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Nanomaterials in concrete: Enhancing strength and durability

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Abstract

Carbon nanotubes (CNTs) have received great attention for their applications in concrete due to their unique properties such as high strength, flexibility, and electrical conductivity. This study aims to investigate the effect of adding carbon nanotubes on the energy combination of the material. Concrete samples were prepared with different concentrations of carbon nanotubes and their mechanical properties were measured and compared with control samples without carbon nanotubes. The results show that the addition of carbon nanotubes increases the compressive and flexural strength of concrete. The findings suggest that incorporating carbon nanotubes into concrete could be a good way to improve concrete's mechanical properties and improve its performance in construction. Compared with white cement M20 samples aged 7, 14 and 28 days. The 28day maximum strength is stated below for 0.0045 wt.% SWCNT and MWCNT and 0.0030 wt.% SWCNT and MWCNT. It was determined that nanocomposites containing a lower proportion of long MWCNTs had properties comparable to nanocomposites containing a higher proportion of short MWCNTs. Many of the walls of the carbon nanotubes reach microcracks, indicating that the carbon nanotubes are cracked and pulled out. Besides the compression test, we also calculated the slit tensile strength by adding different percentages of carbon nanotubes. The usage percentage increased for 0.0015% MWCNTs and 0.0030% and 0.0045% SWNTs.

Keywords: Nanotechnology; Nanomaterials; Carbon nanotubes; High Strength Concrete

1. Introduction

Perhaps one of the most famous references to carbon nanofibers is Hughes and Chambers' 1889 patent for filamentous carbon synthesis. In the early 1950s, Soviet scientists Radosevic and Lukyanov performed the first electron microscopy analysis of carbon nanofibers. They published an article in the "Soviet Magazine" and examined carbon fibres with a diameter of 50 nano meters. Between 1997 and 2003, investment in nanotechnology increased by 40%, reaching 40 billion euros. Nanomaterials, the main element of which is carbon, are becoming increasingly prominent. As examples of this type of carbon nanomaterials, carbon nanotubes and carbon nanofibers are known. In addition, carbon nanofibers are also hydrogen absorbing materials. Nanotechnology involves science at the microscopic scale (1 nm = 1 × 10^-9 m). The aim of this study is to investigate the improvement in hardness and the control of premature breakage of Fibers due to the addition of carbon nanofiber (CNF) at the nanostructure level and the use of two different concentrations of additional carbon nanofibers.; (CNF) micro structured polypropylene microfiber level. The addition of nanofibers increases the flexural strength of cement-based putty, despite some premature cracking problems. The width of the DNA chain is 2 nm. A human hair is approximately 100,000 nanometers. The length of one leaf is 100,000 nm.

2. Experimental Program

Today, nanomaterials such as carbon nanotubes (CNT), carbon nanofibers (CNF), nanosilica, titanium dioxide (TiO2) and polycarboxylates are used in concrete. Among these, carbon nanotubes (CNTs) are particularly popular. Carbon

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nanotubes are thin tubes made of rolled graphene sheets. They come in two types: single walled carbon nanotubes are very thin, 0.4 to 10 nanometers wide; multiwalled carbon nanotubes are 4 to 100 nanometers wide. They can be very long, reaching a micron or a millimetres. These nanotubes are very strong and flexible; It is stronger than materials such as aluminium or steel. In fact, they are approximately 500 times stronger than aluminium and 100 times stronger than steel. Scientists believe that using nanotechnology to create materials such as stone will help increase the strength and durability of natural materials that have evolved over millions of years.

