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PERFORMANCE CHARACTERISTICS OF CARBON - NANOFIBER BLENDED SELF COMPACTING CONCRETE

M.V.N. Sivakumar [1]

Department of Civil Engineering, Birla Institute of Technology and Science,
Pilani, Hyderabad, India

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Semiconducting carbon nanofibers (CNF) are prepared from three different sources, i.e., acetylene, ethanol, and cotton by the chemical vapor deposition (CVD) process. These fibers have rich elastic, engineering and conductivity properties. Fresh self-compacting concrete (SCC) flows into place and around obstructions under its own weight to fill the formwork completely and self-compact, without any segregation and blocking. To obtain maximum benefit from SCC, it has to be adopted in general concrete construction practice. Such practice requires inexpensive and medium strength concrete. This investigation aims to develop a medium strength carbon nanofiber self-compacting concrete (CNFSCC), which improves the fracture resistance characteristics of the concrete. In addition to that, the mechanical and structural properties of self-compacting concrete containing carbon nano-fiber with different concentration are experimentally studied by conducting suitable tests. The test results indicate that the presence of a reasonable concentration of CNF not only enhances mechanical performance, but also improves the structural characteristics of SCC.

Keywords: carbon nanofibers, self-compacting concrete, special concretes, concrete characteristics

1. Introduction

Self-Compacting Concrete (SCC) is defined as a concrete that exhibits a high deformability and a good resistance to segregation. In addition to that it has a high flowability and can be placed without vibration. This kind of concrete is of great interest and has gained wide use especially in

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[1] Assistant Professor

Correspondence to: Dr. M.V.N. Sivakumar, Department of Civil Engineering, Birla Institute of Technology and Science, Pilani–Hyderabad Campus, Jawahar Nagar, Shameerpet, India, E-mail: sivakumar.mvn@gmail.com

the case of difficult casting conditions such as conjusted reinforcement and heavily reinforced sections. High tensile strength, electrical conductivity and superior elasticity properties are typical advantages of carbon fibers. Hence it became an attractive admixture for fiber reinforced concrete (Dhonde et al., 2007).

The three properties that characterize a concrete as self-compacting are flowing ability - the ability to completely fill all areas and corners of the formwork into which it is placed, passing ability - the ability to pass through congested reinforcement without separation of the constituents or blocking, resistance to segregation - the ability to retain the coarse components of the mixture in suspension in order to maintain a homogeneous material. Concretes blended with nano-particles are superior to normal concrete because the small size (10^{-9}) of the particles allows for a homogeneous dispersion throughout the cement-concrete matrix.

The dispersal property of carbon nanofibers is the greatest problem encountered during most of the applications when it is used in conventional concrete. But SCC can help CNFs’ dispersal due to its high flowability which traditional concrete does not have. Well dispersed CNFs facilitate uniform Calcium Silicate Hydrate (CSH) gel formation and improve the performance of nano-composites (Xiao H et. al 2003). The present study is focused to make SCC feasible by using carbon nanofibers. The significance of this research is to investigate the feasibility of using carbon nanofibers in medium strength SCC and its optimum dosage to achieve the best performance characteristics in respect of its structural and fracture parameters and their coupled effects on the relevant properties to reduce the risk of cracking due to the heat of hydration, and therefore improved the durability.

2. Material Properties

The concrete mixtures investigated in this study are prepared with standard 43 grade Portland cement. The cement used conformed to Standard IS 4031- Part 1. Continuously graded crushed basalt aggregate with a nominal particle size of 15 mm is used. Well-graded quartzite sand, with a fineness modulus of 2.72, is employed. The relative density values of the coarse aggregate and sand are 2.80 and 2.52, and their absorption rates are 0.9% and 1.2%, respectively. The grain-size distributions of the coarse aggregate and the sand are given in Table 1. A superpasticizer Conplast SP337 conforms to IS: 9103-1999 is used with 32% solid content and a specific gravity of 1.08.

The coarse aggregate (crushed basalt) had a 15mm maximum size. The maximum aggregate size is selected 15mm in order to avoid the blocking effect in the L-box. The gap between rebars in L-box test was 35 mm. As fine aggregate, a mixture of crushed 0–5mm limestone and natural river sand is used. The grading curve of the aggregate mix is illustrated in Figure 1.

