MODIFYING THE STRENGTH AND DURABILITY OF SELF COMPACTING CONCRETE USING CARBON NANOTUBES

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ABSTRACT. Self-compacting concrete is replacing conventional concrete due to the advantage that it does not require vibration and also flows easily through the congested zones of reinforcing bars. Nanotechnology promises significant enhanced material strength which is critical in constructions. Due to their excellent physical and chemical strength, Carbon Nano Tubes are highly used in construction industry mainly in concrete. Cementitious composites are limited to the applications due to their lesser tensile strength and strain capacity. So it becomes a challenge in this modern world to increase the tensile strength of a particular cementitious composite. Cement composites modified by Carbon Nano Tubes have improved strength, water absorption, corrosion and freeze-thaw resistance. In this study, an attempt is made to understand the effect of Multi Walled Carbon Nanotubes, on Self Compacting Concrete (SCC) of M40 grade with different proportion in relation with the weight of cement. By adopting a systematic procedure and adding super plasticizers an attempt is made to make the concrete Self Compacting. The Compressive, Split Tensile, Flexure parameters at various proportions of CNT are tested at different durations. Along with it Durability parameters of Concrete such as Water Absorption and Rapid Chloride Penetration Tests are also studied. The results concluded that on increasing the content of multi walled carbon nanotubes there is significant enhancement in the strength and durability of self compacting concrete. The detail discussion of the same is done in the paper herewith.

Keywords: Self compacting concrete, Carbon nanotubes, Strength, Durability.

INTRODUCTION

Self-compacting concrete is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. Self compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of Self compacting concrete ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. The elimination of vibrating equipment improves the environment near the construction. The improved construction practice and performance, combined with the health and safety benefits, make Self compacting concrete a very attractive solution for both precast concrete and civil engineering construction.

Nanotechnology is an emerging field of science related to the understanding and control of matter at the nano scale (1 to 100 nm). Nanotechnology encompasses nano-scale science, engineering, and technology that involve imaging, measuring, modelling, and manipulating matter at this length scale. Nanotechnology has paved the way to tailor the properties of materials based on particular requirement by working in atomic or molecular level [1].

The development of nanotechnology has enabled the development of concrete with improved physical, mechanical and durability characteristics. It is clear that concrete utilizes nanotechnology because it contains nano-particles as ingredients including nano-water particles and nano-air voids. Carbon nanotubes have very unique properties of very high Young's modulus, high strength, high electrical and thermal conductivity. Reinforcing the cement matrix by Carbon nanotubes allows the development of material with enhanced performance characteristics. Researchers have found that presence of nanotubes affected the morphology of cement hydration products, both the initial C_3A and the C_3S hydration products. It is also observed that Carbon nanotubes accelerated the rate of hydration process by acting as a matrix for the development of C-S-H and $Ca(OH)_2$ produced during the hydration [2]. Carbon nanotubes acts as nucleating agent during cement hydration by providing more sites for the reaction to occur and encourage the formation of reaction products.

In Carbon nanotube reinforced cement composites, the nucleation of the C-S-H on nanotubes slowed the development of C-S-H coating on the surface of cement grains and eventually accelerated the dissolution and nucleation and growth of hydration products as compared to normal cement paste [2]. Grafting of oxygen-containing groups on the surface of Carbon nanotubes enables chemical interaction between the nanotubes and the cement matrix **[**3]**.**

In this paper, the compressive strength, tensile strength, flexural strength and water absorption parameters of self compacting concrete containing various proportions of multi walled carbon nano tube are tested and presented.

