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Utilizing Nanomaterials to Enhance Durability and Strength in Concrete

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Abstract:

This study investigates the effect of carbon nanotube (CNT) addition in concrete on energy absorption. Concrete samples containing different CNTs were prepared and compared with samples without CNTs. The results showed that the addition of carbon nanotubes increased the compressive and flexural strength of concrete, indicating a potential improvement in building performance. For example, the 28-day ultimate strength of samples containing 0.0045 wt.% single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) was higher compared to 7, 14 and aged plain cement M20 samples. Higher on day 28) and 0.0030 wt.% SWCNT and MWCNT. Interestingly, nanocomposites with lower long MWCNT content showed similar properties to nanocomposites with higher short MWCNT content. Microcracks were found in carbon nanotubes, indicating their ability to bond and resist stress. Moreover, the slit tensile strength increases with the addition of carbon nanotubes, especially in 0.0015% multi-walled carbon nanotubes and 0.0030% to 0.0045% single-walled carbon nanotubes.

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

1. Introduction

One of the earliest reports on carbon nanofibers dates back to Hughes and Chambers' 1889 patent for filamentous carbon synthesis. In the 1950s, Soviet scientists Radosevic and Lukyanov performed the first electron microscopic analysis of carbon nanofibers and published their findings in a Soviet Journal article. They examined carbon fibers with a diameter of 50 nanometers. From 1997 to 2003, investment in nanotechnology increased by 40%, reaching €40 billion; This shows that nanomaterials, especially carbon products such as carbon nanotubes and carbon nanofibers, are increasing. Carbon nanofibers are also known for their ability to absorb hydrogen. This research aims to increase hardness and prevent premature cracking by adding carbon nanofibers (CNF) at the nanostructure level to microstructure polypropylene microfibers. The addition of nanofibers increased the flexural strength of cement-based pastes, although some premature cracking problems were encountered. To give context, a strand of DNA is 2 nanometers wide, while a human hair is approximately 100,000 nanometers long.

2. Experimental Program

Nanomaterials such as carbon nanotubes (CNT), carbon nanofibers (CNF), nano silica, titanium dioxide (TiO2) and polycarboxylates are now widely used in concrete. Among these, carbon nanotubes (CNTs) stand out due to their surface. These nanotubes are thin cylinders made of rolled graphene sheets. They come in two main types: single-walled carbon nanotubes (SWCNTs), which are very thin from 0.4 to 10 nanometers in width, and multi-walled carbon nanotubes (MWCNTs), which are 4 to 100 nanometers in width. They can reach lengths as long as micrometers or millimeters. They are stronger than traditional materials such as aluminum and steel; They are approximately 500 times stronger than aluminum and 100 times stronger than steel. Scientists are exploring the potential of nanotechnology to improve the strength and function of natural materials, such as stone, that have evolved over millions of years.

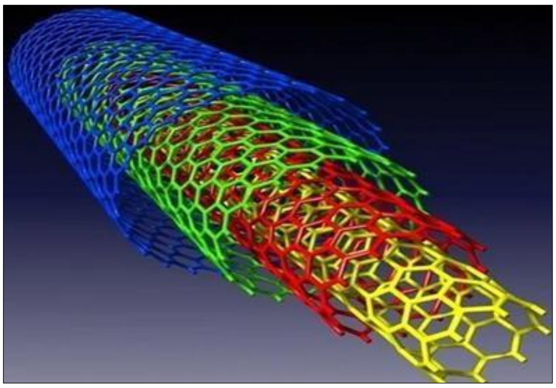

Figure 1 multi-walled CNT's

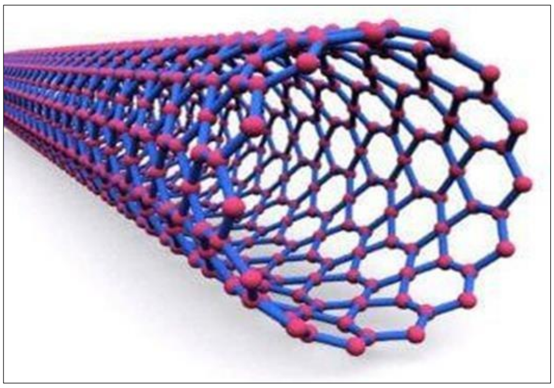

Figure 2 Single-walled CNT's

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	m2/g	110-350	BET
ASH	wt.%	<.9	TGA
EC	s/cm	>100	
Bulk Density	g/cm3	0.04	
Ig/Id	--	--	Raman
-COOH Content	wt.%		XPS & Titration