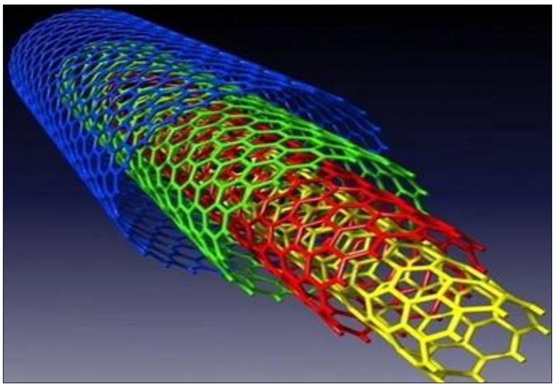

Figure 1 Multi-walled CNT's

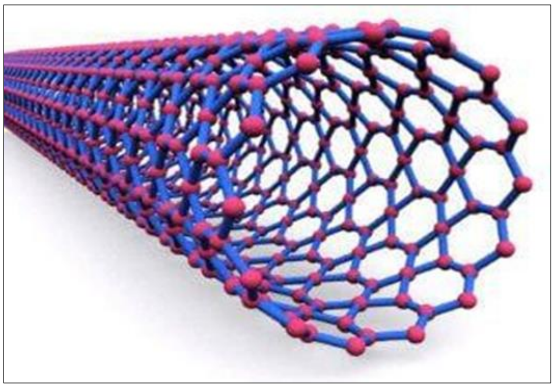

Figure 2 Single-walled CNT's

2.1. Technical Data Sheet: -MWCNTs

Name: Larger Diameter Multi-walled Carbon Nanotubes (MWCNTs). Purity: >99%. OD: 10-30nm [OD=Outer Diameter] L. Making method ： CVD

Table 1 Technical Data Sheet: -MWCNTs

Property	Unit	Value	Method of Measurement
OD	nm	10-30	HRTEM, Raman
ID	nm	5-10	HRTEM, Raman
Purity	wt.%	>99	TGA & TEM
Length	microns	10	TEM
SSA	m^2/g	110-350	BET
ASH	wt.%	<.9	TGA
EC	s/cm	>100	
Bulk Density	g/cm^3	0.04	

I_g/I_d	--	--	Raman
-COOH Content	wt.%		XPS & Titration

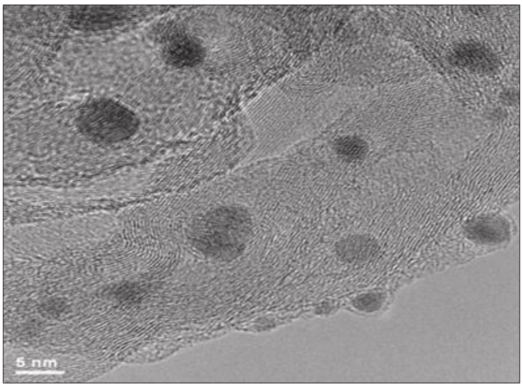

Figure 3 Transmition Electron Microscope View

2.1.1. TEM Image

Figure 4 Multi-walled Carbon Nanotubes

2.2. Technical Data Sheet: -SWCNTs

Name: Larger Diameter Single-walled Carbon Nanotubes (SWCNTs). Purity: >99%. OD: 1.8-4nm [OD=Outer Diameter] L. Making method ： CVD

Table 2 Technical Data Sheet: -SWCNTs

Property	Unit	Value	Method of Measurement
OD	nm	1.8+4	HRTEM, Raman
ID	nm	5-10	HRTEM, Raman
Purity	wt.%	>99.99	TGA & TEM
Length	microns	5	TEM
SSA	m^2/g	490	BET
ASH	wt.%	<.9	TGA
EC	s/cm	>100	
Bulk Density	g/cm^3	0.1	

I_g/I_d	--	--	Raman
Tensile Strength	Gpa	50-500	
-COOH Content	wt.%		XPS & Titration

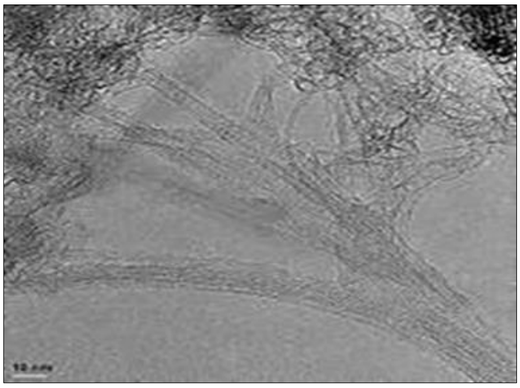

Figure 5 Transmition Electron Microscope View

2.2.1. TEM Image

Figure 6 Single-walled Carbon Nanotubes

Objectives

- Increase the strength and durability of M20 grade concrete by using more carbon nanotubes.
- Comparison of the strength of concrete with and without additives (use of carbon nanotubes).

