VOL. 16, NO. 18, SEPTEMBER 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DURABILITY ANALYSIS OF CONCRETE WITH PARTIAL CEMENT REPLACEMENT WITH FLYASH AND MWCNT INCORPORATION

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ABSTRACT

The concrete incorporated with Multi-Walled Carbon Nanotube (MWCNT) with partial cement replacement with flyash was researched for its durability properties. In this research the concrete was cement replaced with flyash at 20%. The incorporation of the MWCNT were done at 0.025%, 0.05% and 0.075% of the weight of the cement. The incorporation of MWCNT was done with the proper dispersion process and the Poly Carboxylic Ether was used as the dispersant.. The durability properties of the concrete were analysed by conducting the acid resistance, chloride resistance and sulphate resistance tests. It was observed a significant improvement in the durability properties of the concrete after the partial replacement of cement with flyash and the incorporation of MWCNTs. The six numbers concrete cubes of size 150 mm x 150 mm x 150 mm were casted for each mix for each tests.

Keywords: concrete, multi-walled carbon nanotube (MWCNT), durability, poly carboxylic ether (PCE).

INTRODUCTION

Concrete is the most vital construction element. The research in the improvement of concrete properties such as strength and durability is most desired. [12]. This research is mainly based on the improvement of the concrete properties by the incorporation of the MWCNT and flyash. The incorporation of MWCNT was preferred due to the excellent mechanical and durability properties of MWCNT concrete. The partial replacement of the flyash was done as a sustainable concrete method to reduce the usage of the cement in concrete. [10] From the detailed literature review it was observed that the MWCNT in corporation addition of flyash in concrete improve the concrete properties, especially on the durability aspects. [14] Hence the durability analysis of the concrete with regular durability tests such as acid resistance with sulphuric acid and chloride resistance with sodium chloride solution. [1]

Multi-Walled Carbon Nanotubes

The Carbon Nanotubes (CNT) is the strongest elements ever discovered by mankind. The CNT is the allotropes of the carbon which were generated from the various physical and chemical conditions. The basic structure of the CNT is a tubular in nature with diameters of 0.4 to 40 nanometre (10^{-9}m) and length ratio of 1:132,000,000 times. [3] The high mechanical and durability properties of the CNT are utilised in many fields. The CNT are generally classified into two types based on the number wall in the particle. They are Single – Walled Carbon NanoTube (SWCNT) which has single wall and Multi Walled Carbon NanoTubes (MWCNT) which has more than one layer in the particle. In this research the MWCNTs were utilised. [2]

Durability

Durability of the concrete can be explained as the ability to not losing the original properties of the concrete under the any physical and chemical influence. The concrete is termed as durable when the concrete has the ability to withstand the general environmental conditions such moisture, freezing and thawing, chloride attack, acid attack, sulphate attack and many other conditions. [6] In construction the concrete is the primary protection for the reinforcements provided, if the concrete has no ability to withstand these physical and chemical attacks the reinforced concrete undergoes the damages and thereby results in the failure of structure. Hence, it is important to design a concrete as durable concrete. [5]

MATERIALS AND METHODS

Carbon Nanotubes are defined as the modified allotropes of the fullerenes which were derived from the Carbon atoms. Generally CNT have a diameter from 1 to 4 nm and length upto 100 nm. It was defined that the CNT has better properties such as high tensile strength, less weight, high thermal stability. [11]. The CNT were generated by three different methods they are chemical vapour deposition, laser ablation and electric arc discharge method. From this literature it was clearly observed that the incorporation of the CNT in concrete increases the compressive strength, tensile strength and durability properties. [7]

The incorporation of MWCNT in concrete was a recent trend of improving the mechanical properties. The addition of the MWCNTs increases the compressive strength, tensile strength in mechanical properties. [16] The pore in concrete was reduced as a result the porosity of the concrete was reduced. This was achieved by the effective dispersion of the MWCNT in the concrete. [8]

In this research the CNT was incorporated in the concrete by 0.1, 0.2, 0.3, 0.4 and 0.5 % in the weight of the cement. The mechanical and durability properties were analysed. It was observed that the addition of 0.1% CNT has the optimum increase in the both mechanical and durability properties of the concrete. [15] The minimum loss in the compressive strength of the concrete after the salt attack was at 0.1% concrete after 28 days salt test. In the chloride attack test also the concrete with MWCNT showed a lesser impact of 6% where the reference mix

showed upto 13% reduction in the compressive strength. [9]