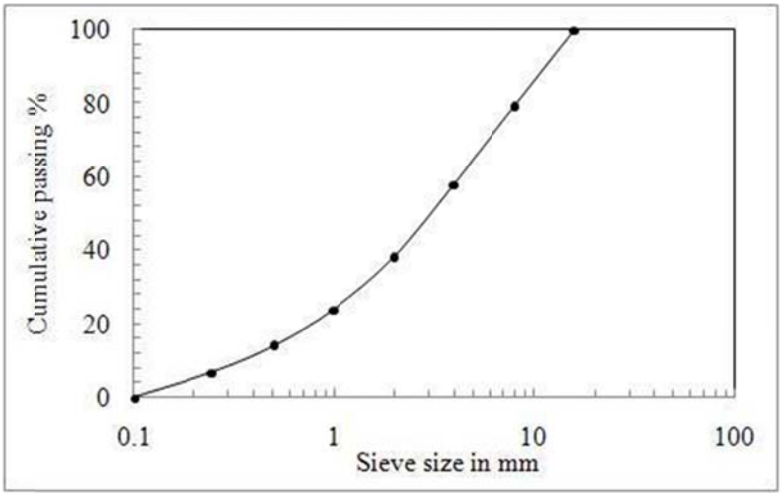

Figure 1. Aggregate grading of SCC mixtures

3. Mixture Proportions

Four SCC mixtures are designed in order to obtain different fresh-state properties. The water content has been reduced and superplasticizer dosage has been increased at the same time to obtain the target slump-flow values. It should be noted that in particular the flowability of mixtures with low water/cement ratios was achieved by abnormally increasing the super plasticizer dosage. Cement content and aggregate grading are kept constant in all mixtures. The compositions of mixtures are presented in Table 1.

Table 1. Mixture proportions

Materials	Weight (kg/m^3)				
	SCC	NCSCC1	NCSCC2	NCSCC3	NCSCC4
Carbon nanofiber (% vol.binder)	0	0.5	1.0	1.5	2.0
Portland cement	354	356	355	357	356
Free water	220	222	220	223	220
Coarse Aggregate	550	552	554	558	556
Fine Aggregate	850	854	852	858	856
Superplasticizer (CONPLSTSP337)	3.0	3.5	6.0	7.2	8.4
W/C (by weight)	0.40	0.48	0.42	0.40	0.38
Unit weight (kg/m^3)	2255	2250	2265	2260	2254

As shown in Table 1, four mixtures are prepared and studied. The mixing sequence consisted of homogenizing the sand, the coarse aggregate, limestone powder and cement in a free fall non-tilting horizontal axis type laboratory mixer. After incorporation of water, superplasticizer was finally introduced to the wet mixture. Twenty percent of the batch was used for fresh concrete tests. The remaining part was used to prepare specimens without any vibration in order to determine the mechanical properties.

For determining the self-compactibility properties, tests are performed and air content of the mixtures was measured. All fresh test measurements are duplicated and the average of measurements is noted. In order to reduce the effect of workability loss on variability of test results, the fresh-state properties of mixtures are determined in a period of 30 min after mixing.

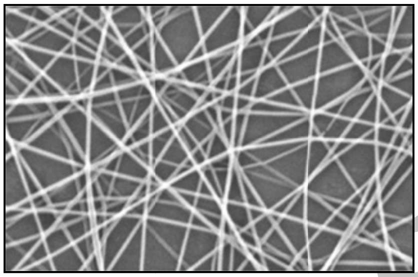

Figure 2. Randomly placed carbon nanofibers

The binder weight includes the total weight of cement and fiber. Herein SCC denotes self-consolidating concrete without fibers. Hence, it is attempted to mix the CNFs in amounts of 0.5%, 1.0%, 1.5%, 2.0% by volume of the binder. Blenders are used to prepare cabon nanofiber, water mixtures. Superplasticizer was added to the blender without any additional mixing. Meanwhile, coarse aggregate, sand and cement were combined in a centrifugal mixer and mixed for 4-5 minutes. Then, the CNF mixture was slowly transferred into the mixer and stirred for several minutes to achieve good workability.

