fig-3) and **(Fig-4)** shows compressive strength test results of the mortar specimen with varying dosages of carbon nanotubes (0%, 0.05%, 0.075% and 0.10%) tested at 7 and 28 days respectively. Low dosages of CNTs (0.05 and 0.05%) weren't found to be effective as their compressive strength values are lower than the reference specimens. However, higher dosage of CNTs (0.10% by wt. of binder) showed an increase in compressive strength compared to the reference one.

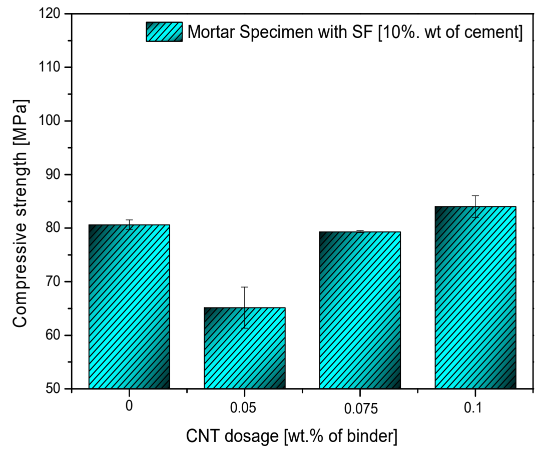

Fig. 3 Compressive strength of carbon nanotube silica fume mortar at 7-days testing

The mortar specimen incorporated with 0.10% CNTs (by wt. of binder) showed 4.2% and 19% higher compressive strength values compared to the reference specimens at 7 and 28 days respectively.

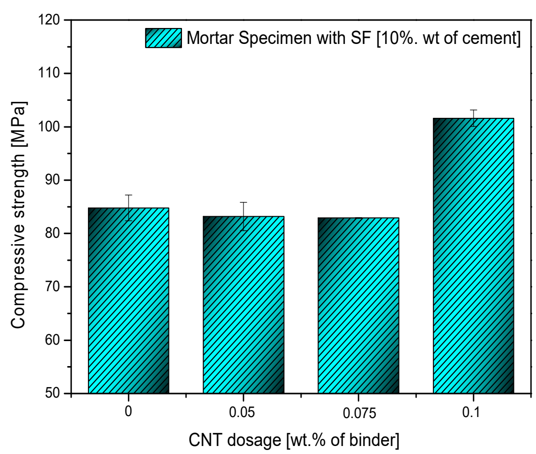

Fig. 4 Compressive strength of carbon nanotube silica fume mortar at 28-days testing

Owing to have smaller particle size, silica fume contributed in dispersion of carbon nano tubes in the matrix (Kim *et al.,* 2014). **(Fig.5)** shows effect of silica fume on agglomerated nanotubes in the matrix. Carbon nanotubes have surface energies ranged from 27 to 45 mJ/m^2 and having very small size they offer high surface area and nucleation sites for the formation of Calcium Silicate Hydrate (C-S-H) (Nuriel *et al.,* 2005). **(Fig.6)** shows effect of nano particles addition on the hydration product. So, the ultimate increment in strength is affiliated to the fact that CNTs were properly dispersed in the matrix that reduces the porosity of the mixture resulting in denser microstructure (Konsta-Gdoutos *et al.,* 2010b). Some of the results are also presented in international conference (Naqi. *et al,* 2017)

