STUDY OF MECHANICAL PROPERTIES OF CONCRETE USING CARBON NANOTUBES

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It is to certify that the

Research and Analytical work titled

STUDY OF MECHANICAL PROPERTIES OF CONCRETE USING CARBON NANOTUBES

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Has been accepted towards the partial fulfillment
of the requirements
for
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STUDY OF MECHANICAL PROPERTIES OF CONCRETE USING CARBON NANOTUBES

Advisor: Dr. Muhammad Rizwan

ABSTRACT

In this research project use of carbon nanotubes as nano reinforcement in concrete to enhance the mechanical properties of concrete are studied. Carbon nanotubes are becoming popular because of their extreme strength and mechanical properties. It is the new material which can be used in the field of structure and transportation engineering. Multi walled CNT's were chosen for this project. Concrete and cement mortar samples were prepared by keeping fix w/c ratio, aggregate/cement ratio with two different concentrations (0.05% and 0.01%) of CNT's. CNT's were dispersed in aqueous solution in the presence of surfactant in ultrasonic mixer. Compression samples were tested after 7, 14, 28 days of curing, while flexural samples were tested after 28 days of curing. Effect of surfactant on mechanical properties of concrete was studied. Tests showed that compression and flexural strength can be improved by very low concentration of CNT's. 0.05% concentration showed relatively good results as compared to 0.1% concentration. Use of higher concentration of surfactant showed poor results. Test on compression showed 50% improved results with 0.05% concentration, while test on flexure showed 138% improvement in results with the same concentration as compared to normal concrete.

DEDICATION

Dedicated to our beloved parents whose prayers, best wishes and support is always with us during the course of this project.

AND

Our respectable, sincere and dedicated instructors who were always willing to put in their best to guide us throughout the tenure of the studies.

ACKNOWLEDGEMENT

We are thankful to Almighty ALLAH for giving us strength and courage to complete this project.

We would like to express our heartiest gratitude to the Commandant MCE and the Chief Instructor for providing us with the requisite opportunities for the fulfillment of this thesis.

Moreover we would like to express our sincere gratitude to our Directing Staff Dr. Muhammad Rizwan for supporting and encouraging us in our project. His suggestions and advices were pivotal in successful completion of this project.

Above all; we must acknowledge the devotion and sincerity of Dr. Syed Tajammul Hussain and the whole crew of National Centre of Physics for their collaboration with our project. Without their strenuous efforts it would not have been possible.

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CHAPTER – 1

INTRODUCTION

1.1 GENERAL:

The word concrete comes from the Latin word "concretus" (meaning compact or condensed), from "con-" (together) and "crescere" (to grow).Concrete is used all over the world. It is the first most widely used man made construction material and second after water most utilized substance on earth. Concrete is a stone like material obtained by carefully proportioned mixing of cementitious material, sand and gravel or other aggregate, and water. The bulk of the material consists of fine and course aggregate. Cement and water combine chemically to form cement-water paste which not only fills the voids but also coats the surface of aggregates to form solid mass. Concrete with a wide range of properties can be obtained by appropriate adjustment of the proportions of the constituent materials.

1.2 PROBLEM STATEMENT:

Concrete is generally characterized as brittle material and have low tensile strength. Tensile strength of concrete is just the value in estimating the load under which cracking will developed. Plain reinforcement is still in use to cater for the tensile strength. Typical reinforcement is usually done at millimeter and centimeter scale. Concrete is also characterized by low strain capacity. Due to these problems long term durability of structure is affected, and so short fibers are widely used to control cracking.

Thus, there is a need to develop such a composite which will benefit in crack prevention, tensile strength and mechanical durability. Carbon nanotubes are one of the most active research areas that have gradually grabbed the attention in the past two decades.

1.3 WORK ON CARBON NANOTUBES IN PAKISTAN:

No significant research work is done in Pakistan on carbon nanotubes in any industry especially in construction industry. In top educational institutions such as UET, NUST, GIK etc. no significant research was carried out.

Recently research was undertaken by BESTWAY cement industry in Pakistan in collaboration with Quaid-e-Azam University Islamabad. In MCE (Military College of Engineering) it is the first time that some project is conducted on carbon nanotubes.

Due to dire need of flexure (tensile) strength of concrete in modern world, it is imperative that research centers of Pakistan should share its responsibility in this aspect.

1.4 OBJECTIVES:

- To study the effects of % of carbon nanotubes on mechanical properties of concrete.
- Study the effect of surfactant on concrete.
- Study the effect of dispersion of carbon nanotubes (CNTs) in concrete mix.
- Carry out experimental work for obtaining materials properties required to evaluate strength of CNT concrete composites and normal concrete.
- Comparison of normal concrete with carbon nanotubes modified concrete.

1.5 AIM:

Keeping in view the above discussion the aim of the study is to check potential of carbon nanotubes to be used in concrete in future as fiber reinforcement without having any effect on positive aspects of concrete.

1.6SCOPE:

Scope of this research work is as under

- Selection of suitable material (aggregate) for the nano-reinforced concrete.
- Evaluation of mechanical properties of concrete reinforced with different concentrations of carbon nanotubes.
- Comparing the properties of normal concrete with CNT's reinforced concrete.

1.7 LIMITATIONS OF CARBON NANOTUBES IN CONSTRUCTION:

- Missing of link between nanomaterial and construction disciplines.
- Lack of knowledge regarding their use and behavior.
- Lack of standards for design and construction.
- Limited research.
- High cost.
- No information about health risk.

To use carbon nanotubes in construction it is necessary that research is to be carried out from initial stages, start of their productions. In the research process different innovative methodologies are to be incorporated to study the possibility of new construction composite.

2.1.1.1 Types of Carbon nanotubes:

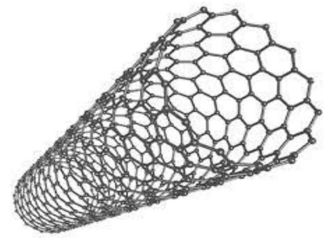


Fig2.1. Single-walled CNT's

- Single- walled CNT's

  Single walled CNT's have only one hollow cylindrical layer.

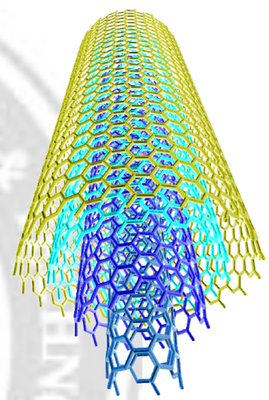


Fig.2.2 Multi-walled CNT's

- Multi-walled CNT's

  Multi-walled CNT's may have 2-20 concentric layers.

2.1.1.2Structure of Carbon nanotubes:

Hollow cylindrical shape of Carbon nanotubes is just like wrapping graphite sheet (allotropic form of carbon) in the form of cylindrical tube. Graphite consists of hexagonal microstructure in which carbon atoms are arranged in a honeycomb lattice. The structure of Carbon nanotubes can easily be distinguished by mapping which specifies vector method. Mapping defines number of unit vectors expressed as (m, n) where m and n are integers.

Metallic properties of Carbon nanotubes depend upon their structure.