For the above mentioned concrete in order to achieve self-compactible highly flowable mixtures, acceptance criteria can be summarized in the following steps:

Step 1: Mixtures with a slump flow value between 65 and 80 cm are accepted. According to this criteria mixtures I–IV fulfilled this requirement.

Step 2: Mixtures with a V-funnel time below 20 seconds are accepted. The mixtures having V-funnel times higher than the upper limit tend to entrap air due to the high viscosity. In this experimental study no visual stability loss has been observed.

Step 3: The mixtures having L-box blocking ratio below 0.6 may have a tendency of blockage between reinforcement due to the high viscosity. All the above mixturs are satisfying the requirement.

The compressive strength is obtained on cubes, cylinders. Flexural strength and tensile strength are obtained using beams and cylinders respectively. Specimens are demolded after 1 day casting and then cured in water at room temperature until tested. Six specimens of each mixture are tested and the mean value was reported.

The splitting tensile strength was determined at 28 days on cylinders measuring 150mm diameter and 300mm height and cured in water until the date of test according the IS: 5816 -1999. Three specimens of each mixture were tested and the mean value was reported.

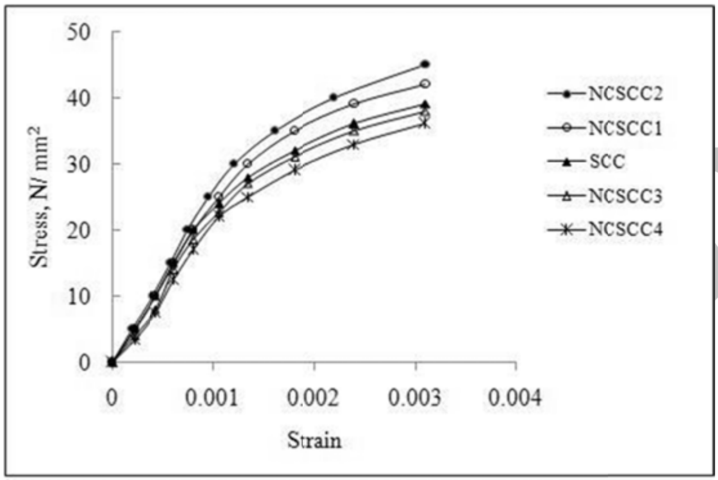

Figure 3. Stress vs. Strain for SCC specimens with varying concentrations of CNFs

Compressive strength tests are carried out at 7 and 28 days as per IS: 516-1959. Flexural strength and splitting tensile strengths of specimens are also determined at 7 and 28 days. It is clear that a rapid strength development can be obtained by reducing the free water content and thereby W/C. When the strength development is in question, water reduction is more dominant than the retardation effect of superplasticizer at higher dosages.

SCC may exhibit different stress–strain behavior relationship since SCC mixtures have a lower amount of coarse aggregate. Various studies on modulus of elasticity of SCC resulted with conflicting conclusions.

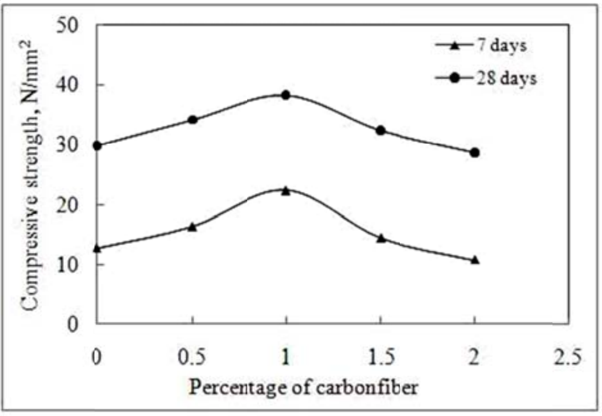

Figure 4. Details of compressive strength results

Figure 3 shows Stress vs. Strain Curves of different concrete mixtures. It is clearly evident that the mixture with different percentages of fibers has shown different peak values. The mixture with 1.0% dose of fiber has shown higher values of stress representing the enhanced behavior. The graph shows higher values of stress for constant strain with 0.5%, 1.0% dosages of fiber. It reveals that the mechanism between nanofibers and concrete improves the engineering properties of the mixture.

