Experimental Studies on Durability Characteristics of Next Generation Nano Based Carbon With Fiber Reinforced Concrete

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Abstract- *This paper presents the detailed experimental studies on Durability characteristics on carbon nanotubes concrete modified with carbon and polypropylene fiber integrated with High performance concrete (HPC) of grade M60, which reviews advancement in the field of fiber reinforced cementitious composites. Cement concrete is a great source for the construction of buildings, bridges,dams and infrastructures etc., because of its high compressive strength but it has resistance to limited tensile and flexural strength. Thus, for improving its properties, cement concrete is reinforced with fibers, carbon nanotubes (CNTs) and polypropylene fibers. CNT reinforced cement concrete enhances tensile and flexural strength in comparison to fiber reinforced cement composite materials. Though significant research has not been done in this area over the past decade, but more challenges are need to be addressed. For durability tests Acid attack, Sulphate attack and Water absorption are performed as per the specifications of ASTM. The test specimen consists of M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF concrete matrices. The present experimental results have shown that there is an improvement in durability properties in concrete by incorporating carbon fiber, Carbon Nano Tubes and polypropylene fiber. It has been recognized as a finer reinforcement which can reduce water absorption and increase acid and sulphate attack resistance of concrete matrices. The results proved that the durability has improved for M60+CNT+PF+CF in comparison with other concrete matrices.*

Keywords- High Performance Concrete(HPC), Carbon Nanotubes(CNTs), Carbon fibers, Polypropylene fibers.

I. INTRODUCTION

Concrete is the requisite engineering material used in most of the structural engineering. Its vogue as the basic building material in construction is because of its economy, strength, durability, and the ease with which it can be produced at the site. Durability in concrete is an important characteristic to assure serviceability, long life and cost effectiveness. However, over the past several years, structural deterioration has become a critical issue. A more economical approach is to prevent deterioration and avoid the resulting high cost of the rehabilitation and replacement with durable concrete. The solution for the durability characteristics is to improve the resistance to acid attack, sulphate attack and water absorption. The key to damage-resistant concrete and long-life concrete structures, which has been known for a long time lies in enhancing the strength and durability of concrete material which is achieved by reinforcing fibers in concrete by incorporating carbon fiber, Carbon Nano Tubes, polypropylene fibers.

II. LITERATURE REVIEW

Durability is a major concern for concrete structures exposed to aggressive environments. When Reinforced concrete structures are exposed to harsh environments, deterioration of concrete will occur due to many reasons like chloride attack, sulphate attack, acid attack and corrosion of reinforcement [11,13,17] etc. The rate of deterioration of concrete subjected to chemical attack depends not only upon the nature of chemicals but also upon the permeability of concrete and passivating effects of the reaction products [1,10,15]. Fibers are used to increase the strength and durability aspects of the concrete structures. Carbon fibers also offer an economical benefit as they are readily available as a waste product from the aerospace industry and offers 2 to 5 times more rigidity

than the other fibers. Carbon fibers possess many potential benefits over other fibers, including a higher strength, higher modulus of elasticity, and increased durability [16,18]. Addition of fibers to the concrete enhances properties of the ductility, tensile strength, flexural strength. Furthermore, adding fibers reduces the possibility of spalling and scabbing failures, prevents crack propagation, and extends the softening region in the concrete matrix[7,12]. The use of fly ash and silica fume is becoming more common because they improve concrete durability and strength, especially where high early age curing temperatures occur [9].From the literature survey it is found that the progress in the area of CNT, Carbon fiber with integration of HPC has been fairly low, partly due to the high material cost and partly to lack of experimental data for new composite. Hence, in the present experimental investigation an attempt has been made to use CNTs, Polypropelene fibers, Carbon fibers to integrate with high performance concrete on durability characteristics in particularacid attack, sulphate attack and water absorption.