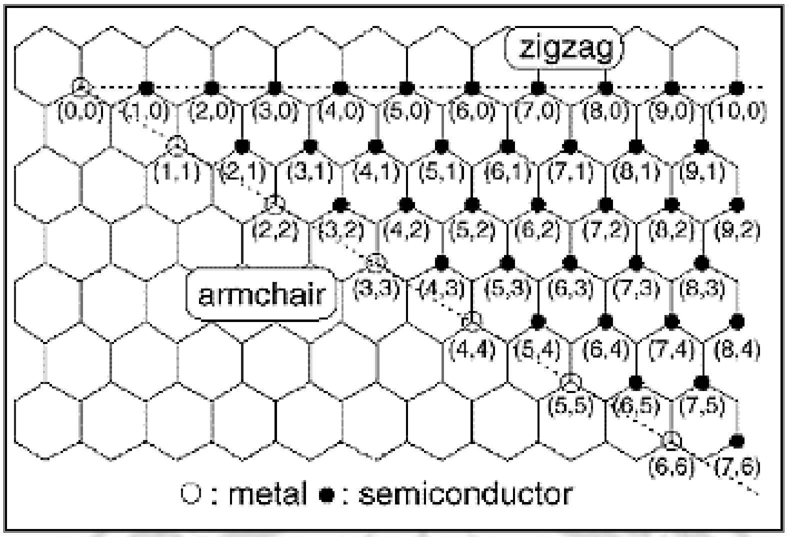


Fig.2.3 (m, n) Vector arrangement

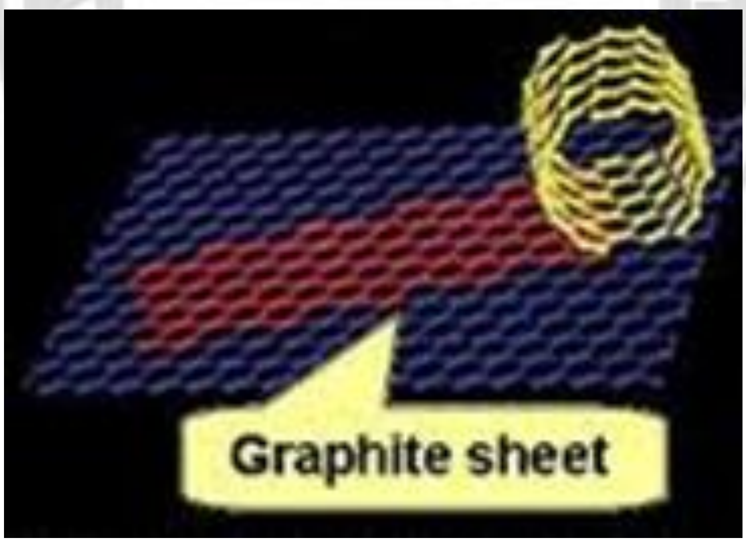


Fig.2.4 Graphite sheet

Three types of structures have been observed.

1. Achiral:

a) Zigzag:

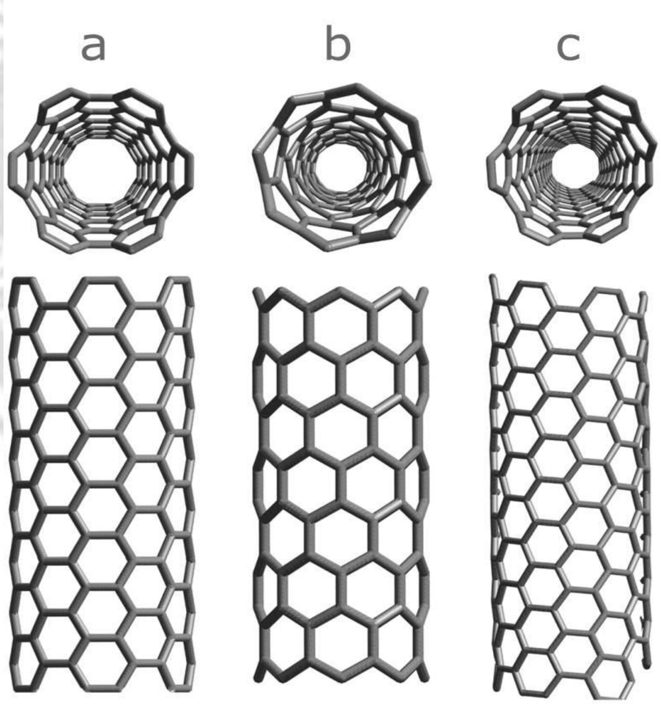
If n=0 then Carbon nanotubes are called zigzag nanotubes.

b) Armchair:

If m=n then Carbon nanotubes are called armchair.

2) Chiral:

All other structure (m,n) in which n‡0and n‡m are called chiral.



a = zigzag; b = Armchair; c = Chiral

Fig.2.5 Structure of CNT's

2.2 HISTORICAL BACKGROUND:

Carbon nanotubes like other forms of carbon were present in nature in the past, the only thing was to discover them. These were first brought to light by Russian scientists L.V.Radushkevich and V.M.Lukyanovichin 1952. The image is shown in Fig.2.6, but at that time these were not recognized.

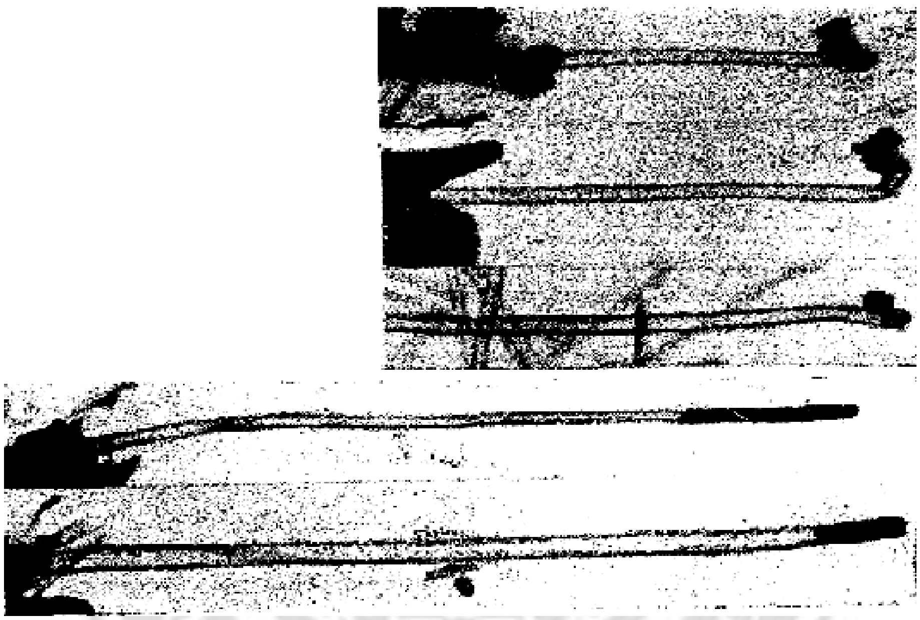


Fig.2.6 CNT's

Later in 1991 the Japanese Scientist Sumio Iijima described CNT's in his article. From that day onward recognition of carbon nanotubes started. Article described multiwall carbon nanotubes. Soon after, large quantities of CNT's were produced by arc evaporation method. Single layered nanotubes were discovered in 1993 by adding metals i-e cobalt to graphite electrodes. With the passage of time new method were developed for their production including most economical method" vapor deposition method".

2.3 APPLICATIONS OF CARBON NANOTUBES IN CONSTRUCTION:

Asphalt and Concrete are widely used construction materials over the centuries. Their use in construction industry has revolutionized the new horizons possibly due to their material properties and structural endurance. Almost 94% of roads in U.S are paved with asphalt. How can one think of constructing without using concrete now days? These materials are often modified in desired manner to lend the structural need like strength, durability and optimum resilience against vulnerable climates.