EXPERIMENTAL PROGRAM

Materials used

The cement used in the present work was a ordinary Portland cement of 53 grade. The river sand having fineness modulus of 2.82 was used as fine aggregates. Two types of coarse aggregates (Type – I: maximum size 20 mm and Type – II: maximum size 10 mm) were used in the mix. Low calcium, Class F fly ash obtained from the Wanakbori Thermal Power Station, Gujarat, India, was used as the filler material. The super plasticizer used in the work was Glenium ACE 30 RJ. Multi walled carbon nano tubes (procured from Cheap Tubes USA) having properties as shown in Table 1, were used in this work. The transmission electron microscope image of the multiwall carbon nano tube is presented in Figure – 1, in which a multidirectional and even distribution of MWCNT is observed. This intern provides very high surface area available for reaction with concrete constituents.

Table 1 Properties of multi walled carbon nano tubes

Property	Value
Purity	90 %
Outer Diameter	20-40 nm
Inner Diameter	5-10 nm
Length	10-30 μm
Specific Surface Area	> 110 m^2/g
Bulk density	0.07 g/cm^3
True density	~2.1 g/cm^3

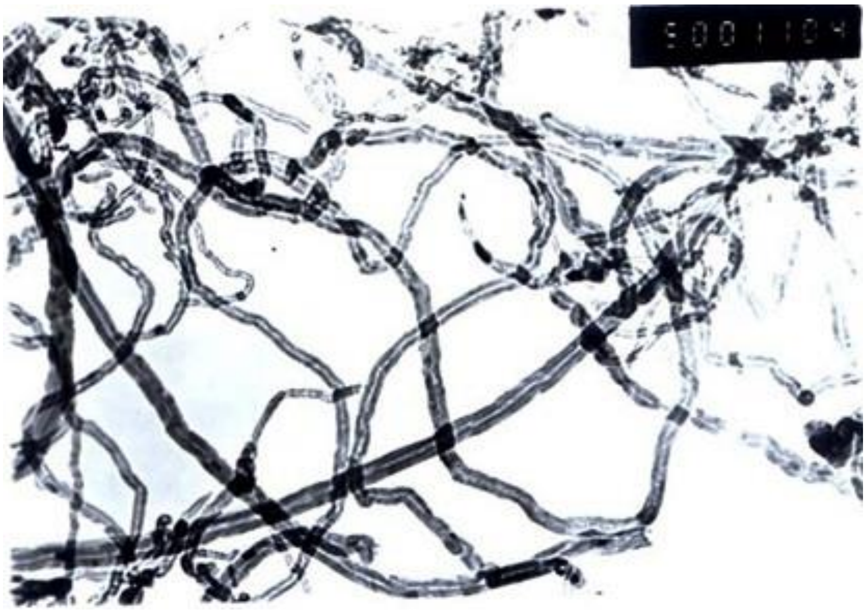

Figure 1 TEM image of multi walled carbon nano tubes

Mix proportion

The mix proportion of self compacting concrete was done as per the European standard “EFNARC” (European Federation of National Associations Representing for Concrete) [4]. The quantities of various ingredients for 1m^3 volume are given in Table – 2. Various mixes designated as shown in Table – 3 were prepared by adding different dosage of multi wall carbon nano tubes.

Table 2 Mix proportion of Self Compacting Concrete for 1 m^3

Grade	Cement (kg)	Coarse Agg–I (kg)	Coarse Agg–II (kg)	Fine Agg (kg)	Fly Ash (kg)	Super Plasticizer (lit)	Water (lit)
M40	393	315	213	601	107	0.5	178

Table 3 Mix Designations of Self Compacting Concrete

Mix Designation	CNT dosage % of Cement weight
SCC 0	0
SCC 0.1	0.1
SCC 0.3	0.3
SCC 0.5	0.5

Tests for qualifying as self compacting concrete

In order to check the flow-ability, passing and filling ability of the SCC, various tests like flow test, L-box test and U-box tests were performed for all mixes as per EFNARC [4] standards.

Figure 2 Slump Flow Test for SCC

The flow property of all the mixes was checked by the slump flow test. The diameter of the flow after 30 seconds for all the tests was found within the limits prescribed by EFNARC standards. A typical flow pattern is shown in Figure – 2 and all the flow values of all the mixes are shown in Table – 4.

