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Experimental Studies on Compression and Flexure Test on Nano based Carbon Fiber with Reinforced Concrete

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Abstract **-This paper presents the experimental studies on compression and flexure strength test on carbon nanotubes concrete modified with carbon and polypropylene fiber integrated with High performance concrete (HPC) of grade M60. High performance concrete (HPC) is a specialized series of concrete designed to give optimized performance characteristics for a given set of load, usage and exposure conditions consistent with the requirements of cost, service life and durability. Few research investigations on concrete members have shown that there is improvement of strain capacity in concrete by incorporating carbon fiber or Carbon Nano Tubes, use of fiber especially polypropylene has been recognized as a finer reinforcement which can reduce brittleness and increase the load carrying capacity of concrete members. This research includes experimental study on the compression and flexure test as per the specifications of IRS T-39 on carbon nanotubes concrete modified with carbon and polypropylene fiber test specimens in comparison with conventional concrete. The results proved that the compression and flexure strength has increased for M60+CNT+PF+CF in comparison with other concrete matrices in the present experimental investigation.**

key words: High Performance Concrete(HPC), Carbon Nanotubes(CNTs), Carbon fibers, Polypropylene fibers, Compression test, Flexure test

1. INTRODUCTION

Concrete plays a vital role in civil engineering construction. However, over the past several years, structural deterioration has become a critical issue, the loss of structural capacity over time is caused mainly by the nucleation and growth of micro-cracks / micro-defects and their evolution into macro-cracks, which degrades the structural strength and stiffness of concrete structures. The control of concrete damage requires implementing inspection, maintenance, and rehabilitation programs, resulting in high costs. A more economical approach is to prevent deterioration and avoid the resulting high cost of the rehabilitation and replacement. The key to damage-resistant concrete and long-life concrete structures, which has been known for a long time, lies in enhancing the tensile strength and fracture toughness of concrete material which is achieved by reinforcing fibers in concrete by incorporating carbon fiber ,Carbon Nano Tubes, polypropylene fibers to enhance the ductility and durability aspect of the concrete .

2. LITERATURE REVIEW

Among various methods, use of fiber has been recognized as a finer reinforcement. The Addition of fibers, in a correct percentage for structural purposes improves the post peak ductility performance, pre-crack, tensile strength, fracture strength, toughness, impact resistance, flexural Strength resistance, load carrying capacity, fatigue performance, reduce brittleness,[4,5,8] etc. The ductility of fiber reinforced concrete depends on the ability of the fibers to bridge cracks at high levels of strain. Synthetic fibers such as polypropylene, polyethylene, PVA and carbon fibers are now the most common fiber types which are being used,their performance depends on their elastic modulus, aspect ratio, surface texture, and also on the matrix type and the bonding properties between the fibers and matrix. Polypropylene/polyethylene (PP) fibers are currently the most commonly used synthetic fibers. Polypropylene fibers are non-Magnetic, rust free, Alkali resistant, chemically inert, compatible with all concrete[1,2,10] chemical admixtures, safe, handled with ease, premixed in a conventional manner, decreases the unit weight of concrete with increases its tensile strength, easy to use and comparatively cheaper. Due to these qualities the concept of polypropylene fiber concrete has added an extra dimension to concrete construction. From the various studies it is observed that the compressive strength did not change significantly, but tensile strength had an increase of about 80 percent, [12]. Improves ductility, energy absorption capacity and impact strength of concrete based on good choice of length and content in fibers [14]. Reduction in water permeability, do not promote shrinkage cracking, particularly effective for arresting shrinkage cracks at early ages and studies have showed has no significant effect on chloride permeability of concrete

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materials [11] [13]. Progress in the area of polymers and fiber in one concrete system has been fairly slow, partly due to the high material cost which may discourage industrial applications, and partly due to the lack of experimental data on the new composites; thus, the potential high performance of these materials has been neglected. Now, however, concretes, and particularly high strength concrete, containing polymers and fibers are of growing interest .Polymer modified cement-based materials and fiber reinforced cementitious composites show great advantages, especially in repair and rehabilitation in civil engineering applications [15]. 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 investigation an attempt has been made to use CNTs, Polypropelene fibers, Carbon fibers to integrate with high performance concrete in particular to concrete matrices used in PSC railway sleepers.