Researchers have found that adding carbon nanotubes (CNT) to asphalt can improve the entire grade of pavements. On the other hand, their addition to concrete gives the flexural strength (a function of tensile strength) to concrete, where lies the concrete's greatest demerit.

CNT can have their vast Engineering applications in construction of bridges covering long spans, Dams, runways, asphalt and concrete construction, and high rise buildings.

2.3.1 CNT IN LONG SPANNED BRIDGES:

Constructing long span bridges solely relies on structure's efficiency and materials incorporated. The overall design of long span bridges has not been practiced to great extent, which can be otherwise achieved by introducing newer and stronger materials. Carbon nanotubes with their extraordinary young's modulus and tensile strength far exceeding that of steel, allow manufacturing of ultra-strong cables which can be used in suspension bridges making them even longer up to 5 KM.

To determine the advantages of cables made of carbon nanotubes applied to cable stayed bridge. The Longfellow bridge replacement was the project done by team composed of MIT students. This bridge crosses over Charles River, between Boston and Cambridge. The cable section for half of the main span was constructed using different cable properties (Young's Modulus and Tensile strength).

2.3.2 CNT IN DAMS:

Carbon nanotubes due to their flexural strength can be of ultimate performance factor in Dams, when it comes to resisting massive hydraulic pressures. There are locations within a concrete Dam where stress concentrations lead to failure such as upstream and downstream base points. These high tensile stresses occur at the sharp corners at the base and points of sudden change of slope. The tensile stresses in concrete Dams are undesirable as they cause cracks in Dam. In arch Dams these are higher at the upstream heal due to water. These tensile stresses need to be dissipated efficiently for a vital structure in an area. Generally the tensile forces are less than 10% in comparison to that of compressive strength, but when an earthquake strikes maximum flexural stresses are almost equal to compressive stresses due to the oscillation produced, and thus needs to be eliminated. Carbon nanotubes adhere in these conditions can be very important for the tensile strength necessary for the structural integrity.

2.3.2CNT IN HIGH RISE BUILDINGS:

Carbon nanotubes possess high tensile strength almost unimaginable than steel but at the same time is very lighter in weight. This unique property of carbon nanotubes can have its magnificent effects on skyscrapers i.e. reducing the overall dead weight of the structure. Meanwhile when used in beams and slabs, can give valuable contributions to counter the flexural stresses in these members.

2.4 MANUFACTURING:

There are 3 methods basic to produce Carbon nanotubes.

2.4.1ELECTRIC DISCHARGE:

In this method electric arc (3000°C) passed through inert medium such as helium, argon etc. which causes vaporization of two carbon rods acting as electrodes and then re-solidification into highly organized CNT structure. Carbon nanotubes produced by this method are 30% pure by weight and SWCNT and MWCNT both can be produced by this method.

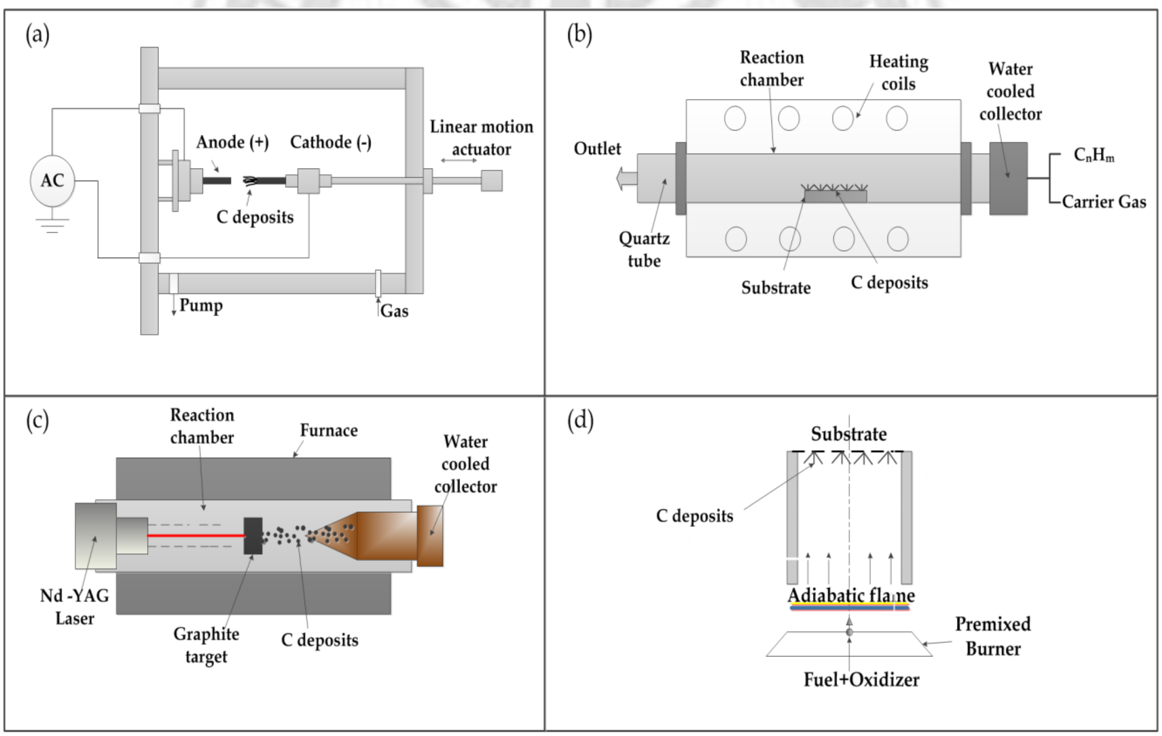


Fig2.7.Electric discharge method

2.4.2 CHEMICAL VAPOR DEPOSITION (CVD):

In this method gas with carbon (ethanol, methane etc.) is used. Supporting catalysts cobalt, nickel and iron metals or combination of all these are used along with carbon based gas to initiate the growth of Carbon nanotubes. CVD is the economical method that is why it is used widely in the production of Carbon nanotubes. Sizes and lengths of Carbon nanotubes are dependent upon the type of gas and catalyst used. Large quantity can be produced with least cost and high purity.

Fig.2.8 Chemical vapor deposition method

2.4.3 LASER METHOD:

It is expensive method due to high cost of laser, produces Carbon nanotubes by vaporization of graphite sheet within an inert gas enclosed in chamber at a specific temperature. Vapors then solidify onto the cooler walls of the chamber and formation of Carbon nanotubes take place. This method produces highly pure Carbon nanotubes.

2.5 MECHANICAL PROPERTIES:

Carbon nanotubes have different properties in axial and radial direction. Experiments have shown elastic modulus up to 1000GPa, tensile strength up to 63 GPa and average ultimate strain of 12%.Carbon nanotubes have low thermal expansion coefficient ranges from 1.5 x 10^{-6}in/in/°F to 2.5 x 10^{-6}in/in/°F. Coefficient of thermal expansion for high strength steel ranges between 6.0 x 10^{-6} in/in/°F to 10.9 x 10^{-6}in/in/°F.

MATERIAL	SPECIFIC DENSITY	E (TPa)	STRENGTH (GPa)	AVERAGE STRAIN (%)	AVERAGE COEFFICIENT OF THERMAL EXPANSION 10^6 in/in/°F
CARBON NANOTUBE	1.3	1	63	12%	2
HS STEEL	7.8	0.2	0.7	0.20%	8

Table 2.1: Mechanical properties of carbon nano tubes &High strength steel

2.5.1 COMPARISON OF HIGH STRENGTH STEEL AND CARBON NANOTUBES:

- Carbon nanotubes have about 5 times more elastic modulus.
- Carbon nanotubes have about 90 times more strength.
- Carbon nanotubes have 60 times more strain capacity.
- Density of Carbon nanotubes is 1/6 times of steel.
- Coefficient of thermal expansion is 4 times less than that of steel.