III. EXPERIMENTAL PROGRAM

The present experimental program was designed to investigate the durability characteristics on carbon nanotubes concrete modified with carbon and polypropylene fiber integrated with High performance concrete (HPC) of grade M60.The experimental studies include casting, curing and testing of sixty (45) number of cube specimens having sizes 150mm and 100mm respectively. All the test specimens are cured for 28 days. Acid attack test as per ASTM C 267-01(2012),sulphate attack test as per ASTM C 452-02(2002) and water absorption test as per ASTM C 642(2006)were conducted. The five different concrete matrices considered in present experimental investigations are viz.,(i)M- 60 (M-60 Grade of concrete, control mix), (ii)M-60+CNT (Carbon Nano Tubes combined with M-60 Grade of concrete),(iii)M-60+CNT+PF (Carbon Nano Tubes and Polypropylene Fibers combined with M-60 Grade of concrete), (iv) M-60+CNT+CF (Carbon Nano Tubes and Carbon Fibers combined with M-60 Grade of concrete), (v) M-60+CNT+PF+CF (Carbon Nano Tubes, Carbon Fibers and Polypropylene Fibers combined with M-60 Grade of concrete).Three cube specimens of size 150 mm each, for acid attack, sulphate attack tests and 100 mm cube for water absorption were used.

3.1 MATERIALS

In present experimental investigation,Special Grade Portland cement (53-S) conforming to IRS-T-40-1985 was used. Physical properties of cement were conducted in accordance with the Indian standards confirming to IS-12269:1987. Manufacture sand(M-sand), Crushed angular coarse aggregate of size 20 mm and 10mm has been used. The tests on the fine aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1964 (Reaffirmed-2002)and confirmed Zone-II for requirement as per IRS T-39 Specifications. The tests on the coarse aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1963 (Reaffirmed-2002). Auracast 270M as Super Plasticizer (chemical admixture), Silica fumes supplied byElkem India Pvt. Ltd, Navi Mumbai and Ground Granulated Blast Furnace Slag (GGBFS) supplied by Nuvoco Vistas Corporation Limited, (formerly Lafarge India Ltd.), Bangalore as mineral admixtures. Polypropylene fibers (Recron 3S) supplied by Ranka Udyog, Pvt, Ltd, Bangalore. Carbon fibres of 6mm chopped length supplied by M/s Baseer Fibers Private Limited, Bengaluru, CNTs supplied by Sigma-Aldrich and ordinary potable water were used. Mix design is carried as per ACI 211.4R-93 method and the mix proportions for Next Generation Nano Based Carbon with Fiber Reinforced Concrete matrix was arrived after trail mixes and their compressive strength for M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF are tabulated in table 1.

Table 1: Compressive strength for 7,15& 28 days

Properties	Age	M60	M60+CNT	M60+CNT+PF	M60+CNT+CF	M60+CNT+PF+CF
	(Days)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
Compressive strength	7	**39.60**	**40.20**	**40.80**	**41.40**	**42.00**
	15	**60.12**	**60.94**	**61.55**	**62.98**	**65.22**
	28	**67.53**	**69.47**	**70.31**	**72.15**	**74.90**

3.1.1. Dispersion of CNTs

The CNT is allotrope of carbon with multiwall. It has to be breakdown by ultrasonication for dispersion through state of art method. The dispersion of CNTs has been done at AZYME BIOSCIENCE PVT. LTD. BANGALORE, first the required water, surfactant and CNTs are measured and then mixed together. In order to ensure a well-dispersed solution, an ultrasonic mixer is used, which can deliver up to 500 watts at 20 kHz. An ultrasonic mixer is a device that uses a high frequency driver to transmit acoustical energy throughout a liquid medium. The energy in the shock waves are extremely high and significantly accelerates chemical reactions and breaks the clumps and agglomerations of particles. To reduce the chances of breaking the nanofilaments, CNTS are mixed for 20 minutes.

