# Experimental Investigation of Carbon Nanotube Concrete

R.Sundharam[1], K.Pavithra[2], K.Ranjitha[3], K.Rasika[4], S.Vinotha[5]
*Assistant Professor [1,] UG Student [2, 3, 4, 5,]*
*Kings College of Engineering, Punalkulam, Gandarvakottai Taluk, Pudukottai District, Tamil Nadu, India.*

***Abstract***

*Concrete is one of the most used materials in various fields for arriving a structure, but still it has weakness and drawbacks. To mitigate this problem, the nanotechnology has been implementing. This paper assigns Carbon Nanotube (CNTs) in the concrete to enhance its properties. It also goes over the sources, properties of CNTs. By revising various papers, for ensure that adding 0.25% and 0.5% of Multi Walled Carbon Nanotubes (MWCNTs) by the weight of cement in the concrete mix. CNT concrete exhibit the multifunctional properties such as self – strain sensing, damage sensing, improves interfacial interaction and also it act as a concrete repair material when it is cement composite. Multifunctionality is attractive for cost reduction, durability enhancement, large functional volume, design simplification and absence of mechanical property loss. Sonication process is carried out to achieve well dispersion of CNTs before adding it into the concrete for improving the strength and durability of CNT used concrete. CNT concrete will upgrade the compressive and tensile strength of concrete compare to conventional concrete. This paper explores more details about the implementation of CNTs as reinforcement for concrete to enhance its tensile properties.*

**Keywords***:* *Concrete - Carbon Nanotube (CNT) - Sonication process - Compressive strength - Tensile strength*

## I. INTRODUCTION

Concrete is a brittle material, composite of cement, fine aggregate, coarse aggregate and water. The development of crack is a major complication. Today, use of reinforcing steel to reduce the development of crack and it also arrest crack at micro level as possible. The behaviours of cementitious materials are significantly dependent on their configurations at the Nano-level. Nanotechnology was first started with a talk entitled by physicist **RICHARD P. FEYNMAN** at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. The cementitious materials at the nanolevel have a great impact on the characteristics of concrete such as: strength, ductility, creep and shrinkage, fracture behavior and durability.

### *A. Nanotechnology*

Nanotechnology is the creation of useful or functional materials, devices and systems through control of matter on the nanometre length scale and exploitation of novel phenomena and properties which arise because of the nanometre length scale. Nanotechnology includes the synthesis, characterization, exploration and utilization of nanostructured materials. The term 'nanotechnology' was used first by the Japanese scientists Norio Taniguchi. The “Nano” in Nanotechnology comes from the Greek word “Nanos” that means dwarf. Scientists use this prefix to indicate $10^{-9}$ or one billionth. Nanotechnology is called a “bottom up” technology by which bulk materials can be built precisely in tiny building blocks. Therefore, resultant materials have fewer defects and higher quality. The branch of technology that deals with dimensions and tolerances of less than 100 nanometers, especially the manipulation of individual atoms and molecules. This technology used to increase the life of concrete, create fire resistant materials and give building materials qualities such as “self – healing” and “self – cleaning”. Various nanoparticles were available and used in the construction field; some of them are Nano Silica, Carbon Nanotube, Titanium dioxide, Carbon fiber. Currently, the use of nanomaterials in construction is reduced, mainly for the following reasons: the lack of knowledge concerning the suitable nanomaterials for construction; the lack of specific standards for design of construction elements; high costs; the unknown of health risks associated with nanomaterials. The field of nanotechnology, in general, is loosely divided into four subareas:

- micro and Nano instruments
- Nano electronics
- Nano bio systems and
- Nano engineered materials.

### *B. Nanoparticles*

The fundamentals of nanotechnology lie in the fact that properties of substances dramatically change when their size is reduced to the nanometer range. When a bulk material is divided into small size particles with one or more dimension (length, width or thickness) in the nanometer range or even smaller, the individual particles exhibit unexpected properties, different from those of the bulk materials. This type of particle is known as nanoparticle. Bulk materials possess continuous physical properties. But when particles assume nanoscale dimension, the principles of classical mechanics are no longer capable of describing their behaviour (movement, energy, etc). The same material at the nanoscale can therefore have properties (eg. Optical, mechanical, electrical, etc) which are very different from (even opposite to) the properties the material has at the macro scale (bulk). One nanometer is one billionth meter that is about 10000 times smaller than the diameter of a single human hair.The particles exist on a Nano meter scale (i.e., below 100 nm in at least one dimension). They can possess physical properties such as uniformity, conductance or special optical properties that make them desirable in materials strength and biology. It have certain properties which make them different from that of the bulk materials, including large fraction of surface atoms, high surface energy, spatial confinement and reduced imperfection.

**Types of nanoparticles:**

- Carbon based nanoparticle
- Ceramic nanoparticle
- Metal nanoparticle
- Semiconductor nanoparticle
- Polymeric nanoparticle
- Lipid – based nanoparticle.