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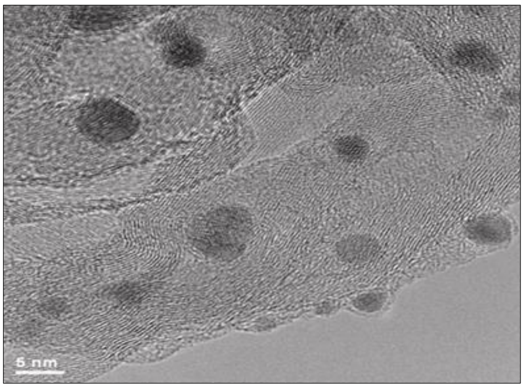


Figure 3 Transmition Electron Microscope View

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	m2/g	490	BET
ASH	wt.%	<.9	TGA
EC	s/cm	>100	
Bulk Density	g/cm3	0.1	
Ig/Id	--	--	Raman
Tensile Strength	Gpa	50-500	
-COOH Content	wt.%		XPS & Titration

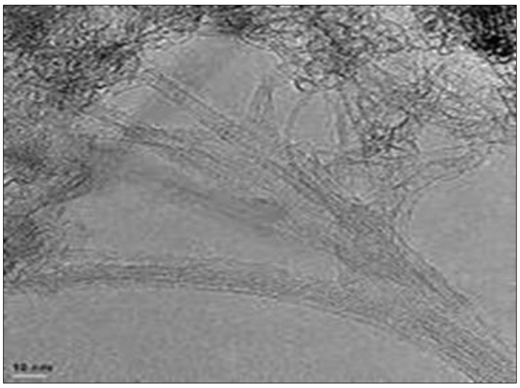


Figure 5 Transmition Electron Microscope View

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, multi-walled carbon nanotubes (MWCNTs) and single-walled carbon nanotubes (SWCNTs) were selected because they were found to improve properties including compressive and tensile strength. M20 grade concrete is prepared as per IS 10262-2019 guidelines with a mix of 1:2.56:3.46 and a water-cement ratio of 0.5 to represent a good mix.

Cubes, cylinders and beams were put to the test to evaluate the performance of concrete by measuring compressive, splitting, tensile and flexural strength.

3.1. Problem Statement

The incorporation of nanomaterials into household products has tremendous potential. Building materials such as concrete contribute to global warming through carbon dioxide emissions. In order to protect the environment, buildings must be made environmentally friendly. By using nanomaterials, we can create green buildings that reduce the damage to the environment. Therefore, the integration of nanomaterials into the construction process plays an important role in promoting sustainable and environmentally friendly construction.

