IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 3 Ser. 2 (May. – June. 2024), PP 61-66
www.iosrjournals.org

Use Of Carbon Nano Particles In Concrete

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Abstract
Over the past 100 years, RCC has been used in construction projects. RCC has been used most extensively in India for the past 50–60 years. We have built a great deal of infrastructure over this time, including buildings, bridges, sports stadiums, and other structures that are essential to a civilized society. These were created with massive resource speculation. Not even the notion of developing such resources from our meager national resources can occur to us. Therefore, keeping them in operational condition is crucial.
This study investigated how to improve the mechanical properties of Portland cement concrete as a building material by utilizing nanotechnology-based nano-elements, such as carbon nanotubes (CNTs) & nanofibers (CNFs), as reinforcement or filler. CNTs and CNFs have been used as excellent R/Fs in enhancing the mechanical and physical properties of polymer, metallic, and ceramic composites because of their extremely high aspect ratios and ultra-high strength. The application of nano-elements in the building sector has received very little research attention. Consequently, the goal of this thesis was to close the knowledge gap between nanomaterials and building supplies. This was accomplished by utilizing cutting-edge methods to test the incorporation of CNTs and CNFs in regular Portland cement paste. Various mixes with varied concentrations of CNTs or CNFs were prepared in fixed proportions (e.g., water-to-cement ratio, air content, admixtures).
Various methods that are frequently employed in current research to assess the CNTs' strength CNT strengths are ascertained by running the cube analysis test, entering the results into the Etabs Model, and comparing the results to find the difference.
After Test & Evaluation on CNTs cube test results with adding of 0.2wt.% by weight of cement, create a computer-based software model & compare normal strength as well as Strength with carbon nanotubes (CNTs) & nanofibers (CNFs). Also, all possible compare taken care like base share match, R/F consumption, cost analysis, etc.
Keywords: *Aggregates, Carbon, Cement, Concrete, Construction, Nano.*

Date of Submission: 26-05-2024 Date of Acceptance: 06-06-2024

I. Introduction

RCC as a common construction material has come into use for the last 100 years. In India, RCC has been utilized widely in the last 50-60 years. During this period, we have created several infrastructural resources in terms of bridges, buildings, sports stadiums etc., which are lifeline for the civilized society. These have been made with gigantic speculation of resources. We can’t even think of recreating such resources out of limited national assets. It is, therefore, essential to maintain them in functional condition.

II. Properties

CNTs are quickly becoming one of the most promising nano-materials due to their unique mechanical properties (Fig. 3). Experimental tests on CNFs have shown them to have a young’s modulus as high as 400 GPa, with a tensile strength of 7 GPa [20]. Alternatively, CNTs have an average young’s modulus around 1 TPa, an average tensile strength of 60 GPa, & an average ultimate strain of 12% [21]. When compared to the strongest steel, CNTs have a modulus of elasticity of approximately 5 times higher, a tensile strength 100 times larger, & can reach elastic strain capacities 60 times greater than steel, & yet a specific gravity one-sixth that of steel.

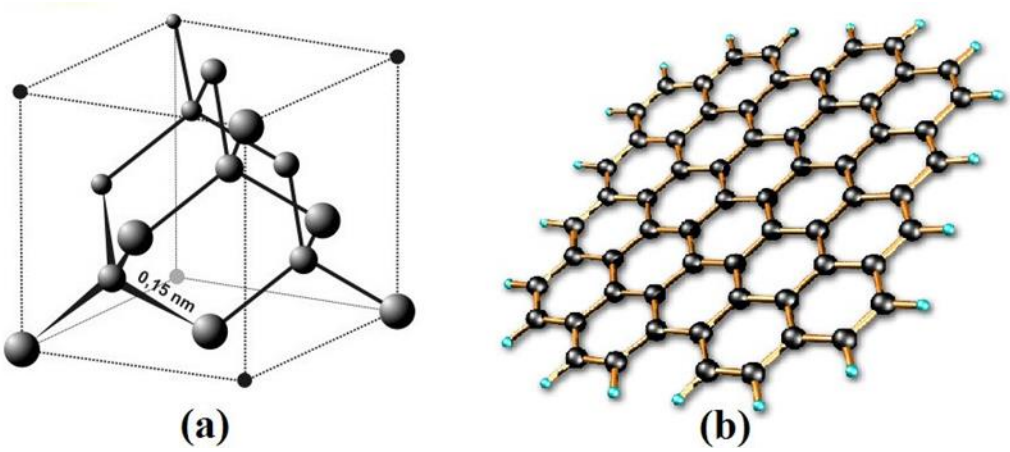

Fig.. Comparison between (a) diamond structure [22] & (b) graphene sheet [23].

