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THE EFFECT OF FIBER DISPERSION ON STRENGTH PROPERTIES OF FIBER-REINFORCED CEMENT COMPOSITES WITH MWCNT

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This experimental study was intended to improve the strength properties of Multi-walled Carbon Nano-tubes (MWCNT) reinforced cementitious composites. CNT is a very promising construction material with excellent mechanical properties. However, the strong van der Waals force between their particles hinders their dispersion, limiting strength development. Therefore, homogeneous dispersion is required to obtain enhanced strength of composites by incorporating MWCNT. With this purpose, the variables considered in this study are the level of sonication, the amount of surfactant, the replacement ratio of silica fume, etc. Studies through an optical microscope indicated that the fiber dispersion of CNT was improved with the increase of sonication period, and that compressive strength was enhanced as the degree of sonication increased. When superplasticizer as a surfactant had a SP/CNT ratio of 4~6, the best improvement in strength was obtained. Silica fume was shown to produce the highest compressive strength at 10% replacement.

Keywords: CNT, Multi-walled, Carbon, Nano, Compressive strength, Superplasticizer, Cementictious material.

1 INTRODUCTION

Recently many researchers have been interested in Carbon Nanotube (CNT) as a reinforcing fiber for cementitous material. Carbon Nanotube (CNT), discovered in 1991, is considered one of the very promising construction materials due to their excellent physical, mechanical and electrical properties. Earlier attempts to incorporate CNT into construction materials were for utilizing its high electrical conductivity (Parka et al. 2003, Li et al. 2007).

As is well known, cement-based materials are the most widely used construction materials because of their high economic efficiency, compressive strength, plasticity, etc. Nevertheless, the brittle nature and the relatively small tensile strength prevent the broadening of their application fields. The most common way to overcome such inherent weakness is adding fibers to the cementitious materials. Numerous types of fibers have been introduced, resulting in considerable improvement in tensile strength and toughness.

CNT is reported to have a strength 100 times greater than steel but to be 6 times lighter. Its elastic modulus and tensile strength are reported to be up to 1 TPa and 200 GPa. Due to such excellent mechanical properties, CNT have been used in various types of composites for the purpose of reinforcing the matrix (Cwirzen et al. 2008), including the cement matrix. Its high aspect ratio (length to diameter), about several hundred to more than a thousand, is also beneficial to the reinforcing effect. However, the strong van der Waals force between their particles hinders their dispersion, limiting strength improvement. Therefore, homogeneous dispersion is necessary to obtain the enhanced strength of composites by incorporating CNTs. This study aimed to find a way to disperse Multi-walled CNTs (MWCNT) uniformly with efficiency.

2 EXPERIMENTS

With the purpose described previously, the variables considered in this study were the sonication period, the amount of surfactant, and the replacement ratio of silica fume. The mix proportion considered in this study was as shown in Table 1. Four hours of sonication was applied for all specimens, and two hours and no sonication were applied for the additional specimens with 10% replacement of silica fume and CNTs.

Table 1. The mix proportion of MWCNT-cement composites.

W/B	Cement (g)	Silica fume (g)	CNT (g)	Superplasticizer (g)
0.4	900	100	0 or 1	0, 2, 4, 6, 8
	1000	-		4
	800	200		
	700	300		

MWCNT used in the experiment has a purity of more than 95%, an average diameter of 20 nm, a length ranging from 1~25 μm, and a surface area of 105~250 m^2/g. Its properties are shown in Table 2.

Table 2. The properties of MWCNT.

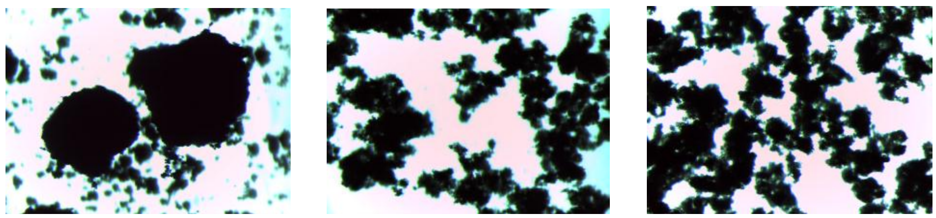
Purity (%)	Avg. Diameter (nm)	Length (μm)	Metal oxide (wt. %)	Bulk density (g/m^3)	Specific surface area (m^2/g)
> 95	20	1-25	< 5	0.03-0.06	150-250

The surfactant used in this study was polycarboxylate superplasticizer, commonly used to improve the workability of concrete. Konsta-Gdoutos et al. (2010) have proven its effectiveness in dispersing CNTs into water. The silica fume, known to weaken the van der Waals force between fibers that agglomerates the CNTs together (Chung 2005), was used in an effort to disperse MWCNTs. The influence of it was estimated quantitatively.

