IMPROVING THE PROPERTIES OF CONCRETE USING CARBON NANOTUBES

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ABSTRACT

Concrete is a mixture which is weak in tension and strong in compression. Past experimental programs have shown that Carbon nanotube can significantly improve the properties of concrete. Therefore, the objective of this literature survey is to summarize the past experimental data on the properties of concrete with carbone nanotubes.. As a solution carbon nanotubes, which consists of multiple sheets of graphite rolled to form a cylindrical structure and stacked concentrically was used. Due to strong Van de Waals forces & electrostatic forces carbon nanotubes tend to aggregate. Thus, ultrasonic dispersion techniques were adopted to disperse them uniformly. Tensile, compressive and bending tests have been conducted on the specimens in the past experimental programs. This paper presents the methodologies & results in reference to three research papers on similar experiments. Moreover, effectiveness of the experiment is discussed based on the comparison of all results obtained.

Keywords: MWCNT, sonication, cement

1. INTRODCUTION

Concrete is a properly proportioned mixture of water, cement, fine and coarse aggregates that can be used as a construction material to build various structures from nuclear radiation shield to very basic structures like houses as it can be poured into any shape unlike most other materials. Out of the above ingredients, cement plays a major role chemically as well as physically to show the properties of the concrete.

Cement is gray color fine powder, chemically formed by raw materials such as calcium oxide (CaO), silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3) heated to a temperature around 1200 – 1400 ^{o} C in kiln. During the process of mixing the ingredients inside the rotary kiln, the four major mineral constituents of cement are born. These are the main compounds that participate in strength gaining of concrete.

Table 1: Major mineral constituents of cement

Compound	**Abbrev -iation**	**Chemical formula**	**Typical Con. %**
Tri-calcium silicate	C_3S	$3CaO•SiO_2$	60-70
Di-calcium silicate	C_2S	$2CaO•SiO_2$	10-20%
Tri-calcium alluminate	C_3A	$3CaO•Al_2O_3$	5-10%
Tetra-calcium alumino-ferrate	C_4AF	$4CaO•Al_2O_3$ $•Fe_2O_3$	3-8%

These four components participate in gaining strength at different stages. Tri-calcium silicate (C_3S) hydrates and hardens rapidly and it is highly responsible for initial set and the early strength gained whereas tri-calcium aluminate (C_3A), hydrates and harden the quickest.C_3A also liberates a large amount of heat immediately and contributes somewhat to the early strength. The quick hardening nature of C_3A is the reason to add gypsum to cement mixture in production. Di-calcium silicate (C_2S) hydrates and hardens slowly and is very much responsible for long term strength increase i.e. beyond one weeks' time. Last but not least contributing the least on strength is tetra-calcium alumino-ferrite (C_4AF), still hydrates rapidly.

At a microscopic level, calcium silicate hydrate can be seen as a cloud like structure were calcium hydroxide is like a rose made of stone like petals and calcium sulfur-aluminate hydrates produce ettrigite i.e. a needle like structure. Even though it is observed that there are different types of shapes inside the structure, the voids are still present. It is one major cause for the weakening of the strength in concrete. Thereby, nanotubes are used to fill in these voids that could be observed at nano-scale. Therefore our objective of this literature survey to summarize the past experimental data on improving the properties of concrete using carbone nanotubes. Therefore, the effects after adding nanotubes into the mixture is concluded by the results obtained upon testing different grades of concrete using different methods of diffusing and tested for compression, tension and bending strengths.

2. LITERATURE REVIEW

There are three main ways to add the carbon nanotubes uniformly to the concrete: adding to cement, adding to water and as admixture.

In one experiment, polycarboxylate ether solution (Super plasticizer) is used. This solution is used as surfactant for preparation of aqueous solution. 0.25% of super plasticizer (SPL) is used by weight of cement used for the sonication process. Water is minimized to increase the strength, setting time and workability. To get the maximum use from the multi wall carbon nano tubes (MWCNT), it should be evenly dispersed in the concrete mix. In sonication process MWCNT and surfactants are added (super plasticizers – polycarboxylate 8H,) 0.25% by weight of cement and also with water. For 0.015% of MWCNT no water, only surfactants are used for sonication. But for other two surfactant amount is less and some amount of water is added. Ultrasound energy is added for 30 minutes. Then sample is kept for magnetic stirring for another 30 minutes. Then when casting specimens, first cement, coarse aggregate and fine aggregate are mixed. After that MWCNT- water mixer is added and mixed rapidly to avoid agglomeration. [2]

In another experiment, carbon nanotubes were used as a high strength nanodispersive reinforcement in compositional crystallohydrated materials to improve the physico-mechanical properties of non-autoclave cement foam concretes. The admixture used was a product with a density of 0.086 g/cm^3. Traditional technology methods with technical foam were used to prepare the cement foam concrete. The admixture wetted poorly, so the surface was treated with a surfactant based on a solution of lignosulfonate salt.[3]

