Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

Effect of Multiwall Carbon Nanotube Incorporation on Mechanical Properties of Concrete with Partial Replacement of Cement With Fly Ash

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Abstract **- Carbon NanoTube incorporation in the various existing materials is gaining more interest among the material science researcher in past few decades. This situation is due to the high strength property of the CNT. This paper is based on the research on Multi-walled Carbon Nanotube incorporation in concrete and its effects on the mechanical properties of the concrete with partial replacement of cement with Fly ash. The partial replacement of cement with fly ash at 20% in volume was also done. Hence the aim of this research is to study the behaviour of normal concrete with Multi Walled Carbon NanoTube and Fly ash. Totally, 75 cube specimens, 30 cube specimens, 30 cylinder specimens and 15 prism specimens were casted for this research as five sets. The Multi Walled Carbon Nanotubes were incorporated as 0.025%, 0.050% and 0.075% on the weight of the cement in concrete. The dispersion was done by the Poly Carboxylate Ether chemical and magnetic stirring for the effective dispersion of the Multi Walled Carbon NanoTube in Concrete. The mechanical tests such as Compression Test and Split tensile Test were conducted on the cube specimens, compression testing was conducted on the cylinder specimens and the Flexural testing was conducted on the prism specimens.**

Keywords: Concrete, Multi Walled Carbon NanoTubes, Fly ash, Compression Strength and Flexural Strength.

I.INTRODUCTION

The most important construction material of modern day construction is concrete. Concrete properties are mostly depends on the various parameters and the constituents which comprises the concrete. The major factors governs the concrete strength are cement property, water-cement ratio, properties of aggregates and so on. The General property of concrete is having high compression load carrying capacity and very low tensile load carrying capacity [3] Foldyna et. al. 2016, stated that the concrete have significant compressive strength and very low tensile strength. This low tensile strength often leads to the formation of the early cracking in concrete. Hence it is necessary to find a solution which can increase the tensile capacity of the concrete.

II.LITERATURE REVIEW

Carbon nanotubes (CNT) are allotropes of carbon. They have a tubular nanostructure with diameter in nanometres. It was observed that it have the largest value of length to the diameter ratio of 1: 132,000,000. Since these CNTs have significant mechanical, physical, electrical and chemical properties it has more attention in the recent past. They are mainly classified as Single and Multi Walled Carbon Nanotubes. [7]. The Carbon NanoTubes are the allotropes of carbon which are discovered from fullerene. These nanotubes have the diameter 1 to 4 nm and the length upto 100 nm. The CNT have many significant properties such as few hundred times higher strength than steel, six times lighter than steel, high thermal stability etc. From these properties it is concluded that the Carbon NanoTubes are the strongest man made material ever generated. These Carbon NanoTubes are five types they are Single Walled Carbon NanoTubes, Multiwalled carbon NanoTubes, Nanotorus, Nanobuds and Polymerised Single Walled Carbon NanoTubes. There are three methods of Carbon NanoTube Growth they are Laser Ablation, Arc Discharge and Chemical Vapour Deposition Method. [8]. In recent times the Carbon NanoTube incorporation in materials has gained more interest due to the very high strength of the Carbon NanoTubes. It was observed that the CNT have effective pores and cracks filling nature which helps as a filler which reduces the pores in concrete and also helps increasing the tensile strength of the concrete. [5]. It was observed that the use of nanomaterial such as CNT, Nano clay, Titanium oxide and Nano silica shows a significant increase in the properties of the conventional materials. It was also shown that the utilization of these nano material similar to the use of micro materials such as metakolin and silica. It increases the strength and durability properties of the mortars and concrete [7].According to Cwirzen et. al. 2008, the major disadvantage in the cementitious composites is its brittle nature. Due the brittle nature this leads to the formation and propagation of the cracking in cementitious composites. These cracks sized from micro to macro level.