### *C. Carbon nanotubes (cnts)*

New shapes for molecules of carbon, known as the bucky ball, which are round and consist of 60 carbon atoms. This led to the discovery of related molecular shape known as the carbon nanotube in 1991. Carbon nanotubes are still one of the most promising areas of nanotechnology as they are about 100 times stronger than steel but just a sixth of the weight; they have unusual heat and conductivity characteristics. Carbon nanotubes are large molecules that are long shaped like tubes as thin as 1 - 3 nanometres and 10 – 15 nm in diameter. This tubes are made up thick sheets of carbon called graphene which were up to form a seam less cylinder. The properties of CNTs are high stiffness, reduce porosity, increases in flexural strength, compressive strength and durability.

**Types of CNT:**

- Single Walled Carbon Nanotube (SWCNTs)
- Double Walled Carbon Nanotube
- Multi Wall Carbon Nanotube (MWCNTs)

## II. PHYSICAL PROPERTIES OF CNT

### *A. Electrical Conductivity*

The structure of a carbon nanotube determines how conductive the nanotube is. When the structure of atoms in a multi walled carbon nanotube minimizes the collisions between conduction electrons and atoms, a carbon nanotube is highly conductive. The strong bonds between carbon atoms also allow carbon nanotubes to withstand higher electric currents than copper. Electron transport occurs only along the axis of the tube. Multi walled nanotubes can route electrical signals at speeds up to 10 GHz when used as interconnects on semi-conducting devices. Adding carbon nanotubes to the cement matrix, the electrical resistivity of cementitious composites changes with the stress conditions under static and dynamic loads.

### *B. Thermal Conductivity and Expansion*

The strength of the atomic bonds in Multi Walled carbon nanotubes allows them to withstand high temperatures. Because of this, multi walled carbon nanotubes have been shown to be very good thermal conductors. Compared to copper wires, which are commonly used as thermal conductors, the multi walled carbon nanotubes can transmit over 15 times the amount of watts per meter per Kelvin. The thermal conductivity of carbon nanotubes is dependent on the temperature of the tubes and the outside environment.

### *C. Field Emission*

Carbon nanotubes possess small radius of curvature at the tip, high mechanical strength all of which are favourable for field emitters. To obtain low operating voltages as well as long emitter lifetimes, the nanotubes should be multi-walled and have closed, well-ordered tips .The SWNTs degrade substantially faster. And it was observed that opening their ends seriously degrades emission performances of MWNTs. The large field amplification factor arising from the small radius of curvature of the nanotube tips is partly responsible for the good emission characteristics. It can be concluded that the density of states at the tip of carbon nanotubes is non metallic, appearing in the form of localized states with well defined energy levels and that the presence of such states influences greatly the emission behaviour.

### *D. Aspect Ratio*

The two main challenges to encounter in order to achieve an effective CNTs/cement composite are, well dispersed CNTs within cement paste matrix and the bonding between nanotubes and the cement paste. High aspect ratio and strong surface attraction between CNT particles make it extremely difficult to ensure uniform dispersion within the cement paste. The effect of different concentrations of long multi-walled carbon nanotubes (MWCNTs) is high length/diameter aspect ratios of 1250 to 3750 and short MWCNTs aspect ratio of about 157 in cement paste.

### *E.* Absorbent

MWCNT/Portland cement (PC) composites have been prepared to evaluate their electromagnetic wave absorbing properties. The effects of MWCNTs content and sample thickness were discussed in the frequency ranges of 2–18 GHz. The absorbing electromagnetic wave properties of MWCNTs-reinforced cement mortar were explored in the frequency ranges of 8–18 GHz using the radar cross-section (RCS) method.

## III. MECHANICAL PROPERTIES OF CNT

### *A. Strength*

It is observed that the addition of carbon nanotubes to cement can enhance its compressive strength, tensile strength and flexural strength of concrete. This enhancement is due to the improvement of material microstructure. MWCNTs fill the fine pores and decrease the porosity of cement composites. The dispersion of CNTs in a concrete mix results in cresting a strong covering for solid particles including cement and fillers, which causes these particles to be more interlocked with the aggregate surfaces. Carbon nanotubes are stiffest and strongest materials. In the case of individual, the carbon Nanotubes shows that strength will have extremely high and weak interactions between the adjacent shells because of its aspect ratio. Due to this sometimes carbon Nanotubes will reduces the strength and the carbon Nanotubes bundles will down to only a few GPA. Multi-walled carbon Nanotubes the strength will reaches up to 60 GPA and 17 GPA for double walled carbon Nanotubes.

### *B.* young's modulus

Carbon Nanotubes has high stiffness and axial strength as a result of its carbon-carbon sp2 bonding. The case of utilization of these carbon Nanotubes requires the fracture, elastic response, yield strength, inelastic behaviour and buckling. Carbon Nanotubes will have the stiffest fibre with young's modulus of 1.4 TPA and also the elongation failure of 20-30% which will have a tensile strength of 100 GPa .In case of the young's modulus the steel will have 200 GPa and the tensile strength will lies between 1GPA-2 GPa.