2.6 LITERATURE REVIEW:

Previously in the past much consideration was given on use of CNT's in polymer composite as compared to its use in cementitious composites. Researchers were facing two major challenges in using CNT's in cementitious material.

- Dispersion of CNT's so that tubes get mixed uniformly in binding paste of cement.
- Bonding of outer surface of CNT's with cement paste or adhesion strength between these two materials.

Due to high surface area of CNT's strong Vander wall's forces are developed making their bundles due to strong attraction force. These complex bundles are difficult to separate/disperse. Dispersion can be done by adding surfactant in an aqueous solution and mixing in ultrasonic mixer. Required level of dispersion can be achieved by specific amount of time and energy. If due consideration is not given to energy and time, there is probability of structure alteration. Amount of surfactant used is another aspect need to be considered. Hydration process of cement (hardening of cement paste) and chemical reaction could be delayed or even ceased by using surfactant more than appropriate.

Marker et al (2003) performed sonication on CNT's in ethanol for 2hrs, then author mixed cement powder in that and sonicated for 5hrs. Mixture was dried, ethanol a hydrocarbon was evaporated, and remnant was grounded and observed under SEM (scanning electron microscope). Images confirm the presence of CNT's around cement particles. Author also observed the changes in cement particles, he referred those changes to ultrasonication process.

Cwirzen et al (2009) made an effort to mix CNT's directly in cement paste in order to save time and effort needed to disperse CNT's.

Marker et al (2005) performed tests on cement grains before and after the hydration process. SEM suggested difference between those two.

Li et al (2007) also performed tests but rather differently. Her made functionalized MWCNT,s treating with acids (HNO_3/H_2SO_4) and tested both functionalized and non-functionalized CNT's in cement matrix with w/c ratio of 0.4.He prepared sample of functionalized CNT's with aqueous solution and mixed with cement with emulsifier. He concluded 4% more compressive strength of functionalized CNT's matrix as compared to non-functionalized CNT's.

Cwizren et al (2005) adopted new approach to disperse CNT's. He used poly (acrylic acid) with gum arabic (0.8% of cement by weight) which delayed the hydration process for 3 days still not affecting the material strength. 0.045% CNT's by weight of cement were used and compressive and flexure properties were evaluated by casting into 10mm*60mm molds. 50% improvements in results were obtained.

Nasibulin et al (2009) stepped up with another procedure of directly preparing cement composite with CNT's in chemical vapor deposition method. Author used acetylene gas to provide carbon and cement particles were continuously fed by rotary feeder.10mm*10mm*60mm molds were used for testing; more than 100% enhanced results were obtained.

Shah et al (2009) tested MWCNT's cement composites for flexure and elastic modulus. Up to 40% increase in flexure strength and 55% increase in elastic modulus have been reported with w/c ratio 0.3 and ultrasonicated MWCNT,s percentage of 0.1 by dry weight of cement.

Konsta-Gdoutos et al (2009) made a comparison between effect of short and long MWCNT's and .025% and0 .08 weight% concentration for long MWCNT,s and 0.025 and 0.1 weight% concentration for short MWCNT's was used. Experiment showed that MWCNT's concentration depend upon their aspect ratio. Good results were obtained with the use of 0.08 weight% for short and less than .05 weight% for long MWCNT's.

In 2010, author recommended mechanical properties are dependent upon dispersant concentration used in CNT's.

Tyson and Abu-Al-Rub et al (2011) studied effect of different parameter on mechanical properties of cement composites. They studied properties like Strength, modulus of elasticity, toughness and ductility. They compared results of 7, 14 and 28 days from day of casting with plain cement. They also studied functionalization effect and comparison between use of CNF and CNT's. They kept w/c ratio of 0.4 and concentration of CNT's cement was also different. CNF's cement composites showed better results than CNT's cement composites. The non-functionalized nanotubes showed delay in gaining strength. The important aspect of their work is loss in strength with time .They reported that over the time period functionalized CNF's and MWCNT's showed degradation in mechanical properties. They also concluded reason for that; Degradation is due to formation of ettringite.

Lue et al (2011) performed three point flexure tests on specimen 160mm x 8mm x 36mm. Dispersion of MWCNT's was done by usual method by using surfactant and ultrasonication. Three concentrations were compared (0.1, 0.5,1 wt. %) w/c ratio was kept at 0.96 and silica fume was also used.

Tests were conducted after 28 days from day of casting. Results showed improvement in strain and Modulus of rupture by 80% and 90% respectively. In another publication 45% increase in structural damping capacity was reported as compared to plain cement paste with same concentration of MWCNT's.

Hunashyal et al (2011) tested MWCNT's with carbon microfibers at four concentration 0.25, 0.5, 0.75 and 1 wt. %of dry cement. W/C ratio was kept at 0.4. Mold of size (20mm x 20mm x 80mm) was used for casting and tested under four point bending. MWCNT's and carbon fibers were separately sonicated in the presence of surfactant for a long period of time; 90 minutes for MWCNT's and 20 minutes for carbon fibers. These fibers were mixed with cement particles and for another half an hour sonication was applied. After 28 days curing, tests were conducted; up to 90% increase in flexure strength was reported.

2.7 REQUIREMENTS FOR USE OF CNT'S IN CEMENT:

Four main necessities should be taken care of while employing CNTs and CNFs as reinforcement within the cement matrix.

- Fine dispersion
- Large aspect ratios
- Uniform alignment
- Bond strength

The first necessity is dispersion of nano-fibers within the cement medium since Vander Waals forces are present in CNTs and CNFs which helps in their attraction due to which agglomerates (bundles) in the form of knotted ropes and bunches are formed that is very difficult to disentangle. These agglomerates form large voids within the cement matrix and stresses cannot be transferred. A well dispersed matrix of nanotubes/nano fibers helps make sure that every nano-strand is uniformly coated with cement. This will helps in transfer of stresses from the cementitious matrix to the nano-fibers. This decreases stress concentrations caused by irregular dispersion of nano-fibers.

The second requirement is to have a large aspect ratio. To optimize the bond between cement and nano-fibers, the surface area should be maximized. However, too large of an aspect ratio can cause problems with dispersing the nano-fibers.

The third requisite is the alignment of nano-fibers. Alignment will help produce an even stress transfer under axial loads. The proposal behind aligning the nano-fibers is that the nano-fibers are at right angles to the primary stresses cannot transfer stresses along its axis efficiently. However, if the nano-fibers are aligned parallel to the primary stress direction, this can help in good stress transfer. This uni-axial alignment is not always beneficial. Anisotropy is the main disadvantage of uniform alignment, which can affect mechanical properties.

If the bonding between the cement matrix and fibers is weak, this will causes nano fibers to slide out of the cement matrix under much lower load than the strength of the individual nanotubes. Proper bond with cementitious matrix is very difficult to achieve; therefore, the nano-fibers can be pulled out of the matrix very easily. Also, due to the very smooth surfaces of the CNTs and CNFs, frictional forces are very small to holdup complete pullout. This sliding turns out to be more pronounced within the bundles if the nano-fibers be deficient in proper dispersion. In order to utilize as much of the nanotubes' mechanical properties as possible, the interfacial bonding and frictional properties need to be made effective.