The MWCNTs were incorporated in the concrete at the 0.05%, 0.10% and 0.15% with the proper dispersion of MWCNT with gum Arabic dispersant and sonication process. It was observed a 42.4% reduction in the chloride diffusion of the concrete in the 0.1% MWCNT incorporated concrete. In all the other durability tests such as the sulphate resistance the 0.1% MWCNT concrete has a resistance index greater than 1.0. [4]

In this article the various durability properties such as the sorpitivity, water permeability, chloride diffusivity and porosity were tested on concrete with MWCNT at 0.5%, 0.1% and 0.25% in the weight of the cement. Among them the 0.1% MWCNT concrete was concluded as the optimum amount to incorporate CNT in concrete as it showed significant increase in the properties of the concrete. The 0.1 % MWCNT showed the less water sorpitivity of 32% lesser value than the control mix. The chloride diffusion rate was observed as 63% lesser than the control mix. Thereby it was predicted as the concrete has a 2.7 times life span than the control mix. [13]

Experimental Investigations

In this research the concrete specimens were casted by incorporating the MWCNT at 0.025%, 0.05% and 0.075% at the weight of the cement. The class-F flyash was used to replace the cement by 20%. The research was planned to analyse the reduction in the density and compressive strength of the concrete after chemical curing. There were totally three tests carried out in the research. The incorporation of the MWCNT in the concrete was done after the dispersion of MWCNT in polycarboxylic ether solution. This process was done with the help of magnetic stirrer at 110 rpm at 60^0 c temperature for one hour in each mix.

All the concrete cubes were casted as per the codal guidelines. Then the specimens were placed in immersion curing for 28 days. The after 28 days the specimens were taken out of the water and weighed. In all the specimens three specimens in each mix were tested for the 28 days compression strength. The remaining specimens in the each mixes were placed in chemical for the chemical curing period of 28 days. The chemical pH was tested once in every 7 days to ensure the proper chemical attack on the specimens. After 28 days of the chemical curing the specimens were taken out and the surface of the specimens were cleaned to remove the loose materials. Then it was weighed and the tested to find the compression strength. The specimen description of the research is given in the Table-1 and in Table-2 the mix proportion of the concrete is given.

Table-1. Specimen description.

Mix Description	Fly ash	CNT
CC	-	-
CF	20%	-
CNT 1	20%	0.025%
CNT 2	20%	0.050%
CNT 3	20%	0.075%

Table-2. 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 three durability tests conducted were

a. Acid Resistance Test

The acid resistance tests on the concrete specimens were conducted with the 3% sulphuric acid solution for the period of 28 days.

b. Chloride Resistance Test

The chloride resistance test was conducted with the 5% sodium chloride solution.

The number of specimens for each testing is given in Table-3. The typical chemical testing is given in Figure-1.

Table-3. Specimen testing details.

Specimen	Mix Description	Compressive Test after 28 days curing	Acid Resistance Test	Chloride Resistance Testing
Cube (150 mm x 150 mm x 150 mm)	CC	3	3	3
	CF	3	3	3
	CNT 1	3	3	3
	CNT 2	3	3	3
	CNT 3	3	3	3

Figure-1. Typical chemical testing.

RESULTS AND DISCUSSIONS

As mentioned earlier the specimens were tested for the compression strength after the chemical immersion. This is done in order to find the compressive strength reduction in the concrete due to the chemical attack on the concrete. In addition, the weight loss was also calculated in order to find the loss in the density of the concrete.

a) Acid Resistance Test

The acid resistance tests of the specimens were done with the sulphuric acid as mentioned earlier. The testing was conducted after the chemical curing period of 28 days. After the 28 days the specimens were removed from the chemical and allowed to dry and cleaned with the nylon brush to remove loose particles on the surface of the specimens. Then, the specimens were weighed and the compression tests were conducted. The Table-4 gives the loss in the compression strength and weight of the specimen. In the Figures 2 and 3 the loss in the weight and compressive strength of the specimens are given respectively.

Table-4. Loss in weight and compressive strength from acid resistance test.