The characteristic compressive strength increased around 29.4% when the CNF concentration is 1.0%. The details of results are shown in Figure 4. This indicates the best concentration among these mixtures is around 1.0% in addition to that the above results show that the stiffness of SCC containing CNFs mix is greater than normal SCC mixture.

Figure 5 shows the details of the flexural strength of the different concrete mixtures. The flexural strength is evaluated at an age of 7 days and 28 days according to IS:516-1959. The flexural strength increased in the initial stage with 0.5% and 1.0% dosage of fiber and later decreases as the percentage of fiber increases. However, the trend is similar and the concrete still can be sensitive in engineering behavior when apply load on it if containing appropriate amount of CNFs.

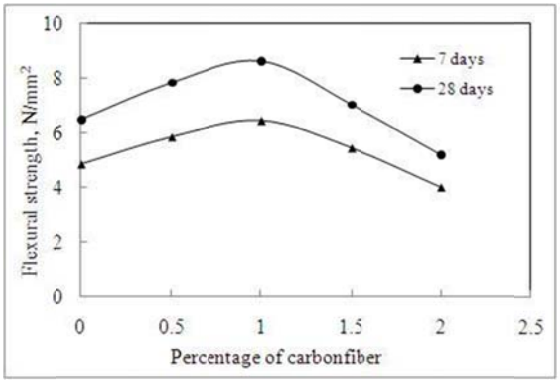

Figure 5. Details of flexural strength results

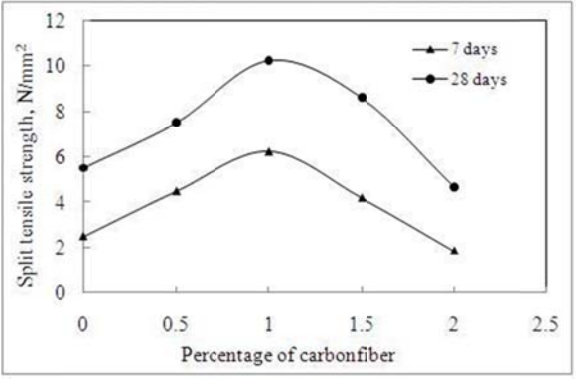

Figure 6. Details of tensile strength results

Similarly, Figure 6 shows the performance of normal SCC and CNFSCC in split tensile test according the IS: 5816 -1999. The maximum variations are about 0.6% for NCSCC2. It is observed that the variations are smaller in this case because the concrete is subjected to combined compressive and tensile stresses instead of a simple compressive stress in the experiments conducted. Here also the trend is observed to be similar to that of earlier cases.

4. Conclusions

The above experimental program leads to emphasize the effects of carbon nanofibers on the rheological properties of concrete. It is observed from the results that the presence of carbon nanofiber increases the overall performance of the concrete. The enhancement in engineering properties has clearly shown in all the above mentioned experiments. Basically the superiority of the self-compacting concrete mainly lies in the strength and durability characteristics of the concrete mixture.

The maximum gain in strength and stiffness is achieved at 1.0% concentration of fiber. This is due to well dispersion of nanofibers in the mixture at that particular volume. In all the experimental cases the trend shows improvement in 0.5%, 1.0% concentrations only. Later in 1.5%, 2.0% concentrations it shows the downward trend. From this we can observe that the presence of larger concentration of fibers is the cause for the decreased performance of the concrete mixture. In case of mixtures with higher concentration of fibers, it is observed that these fibers are dispersed randomly and leaving provision for less stiffness because of their excess presence. Hence it is meant that an optimum dosage will result in the best performance.

Optimum dosage of the fiber is found to be 1.0% from the above studies. At this concentration it has shown its well dispersed nature and subsequent enhancement in strength and stiffness of the concrete mixture. Finally, test results enable us to understand the effect of carbon nanofiber and its performance in association with self-compacting concrete to design superior concrete mixture with best strength and stiffness properties.

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