2.8 EFFECT OF SURFACTANT ON CONCRETE STRENGTH:

Scanning electron microscope (SEM) images of fractured surface shown by Maria S. Konsta-Gdoutos at 1 µm scale are presented in Fig.2.9, and 2.10. In Fig.2.9 surfactant to CNT's ratio is 1.5; agglomeration and bundles of CNT's can be seen on SEM image showing that dispersion was not effective, while in Fig.2.10 individual dispersed CNT's can be seen by the addition of 4 x CNT's concentration.

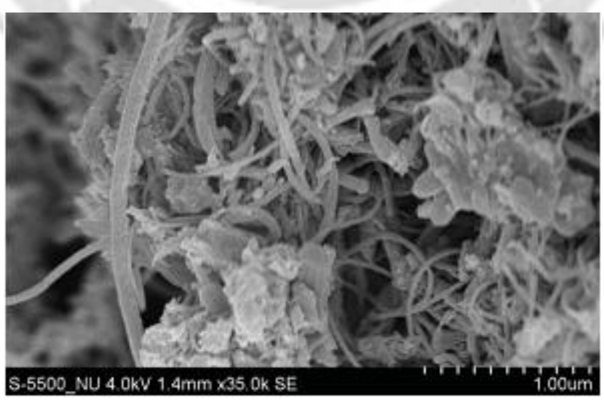


Fig.2.9 Dispersant to CNT's ratio = 1.5

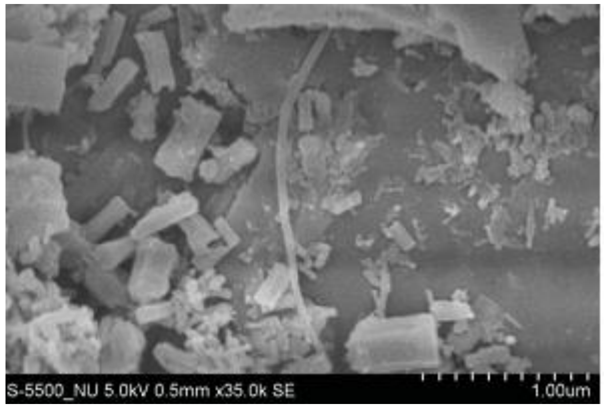


Fig.2.10 Dispersant to CNT's ratio = 6.25

According to Maria S. Konsta-Gdoutos addition of surfactant largely affects the hydration process of cement. Surfactant delays the hydration process of cement. By the addition of more surfactant then required, hydration process may even cease, thus not giving the true strength.

2.9CNT DISPERSION AND FUNCTIONALIZATION:

2.9.1 DISPERSION:

Scattering the carbon nanotubes individually in a way that agglomerates and bundles should not form. It is required in mixing CNT's in cementitious composites.

Two types of Techniques are used:

1. Mechanical
2. Chemical

2.9.2 MECHANICAL DISPERSION:

This specific type of dispersion is done by ultra-sonication of CNT's in the presence of surfactant in aqueous solution that breaks the Van der Waal's forces. Without surfactant Van der Waal's forces develops again.

2.9.3 FUNCTIONALIZATION OR CHEMICAL DISPERSION:

Chemical dispersion is done chemically also known as Functionalization of CNT's. Prime function of chemical dispersion is to provide functional group to surface of CNT's such as

Oxygen (hydroxyl, Carboxyl, carbonyl, ester, side group)
Halogen (Chloro, Floro)
Hydro carboxyl (alkenyl, alkyl)

Two types of chemical dispersion

a) Covalent Bonding
b) Non Covalent Bonding

2.9.4 COVALENT BONDING:

This kind of Functionalization can be done by four different ways.

- Air Oxygen Treatment
- Acid Treatment
- Ozone Treatment
- Plasma Oxidation

2.9.5 ACID TREATMENT:

This type of functionalization is done by treating acids (with H_2SO_4 and HNO_3) with CNT's which causes functional group to develop on the surface of CNT's. Functional group increases the reactivity and bond between CNT's and cement matrix.

2.9.6 DEFECT SITE FUNCTIONALIZATION:

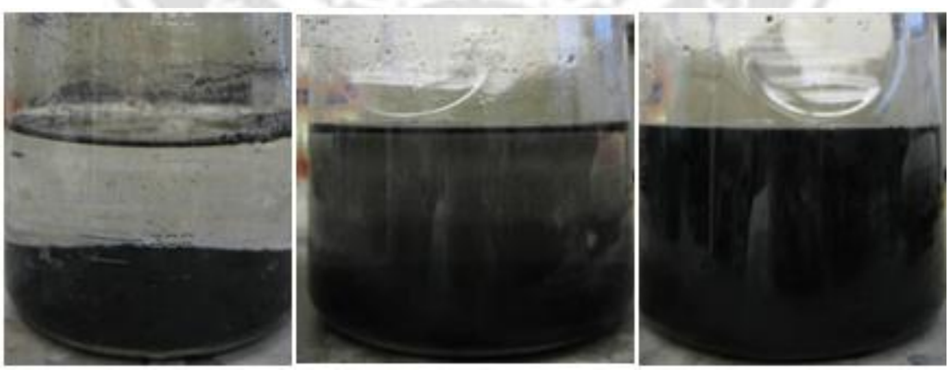
A covalent bond is formed by a strong oxidizing agent (like H_2SO_4). H_2SO_4defects surface of CNT's and HNO_3 upon interaction with these defects make covalent bond and functional group is provided.

2.9.7 END CAP FUNCTIONALIZATION:

It is almost the same as defect site functionalization but $H_2SO_4$is not used Without H_2SO_4, HNO_3works on predefect locations.

2.9.8 SIDE WALL FUNCTIONALIZATION:

This sort of functionalization uses some salts or fluorine gas instead of strong oxidizing agent. Defect group gives better pull out resistance to CNT's fibers in cementitious material.



A. **B.** **C.**

Fig.2.11 CNT's solution with surfactant

(a) Hand stirring, (b) Hand shaking, (c) Ultrasonic mixing

2.9.7 NON COVALENT BONDING:

These include only surfactant. Surfactants are amphiphilic, they have two groups.

a) Hydrophilic (Polar)
b) Hydrophobic (Non Polar)

As water is polar and CNT's are non-polar, so hydrophobic group of surfactant will be attracted by CNT's and hydrophilic end to water molecules and so CNT's stay dispersed in aqueous medium.

Using high energy along with acid treatment can damage the CNT's and break them into pieces.

CHAPTER – 3

MATERIALS

3.0 MATERIALS:

The materials along with specifications, which were used for this project, are summarized below.

3.1 FINE AGGREGATE:

Dry Lawrancepur sand graded between 4.75mm (No.4) sieve and 150 µm (No.100) was used for all samples. The sieve analysis was performed in accordance with ASTM C136 - 04. The specific gravity and the percentage of water absorption were determined in accordance with ASTM C128 - 04.

3.1.1 SIEVE ANALYSIS OF FINE AGGREGATE:

ASTM SIEVE #	MASS RETAINED (gm)	CUMMULATIVE MASS RETAINED (gm)	% RETAINED	CUMMULATIVE % RETAINED	% PASSING	ASTM RANGE
4	0	0	0.0	0.0	100.0	95-100
8	19	19	3.1	3.1	96.9	80-100
16	86	105	13.9	17.0	83.0	50-85
30	198	303	32.1	49.1	50.9	25-60
50	225	528	36.5	85.6	14.4	10-30
100	73	601	11.8	97.4	2.6	2-10
200	4	605	0.6	98.1	1.9	0
PAN	12	617	1.9	100.0	0.0	
TOTAL	**617**			**252.2**		

Table3.1: Sieve analysis of fine aggregate

The results of sieve analysis of fine aggregate as compared with the requirement of ASTM C33 - 04 are shown in Table 3.1, and particle size distribution in Fig.3.1.