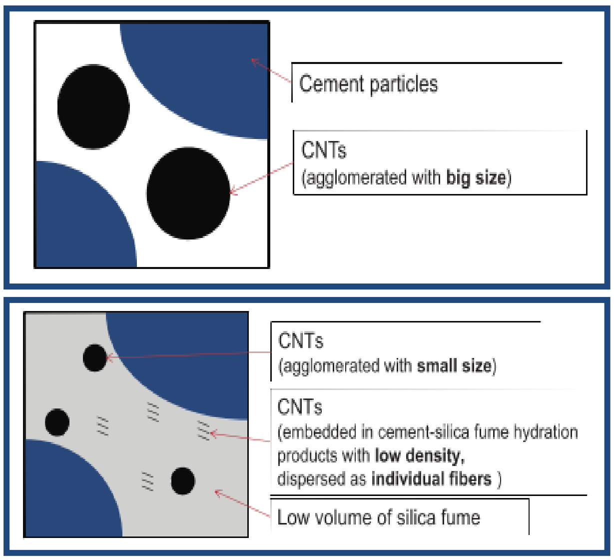

Fig. 5 Dispersion of MWCNTs in cement matrix with and without addition of silica fume.

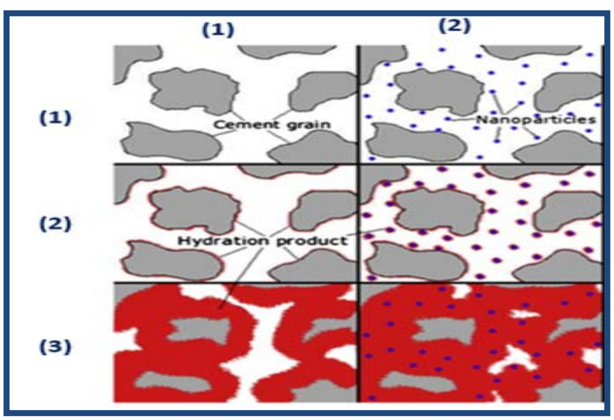

Fig. 6. Hydration of cement with nano particles at different times after mixing

It is clear from the SEM images **(Fig.7-8)** that CNTs were individually dispersed in the matrix. And individual fibers also help in bridging the hydrates forming a stronger interfacial bond that resulted in higher compressive strength values (Makar and Chan, 2009; Li *et al.,* 2005) .

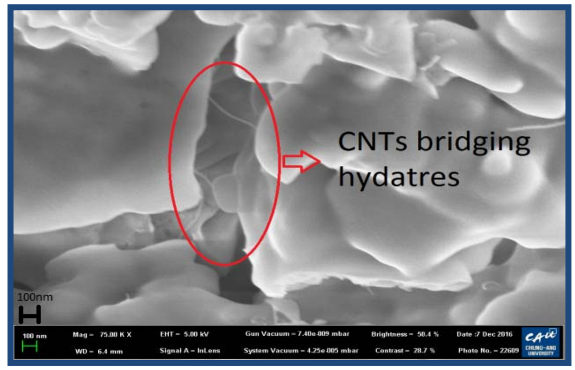

Fig. 7. SEM image showing CNTs bridging hydrate

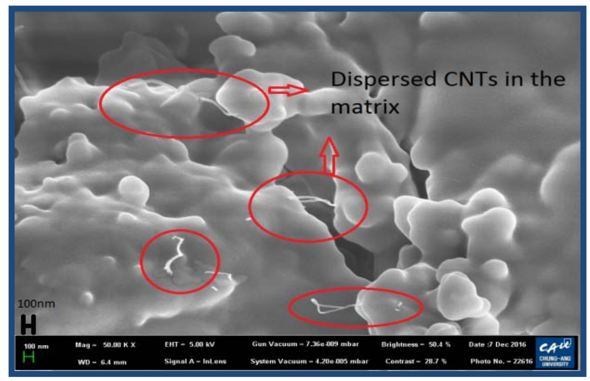

Fig. 8. SEM image showing well dispersed CNTs in cement matrix

5. CONCLUSION

In this study, pristine multi-walled carbon nanotubes were added in mortar specimen to investigate its effect on strength development. All aggregates were dry mixed in standard Hobart mixer. Silica fume aided dispersion of MWCNTs in cement composites formation of C-S-H. FESEM images confirmed individually dispersed nanotubes in the cement matrix. Experimental results have shown an increment in strength for specimens with a dosage of 0.1% MWCNTs (by weight of cement) compared to the reference specimen. However, Lower dosages of MWCNTs were not found effective in strength development.