3.2 MIX PROPORTIONS

The concrete mix having a compressive strength of 60 N/mm^2 was aimed in the present research investigation, the design mix proportion was obtained by **ACI 211.4R-93**

Method of mix design for high strength concrete. Based on the same, the mix proportions arrived are tabulated in table 2. The Polypropylene fibre, carbon fiber, Auracast 270M, Silica Fumes, GGBS and CNT's were included in this mix proportion as per the predetermined optimum percentages subject to the required workability. 8% of Silica Fumes is replaced by weight of cement, 21.6% of GGBS as replaced by weight of cement, 0.125% of carbon nano tube (CNT) has been replaced by weight of cement, 900gm/cubic meter of volume of concrete of polypropylene fibres, 0.5% of volume of concrete of carbon fibers and 0.4% of Super plasticizer by weight of cement were included into the concrete mix in the present investigation.

Table2: Mix proportions for different concrete matrices

Mix	cement	Fine aggregate	Coarse aggregate	w/b	water	Carbon fibre	Polypropylene fibre	Super plasticizer	GGBS	Silica fumes	CNT
Specimens	(kg/m³)	(kg/m³)	(kg/m³)		(kg/m³)	(kg/m³)	(kg/m³)	(litres/m³)	(kg/m³)	(kg/m³)	(litres/m³)
M60	450	477.69	1124.64	0.26	168.15	-	-	2.02	138.2	51.15	-
M60+CNT	450	477.69	1124.64	0.26	168.15	-	-	2.02	138.2	51.15	0.63
M60+CNT+ PF	450	477.69	1124.64	0.26	168.15	-	0.9	2.02	138.2	51.15	0.63
M60+CNT+ CF	450	477.69	1124.64	0.26	168.15	8.8	-	2.02	138.2	51.15	0.63
M60+CNT+ PF+CF	450	477.69	1124.64	0.26	168.15	8.8	0.9	2.02	138.2	51.15	0.63

IV. METHODOLOGY OF TEST

The experimental test program includes the following testsas per German standard and ASTM specifications different concrete matrices.

4.1 Acid attack test: Acid attack test was carried out as per ASTM C 267-01 (2012) method, which consists of cube specimens of size 150 mm were casted and cured for 28 days. The initial weight of test specimens and compressive strength were taken. Then after 28 days of water curing again the test specimen subjected to extended curing by adding calculated amount of 5% of concentrated Sulphuric acid by weight to the curing water. After 56 days (28 days water curing+28 days acid solution) then specimens are taken out from acid solution and outer surfaces are cleaned properly. The final weight, visual appearance and compressive strength were determined. The resistance to acid attack is obtained from differences in weight and the compressive strength before and after the acid attack test.

4.2 Sulphate attack test: Sulphate attack test was carried out as per ASTM C 452-02 (2002) method, which consists of cube specimens of size 150 mm were casted and cured for 28 days. The initial weight of test specimens and compressive strength were taken. Then after 28 days of water curing again the test specimen subjected to extended curing by adding calculated amount of 5% of sodium sulphate by weight to the curing water. After 56 days (28 days water curing+28 days base solution) then specimens are taken out from base solution and outer surfaces are cleaned properly. The final weight, visual appearance and compressive strength were determined. The resistance to sulphate attack is obtained from differences in weight and the compressive strength before and after the sulphate attack test.Figure 1 shows specimens curing in 5% H_2SO_4 and 5% Na_2SO_4.

Figure 1: Specimens curing in 5% H_2SO_4(acid attack test) and 5% Na_2SO_4(sulphate attack test)

4.3 Water absorption test: Water absorption test was conducted as per ASTM C 642 (2006) specifications. It employs a cube specimen of 100 mm size and cured for 28 days. Determine the mass of test specimen and dry in an oven at a temperature of 100^0 to 110^0 C for not less than 24 hours. After removing each test specimen from the oven, allow it to cool in dry air (preferably in desiccator) to a temperature of 20 to 25^0 C and determine the mass A. Determination of final surface dry mass B after immersion in water at approximately 21^0 C for not less than 48hours. Percentage of Water absorption=[(B-A)/A]x100.