The diamond structure consisting of a carbon atom bonded to four other carbon atoms is a tetrahedral geometry. The graphene sheets consist of hexagonally bonded carbon atoms.

CNTs differ from diamonds in that a diamond is formed by a three-dimensional lattice where a carbon atom is attached to four other carbon atoms, which gives diamonds their exceptional strength, as shown in Fig. 3a. On the other hand, CNTs form two-dimensional lattice structures where the carbon atom is attached to three other carbon atoms, as shown in Fig. 3b. One of the carbon-carbon (C-C) bonds consists of a double bond. This creation of a two-dimensional hexagonal structure gives CNTs stronger bonds than a diamond along the plane, & relatively weak interplanar bonds. This allows the different tubes within MWCNTs to slide relative to one another.

III. Methodology

Cube tests are performed to determine the strength of nominal mix & Design Mix with CNTs. 21 cubes prepared for 1 Test Specimens. Also, two test Sample Created for same Cement weight to get accurate result. After getting all results of cubes after 28 days same result information transferred to Etabs Software & two model generated from that. One for nominal mix & other for design Mix with CNTs. After getting result from ETABS software comparative analysis in different aspect will be performed.

IV. Need Of Study

The focus of this thesis is on exploring the use of nanotechnology-based nano-filaments, such as carbon nanotubes (CNTs), as R/F to improve the mechanical properties of Portland cement mix as a construction material. Due to their ultra-high strength & very high aspect ratios, CNTs & CNFs have been used as excellent R/Fs in enhancing the physical & mechanical properties of polymer, metallic, & ceramic composites. Very little attention has been devoted to exploring the use of nano filaments in the construction industry. Therefore, this study aimed to bridge the gap between nano-filaments & concrete materials. This was achieved by testing the integration of CNTs & CNFs in ordinary Portland cement paste through state-of-the-art techniques. Different mixes in fixed proportions (e.g. water-to cement ratio, air content, admixtures) along with varying concentrations of CNTs or CNFs were prepared. With 0.1% CNFs, the ultimate strain capacity increased by 142%, the flexural strength increased by 79%, & the fracture toughness increased by 242%. A scanning electron microscope (SEM) was used to discern the difference between crack bridging & fiber pullout. Test results showed that the strength, ductility, & fracture toughness can be improved with the addition of low concentrations of either CNTs or CNFs.

V. Literature Review

While considerable research on CNTs/CNFs has been focused on their incorporation within polymers, very little attention has been focused on combining CNTs/CNFs with cement. Therefore, the research on integration of CNTs/CNFs in cementitious materials is at a relatively novel stage; currently, very limited research regarding their effectiveness in enhancing the tensile strength or toughness of concrete has been conducted. Within the area of dispersion techniques applicable to cementitious materials, Makar, & Beaudoin have shown promising results in the dispersion of carbon nanotubes in cement by mixing 1.6 wt. % by weight of cement of nanotubes first with ethanol & sonicating for 2 hrs., then adding cement powder to the mixture & further sonicating for 5 hours. After the sonication was completed, the ethanol was allowed to evaporate, leaving behind un-hydrated cement with nanotubes dispersed throughout. This dried mixture was then ground with a mortar & pestle & viewed under a scanning electron microscope (SEM). These images showed evidence of cement powder coated with CNTs.