Mix Description	Specimen weight (kg)		% Loss	Compressive strength (Mpa)		% Loss
	Before Immersion	After Immersion	Avg.	Before Immersion	After Immersion	Avg.
CC	8.79	8.51	3.37	43.57	41.43	5.15
CF	8.62	8.33	3.48	36.05	34.13	5.63
CNT 1	8.60	8.38	2.62	40.86	39.69	2.95
CNT 2	8.58	8.36	2.67	42.49	41.29	2.89
CNT 3	8.57	8.34	2.80	46.73	45.42	2.88

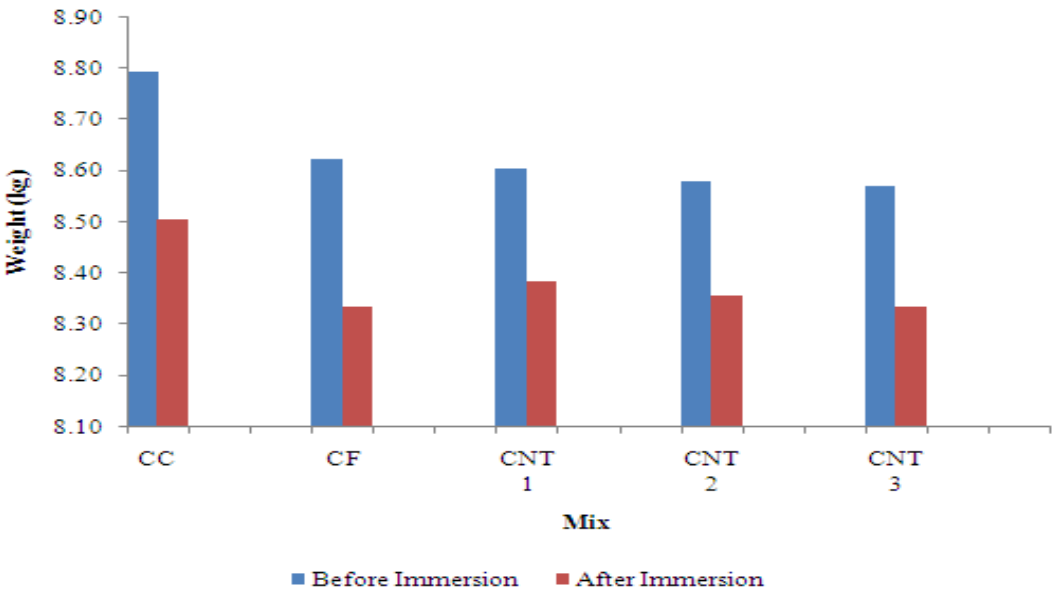

Figure-2. Loss in weight after.

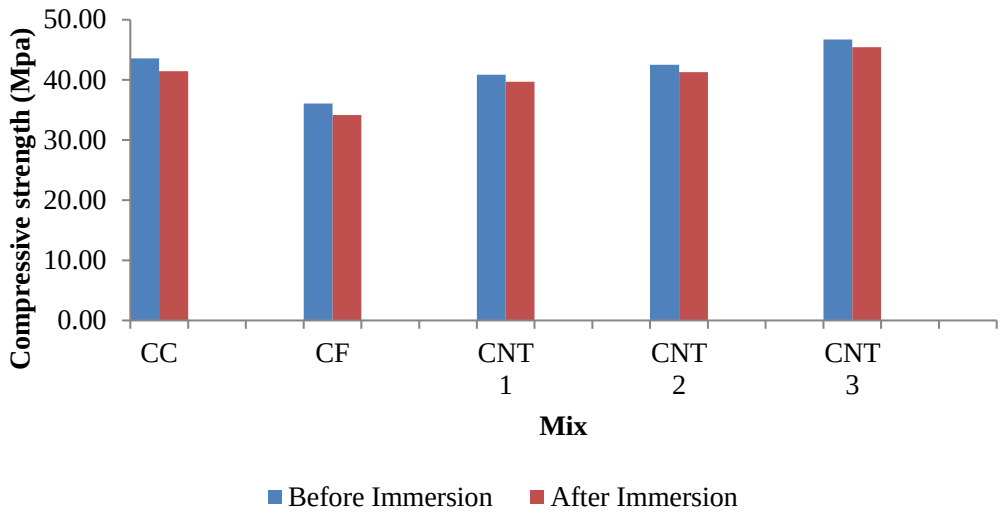

Figure-3. Loss in compressive strength.

b) Chloride Resistance Test

The chloride resistance test was conducted on 5% sodium chloride solution. All the curing and testing procedure are similar to the acid resistance test. The Table-5 shows the detailed values of the chloride resistance test. In the Figures 4 and 5 the graphical representation of the loss of weight and loss of compressive strength is given respectively.

Table-5. Loss in weight and compressive strength from chloride resistance test.