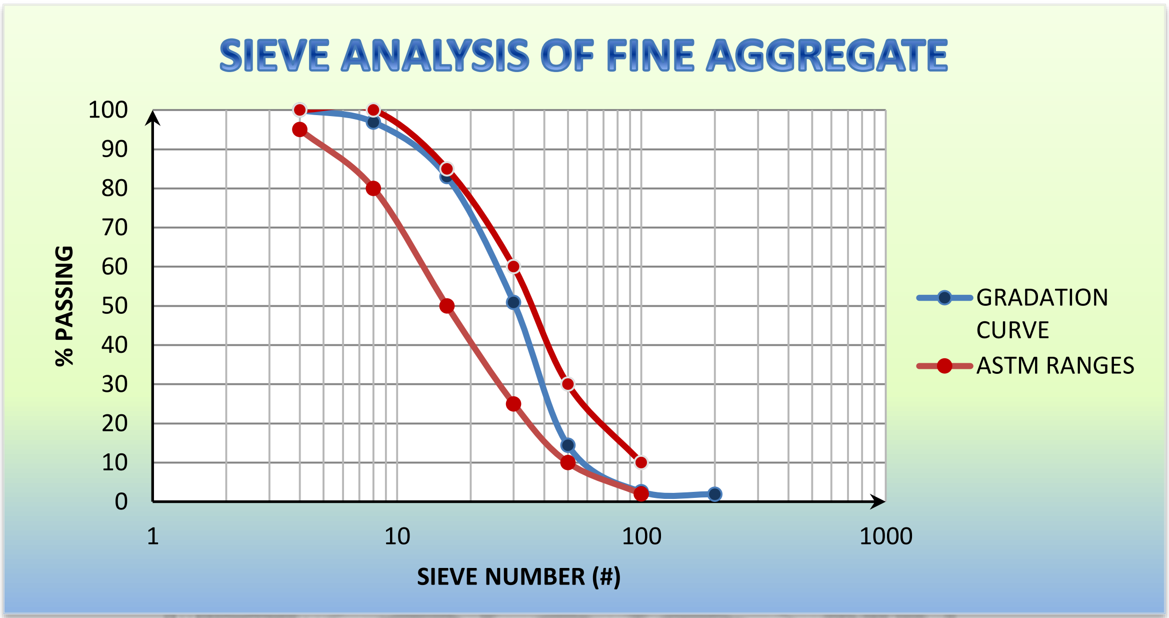


Fig.3.1, Sieve analysis of fine aggregate

3.1.1.1 Fineness Modulus:

$$\text{Fineness Modulus} = \frac{\text{(summation of cumulative \% retained)}}{100}$$

$$\text{Fineness Modulus} = \frac{(252)}{100}$$

Fineness modulus = 2.52

Results:

- Gradation curve lies within ASTM standard range.
- Fineness modulus is 2.52

3.1.2 SPECIFIC GRAVITY OF FINE AGGREGATE:

DESCRIPTION	SYMBOL	S1	S2
WEIGHT OF SATURATED SURFACE DRY (SSD)	A	510.0	508.0
WEIGHT OF OVEN DRIED SAMPLE	B	503.2	501.1
WEIGHT OF PYCNOMETER *FILLED* WITH WATER	C	661.8	661.8
WEIGHT OF PYCNOMETER + SAMPLE (SSD) + WATER	D	978.8	976.8

Table 3.2: Specific gravity of fine aggregate

Bulk Specific Gravity of Specimen S1:

= A / (A + C – D)

= 510 / (661.8 + 510 – 978.8)

= 2.642

Bulk Specific Gravity of Specimen S2:

= 508 / (661.8 + 508 – 976.8)

= 2.632

Average Bulk Specific Gravity:

= 2.637

Results:

- Bulk specific gravity = 2.637

3.1.3 Absorption Of Fine Aggregate:

Absorption of Specimen A:

= [(A – B) / B] x 100

= [(510 – 503.2) / 503.2] x 100

= 1.35 %

Absorption of Specimen B:

= [(508 – 501.1) / 501.1] x 100

= 1.37 %

Average Absorption = 1.36 %

Results:

- Absorption of fine aggregate is 1.36%

3.1.4 UNIT WEIGHT OF FINE AGGREGATE:

A = MASS OF THE SAND + THE MEASURE (Kg)	**7.9**
	8.1
	8.1
AVERAGE A	**8.03**
B = MASS OF THE MEASURE (Kg)	**2.69**
V= VOLUME OF THE MEASURE (Cu-ft)	**0.15**

Table 3.3: Unit weight of fine aggregate

Unit Weight of Fine Aggregate:

= (A – B) / V

= (8.03 – 2.69) / 0.15

= 35.6 kg/ft^3

Results:

- Unit weight of fine aggregate = 35.6 kg/ft^3

3.1.5 FREE MOISTURE ON FINE AGGREGATE:

Weight of Fine Aggregate sample = 570 gm.

After getting oven dried for 24 hours;

Weight of Fine Aggregate sample = 567 gm

Free Moisture = ((570 – 567) / 570) x 100

= 0.53 %

Results:

UNIT WEIGHT (Kg/ft^3)	BULK SPECIFIC GRAVITY (SSD)	ABSORPTION	FREE MOISTURE	FINENESS MODULUS
35.6	2.637	1.36	0.53	2.52

Table 3.4: Results

3.2 COARSE AGGREGATE:

Crushed stone (Margala crush) having nominal maximum size of 20 mm (1 in) was used as coarse aggregate. The sieve analysis was determined in accordance with ASTM C136 - 04. The specific gravity and the percentage of water absorption were determined in accordance with ASTM C 128-04.

3.2.1 SIEVE ANALYSIS OF COARSE AGGREGATE:

The results of sieve analysis as compared with the requirement of ASTM C33 - 04 are shown in Table 3.5 and particle size distribution in Fig 3.2.

SIEVE SIZE (in)	MASS RETAINED (gm)	CUMMULATIVE MASS RETAINED (gm)	% RETAINED	CUMMULATIVE % RETAINED	% PASSING	ASTM RANGE
1 1/2"	0	0	0.0	0.0	100.0	
1"	30	30	0.3	0.3	99.7	90-100
3/4"	2370	2400	20.7	20.9	79.1	40-85
1/2"	5826	8226	50.8	71.8	28.2	10-40
3/8"	2044	10270	17.8	89.6	10.4	0-15
3/16"	1072	11342	9.4	99.0	1.0	0-5
PAN	119	11461	1.0	100.0	0.0	-
TOTAL	11461					