- **In a research study 2023 Mr. R. Sundharam** demonstrate that adding 0.25 % of the weight of MWCNT to the cement improves the load carrying capacity and, consequently, the mechanical properties of the concrete. The tensile strength & compressive strength of CNT concrete improved by 42% and 32%, respectively. It acts as a filler material to increase bond strength & prevent crack propagation because of its small size. Steel is used less in structural components as tensile strength increases. CNTs' high modulus of elasticity prolongs the life of the construction.
- **Makar et al.** develop cement paste using 2 wt.% of SWCNTs-coated cement produced with a similar method. Through SEM imaging of the fractured surface of dry paste, they found that the distribution of the CNTs in the hydrated samples is not the same as seen on the non- hydrated cement particles. CNT bundles were smaller in apparent diameter & more widely distributed in the hydrated matrix. The smallest bundles imaged had diameters less than 5 nm, suggesting that they were composed of only a few 1.4 nm diameter SWCNTs. Moreover, the SEM images of the broken samples showed evidence of crack bridging across cracks approximately 500 nm wide, while the surface of the samples broken completely apart have shown the nanotubes experienced Fiber pull-out rather than remaining attached to each side. Early in the hydration process, the carbon nanotube composites' hardness increased significantly according to the Vickers hardness test; however, as the hydration process neared its conclusion, the carbon nanotube composites' hardness about equaled that of the plain cement samples. On the other hand, no mechanical testing has been reported by Makar & Beaudoin & Makar et al.
- **Sáez de Ibarra in 2021** employed a very fine cement, which they believed would be ideal for embedding nanotubes. To raise the young's modulus & hardness, they employed single- & multi-walled nanotubes distributed in either ordinary distilled water or water with gum Arabic. Each sample had varying amounts of carbon nanotubes (0.05% to 0.20% by weight of cement). The mixtures were put into prism-shaped molds measuring 10 mm by 10 mm by 160 mm, & they were left to cure for 28 days. With the use of a nano-indentation device & an atomic force microscope, the mechanical characteristics of every sample were assessed. Due to the challenges in dispersing the nanotubes, overplease samples devoid of gum Arabic had inferior mechanical characteristics than the plain cement sample. They added that because they are straighter, more flawless, & more challenging to spread, single-walled nanotubes are inferior to multi-walled nanotubes. The young's modulus of the single-walled & multi-walled nanotubes in the samples containing gum Arabic rose. Nonetheless, the hardness dropped in comparison to the sample of plain cement.

VI. Scope

The Scope of the proposed research is to investigate the potential use of nano-filaments such as CNTs & CNFs as nano-R/F to improve the tensile & flexural strength, as well as the fracture toughness of Portland cement paste. CNTs & CNFs are carbon fibers that have a combination of desirable properties such as ultra-high strength, stiffness, & elongation at ultimate capacity. These nano-filaments will be added to the cement paste to act as bridges across micro- & nano-cracks to form the reinforcing mechanism in shear & tensile zones.Due to their high surface area & aspect ratio, they can act as excellent R/Fs in carrying internal stresses.

To investigate the potential use of CNTs & CNFs as nano R/F in cement paste, two main obstacles must be overcome. The first obstacle lies in the difficulty of dispersing the nano-filaments into the cement matrix. CNTs & CNFs tend to adhere together due to van der Waals forces. The second obstacle lies in creating a sufficient bond between the nano-filaments & the cement matrix. Bonding between either the CNTs, or CNFs, & the cement paste matrix experiences a very low pullout force; therefore, it is unable to utilize the full strength of the nano-filaments. The main tasks can be broken down into four major areas in interest:

- Dispersion of nano-filaments into the cement matrix,
- Bonding between the CNT/CNF & the cement matrix,
- Micromechanical testing, &
- Micromechanical characterization of the nanocomposite cement microstructure.

The following chapters are broken down into the following areas of interest. Chapter 2 discusses the challenges involved in obtaining a uniform dispersion by both surfactants & surface functionalization. Chapter 3 discusses a Performance & Design method to quantify the CNTs with concrete in both aqueous as well as hydrated cement samples. Chapter 4 describes the methods involved in analysis of the CNTs with cement. That includes details micro mechanical testing of small-scale specimens & Compression. Furthermore, both experimental results as well as microstructural characterization using CNTs, & nominal mix concrete are presented. Chapter 5 summarizes the research’s main conclusions & discusses possible future research in the field of nano-filament-reinforced cementitious materials.

VII. Objectives Of The Work

The focus of this study is on exploring the use of nanotechnology-based nano-filaments, such as carbon nanotubes (CNTs) & nanofibers (CNFs), as R/F in improving the mechanical properties of Portland cement paste as a construction material.