In the third experiment, high-molecular-weight polyelectrolyte [i.e., poly(sodium 4-styrenesulfonate) or PSS] was used to disperse MWCNTs because of the potential negative influence of MWCNT polymer solutions on the mix's workability. A second type of sample was prepared by directly dispersing MWCNTs in a suitable SPL based on poly (carboxylate ether). A dispersed MWCNT–SPL solution (3.3% solid SPL diluted with water, 1 mg of MWCNT per 1 mL of water–SPL) behaves as a one-phase system that is black and ink-like. Dispersion quality was compared by SEM by pipetting and air-drying droplets of different MWCNT–SPL solutions on silicon wafer chips. The dispersed MWCNT– SPL solution contains only individual and small bundles of MWCNTs. A non-dispersed solution is characterized by extensive aggregation of nanotubes to form macro-sized particles visible to the naked eye. Equilibrium of dispersion was maintained for long periods of time (up to 6 months). The designed MWNT–SPL solution was incorporated in the concrete mix. [1]

A number of different percentages of MWCNT are used: MWCNT with 0.015%, 0.022% 0.03%, 0.045% by weight of cement. In another experiment, the choice of the composition to be used for foam concrete mixture preparation was made based on the desired grade of foam concrete up to a density of 350 kg/m^3. The amount of reinforcement phase in the mixture was 0.05 % based on the initial mass. [1-2]

CNTs with specific strength of upto 48,000 kN·m·kg^{-1} which is infact the best of known materials, compared to high-carbon steel's 154 kN·m·kg^{-1}. Some properties of MWCNTs: Carbon Purity of above 90%, diameter in a range of 20-40 nm, length ranging from 1-10 μm, no. of walls: 3-15, density: 0.15-0.35 g/cm^3 & surface area: 350 m^2/g. [1-2]

In a different experiment, carbon nanotubes with a diameter of (40 – 60) nm, which is filled with copper is used. Then in the third one, straight fibers with diameter: 0.2 mm, length: 13 mm & tensile strength: 2600 MPa and twisted fibers with no of twists ranging from 6-8, diameter: 0.3 mm, length: 30 mm & tensile strength: 3100 MPa are used. [3]

3. RESULTS & DISCUSSION

Table 2: Type 1 - MWCNT filled with copper, added as admixture [3]

№	Amount of nanotubes, % based on the composition mass	Average density, kg/m^3	Compressive strength, MPa
1	0	330	18
2	0.05	309	30.6

Table 3: Type 2 - MWCNT added to water [2]

Specimen No	Comp. failure Load (kN)	Compressive Strength (N/ mm2)	% increase	Split tensile strength failure load (kN)	Split tensile strength	% increase
Conventional Concrete	875	38.22	-	160	2.27	-
0.015% MWCNT	930	41.48	2.75	210	2.97	30.84
0.030% MWCNT	1010	45.18	16.38	235	3.30	45.37
0.045% MWCNT	1100	49.18	26.69	265	3.775	66.30

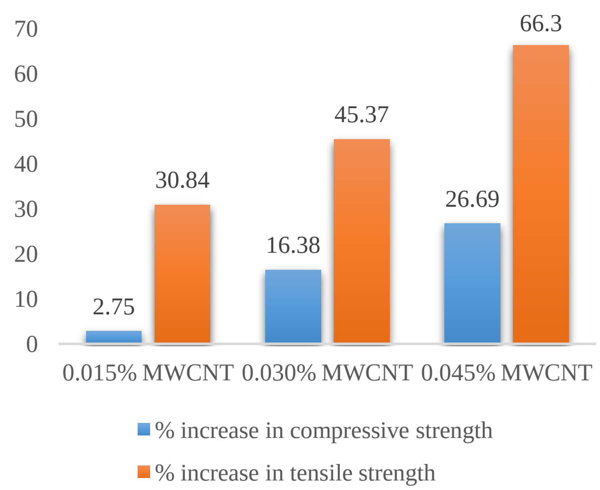

Figure 2: Type 2: Percentage increase in strength values

Table 3: Type 3 - Twisted MWCNT (0.022 wt.%) added to water [1]

Specimen no.	Term	Compressive strength (MPa)
1	UHPC	200
2	UHPC-MWCNTRC	194
3	UHPC*	212
4	UHPC-MWCNTRC*	217

*- Heat treated after 24h of specimen casting for a total of 48h at 650C

UHPC- Ultra- High Performance Concrete UHPC-MWCNTRC – Ultra- High Performance Concrete-Multi Walled Carbon Nanotubes Reinforced Concrete

The average bending test results do not show any significant improvements with regard to specimens' equivalent bending strengths. Besides the low concentration of MWCNTs, other factors that lead to similar performances in pristine and MWNT-SPL enhanced UHPC specimens might be that bonding behavior is insufficient to use its material properties, and the length of MWNTs is too short to bridge micro cracks for enhancing the mechanical properties of the bulk cementitious composite. [1]

4 CONCLUSIONS

Based on the above experimental investigations, the following conclusions can be drawn:

From the results, it is understood that increasing the proportions of functionalized MWCNT into concrete increases the compressive strength (Table 2, 3). In fact the compressive strength of the concrete with a proportion of 0.045% of functionalized MWCNT increases by 26.69%.

The split tensile strength increases with the increase in MWCNT (Table 3). In fact, the split tensile strength increased by 66.3% for 0.045% of MWCNT.

With the increase in MWCNT, the rate of increase of tensile strength is greater than that of the rate of increase of the compressive strength.

5 REFERENCES

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