V. RESULTS AND DISCUSSIONS

The experimental values obtained for Water permeability, acid attack test, sulphate attack and water absorption test in the present investigation are tabulated in following tables and corresponding graphs.

5.1 Results for Acid attack test

In the present experimental investigation, the Acid Attack test employs for a hardened concrete cube specimen(28 days cured in water) of 150 mm size were immersed in 5% of concentration Sulphuric Acid solution for a period of 28 days in acid solution. The result of final weight and compressive

strength after 56 days of total immersion are tabulated in table no 3, 4 and figure 2, 3and 4.

Figure 2: Compression test under progress after total immersion of 56 days

Table 3: Percentage weight loss of test specimens before and after immersion in 5% H_2SO_4 solution for acid attack test

Sl No	Type of concrete Specimen	Weight of specimen before immersion in acid (kg)	Weight of specimen after immersion in acid (kg)	% weight Loss	% weight Loss ratio w.r.t NC
1	M60 (Control mix)	8.48	7.75	8.61	1.00
2	M60+CNT	8.55	7.85	8.19	0.95
3	M60+CNT+PF	8.29	7.63	7.96	0.92
4	M60+CNT+CF	8.61	8.02	6.85	0.80
5	M60+CNT+CF+PF	8.19	7.84	4.27	0.50

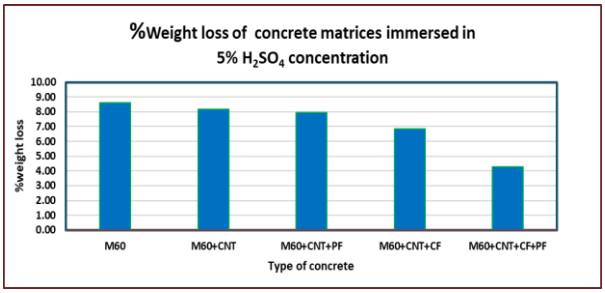

Figure 3: Percentage weight loss of test specimens after immersed in 5% H_2SO_4 solution

Table 4: Percentage Compressive Strength loss of test specimens after immersed in 5% H_2SO_4 solution

Sl No	Type of concrete Specimen	Compressive strength N/mm^2	Compressive strength after 28 days of immersion in acid(N/mm^2)	% Strength Loss	% Strength Loss ratio w.r.t NC
1	M60 (control mix)	67.53	28.22	58.21	1.00
2	M60+CNT	69.47	31.11	55.22	0.94
3	M60+CNT+PF	70.31	35.11	50.06	0.86
4	M60+CNT+CF	72.15	37.77	47.65	0.81
5	M60+CNT+CF+PF	74.9	40.89	45.41	0.78

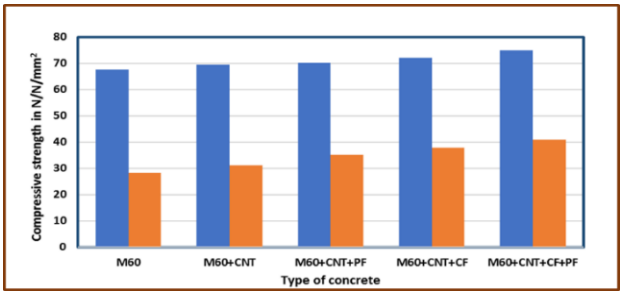

Figure 4: Percentage compressive strength loss of test specimens after immersed in 5% H_2SO_4 solution

Table 3and figures 3 shows the %weight loss of different test specimensviz M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M60+CNT+PF+CF are 8.61%, 8.19%,7.96%, 6.85% and 4.27% respectively**.** It is can be seen that the reduction in weight is lowest in case of M60+CNT+PF+CF test specimen as compared to other test specimens under consideration.