EXPERIMENTAL PROGRAM

The present experimental program was designed to investigate the compression and flexure test on carbon nanotubes concrete modified with carbon and polypropylene fiber integrated with High performance concrete (HPC) of grade M60, It consists of casting and testing of cubes and prisms specimens of five concrete matrices (i)S1: M- 60 (M-60 Grade of concrete, control mix), (ii)S2: M-60+CNT (Carbon Nano Tubes combined with M-60 Grade of concrete), (iii)S3: M-60+Fiber+CNT (Polypropylene Fibers and Carbon Nano Tubes combined with M-60 Grade of concrete), (iv)S4: M-60+CNT+Fiber (Carbon Nano Tubes and Carbon Fibers combined with M-60 Grade of concrete), (v)S5: M-60+CNT+Fiber+Fiber (Carbon Nano Tubes, Carbon Fibers and Polypropylene Fibers combined with M-60 Grade of concrete) . The experimental studies include casting and testing of forty five (45) cube specimens for compression test, forty five (45) prism specimens for flexural test. The test is conducted as per IS: 516:1959 and IRS T-39 specifications. Test specimens are as shown in table 1.

Table 1: Test specimens

Test specimens	S1	S2	S3	S4	S5
Concrete matrices	M60	M60+C NT	M60+C NT+PF	M60+CN T+CF	M60+CN T+PF+CF

2.1 MATERIALS

In this experiment, Special Grade Portland cement (53-S) conforming to IRS/T-40-1985 was used. To ascertain the physical characteristics of the cement, tests were conducted in accordance with the Indian standards confirming to IS-12269:1987. Locally available crushed sand was used. The tests on the fine aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1964 (Reaffirmed-2002) for requirement as per IRS T-39 Specifications to determine Specific gravity, Bulk density and Fineness modulus. The results conform to IS : 2383 (Reaffirmed 1990). Crushed angular of 20 mm and 10mm maximum size has been used as coarse aggregate. The sieve ana1ysis of combined aggregates confirms to the specifications of IS 383: 1970 for well graded aggregates. The tests on the coarse aggregate were conducted in accordance with IS 2386 Part 1 to Part 4-1963 (Reaffirmed-2002) to determine Specific gravity, Bulk density and Fineness modulus. In the present investigation for mix design of HPC, Auracast 270M as Super Plasticizer (chemical admixture) was used. Silica fumes supplied by Elkem India Pvt. Ltd, Navi Mumbai and Ground Granulated Blast Furnace Slag (GGBFS) supplied by Nuvoco Vistas Corporation Limited, (formerly Lafarge India Ltd.), Bangalore are used as mineral admixtures. Carbon fibres of 6mm chopped length supplied by M/s Baseer Fibres Private Limited, Bengaluru was uesd. Polypropylene fibers (Recron 3S) supplied by Ranka Udyog, Pvt, Ltd, Bangalore was used. CNTs supplied by Sigma-Aldrich was used. Ordinary potable water was used for mixing and curing purpose.

2.1.1. Dispersion of CNTs

Dispersion of CNTs has been done at AZYME BIOSCIENCE PVT. LTD. BANGALORE, firstly 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 is 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.

2.2 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 replacement, 0.125% of weight of cement of carbon nano tube, 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. Based on the trial mixes following compressive strength has been arrived for different concrete mixes under considerations and the same has been tabulated in table 3.