Kowald et. al. 2004 stated that the there is 12% increase in the concrete which consists of 0.5% of CNT by the weight of cement with the W/C ratio of 0.22 but he found that there was as decrease in the compressive strength of the concrete as 2.5%. Hence he concluded that was not the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

optimum amount of incorporation to achieve more flexural and compressive strength simultaneously.

Cwirzen et. al. 2008, studied the effects of various surface modification in the CNT incorporated concrete. They studied the effects of surface modified CNTs and normal CNTs for incorporation. The polyacrylic acid and gum Arabic chemicals were used for surface modification with Ultrasonication. There are totally three different sets were made they are 0.023%, 0.1%,0.14% with poly acrylic acid as dispersant and 0.023% and 0.1% of CNTs with gum Arabic and 0.14%, 05% and 0.15% with polyacrylic acid were added with functionalised CNTs. The maximum increase in the compressive strength of the concrete was observed in the 0.045% functionalised CNT with polyacrylic acid as 50%. It also showed a significant increase in the workability and the increase in the properties of concrete based on the amount of CNT incorporation and the dispersant.

The study on the effect of CNT incorporation in the articles of Metaxa et al., 2009 stated that there is a significant increase in the properties of the cement matrix flexural strength as 50 % and elastic modulus as 25% when the water cement ratio of the concrete is kept as 0.5.

Collins et. al. 2012 studied the CNT incorporation with the various surface modification agents such as Polycarboxylate, Calcium naphthalene sulphate, Lignosulfate and Naphthalene sulphonic acid. It was conducted with the CNT incorporation at 0.5%, 1% and 2% in the weight of the cement. Among them the specimens with the Poly Carboxylate showed a significant increase in the compressive strength as 42% than the control mix when the surfactant was added at 0.8%.

Hamzaoui et. al. 2012 stated the effects of incorporating CNT in cementitious composites by adding 0.004 and 0.004% for concrete and 0.01%, 0.02%, 0.03% and 0.06% in cement mortar in weight of cement. The maximum increase in compressive strength was obtained from the 0.01% incorporation as 21.2% in mortar and 0.003% showed an increase of 17.65% than the conventional composites. And there was also observed the constant decrease in the strength in the composite on further additions. Hence it was concluded that the optimal amount of CNT incorporation can be done at 0.01% for mortar and 0.003% for concrete.

In a study conducted by Haddad et. al. 2013, three ratios of CNT incorporation were done. They are 0.2%, 0.4, 0.6% in weight of cement in mortar and conducted mechanical tests. Among the various ratios 0.4% added CNT incorporated mortar showed a significant increase in the mechanical tests. It showed an increase of 40% in compressive testing and 30% in tensile testing and 15% in flexural testing. This was concluded as the optimum value of CNT to be added in a cementitious composite in that study since 0.2% and 0.6% did not show any significant increase in mechanical testing.

Rhee et. al. 2013, studied the effects of incorporation of CNT in cementitious composite with 0.25%, 0.5%, 0.75%, 1.0%, 1.25% and 1.5% of CNT in the weight of the cement. The CNTs were treated with surface modification dispersant sodium naphthalene sulfonate formaldehyde solution and sonication process. The mechanical tests such as compressive testing, split tensile testing was carried out in the research. The maximum value of increase in compressive strength of the concrete was achieved at the 1.0% incorporation as 40% than the control mix. The split tensile strength was increased at 72% at the same 1.0% incorporation. It also showed less permeability and electrical conductivity in the respective tests. It was observed that there was an increase in the properties in a constant trend from the lower amount to higher amounts. Hence at the inflection point which 1.0% is showed the maximum values and thereafter steep decreases in properties were found.

Sahranavard et. al. 2014, conducted research on effects of Multiwalled Carbon NanoTubes incorporation in cementitious composites. They conducted testing by adding 0.1% of MWCNT with the concrete. The MWCNT was functionalised with ultrasonic energy and incorporated. The mechanical test such as compressive, flexural and impact resistance tests were conducted. The increase in the compressive strength and impact resistance were found 58% and 1400% respectively than the control mix. But there was observed only 2% of increase in the flexural strength of the concrete with MWCNT. And they concluded that only small amount of MWCNTs shows a significant increase in properties of the cementitious composite.