Table 3.5: Sieve analysis of coarse aggregate

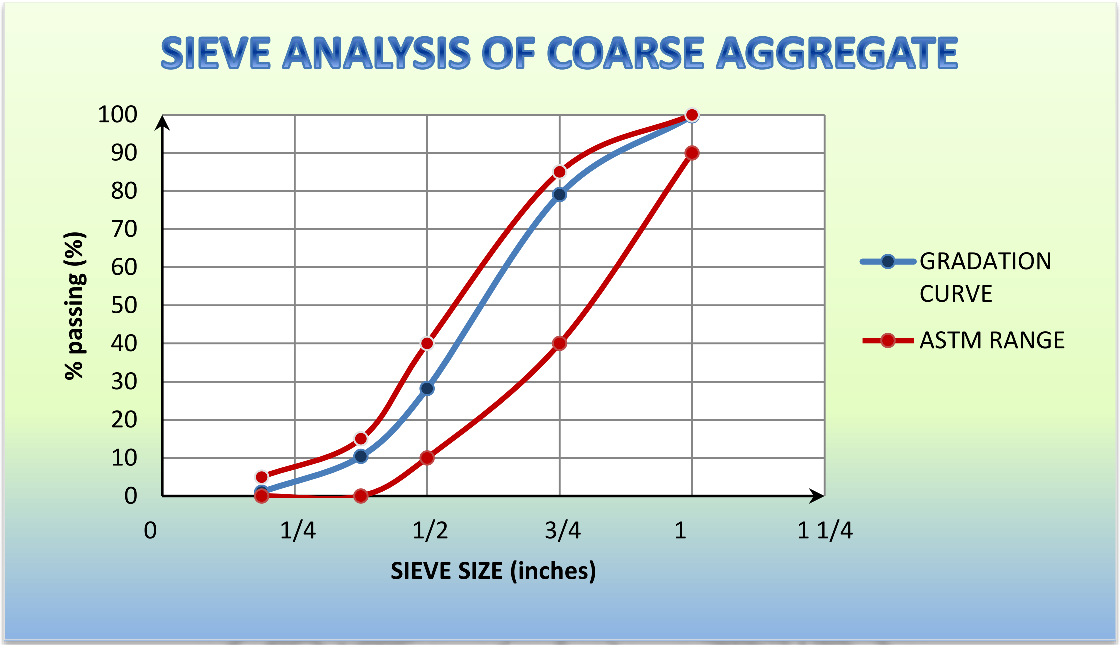


Fig. 3.2Sieve analysis of course aggregate

3.2.2 SPECIFIC GRAVITY OF COARSE AGGREGATE:

DISCRIPTION	(GM)
WEIGHT OF SATURATED SURFACE DRY (SSD)	1267.6
WEIGHT OF OVEN DRIED SAMPLE	1259.2
WEIGHT OF SATURATED SAMPLE IN WATER	813.3
BULK SPECIFIC GRAVITY (SSD)	2.79
BULK SPECIFIC GRAVITY (OVEN DRIED)	2.77
APPARENT SPECIFIC GRAVITY	2.82
% OF ABSORPTION	0.667

Table 3.6: Specific gravity of coarse aggregate

Bulk Specific Gravity:

= A / (A – C)

= 1267.6 / (1267.6– 813.3)

= 2.79

Results:

- Bulk specific gravity of coarse aggregate is 2.79

3.2.3 ABSORPTION:

Absorption of coarse aggregate = [(A – B)/B] x 100

= [(1267.6–1259.2) / 1259.2] x 100

= 0.667%

3.2.4 UNIT WEIGHT:

A = MASS OF THE COARSE AGGREGATE + THE MEASURE (KG)	60.4
	60.5
	60.9
AVERAGE A	60.6
B = MASS OF THE MEASURE (KG)	17.2
V = VOLUME OF THE MEASURE (CU-FT)	1

Table 3.7: Unit weight of coarse aggregate

Unit Weight of Coarse Aggregate

= (A – B) / V

= (60.6–17.2) / 1= 43.4 kg/ft^3

3.2.5 FREE MOISTURE:

Weight of Course Aggregate sample = 598 gm.

After getting oven dried for 24 hours

Weight of Fine Aggregate sample = 597 gm

Free Moisture = ((598 – 597) / 598) x 100

= 0.167 %

The summary of the physical properties of coarse aggregate is given below

UNIT WEIGHT (Kg/ft^3)	BULK SPECIFIC GRAVITY (SSD)	ABSORPTION	FREE MOISTURE
43.4	2.79	0.667%	0.167%

Table 3.8: Physical properties of coarse aggregate

3.2.6 IMPACT VALUE TEST:

This test tells the toughness of coarse aggregate against impact loading. Test was performed in accordance BS 812: 1967.

IMPACT VALUE TEST

WEIGHT OF DRY SAMPLE	w1	316
WEIGHT PASSING #7 SIEVE	w2	48
WEIGHT RETAINED ON #7 SIEVE	w3	268
COMBINED WEIGHT		316
AGGREGATE IMPACT VALUE		15.19

Table 3.9: Impact value test

Limits:

SPECIFICATIONS	
< 10%	EXCEPIONALLY STRONG
10 - 20 %	STRONG
10 - 30 %	SATISFACTORY FOR CONCRETE
>45 %	NOT SUITABLE FOR CONCRETE

Table 3.10: Specifications

Results:

Impact value is 15% .Aggregate is strong.

3.2.7 CRUSHING VALUE TEST:

CRUSHING VALUE TEST		
WEIGHT OF DRY SAMPLE	w1	2860 gm
WEIGHT RETAINED #7 SIEVE	w2	2194 gm
WEIGHT PASSING #7 SIEVE	w3	666 gm
CRUSHING VALUE		23.29 %

Table 3.11: Crushing value test

Limits:

SPECIFICATIONS	
CRUSHING VALUE	USAGE
MAXIMUM OF 30%	CEMENT CONCRETE
MAXIMUM OF 45 %	WEARING SURFACE

Table 3.12: Specifications

Results:

Value is 23% < 30%. Aggregate is satisfactory.

3.3 CEMENT:

Portland cement was first produced by Joseph Asp din a British bricklayer in 1800.Portland cement is having adhesive and cohesive properties which provides a binding medium for different constituents. Portland cement is obtained by burning together natural occurring alumina and lime at high temperature of 1450 °C in rotary kiln. Calcium carbonate reacts with silica bearing minerals to give calcium silicates. Calcium silicates develop strength on interaction with water.

In this experimental investigation, ordinary Portland cement (OPC) conforming to ASTM C150 Type I, from DG cement factory was used.

OXIDES	PERCENTAGE %
SILICON DIOXIDE (SIO_2)	20.2
ALUMINUM OXIDE (AL_2O_3)	8.67
FERRIC OXIDE (FE_2O_3)	2.26
CALCIUM OXIDE (CAO)	62
MAGNESIUM OXIDE (MGO)	1.33
SULFUR TRIOXIDE (SO_3)	2.63
SODIUM OXIDE (NA_2O)	0.84
POTASSIUM OXIDE (K_2O)	0.69
MOISTURE CONTENT	…
LOSS ON IGNITION	1.38

Table 3.13: Chemical composition of cement

3.3.1 CONSISTENCY TEST:

Consistency is actually required for testing acceptance of cement i-e, determination of setting time and soundness. As per ASTM consistency is amount of water required to make a cement paste through which vicat plunger penetrate 10 mm below the surface of cement paste in 30 sec. Consistency was determined according to ASTM C187 – 98.

Standard Vicat apparatus was used. Normal consistency of the paste decreases as surfactant is added in the paste. The decrease in consistency is due to a bit foamy texture.