Table 4 Slump flow test results

S.No	Mix ID	Flow obtained in 30 seconds	Permissible range as per EFNARC
1	SCC 0	66 cm	60-85cm
2	SCC 0.1	65cm	60-85cm
3	SCC 0.3	69cm	60-85cm
4	SCC 0.5	67cm	60-85cm

The passing and filling ability of the mix were checked by L-box and U-box tests. The results obtained by these tests were within the prescribed limits of EFNARC standards. The results from L-box and U-box are tabulated as shown in Table – 5 and 6 respectively.

Table 5 L Box test results

S.No	MIX ID	H_2/H_1	Permissible limits of H_2/H_1
1	SCC 0	0.83	0.8-1.0
2	SCC 0.1	0.86	0.8-1.0
3	SCC 0.3	0.82	0.8-1.0
4	SCC 0.5	0.88	0.8-1.0

Where, H_1= Horizontal distance on L box filled with concrete, H_2= Vertical distance on L box filled with concrete.

Table 6 U Box test results

Sr.No.	MIX ID	H_2-H_1	Permissible limit of H_2-H_1
1	SCC 0	0	0
2	SCC 0.1	0	0
3	SCC 0.3	0	0
4	SCC 0.5	0	0

Here **H_1**= Distance on U box right side filled with concrete
H_2= Distance on U box left side filled with concrete

Tests for strength and durability

The compressive, split tensile, flexural strength and water absorption tests were carried out for all the SCC samples.

RESULTS

Compressive strength

The compressive strength was measured by casting concrete cubes of standard size and testing them after 7 and 28 days of curing with 0%, 0.1 %, 0.3% and 0.5% dosage of multi walled carbon nano tubes. The results of compressive strength are shown in Figure – 3.

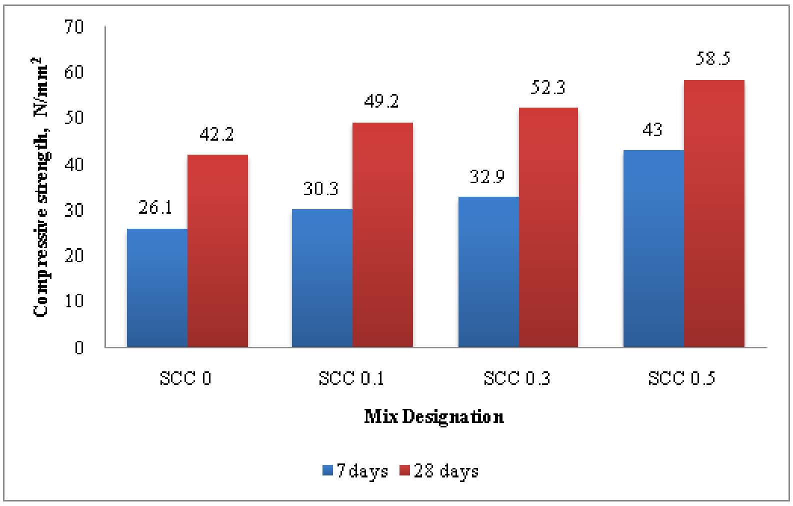

Figure 3 Results of compressive strength for various mixes

Split tensile strength

The tensile strength of concrete was measured by casting standard cylinders.The split tensile strength of the concrete was tested at 28 days with 0%, 0.1 %, 0.3% and 0.5% dosage of multi walled carbon nano tubes. The split tensile strength results are shown in Figure – 4.