Samchenko et. al. 2014, studied the surface modification of the CNT with Poly Carboxylic Ether during the incorporation in the composite materials. This paper studied the dispersion of CNT with the various surface modification materials such as Metaflux and water. It was observed that the CNT with the Poly carboxylic ether showed a significant stabilisation.

Foldyna et. al. 2016, studied the various difficulties in CNT incorporation in cementitious composites. It showed the various dispersion methods such as Ultrasonication, Chemical dispersion and some other techniques for dispersion of CNT in the cementitious composites. This paper also explained that the effective dispersion shows significant results as improvements in the properties of the composites, and less improvement in the poor dispersed composite.

III. EXPERIMENTAL INVESTIGATION

a. Casting of Specimens

From the above literature study the method of CNT incorporation and amount of incorporation were finalised. Based on the arrived details the Multi Walled Carbon NanoTubes were selected for the incorporation. The Poly Carboxylic Ether solution was used as dispersant. The M30 grade of concrete was selected as control mix. The addition of class F Fly ash was also made partial replacement to study the composite property of the concrete. There were totally five mixes. The materials were tested for preliminary tests for arrival of the proper mix design. The water-cement ratio was finalised after the slump tests. The specimens were casted. The property of CNT is shown in the Table 1. Table 2 shows the various mix which are

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

arrived for the research. The Table 3 Shows the Mix proportion of the concrete.

Table 1 Properties of CNT

S.NO.	PROPERTY	DESCRIPTION
1	Diameter	~10 nm
2	Length	6-9 micron
3	Purity	>98%
4	Metal Particles	<1%
5	Amorphous Carbon	<1%
6	Specific Surface Area	250-300 sq.m/g
7	Bulk Density	0.10-0.06 g/sq. cm

Table 2 Specimen Description

S.No	Mix Description	Fly ash	CNT
1	Conventional Concrete (M30)	-	-
2	CF	20%	-
3	CNT 1	20%	0.025%
4	CNT 2	20%	0.050%
5	CNT 3	20%	0.075%

Table 3 Mix Proportion

Description	Cement	FA	CA	W/C	SP
Mix Ratio	1	2.26	3.6	0.4	0-3%
Weight	345(kg/m^3)	782(kg/m^3)	1276(kg/m^3)	138(lit)	3.45

The concretes specimens were casted for the mechanical tests such as the Compressive test, Split Tensile test and Flexural Tests. The specimen details are shown in the Table 4. The standard size concrete test cubes 150mm X 150mm, Cylinder of 150mm X 300mm and the Prism of size 100 mm X 100 mm X 500mm were used for the testing. The mechanical testing and the number of specimens used are shown in Table 5. After the arrival of the number of the specimens and the testing the casting was arranged.

Table 4 Specimen Testing Details- Based of Specimens

S.No	Mix Description	Cube	Cylinder	Prism
1	Conventional Concrete (M30)	6	6	3
2	CF	6	6	3
3	CNT 1	6	6	3
4	CNT 2	6	6	3
5	CNT 3	6	6	3

Table 4 Specimen Testing Details- Based of Mechanical Testing

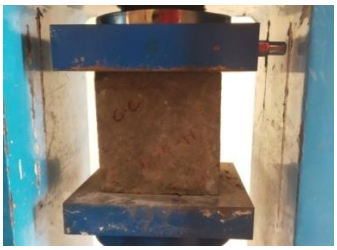
S. No.	Specimen	Compressive Test	Split Tensile Test	Flexural Testing
1	Cube	3	3	-
2	Cylinder	3	3	-
3	Prism	-	-	3

a. Surface Decoration

Surface Decoration of the Multiwalled Carbon Nanotubes plays an important role in the dispersion and the increasing the strength of the CNT incorporated concrete. Hence the surfactant was selected with excessive care. The Poly Carboxylic Ether solution (PCE) was selected for the surface decoration and the surface decoration was done with the help of magnetic Stirrer. The CNT was added with the PCE and stirred with the magnetic stirrer for 60 minutes at 600 rpm. This was done to avoid the agglomeration effect on the concrete. Then materials for the casting of the concrete such as cement and aggregates were batched. The OPC 53 grade cement was used for the concrete. All the preliminary arrangements for the casting of the specimens were done. Then the mixing of the concrete was done with the concrete mixer. The casting was done as five sets. Each set consists of six cubes, six cylinders and 3 prisms. After the casting of cubes as five sets it was cured for 28 days immersed curing. Then the mechanical tests were conducted.