## IV.TEST ON FRESH CONCRETE

Concrete is one of the most common construction materials and consists of two phases: mortar phase comprised of concrete, water, air and the aggregate phase comprised of coarse and fine aggregates. There are two key considerations when designing a concrete mix. First, the concrete must be workable and easy to cast in the forms in its fresh condition, even when the forms are packed with steel reinforcement. Second, the mix must produce a hardened concrete of specified strength at 28 days (or similar specified time) that is durable and provides good serviceability.

| S.NO | TESTS | NORMAL CONCRETE | CNT CONCRETE |
|---|---|---|---|
| 1. | Slump cone | 160 mm | 170 mm |
| 2. | Flow table | 52 % | 70 % |
| 3. | Compaction factor | 0.93 | 0.95 |

## V.TEST ON HARDENED CONCRETE

Concrete can be described as a two phase system, comprising of cement paste and aggregate. Aggregates are inert, while the structure of the hydrated cement paste keeps evolving over time. The structure of the hydrated cement paste and the different forms of water held within it are described in the Cement. One aspect of primary importance is the zone at the interface of the paste and aggregate – that is simply called the 'Interfacial Transition Zone (ITZ)'. According to researchers, the porosity of the paste as well as the proportion of calcium hydroxide in this zone is considerably higher than in the bulk paste. Furthermore, the ITZ sees a shift from a component of high stiffness (aggregate) to a component of low stiffness (paste). This mismatch can cause crack formation in the ITZ at low load levels, or even as a result of indirect effects such as shrinkage or thermal stresses. Thus, this zone forms the weak link in the concrete, both from a strength and durability point of view.

| S.NO | TESTS | NORMAL CONCRETE | CNT CONCRETE |
|---|---|---|---|
| 1. | Compressive strength | 20 N/mm2 | 30 N/mm2 |
| 2. | Tensile strength | 2 - 3 N/mm2 | 15 N/mm2 |

## VI. SONICATION

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. The enhancement in the extraction of bioactive compounds achieved using sonication is attributed to cavitations in the solvent, a process that involves nucleation, growth, and collapse of bubbles in a liquid, driven by the passage of the ultrasonic waves. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultra-sonication or ultra-sonication**.**

In the laboratory, it is usually applied using an ultrasonic bath or an ultrasonic probe, colloquially known as a sonicator. In paper machine, an ultrasonic foil can distribute cellulose fibres more uniformly and strengthen the paper. Sonication has numerous effects, both chemical and physical. The chemical effects of ultrasound are concerned with understanding the effect of sonic waves on chemical systems, this is called sonochemistry. The chemical effects of ultrasound do not come from a direct interaction with molecular species.

No direct coupling of the acoustic field with chemical species on a molecular level can account for sonochemistry or sonoluminescence. Instead, in sonochemistry the sound waves migrate through a medium, inducing pressure variations and cavitations that grow and collapse, transforming the sound waves into mechanical energy. Sonication can be used for the production of nanoparticles, such as Nano emulsion, nanocrystals, lipsomes and wax emulsions, as well as for wastewater purification, degassing, extraction of seaweed polysaccharides and plant oil, extraction of anthocyanins and antioxidants, production of biofuels, crude oil desulphurization, cell disruption, polymer and epoxy processing, adhesive thinning, and many other processes. It is applied in pharmaceutical, cosmetic, water, food, ink, paint, coating, wood treatment, metalworking, nanocomposite, pesticide, fuel, wood product and many other industries.

In biological applications, sonication may be sufficient to disrupt or deactivate a biological material. For example, sonication is often used to disrupt cell membranes and release cellular contents. This process is called sonoporation. Sonication is commonly used in nanotechnology for evenly dispersing nanoparticles in liquids. Additionally, it is used to break up aggregates of micron-sized colloidal particles. Sonication is the mechanism used in ultra cleaning—loosening particles adhering to surfaces. Soil samples are often subjected to ultrasound in order to break up soil aggregates; this allows the study of the different constituents of soil aggregates without subjecting them to harsh chemical treatment. Sonication is also used to extract microfossils from rock.

**Fig. 1 CNT dispersion in water after sonication**


**Fig. 2 sonication**

## V. CONCLUSION

Addition of 0.25 % of dipersing MWCNT by the weight of cement improve the load carrying capacity and thus enhance the mechanical property of concrete. In CNT concrete, the compressive strength increase by 32% and tensile strength by 42% respectively. Because of the tiny nature, it behaves as a filler materaial to improve bond strength and to resist crack propogation. Enhancement in tensile strength reduce the usage of steel in structural components. CNT increase the life of structure due to the high modulus of elasticity.

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