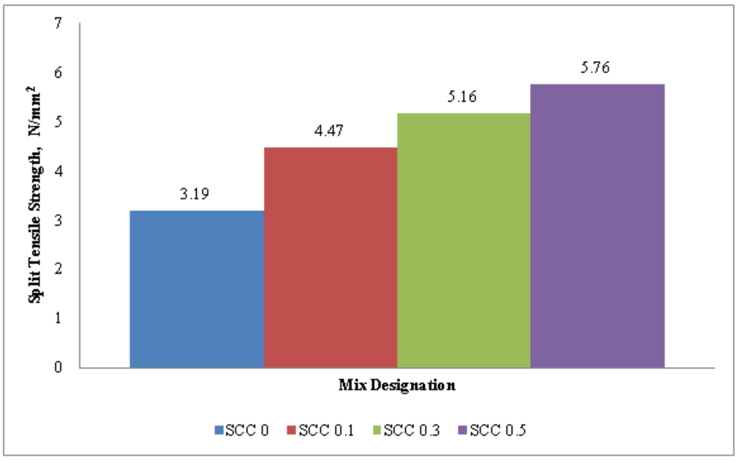

Figure 4 Results of split tensile strength for various mixes

Flexural strength

The Flexure strength of concrete was testedby casting beams of standard size 50cm x 10 cm x 10cm and testing under two point bending test at 28 days with 0%, 0.1 %, 0.3% and 0.5% dosage of multi walled carbon nano tubes. The flexure strength the results are shown in Figure – 5.

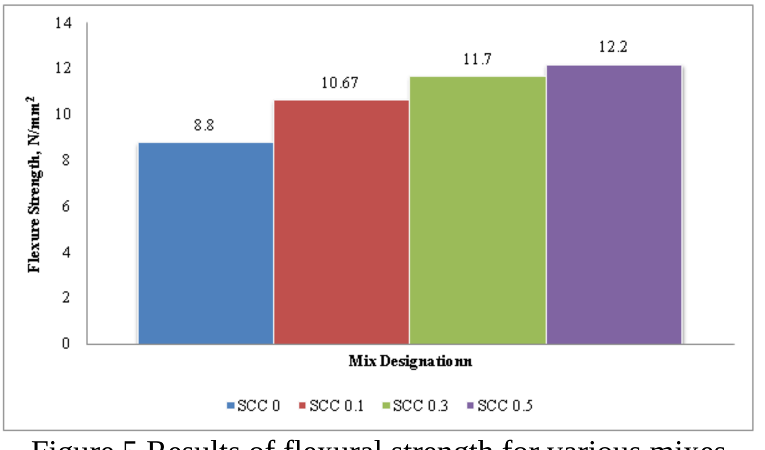

Figure 5 Results of flexural strength for various mixes

Water absorption

The durability of self compacting concrete was measured by performing the water absorption tests with cubes of 5cm x 5cm x 5cm size for 0%, 0.1 %, 0.3% and 0.5% dosage of multi walled carbon nano tubes. The results of water absorption tests are shown in Figure – 6.

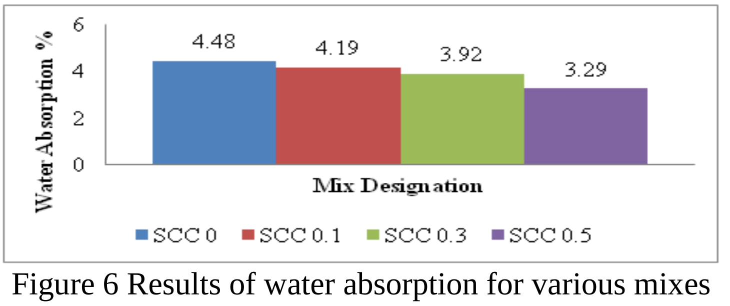

Figure 6 Results of water absorption for various mixes

Rapid chloride penetration test

The Rapid Chloride Penetration test was also performed by casting concrete cubes of standard size and testing them after 28 days of curing with 0%, 0.1 %, 0.3% and 0.5% dosage of multi walled carbon nano tubes and the following results were obtained.