6. ACKNOWLEDGEMENTS

This research was supported by Construction Technology Research Program, Ministry of Land, Infrastructure and Transport of Korean Government. Furthermore, the support from Korean Conformity Laboratories staff in testing of specimens is greatly appreciated. This research was also partially supported by Faculty of Engineering, Mechanical Engineering Department, University of Central Punjab, Lahore, Pakistan

REFERENCES:

Coleman, J. N., U. Khan, W. J. Blau, Y. K. Gun'ko, (2006). Small but strong: a review of the mechanical properties of carbon nanotube–polymer composites. *Carbon,* 44(9)**,** 1624-1652.

Kim, H., I. Nam, H. Lee, (2014). Enhanced effect of carbon nanotube on mechanical and electrical properties of cement composites by incorporation of silica fume. *Composite Structures,* 107, 60-69.

Konsta-Gdoutos, M. S., Metaxa, Z. S. & Shah, S. P. 2010a. Highly dispersed carbon nanotube reinforced cement based materials. *Cement and Concrete Research,* 40(7)**,** 1052-1059.

Konsta-Gdoutos, M. S., Z. S. Metaxa, S. P. Shah, (2010b). Multi-scale mechanical and fracture characteristics and early-age strain capacity of high performance carbon nanotube/cement nanocomposites. *Cement and Concrete Composites,* 32(2)**,** 110-115.

Lelusz, M. (2015). Carbon nanotubes influence on the compressive strength of cement composites. *Czasopismo Techniczne*.

Li, G. Y., P. M. Wang, X. Zhao, (2005). Mechanical behavior and microstructure of cement composites incorporating surface-treated multi-walled carbon nanotubes. *Carbon,* 43(6)**,** 1239-1245.

Li, H., M. H. Zhang, J. P. Ou, (2006). Abrasion resistance of concrete containing nano-particles for pavement. *Wear,* 260(11)**,** 1262-1266.

Makar, J. M. G. W. Chan, (2009). Growth of Cement Hydration Products on Single- Walled Carbon Nanotubes. *Journal of the American Ceramic Society,* 92(6)**,** 1303-1310.

Manzur, T. N. Yazdani, (2010). Strength enhancement of cement mortar with carbon nanotubes: early results and potential. *Transportation Research Record: Journal of the Transportation Research Board,* 2142)**,** 102-108.

Nuriel, S., L. Liu, A.Barber, H. Wagner, (2005). Direct measurement of multiwall nanotube surface tension. *Chemical Physics Letters,* 404(4)**,** 263-266.

Naqi, A., N Abbas. (2017). I Experimental investigation on the contribution of pristine multi-walled carbon nanotubes (MWCNTs) addition to the strength enhancement of cement composites. The IEEE 3rd International Conference on Engineering, Technologies and Social Sciencs.Bankok-Thailand.
doi: 10.1109/ICETSS.2017.8324183

Patton, R., C. Pittman, L. Wang, J. Hill, A. Day, (2002). Ablation, mechanical and thermal conductivity properties of vapor grown carbon fiber/phenolic matrix composites. *Composites Part A: Applied Science and Manufacturing,* 33(2)**,** 243-251.

Sanchez, F. C. Ince, (2009). Microstructure and macroscopic properties of hybrid carbon nanofiber/silica fume cement composites. *Composites Science and Technology,* 69(7)**,** 1310-1318.

Vera-Agullo, J., V. Chozas-Ligero, D. Portillo-Rico, M. García-Casas, A. Gutiérrez-Martínez, J. Mieres-Royo, J. Grávalos-Moreno, (2009). Mortar and concrete reinforced with nanomaterials. *Nanotechnology in Construction 3.* Springer, Berlin, 383-388.