Table 2: Mix proportions for different concrete matrices

Mix	cement	Fine aggregate	Coarse aggregate	w/c	water	Carbon fiber	Polypropylene fiber	Super plasticizer	GGBS	Silica fumes	CNT
Test specimen	(kg/m³)	(kg/m³)	(kg/m³)		(kg/m³)	(kg/m³)	(kg/m³)	(litres/m³)	(kg/m³)	(kg/m³)	(litres/m³)
S1:M60	450	477.69	1124.64	0.373	168.15	-	-	2.02	138.2	51.15	-
S2:M60+CNT	450	477.69	1124.64	0.373	168.15	-	-	2.02	138.2	51.15	0.631
S3:M60+CNT +PF	450	477.69	1124.64	0.373	168.15	-	0.9	2.02	138.2	51.15	0.631
S4:M60+CNT +CF	450	477.69	1124.64	0.373	168.15	8.8	-	2.02	138.2	51.15	0.631
S5:M60+CNT +PF+CF	450	477.69	1124.64	0.373	168.15	8.8	0.9	-	138.2	51.15	0.631

Table 3: Materials required for respective test sleeper specimen

Mix	cement	Fine aggregate	Coarse aggregate	water	Carbon fibre	Polypropylene fiber	Super plasticizer	GGBS	Silica fumes	CNT
Test specimen	(Kg)	(Kg)	(Kg)	(litres)	(Kg)	(gm)	(ml)	(Kg)	(Kg)	(ml)
S1:M60	54.93	58.25	137.25	9.63	-	-	220	16.86	6.2	-
S2:M60+CNT	54.93	58.25	137.25	9.63	-	-	220	16.86	6.2	68.66
S3:M60+CNT+PF	54.93	58.25	137.25	9.63	-	108	220	16.86	6.2	68.66
S4:M60+CNT+CF	54.93	58.25	137.25	9.63	1.06	-	220	16.86	6.2	68.66
S5:M60+CNT+PF+CF	54.93	58.25	137.25	9.63	1.06	108	220	16.86	6.2	68.66

3.0 METHODOLOGY OF TEST

The experimental test program includes the following tests as per the specification of IRS T-39(Fifth revision, February 2016) and As per IS: 516:1959 (Reaffirmed 1999) on test specimens with five different concrete matrices

a. Compression test: The cubes of size 150mm are tested in 200T (2000kN) capacity compressive testing machine to get the compressive strength.
b. Flexural test: The flexural strength test for concrete employs a prism specimen of 100x100x500mm size and cured for 15 days. The prism specimens is placed in machine such a way that the load is applied to the upper most surface as cast in the mold, along two – lines spaced 13.3cm apart. The load is applied without shock and increasing continuously at a rate such that extreme fiber stress increased at approximately 0.7 Kg/cm^2/min that is, 180 Kg/min, the load is increased until the specimen failure.

4.0 RESULTS AND DISCUSSIONS

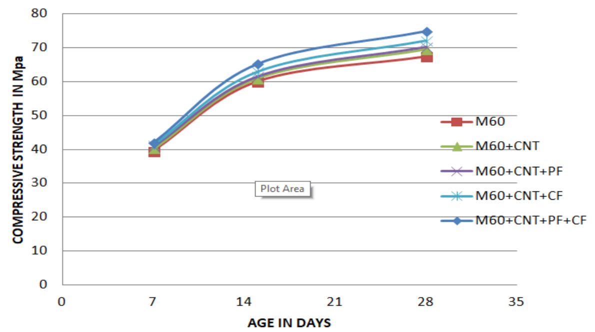
The experimental values obtained for different concrete mixes used in the present investigation are tabulated in following tables and corresponding graphs.

4.1.1 Results for compressive strength

The compressive strength is the main criteria for the purpose of structural design, the compression tests are relatively easy to carry out. The test for determining compressive strength for concrete, employs a cube specimen of 150mm size and cured for 7, 15, and 28 days which is subjected to compression in a compression testing machine.