Mix Description	Specimen weight (kg)		% Loss	Compressive strength (Mpa)		% Loss
	Before Immersion	After Immersion	Avg.	Before Immersion	After Immersion	Avg.
CC	8.79	8.51	3.37	43.57	42.09	3.50
CF	8.62	8.33	3.48	36.05	35.93	0.35
CNT 1	8.60	8.38	2.62	40.86	40.35	1.26
CNT 2	8.58	8.36	2.67	42.49	42.04	1.05
CNT 3	8.57	8.34	2.80	46.73	46.27	0.99

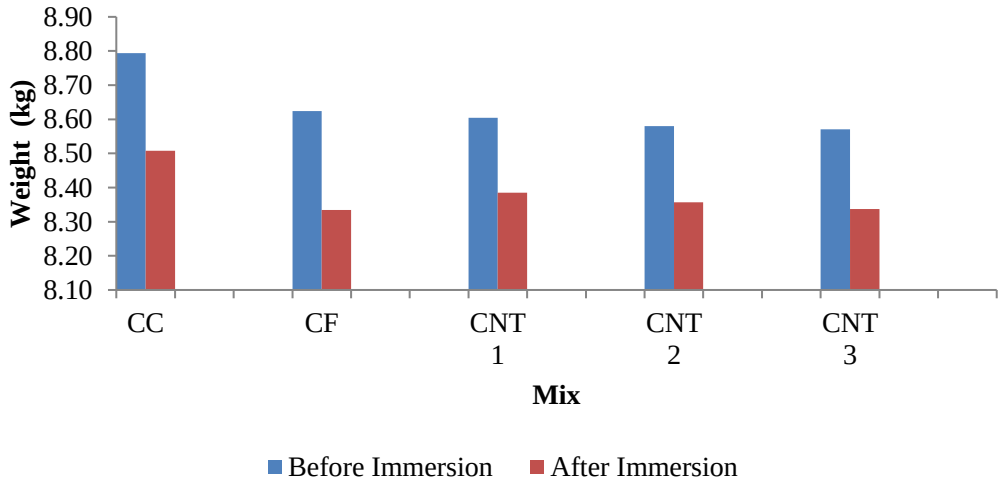

Figure-4. Loss in weight.

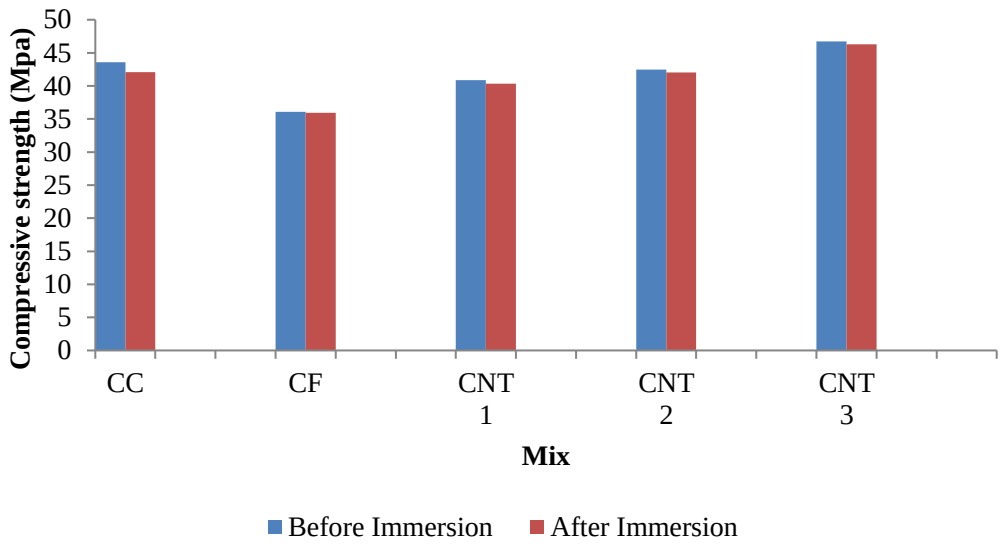

Figure-5. Loss in compressive strength.

CONCLUSIONS

From the durability analyses of the concrete with partial cement replacement with flyash and MWCNT the following conclusion were arrived.

- In the acid resistance test, the CNT 3 mix possessed the minimum loss in the compressive strength and weight as 2.88% and 2.80% respectively.
- In the chloride resistance test, the CNT 3 mix possessed the minimum loss in the compressive strength of 0.99% and loss of weight as 2.80%.
- It was concluded that the CNT 3 mix with 0.075% MWCNT posses the significantly high durability properties compared with the other mixes and it was the optimum incorporation of the MWCNTs of this research.

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