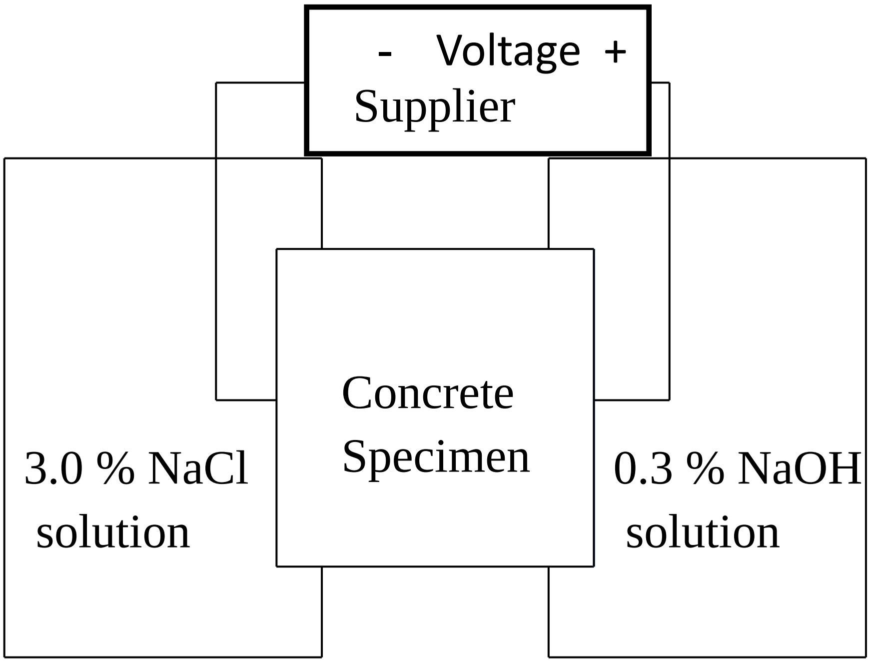

Figure 7 Rapid chloride penetration test mechanism

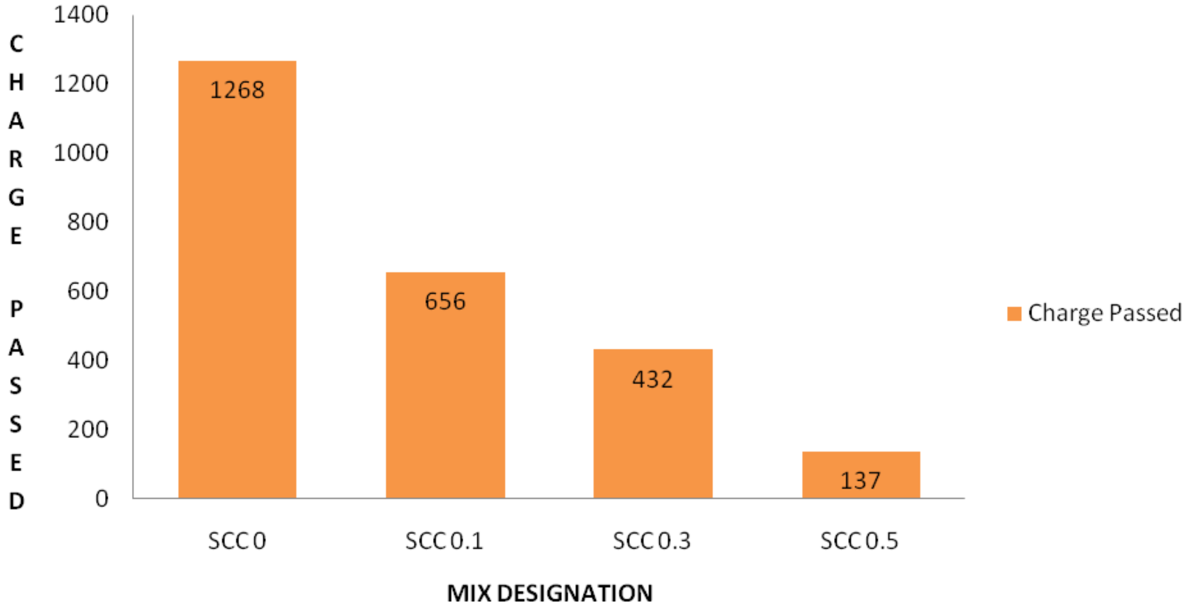

Figure 8 Rapid chloride penetration test results

The self compacting concrete with addition of MWCNT has shown a better performance in mechanical strength improvement as well as reduced water absorption. It can be attributed to the bonding of carbon nano tubes with cement particles. A typical Scanning Electron Microscope (SEM) image of SCC sample with MWCNT is shown in Figure – 9.

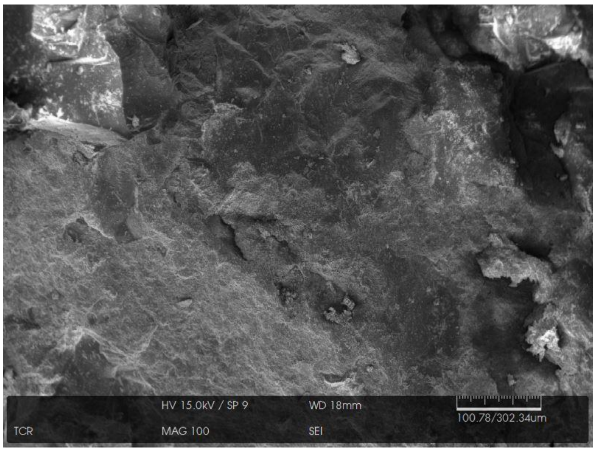

Figure 9 SEM image of concrete with nano tube

CONCLUSIONS

The effect of multi walled carbon nano tubes on the strength (compressive, tensile, flexure) and water absorption of self-compacting concrete is presented. Various dosage of multi walled carbon nano tubes were added to the self compacting concrete mixes. The following are the broad conclusions made from the above test results:

1. The 28 days compressive strength of self compacting concrete mixes containing multi walled carbon nano tubes increases by 16.58%, 23.93% and 38.62% for 0.1%, 0.3% and 0.5% respectively in comparison with self compacting concrete without nano tubes. This is due to increased surface area effect on reactivity and through filling the micro- and nano pores of the concrete. The similar results were obtained for early strength (7days) too.