After Test & Evaluation on CNTs cube test results with adding of 0.2wt.% by weight of cement, create a computer-based software model & compare normal strength as well as Strength with carbon nanotubes (CNTs) & nanofibers (CNFs). Also, all possible compare taken care like base share match, R/F consumption, cost analysis, etc.

VIII. Experimental Findings

In this thesis work, CNTs design of a G+2+ Mumty storied RCC building structure has been performed evaluating their performance using software analysis & all relevant analysis like R/F, base share, cost etc. R/F of various structural elements of the structure i.e. the beams & the columns still same or reduced with different combinations & their effect on the CNTs on the structure was studied. Nominal mix & 0.2% CNTs add in concrete by weight of cement is taken during cube cast. The design of R/F was done in ETABS & further non-linear analysis was carried out software tool.

MIX DESIGN OF THE TEST SPECIMENS.

Test Specimens Reference	Water/cement ratio	CNTs: % weight of cement	weight of cement (Kg)	Remarks
N1	0.4	0	305	M25
N2	0.4	0	305	M25
N3	0.4	0	400	M40
N4		0	400	M40
C1	0.4	0.2	305	M25 M50 achieved
C2	0.4	0.2	305	M25 M50 achieved
C3	0.4	0.2	400	M40 M60 achieved
C4	0.4	0.2	400	M40 M60 achieved

Notes: - Two test Sample Created for same Cement weight to get accurate result with 21 cubes each. Annexture A for Reference Pic.
N stands for nominal mix
C Stands for CNTs Mix

Figure 1: Cube strength test with CNTs 0.2% weight of cement with Average result Value 60 Mpa after 28 days.

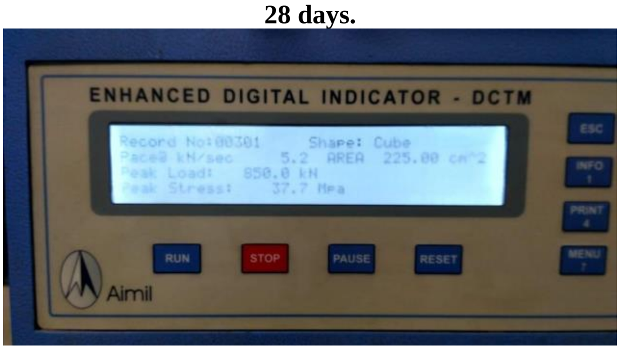

Figure 2: Cube strength test M25 grade of concrete after 28 days of casting.

IX. Conclusions

Based on the present study, the following conclusions can be drawn & pointed out:

1. strength increases by adding CNTs in concrete R/F.
2. The R/F remains same or even reduced in columns only results in a nominal increase in base shear.
3. It is observed that changing nominal concrete with CNTs Concrete at all levels does not affect base shear more.
4. Performance of the building increases when the CNTs add in concrete of beams & columns & keeping same R/F at all levels.
5. Increment in CNTs in concrete R/F of beams & columns both result in an appreciable decrement in roof displacement in building.
6. The CNTs based seismic design obtained by the above procedure satisfies the acceptance criteria for immediate occupancy & life safety limit states for various intensities of earthquakes.
7. CNTs based seismic design obtained leads to a small reduction in steel R/F when compared to code based seismic design (IS 1893:2016) obtained by ETABS.
8. The results we get in terms of strength, capacity & R/F show the real behaviors of structure.

As a concluding statement, one may state that a design based on CNTs results in a structure with a superior seismic load carrying capability, thus accomplishing the goal of CNTs as well as ECONOMY. However, there is undoubtedly room for development in the previously mentioned method.

X. Scope Of Future Work

Within the limited scope of the present work, broad conclusions can be drawn from this work have been reported.

However, further study can be undertaken in the following areas & portions:

1. In this case, the CNTs analysis has been carried out over G+2+ Mumty storied RCC buildings. This study can further be extended for tall buildings as well.
2. In this present study, the conceptual design i.e., the sizes of beams & columns are kept same. Work can be done to optimize the sizes of various frame elements using Non-linear Software analysis.
3. A comparative study can be done to see the effect of shear R/F on CNTs based design using software analysis.

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