Table 4: Summary of 7, 15 and 28 days Compressive Strength of Test Specimens

Properties	Age	M60	M60+CNT	M60+CNT+PF	M60+CNT+CF	M60+CNT+PF+CF
	(Days)	(N/mm²)	(N/mm²)	(N/mm²)	(N/mm²)	(N/mm²)
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



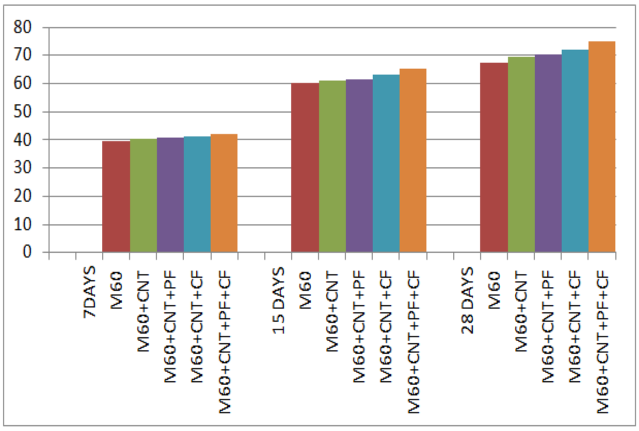


Figure 1: Comparison of Compressive Strength with Age of different concrete matrices

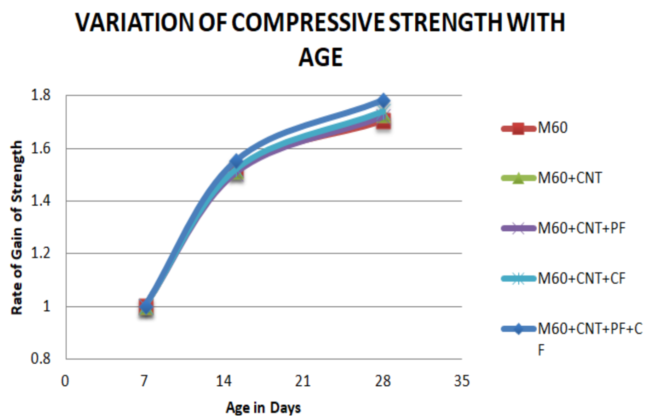


Figure2: Variation of Compressive Strength with Age in terms of Compressive Strength for all Concrete matrices

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The experimental compressive strength values obtained for different concrete mixes at 7, 15 and 28 days are tabulated in Table 2 and the same is shown in Figure 1. As per the IRS T-39 specifications, the minimum compressive strength for 15-days with water curing is 60.00 N/mm2. From the Table 2 the compressive strength of M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF is 67.53 N/mm2, 69.47 N/mm2, 70.31 N/mm2, 72.15 N/mm2 and 74.90 N/mm2 respectively which is more than the prescribed strength as per IRS T-39 and the same is higher than the minimum specified by IRS T-39 by 12.54%, 15.78%, 17.19%, 20.25% and 24.84% respectively. It can be noted that the Rate of Gain of the Strength is higher from 7-days to 15-days strength (average 52%) when compared to 15-days to 28-days strength (average 14%) for all concrete matrices. It is found that the Rate of Gain of Strength is highest in case of M60+CNT+PF+CF matrix.

4.1.2 Results for flexural strength

When concrete is subjected to bending, Tensile, compressive stresses and in many cases direct shearing stresses occur. The most common example of concrete structure subjected to flexure are highway pavements and the strength of concrete for pavements is commonly evaluated by means of bending tests on 100x100x500mm beam specimens. Flexural strength is expressed in terms of "Modulus of rupture" which is the maximum tensile (or compressive) stress at rupture.

Table 5: Summary of 7, 15 and 28 days Flexural Strength of Test Specimens

Properties	Age	M60	M60+CNT	M60+CNT+PF	M60+CNT+CF	M60+CNT+PF+CF
	(Days)	(N/mm2)	(N/mm2)	(N/mm2)	(N/mm2)	(N/mm2)
Flexural strength	7	5.05	5.65	6.05	6.50	7.80
	15	5.84	6.60	8.00	8.56	9.85
	28	8.40	8.90	10.33	11.32	14.10