b. Testing of Specimens

The mechanical testing of the cubes and cylinder were done on the compressive testing machine. The flexural testing was conducted in the flexural testing machine. The testing was conducted based on the codal provisions. The Figure 1.a to 1.d shows the mechanical testing of the Specimens.



a. Compressive Testing - Cube

b. Split Tensile Testing - Cube

c. Compressive Testing - Cylinder

d. Flexural Testing

Fig. 1 Mechanical Testing of Specimens

IV. RESULTS AND DISCUSSIONS

After the testing of specimens the results were computed based on the conventional procedure. The compressive strength for the cube and cylinder specimens and the Split tensile Strength for the Cube specimens and the Flexural strength for the prisms were computed. The Figure2 shows the Compressive Testing results of Cube specimens, Figure3 shows the Compressive Testing results of Cylinder specimens Figure 4 shows the Split Tensile testing results of Cube specimens Figure 5 shows the Flexural Testing results of Prism specimens.

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ISSN: 2278-0181
Vol. 9 Issue 09, September-2020

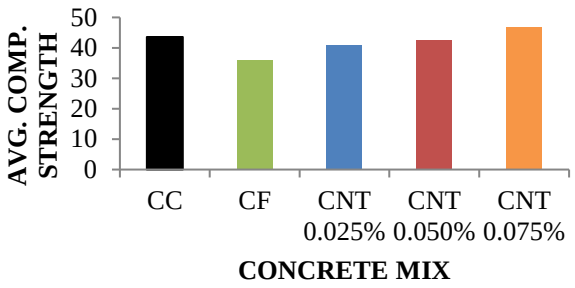

Fig. 2 Compressive Test of Cube specimens

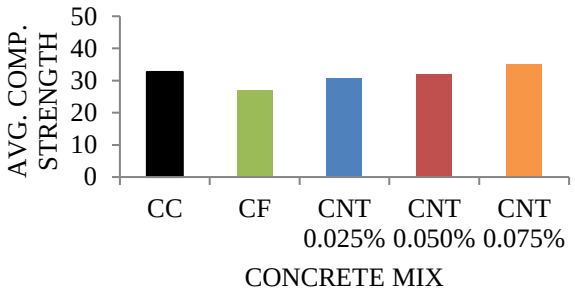

Fig. 3 Compressive Test of Cylinder specimens

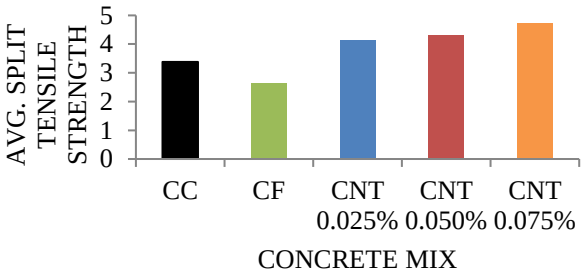

Fig. 4 Split Tensile Test of Cube specimens

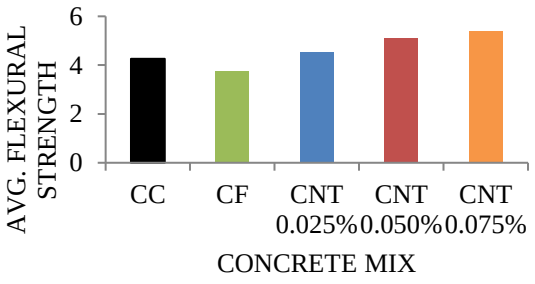

Fig. 5 Flexural Test of Prism specimens

From the compression testing of the cube specimens the increase of 29.6% and 7.25% was observed in the 0.075% CNT concrete than the Fly ash and Conventional concrete respectively was observed. In the Cylinder compressive strength testing 5.45% and 22.2% of increase in strength was observed in the 0.075% CNT concrete then the conventional and Fly ash concrete respectively. The Split tensile testing of the 0.075% CNT concrete showed a 78.78% and 39.64% increase in strength compared to the conventional and Fly ash concrete. The Flexural testing of the 0.075% CNT concrete showed an increase in strength of 26.76% and 14.02% the Fly ash and the conventional concrete respectively.

V. CONCLUSIONS

- There was found a significant increase in the strength of concrete incorporated with CNT.
- The increase in the strength was observed as increasing gradually as the amount of CNT increases in the concrete.
- The 0.075% CNT concrete was observed as the most significant mix as it shows the higher values in all the mechanical tests.
- It was observed that the strength increases as the voids of the concrete reduces.