MWCNTs were first dispersed in water using the surfactant and ultrasonic process. Constant ultrasonic energy was applied using a 750 W cup-horn high-intensity ultrasonic processor with a cylindrical tip (VCX 750). After the sonication, cement and silica fume were added into the CNT suspension. After mixing, the fresh composites were casted into the 50 mm × 50 mm × 500 mm cube molds to fabricate specimens for a compressive strength test. The compressive strength was measured 14 days after casting.

3 RESULTS AND DISCUSSION

Figure 1 compares CNTs dispersions with different sonication periods. The images of CNTs dispersions were obtained using optical microscope (ICC50). It was observed that the increase of sonication time made CNTs more uniformly dispersed.



(a) No sonication (b) 2hrs sonication (c) 4hrs sonication

Figure 1. CNTs dispersions with different sonication periods.

The effect of MWCNT dispersion was demonstrated by a comparison of compressive strength of CNT-cement composites. Figure 2 presents the compressive strength of the specimens made with CNT suspensions subjected to different sonication periods. In Figure 2, it can be easily seen that CNT dispersion had a remarkable influence on the compressive strength directly.

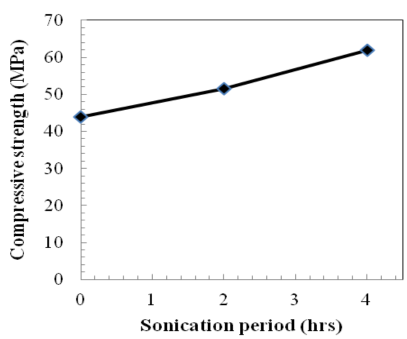


Figure 2. The effect of sonication period on the compressive strength.

The effect of the amount of superplasticizer on CNT dispersion and the consequent compressive strength can be seen in Figure 3. The amount of superplasticizer in the considered range in this study had little effect on the compressive strength in the specimens without CNT. For the specimens with CNTs and superplasticizer, an improvement in compressive strength with the increase in the amount of the surfactant was found until 4 or 6 g superplasticizer was added. However, 8 g dosage reduced the strength inversely compared to 6 g dosage. This result seems to indicate that CNT-cement composites have an optimized amount of surfactant with respect to CNTs dispersion and strength.

The effect of partial replacing cement with silica fume was also investigated by comparing the compressive strength. Silica fume is generally known to be beneficial to improve the strength of cementitious materials when it is substituted for cement in partial fractions. In order to estimate the role of silica fume for CNTs dispersion in

CNT-cement composites, the strengths of the specimens with and without CNTs at the same volume of silica fume were compared.

Figure 4 presents the difference in the strength for several replacement ratios of silica fume. 10% of replacement of silica fume was found to be the most effective in strength improvement. It is thought that the improvement was closely related to the fact that silica fume facilitates dispersion of micro-sized fibers in cement paste as mentioned previously.

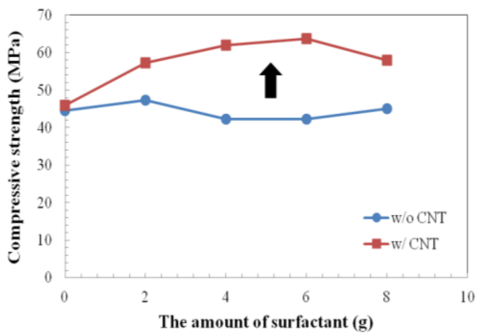


Figure 3. The effect of adding superplasticizer as a surfactant.

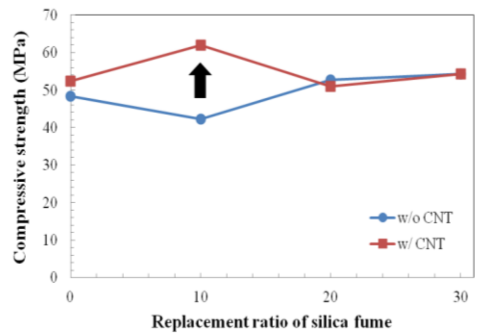


Figure 4. The effect of replacement of silica fume.

4 CONCLUSIONS

In this study, the strength improvement of MWCNT reinforced cement paste was investigated with the variables of the sonication period, the amount of surfactant, and the replacement ratio of silica fume which are considered to have an influence on CNTs dispersion. The experimental results revealed that (1) the increase of sonication period could disperse CNTs more uniformly and thus improve the strength; (2) adding superplasticizer in a SP/CNT ratio of 4~6 produced the most enhancement of strength; (3) silica fume was most effective when it was substituted for 10% of cement.

Acknowledgments

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