Scope

- To increase compressive strength and durability in concrete.
- To improve the efficiency of energy transmission.
- To reduce cracks from the concrete.
- Can enhanced resistance to corrosion, fatigue, wear, and abrasion.

3. Methodology

In this study, it was decided to use multi-walled carbon nanotubes and single-walled carbon nanotubes as they were seen to improve concrete properties such as compressive and tensile strength. M20 grade concrete prepared as per IS 10262-2019. The composition of the mixture is 1:2.56:3.46 and the water-cement ratio is 0.5, which is a good mixture.

In this study, we decided to cast cubes, cylinders and beams in order to evaluate the properties of concrete such as compressive, splitting, tensile and bending strength.

3.1. Problem Statement

Nanomaterials can do a lot when added to building materials. Rocks cause global warming by releasing carbon dioxid. To protect the environment, buildings must be environmentally friendly. Using nanomaterials to make green building. Therefore, the use of nanomaterials in construction is very important for green buildings.

4. Result

Table 3 Results for Compressive Strength: -For MWCNTs

Sr. No.	**Curing Days**	**Control Mix (MPa)**	**MWCNT's 0.0015% (MPa)**	**MWCNT's 0.0030% (MPa)**	**MWCNT's 0.0045% (MPa)**
1	7	16.52	17.78	20.34	22.11
2	14	18.0	22.4	27.71	28.96
3	28	26.4	31.0	31.85	33.9

Table 4 Results for Compressive Strength: -For SWCNTs

Sr. No.	**Curing Days**	**Control Mix (MPa)**	**SWCNT's 0.0015% (MPa)**	**SWCNT's 0.0030% (MPa)**	**SWCNT's 0.0045% (MPa)**
1	7	16.52	19.23	24.57	31.6
2	14	18.0	21.0	28.43	34
3	28	26.4	27.7	31.24	37.4

Table 5 Results for Split Tensile Strength: -For MWCNTs

Sr. No.	**Curing Days**	**Control Mix (MPa)**	**MWCNT's 0.0015% (MPa)**	**MWCNT's 0.0030% (MPa)**	**MWCNT's 0.0045% (MPa)**
1	7	4.0	4.15	5.3	6.9
2	14	12.0	12.6	13.3	12.9
3	28	13.2	13.5	13.8	13.9

Table 6 Results for Split Tensile Strength: -For SWCNTs

Sr. No.	**Curing Days**	**Control Mix (MPa)**	**SWCNT's 0.0015% (MPa)**	**SWCNT's 0.0030% (MPa)**	**SWCNT's 0.0045% (MPa)**
1	7	3.63	4.13	4.83	5.7
2	14	12.0	12.2	13.1	13.7
3	28	13.3	13.6	14.1	14.3

5. Conclusion

From the experimental investigation following conclusions can be drawn

- Adding 0.0015% of MWCNTs increased compressive strength by 17.42%, while SWCNTs increased it by 4.92% compared to the control mix.
- Introducing 0.0030% of MWCNTs led to a 20.64% boost in compressive strength, with SWCNTs increasing it by 18.33% over the control mix.
- Incorporating 0.0045% of MWCNTs resulted in a 28.40% increase in compressive strength, while SWCNTs showed a 41.66% increase compared to the control mix.
- For split tensile strength, adding 0.0015% of both MWCNTs and SWCNTs increased it by 2.27% and 2.25%, respectively, compared to the control mix.
- Using 0.0030% of MWCNTs and SWCNTs raised split tensile strength by 4.54% and 6.01%, respectively, compared to the control mix.
- With 0.0045% of MWCNTs and SWCNTs, split tensile strength increased by 5.30% and 7.51%, respectively, compared to the control mix.
- The lab results show that increasing the percentage of MWCNTs and SWCNTs enhances compressive strength.
- Future studies should focus on evaluating the impact of multi-walled carbon nanotubes and single-walled carbon nanotubes on concrete properties and investigate proper mixture proportioning methods.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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