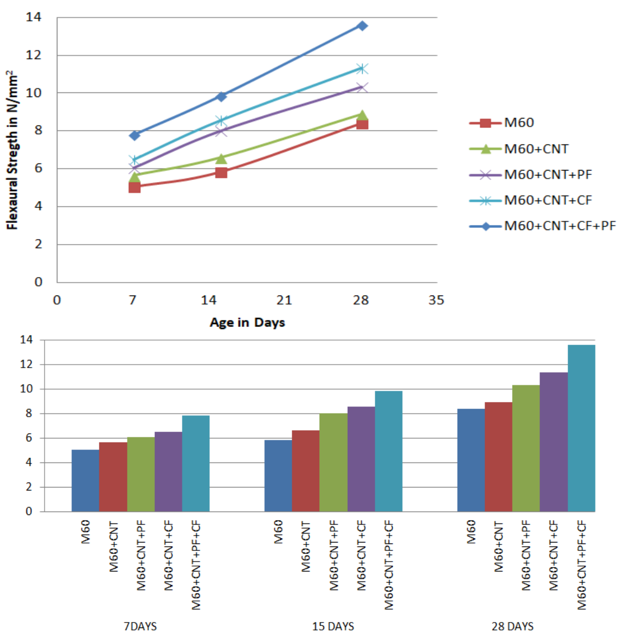

Figure3 : Comparisons of Flexural Strength of different concrete matrices

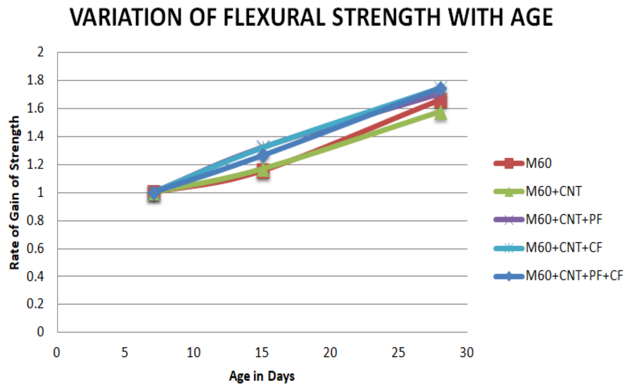

Figure 4 : Variation of Flexural Strength with Age in terms of Compressive Strength for all Concrete matrices

Table 3 shows the results of 7, 15 and 28 days flexural strength and comparison of flexural strength of various concrete matrices M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF concrete prisms and the corresponding graphs is shown in Figure 3. As per IRS T-39 specifications, Flexural strength of concrete should not be less than 5 N/mm2 when cracks occur within middle third of the span. From the Table 3 the flexural strength of M-60, M-60+CNT, M-60+CNT+PF, M-60+CNT+CF, M-60+CNT+PF+CF test specimens is 8.40 N/mm2, 8.90 N/mm2, 10.33 N/mm2, 11.32 N/mm2 and 12.10 N/mm2 respectively which is more than the prescribed strength as per IRS T-39 and the same is higher than the minimum specified by IRS T-39 by 68%, 78%, 106.6%, 126.4%, 142% respectively. It is found that the Rate of Gain of Strength is highest in case of M60+CNT+PF+CF matrix.

5. CONCLUSION

Based on the results of the experimental investigation the following conclusion are drawn.

(1) A number of variables can cause changes in the physical and mechanical behaviour of concrete. These include the composition of concrete mix, type of aggregate and their shape, admixtures and addition of fibres and other complementary reinforcement.

(2) The rate of gain of the 28 days compressive strength is highest for M60+CNT+PF+CF in comparison with other concrete matrices used in this investigation i.e. 24.84% than that of 28 days strength of M60 followed by M60+CNT, M55+ CNT+PF,M60+CNT+CF and M60+CNT+ PF+CF had an increase of 12.54%, 15.78%, 17.19%, 20.25% respectively.

(3) The rate of gain of 28 days flexural strength is highest for M60+CNT+PF+CF test specimen in comparison with M60 used in this investigation i.e. 142% than that of 28 days strength of M60+CNT, M55+ CNT+PF,M60+CNT+CF and M60+CNT+ PF+CF which was 68%, 78%, 106.6%, 126.4%, respectively.

From the experimental results it is evident that a new composite (M60+CNT+PF+CF) is an innovative ,novel advanced concrete matrix which has potential to be used in the production of PSC railway sleepers . It also satisfies the compression and flexure strength requirements as per IRS T-39.

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