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

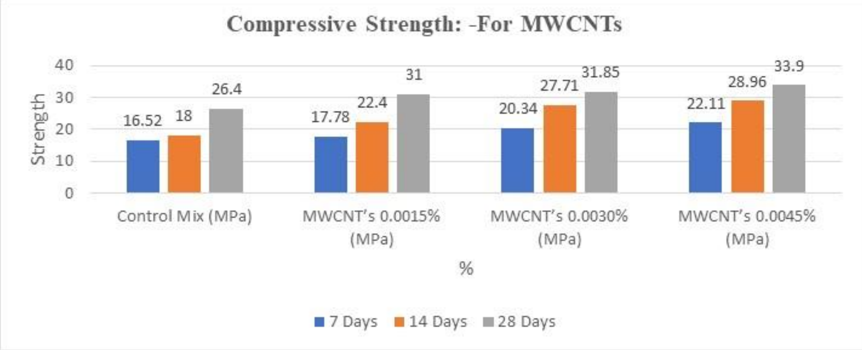


Table 4 Results for Compressive Strength: -For SWCNTs

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

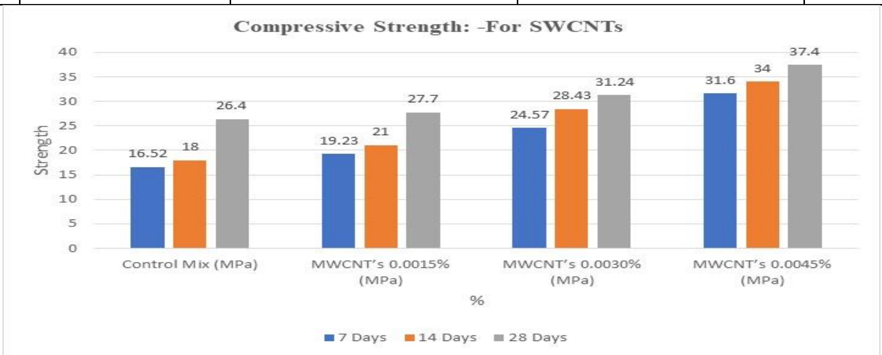


Table 5 Results for Split Tensile Strength: -For MWCNTs

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

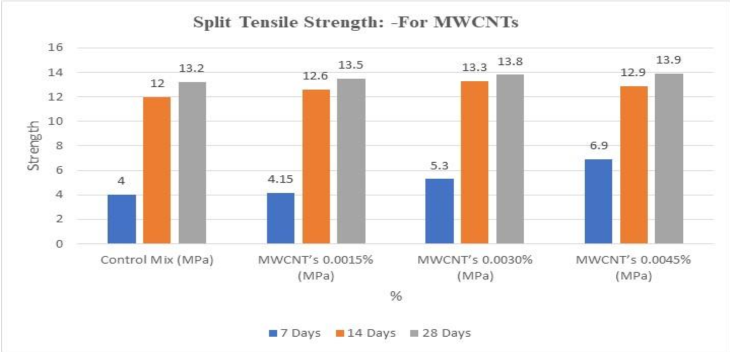
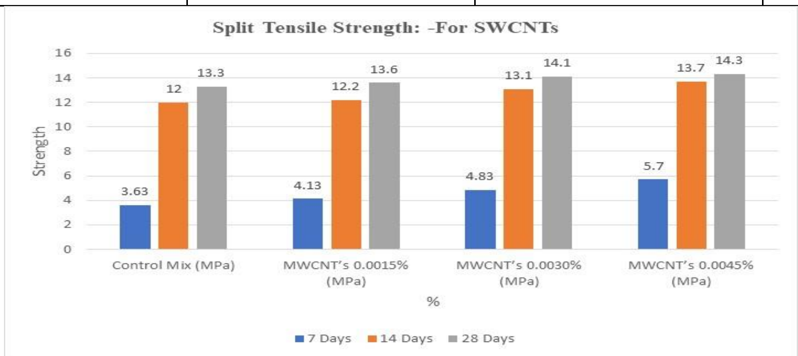


Table 6 Results for Split Tensile Strength: -For SWCNTs

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

- The addition of 0.0015% MWCNTs led to a 17.42% increase in compressive strength, while SWCNTs increased it by 4.92% compared to the control mix.
- Incorporating 0.0030% of MWCNTs resulted in a 20.64% increase in compressive strength, while SWCNTs showed an 18.33% increase over the control mix.
- Adding 0.0045% of MWCNTs led to a 28.40% increase in compressive strength, while SWCNTs showed a 41.66% increase compared to the control mix.
- For split tensile strength, the addition of 0.0015% MWCNTs and SWCNTs increased it by 2.27% and 2.25%, respectively, compared to the control mix.
- Employing 0.0030% of MWCNTs and SWCNTs increased split tensile strength by 4.54% and 6.01%, respectively, compared to the control mix.
- With the inclusion of 0.0045% of MWCNTs and SWCNTs, split tensile strength saw an increase of 5.30% and 7.51%, respectively, compared to the control mix.

- Laboratory results indicate that increasing the concentration of MWCNTs and SWCNTs improves compressive strength
- Future research should concentrate on assessing the influence of multi-walled carbon nanotubes and single-walled carbon nanotubes on concrete properties, as well as exploring appropriate mixture proportioning techniques.

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