- The surface decoration with the Poly Carboxylic Ether solution was observed as effective way of dispersion.

REFERENCES

[1] Collins, F., Lambert, J., & Duan, W. H. (2012). The influences of admixtures on the dispersion, workability, and strength of carbon nanotube–OPC paste mixtures. *Cement and Concrete Composites*, *34*(2), 201-207.

[2] Cwirzen, A., Habermehl-Cwirzen, K., & Penttala, V. (2008). Surface decoration of carbon nanotubes and mechanical properties of cement/carbon nanotube composites. *Advances in cement research*, *20*(2), 65-73.

[3] Foldyna, J., Foldyna, V., & Zeleňák, M. (2016). Dispersion of carbon nanotubes for application in cement composites. *Procedia engineering*, *149*, 94-99.

[4] Haddad, A. N., de Morais, J. F., & Evangelista, A. C. J. (2013). Variation of Concrete Strength with the Insertion of Carbon Nanotubes. In *Advanced Materials Research* (Vol. 818, pp. 124-131). Trans Tech Publications.

[5] Hamzaoui, R., Bennabi, A., Guessasma, S., Khelifa, R., & Leklou, N. (2012). Optimal carbon nanotubes concentration incorporated in mortar and concrete. In *Advanced Materials Research* (Vol. 587, pp. 107-110). Trans Tech Publications.

[6] Kowald, T., & Trettin, R. (2004, September). Influence of surface-modified carbon nanotubes on ultrahigh performance concrete. In *Proceedings of International Symposium on Ultra High Performance Concrete* (pp. 195-203).

[7] Norhasri, M. M., Hamidah, M. S., & Fadzil, A. M. (2017). Applications of using nano material in concrete: A review. *Construction and Building Materials*, *133*, 91-97.

[8] Purohit, R., Purohit, K., Rana, S., Rana, R. S., & Patel, V. (2014). Carbon nanotubes and their growth methods. *Procedia materials science*, *6*, 716-728.

[9] Rhee, I., & Roh, Y. S. (2013). Properties of normal-strength concrete and mortar with multi-walled carbon nanotubes. *Magazine of Concrete Research*, *65*(16), 951-961.

[10] Sahranavard, S., Haji-Kazemi, H., & Abbasi, S. (2014). Effect of multi-walled carbon nanotubes on mechanical properties of high-performance mortar. *Magazine of Concrete Research*, *66*(18), 948-954.

[11] Samchenko, S. V., Zemskova, O. V., & Kozlova, I. V. (2014). Stabilization of carbon nanotubes with superplasticizers based on polycarboxylate resin ethers. *Russian Journal of Applied Chemistry*, *87*(12), 1872-1876.

[12] Shah, S. P., Konsta-Gdoutos, M. S., Metaxa, Z. S., & Mondal, P. (2009). Nanoscale modification of cementitious materials. In *Nanotechnology in Construction 3* (pp. 125-130,Springer,Berlin,Heidelberg