2. The Split tensile strength of self compacting concrete mixes containing multi walled carbon nano tubes increases by 40.13%, 61.76% and 80.56% for 0.1%, 0.3% and 0.5% respectively in comparison with self compacting concrete without nano tubes.
3. The Flexure strength of self compacting concrete mixes containing multi walled carbon nano tubes increases by 21.25%, 32.95% and 42.05% for 0.1%, 0.3% and 0.5% respectively in comparison with self compacting concrete without nano tubes.
4. The water absorption of self compacting concrete mixes containing multi walled carbon nano tubes decreases by 6.47%, 12.50% and 26.56% for 0.1%, 0.3% and 0.5% respectively in comparison with self compacting concrete without nano tubes. It shows that the addition of CNT in the SCC reduces the porosity of the concrete thereby decreasing the permeability. This parameter shows that the durability of such concrete can be much more than normal concrete as there is a lesser chance of water percolation in the concrete.
5. The chloride penetration of self compacting concrete mixes containing multi walled carbon nano tubes decreases by 48.26%, 65.93% and 89.19% for 0.1%, 0.3% and 0.5% respectively in comparison with self compacting concrete without nano tubes. It shows that the addition of CNT in the SCC reduces the penetration of chloride in concrete.

From the above, it could be concluded that on increasing the content of multi walled carbon nanotubes there is significant enhancement in the strength and durability of self compacting concrete.

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