Effect of Multiwalled Carbon Nanotubes On Mechanical Properties of Concrete

Engineering

KEYWORDS : Multiwalled carbon nanotubes, concrete, Compressive strength, Split tensile strength, Water absorption.

Dr.T.Ch.Madhavi	Professor & Head, Dept of Civil Engineering, SRM University, Ramapuram, Chennai – 600089
Pavithra.P	Final Year, BTech (Civil), Dept of Civil Engineering, SRM University, Ramapuram, Chennai – 600089
Sushmita Baban Singh	Final Year, BTech (Civil), Dept of Civil Engineering, SRM University, Ramapuram, Chennai – 600089
S.B.Vamsi Raj	Final Year, BTech (Civil), Dept of Civil Engineering, SRM University, Ramapuram, Chennai – 600089
Surajit Paul	Final Year, BTech (Civil), Dept of Civil Engineering, SRM University, Ramapuram, Chennai – 600089

ABSTRACT

This paper discusses the effect of multiwalled carbon nanotubes (CNT) on strength characteristics and durability of concrete. Sonication process is carried out by adding MWCNT with surfactants (super plasticizers - polycarboxylate 8H), 0.25% by weight of cement and also with water. 36 Specimens with MWCNTs of 0.015%, 0.03% and 0.045% of cement (by weight) were tested after 28 days of curing. Results show an increase in compressive and splitting-tensile strengths of the samples with increasing MWCNT. 0.045% of MWCNT has improved the 28 days compressive strength by 27 % while the split tensile strength increased by 45%. Crack propagation was reduced and water absorption decreased by 17% at 28 days curing.

INTRODUCTION

Improving concrete properties by addition of nano particles has shown significant improvement in conventional concrete. Nanotubes are only nanometers wide (billionths of a meter) but microns (millionths of a meter) long, have very interesting electrical, optical, heat, and mechanical properties. Nano concrete will have higher compressive and tensile strength, good workability. The nano scale structure of the concrete mix helps to faster the setting time of concrete. Since carbon nanotubes have a low density for a solid of 1.3 to 1.4 g/cm3, its specific strength of up to 48,000 kN·m·kg−1 is the best of known materials, compared to high-carbon steel's 154 kN·m·kg−1.

Due to their excellent physical and chemical strength Carbon nanotubes are highly used in construction industry mainly in concrete. Hence, this paper focus on the strength characteristics and water absorption of concrete with varying proportions of multi walled carbon nanotubes.

dispersion method is a major step in efficiently utilizing MWCNTs in cementitious materials (Kay Ville et al. (2010). Addition of carbon nanotubes can fine the pores size distribution and decreases porosity and also found that the addition of CNT to cement greatly enhance its flexural and compressive strengths (Geng Ying Li et al., 2004). Bryan et al. (2011) explained that by adding 0.02% and 0.04% of functionalized MWCNT by weight of cement to the cement paste increases the mechanical properties. Abdullah (2007) experimented on nanofibre materials added in cement concrete mix that these materials are showing improved mechanical and physical properties. Nanosilica fills the voids and makes the cement structure denser, accelerates the hydration process, has a pozzolonic effect, improves reology and increases the compressive strength (J.Vera-agullo, and V.Chozas-Ligereo

EXPERIMENTAL INVESTIGATION

total of 36 concrete specimens were casted out of which 27 specimens have multi walled carbon nanotubes of proportions 0.015%, 0.030% and 0.045%. In 36 specimens, 27 specimens contain MWCNT and other six are conventional concrete specimens. The specimens are water cured for 28 days and tested for **Water Absorption Test, Compressive Strength Test and Split Tensile Strength Test** using cubes of size 150 mm x 150 mm x 150 mm and cylindrical specimens of diameter 150 mm and height 300 mm

CASTING

M30 grade concrete is used. Ordinary Portland cement of 43 Grade is used and River sand passing through 4.75 mm sieves and coarse aggregate of size 20 mm were used. Portable Water was used for both mixing and curing. Water-cement ratio is 0.4 and the mix ratio is 1: 1.26 : 2.48

Multi Walled Carbon Nanotubes (MWCNT)

The properties of MWCNT are

- Carbon Purity: Above 90%
- Diameter: 20-40 nm
- Length: 1-10 µm
- No of walls: 3-15
- Density: 0.15-0.35 g/cm^3
- Surface Area: 350 m^2/g

USING POLY CARBOXYLATE ETHER SOLUTION

Poly Carboxylate Ether Solution is used as surfactant for preparation of aqueous solution. Super plasticizer (polycarboxylate 8H) is used during the sonication of MWCNT. 0.25% of super plasticizer by weight of cement used for the sonication process. Hence the water is reduced due to the addition of super plasticizer which in turn increases the strength, setting time and workability.

SONICATION OF MWCNT

Multi walled carbon nanotube is having the property of increasing the mechanical and durability properties of the concrete, if it is evenly dispersed on the concrete mix. To avoid agglomeration of the MWCNT, sonication process is carried out by adding MWCNT with surfactants (super plasticizers - polycarboxylate 8H,), 0.25% by weight of cement and also with water. For 0.015% of MWCNT, no water is required only surfactant is enough for sonication process. But for the other two proportions of MWCNT the surfactant amount will be less, so some amount of water is added with it. The ultrasound energy was applied for a sonicated period of 30 minutes. Then the sample is kept for magnetic stirring for another half an hour to get an uniform mixture.