Table 4and figures 4 shows the results of % loss in compressive strength of various test specimens after immersed in 5% H_2SO_4 for M-60, M-60+CNT, M60+CNT+PF,M60+CNT+CF,M60+CNT+PF+CF are 58.21%, 55.22%, 50.06%, 47.65% and 45.41% respectively**.** It is found that the reduction in compressive strength is lowest in case of M60+CNT+PF+CF test specimen as compared to other test specimens under consideration.

5.2 Results of Sulphate Attack Test

In the present experimental investigation, the sulphate Attack test employs a hardened concrete cube specimen of 150 mm size(28 days cured in water) and subsequently same test specimen was immersed in 5% of sodium sulphate solution for a period of 28 days in base solution. The results of final weight and compressive strength after 56 days of total immersion(water + base solution)are tabulated in table no 5and 6 and figure 5, 6 and 7 respectively.

Figure 5: Compression test under progress

Table 5: Percentage Weight loss of concrete matrices immersed in 5% Na_2SO_4 solution

Sl No	Type of concrete Specimen	Weight of specimen before immersion in base (kg)	Weight of specimen after immersion in base (kg)	% weight Loss	% weight Loss ratio w.r.t NC
1	M60 (Control Mix)	8.185	8.175	0.1222	1.000
2	M60+CNT	8.345	8.335	0.1198	0.981
3	M60+CNT+PF	8.365	8.355	0.1195	0.978
4	M60+CNT+CF	8.425	8.415	0.1187	0.972
5	M60+CNT+CF+PF	8.435	8.425	0.1186	0.970

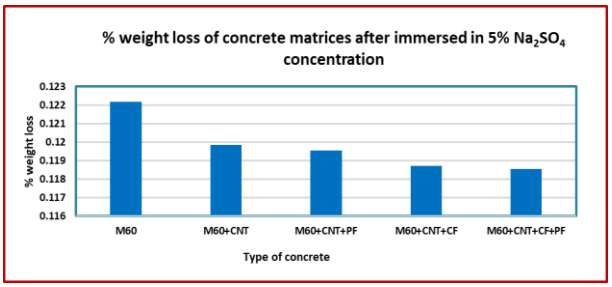

Figure 6: Percentage weight loss of concrete matrices after immersed in 5% Na_2SO_4 solution

Table 6: Percentage Compressive Strength loss of concrete matrices after immersed in 5% Na_2SO_4 solution

Sl No	Type of concrete Specimen	Compressive strength N/mm²	Compressive strength after 28 days of immersion in base(N/mm²)	% Strength Loss	% Strength Loss ratio w.r.t NC
1	M60 (Control Mix)	67.53	40.22	40.44	1.00
2	M60+CNT	69.47	48.44	30.27	0.75
3	M60+CNT+PF	70.31	52.88	24.79	0.61
4	M60+CNT+CF	72.15	56.22	22.18	0.55
5	M60+CNT+CF+PF	74.90	58.66	21.68	0.54

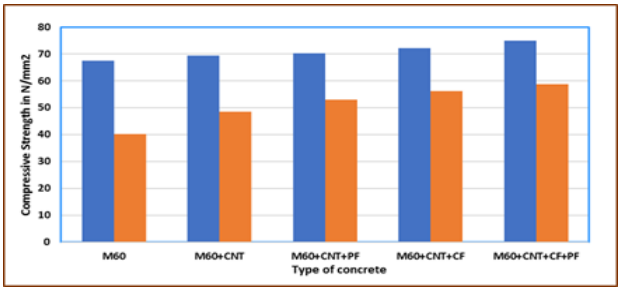

Figure 7: Compressive Strength before and after immersion in 5% Na_2SO_4 solution

Figure 6 and Table 5 shows the results of % weight loss due to sulphate attack on various test specimens viz: M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M60+CNT+PF+CF are0.1222%, 0.1198%, 0.1195%, 0.1187% and 0.1186% respectively. It is can be seen that the reduction in weight is lowest for M60+CNT+PF+CF test specimen and followed by M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF.