CASTING OF SPECIMENS

After sonication process, the MWCNT solution is mixed with water that has to be added to the concrete. Firstly Cement, Coarse Aggregate and Fine aggregate are dry mixed. After drying mixing, MWCNT - Water mixture solution is added to the dry mix and rapid mixing is done to avoid any chance of agglomeration. The specimens were water cured for 28 days.

RESULTS AND DISCUSSIONS

WATER ABSORPTION TEST

The water absorption test for concrete is done after 28 days as per ASTM C642-81 The test results of the water absorption test are shown in Table 1 below. **I**ncreasing MWCNT proportion the percentage of water absorption is decreased. About 17.76% of decrease of water absorption is obtained by adding 0.045%. Such minor addition of MWCNT having the potential to decrease the percentage of water absorption to that amount explains that MWCNT have been dispersed properly and resulting in high resistivity to water or any other liquids. The nanoscale pore structure of the concrete mixed with MWCNT is found to be arrested by MWCNT.

Table 1 Water absorption

Sl.No.	% of MWCNT	% of water absorption	% Reduction in water absorption
1	Conventional Concrete	0.5873	-
2	0.015	0.5273	10.22
3	0.030	0.5027	14.41
4	0.045	0.483	17.76

The pore structure is generally classified as intrinsic pores in the cement gel resulting from hydration and capillary pores originating from the space initially filled with water. Thereby, it has been observed that the intrinsic pores size in the cement gel during hydration might be in a range of 3 nm to 10 nm. Such space might be occupied by nanotubes used of size 9nm which is found to be logical and the above test result is found to be a proof. While the capillary pores size generally greater than 10nm, such space might be occupied by numerous amounts of MWCNT's. The deposits of cement hydration on the aggregate surface consists of oriented crystals of $Ca(OH)_2$ and CSH fibres film. Such zone is found to be less stress resistant and highly porous. MWCNT arrest such zone and makes them less porous and highly stress resistant.

COMPRESSIVE STRENGTH

The test is conducted as per IS 416-1959 on cubes of size 150 x 150 x 150 mm after 28 days of curing till failure. The maximum failure load and its failure pattern is noted and results are presented in table 2 below.

Table 2 Compressive & split tensile Strength

Specimen No	Comp failure Load (kN)	Compressive Strength (N/mm^2)	% 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

With addition of functionalised MWCNT, the compressive strength of concrete increased. MWCNT in cement increases the amount of stiffness of C-S-H gel resulting in stronger material. The reasons for enhanced mechanical properties of concrete might be due to the reason that the in case of MWCNT concrete the nanostructure gets occupied by the MWCNT which in turn makes them more crack resistant during the period of loading. The failure patterns are shown in fig 2 above MWCNT used having the elastic modulus of about 270 -950 GPa in turn increases the stress carrying capacity of the material. For 0.015% MWCNT concrete increase in compressive strength is about 13% more. Hence this proportion of MWCNT into concrete is not having the potential to be advantageous and economical. The total cost used for this proportion is found to be relatively higher than the concrete with admixtures in addition to its strength and durability. The increase in compressive strength shows that agglomeration of nanotube in the cementitious product have been minimised due to proper dispersion of MWCNT in the cement concrete. The agglomeration is mainly resisted by sonication and magnetic stirring process. If the nanotubes are not properly dispersed there might not be any increment in mechanical properties of concrete. MWCNT having larger surface area which in turn improves the concentration of stress in the mortar aggregate interface. The bond cracks existence prior to loading constitutes one of the weakest links in the heterogeneous concrete mix. Such space of existence has been filled up by the existence of MWCNT.

SPLIT TENSILE STRENGTH TEST

The split tensile strength was done as per IS 5816-1999. Cylindrical Specimens of height 300 mm and diameter 150 mm were used for testing. The breaking load (P) and failure patterns are noted as shown fig 1.

Figure 1: Failure of cylinders

The table 2 shows gradual increase in split tensile strength of concrete cylindrical specimens with increase in proportions of MWCNT. The split tensile strength of MWCNT concrete specimen having 0.015%, 0.030% and 0.045%, had a split tensile strength higher than the conventional concrete specimen by 30.83%, 45.38% and 66.3% respectively.

CONCLUSIONS

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

1. The **slump value remains constant** for various proportions of MWCNT in concrete mix.
2. From the results, it is understood that increasing the proportions of functionalized MWCNT into concrete **increases the compressive strength.** The compressive strength of the concrete with a proportion of 0.045% of functionalized MWCNT increases by 26.69% .
3. By increasing the percentage of functionalized MWCNT to the concrete, the **water absorption is reduced** to a greater extent which helps in improving the concrete to be more durable and water resistant. The water absorption for 0.015% functionalized MWCNT into concrete decreases by 10.22% and for 0.045 % addition, the water absorption de-

creased by 17.76%.

4. The split tensile strength increases by with increase in MWCNT. The **split tensile strength increased** by 66.3% for 0.045% of MWCNT.

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