Figures 7 and Table 6 shows the results of % loss in compressive strength of various test specimens after immersed in 5% Na_2SO_4 for M-60, M-60+CNT, M-60+CNT+PF,M-60+CNT+CF,M60+CNT+PF+CF are 40.44%, 30.27%, 24.79% ,22.18% and 21.68 %respectively**.** From the experimental results it can be seen that reduction in compressive strength is lower in case of M60+CNT+PF+CF test specimens as compared to other test specimens under consideration.

5.3 Water absorption test

The Water absorption test for concrete employs a cube specimen of 100 mm size and cured for 28 days. The experimental obtained water absorption values for M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF test specimens are tabulated in Table 7.

Table 7: Water absorption of different concrete matrices

Type of concrete matrix	Weight of oven dried sample	Weight of sample after 24 hours of immersion in water	Water absorption in %
M60 (control Mix)	2.76	2.84	2.90
M60+CNT	2.84	2.92	2.82
M60+CNT+PF	2.65	2.73	3.02
M60+CNT+CF	2.86	2.94	2.80
M60+CNT+PF+CF	2.57	2.64	2.72

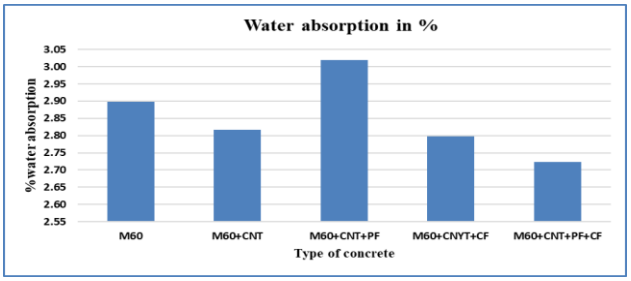

Figure 8: Water absorption of different concrete matrices

From Table7 and Figure 8, the obtained water absorption values for M-60, M-60+CNT, M60+CNT+PF, M60+CNT+CF, M60+CNT+PF+CF test specimens are 2.90%, 2.82 %, 3.02%, 2.80%, 2.72 % respectively. It can be seen that the variation in water absorption is from 2.72% to 3.02%. Whereas in case ofM-60+CNT+PF+CF the % water absorption is least as compared to the other test specimens.

VI. CONCLUSION

Based on the experimental investigation results the following conclusions are drawn.

A number of variables can cause changes in the physical and durability properties of concrete. These include the composition of concrete mix, type of aggregate and their size and shape, admixtures and addition of fibers and other supplimentary reinforcing materials.

(1) For acid attack test, the percentage weight loss of M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF and M-60+CNT+CF+PF test specimensare8.61%,8.19%,7.96%,6.85%and 4.27%respectively. And percentage strength loss are58.21%,55.22%,50.06%, 47.65% and 45.41% respectively. Percentage weight loss and strength loss are least in case of M60+CNT+PF+CFtest specimenin comparison with other test specimens.

(2) For sulphate attack test, the percentage weight loss of test specimensviz: M-60, M-60+CNT, M-60+CNT+PF,M60+CNT+CF,M60+CNT+PF+CF are 0.1222%, 0.1198%, 0.1195%, 0.1187% and 0.1186% respectively. The percentage loss in compressive strength are 40.44%, 30.27%, 24.79%,22.18% and 21.68 % respectively**.** Percentagereduction in weight and compressive strength is lower in case of M60+CNT+PF+CF test specimen as compared to other test specimens.

The percentage of water absorption capacity for M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF are2.90%, 2.82%, 3.02%, 2.80% and 2.72%. It can be seen that the variation in water absorption isfrom2.72% to 3.02%. Whereas in case ofM-60+CNT+PF+CF the % water absorption is least as compared to other test specimens.

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