S.NO	WATER (ml)	CEMENT	AMOUNT OF WATER (WT % CEMENT)	PENETRATION (mm)
1	130	500	26	8
2	150	500	30	10
3	175	500	35	13

Table 3.14: Consistency Test for cement without surfactant

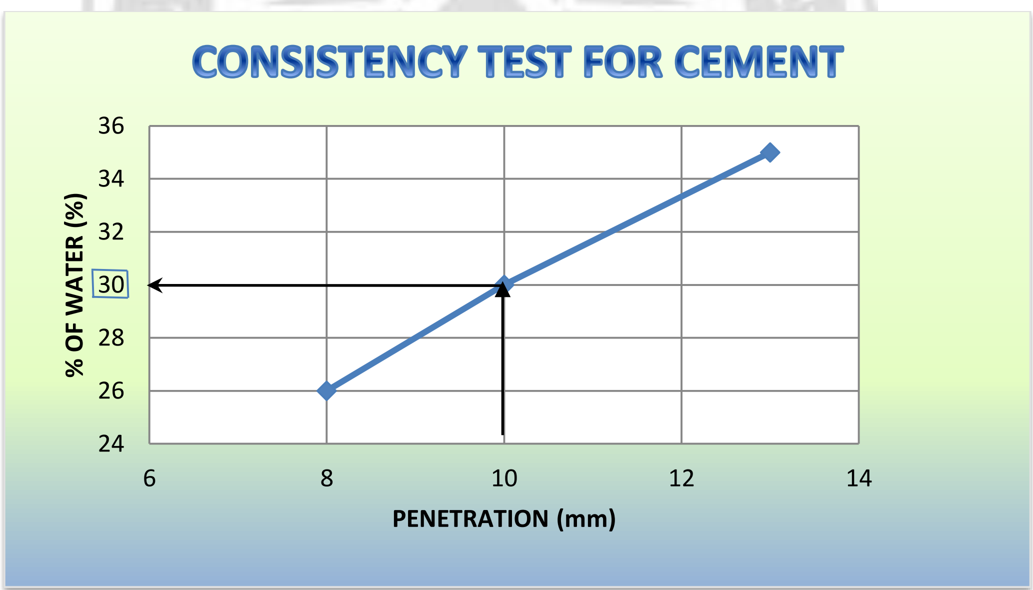


Fig. 3.3Consistency test for cement

Results:

CONSISTENCY OF CEMENT = 30 %

S.NO	WATER (ml)	SURFACTANT (ml)	CEMENT WITH SURFACTANT	AMOUNT OF WATER + SURFACTANT (WT % CEMENT)	PENETRATION (mm)
1	129	1	500	26	9
2	149	1	500	30	11
3	174	1	500	35	14

Table 3.15: Consistency test for cement with surfactant

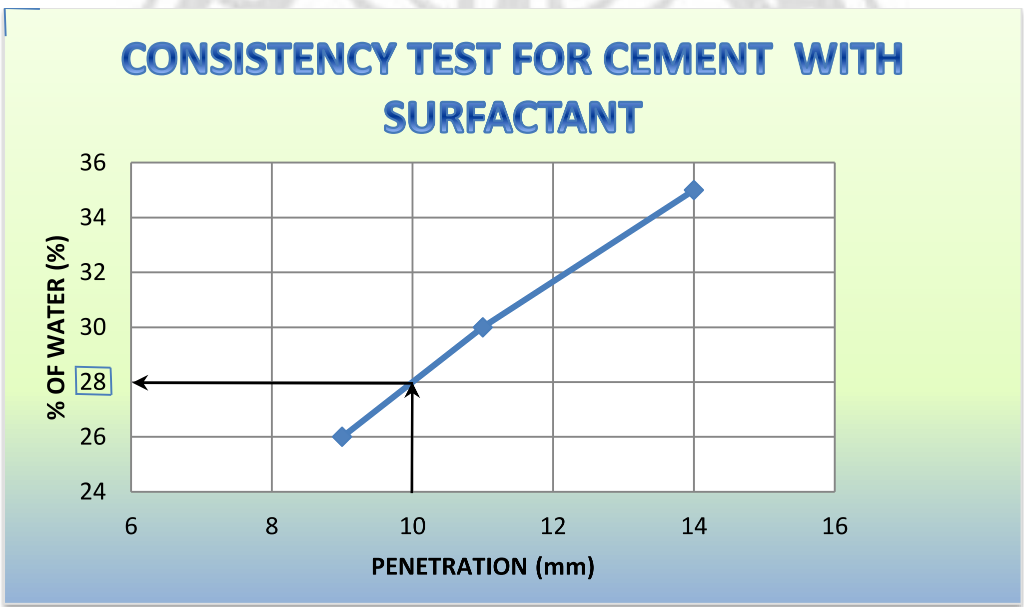


Fig.3.4 Consistency test for cement with surfactant

Results:

Consistency of cement = 28 %

3.3.1 SPECIFIC GRAVITY OF CEMENT:

SPECIFIC GRAVITY OF CEMENT		
WEIGHT OF DRY BOTTLE = W_1		215.2 gm
WEIGHT OF BOTTLE FILLED WITH DISTILLED WATER = W2		718.6 gm
WEIGHT OF BOTTLE FILLED WITH KEROSENE (K2) OIL = W3		605 gm
WEIGHT OF BOTTLE + OIL + CEMENT = W4		649.9 gm
WEIGHT OF CEMENT POURED = W5		60 gm
SPECIFIC GRAVITY OF KEROSENE OIL	$W_3 – W_1 / W_2 – W_1$	0.77
SPECIFIC GRAVITY OF CEMENT	[W5 / (W5 + W3 – W4)] X SG OF K2	3.06

Table 3.16: Specific Gravity of cement

3.3.3 SETTING TIME TEST:

Setting is the transition of fluid nature of cement to a stiff nature. Initial setting time of cement is the time taken by the cement from the moment water is added until cement paste begins to stiffen considerably. Initial setting time is important as before setting time cementitious material should be mixed, placed and finished.

Test was conducted according to ASTM C191- 99.

Vicat needle apparatus was used. Results are shown below in the table 3.17. The increase in setting time is due to delay in the hydration process of cement by the addition of surfactant.

S.NO	MIX	CONSISTENCY (%)	WATER (gm)	INITIAL SETTING TIME (min.)
1	CEMENT	30	195	97
2	CEMENT + SURFACTANT	28	182	109

Table 3.17: Setting time test

3.4 CNT's:

CNT's	
SURFACTANT USED	TRITON X 100
TYPE OF CARBON NANOTUBES	MWCNT's
PREPARATION METHOD	CHEMICAL VAPOR DEPOSITION
METHOD OF DISPERSION	CHEMICAL AND MECHANICAL METHOD
ULTRASONIC FREQUENCY	60 KHz
FUNCTIONALIZATION METHOD	ACID TREATMENT
TIME OF ULTRASONICATION	6 HOURS
AMOUNT OF SURFACTANT	12 gm FOR 3 gm OF CNT's

Table 3.18: Characteristics of CNT's used

3.5 Water:

Ordinary water of Risalpur was used in specimen preparation and their curing. Water was provided to pH public health Lab for testing. The report is as under.

WATER QUALITY ANALYSIS REPORT

ser #	parameter	Unit	WHO Permissible Limits	Results
1	pH	µS/cm	6.5-8.5	7.8
2	ELECTRIC CONDUCTIVITY	NTU	-	-
3	TURBIDITY	unit	5	1.22
4	COLOUR (TRUE)	mg/L	5	-
5	ALKALINITY	mg/L	-	-
6	TOTAL HARDNESS	mg/L	500	-
7	CHLORIDE	mg/L	250	283
8	SULPHATES	mg/L	250	310
9	PHOSPHATES	mg/L	-	0.42
10	NITRATE	mg/L	10	0.38
11	TOTAL DISSOLVED SOLIDS (TDS)	mg/L	1000	1000 TDS= 20mg/l
12	ARSENIC	µg/L	10	-
13	IRON	mg/L	0.3	-
14	CHROMIUM	µg/L	50	-
15	DISSOLVED OXYGEN	mg/L	-	-
16	TOTAL COLIFORM	MPN/100mL	Nil	-
17	FECAL COLIFORM	MPN/100mL	Nil	-

Table 3.19 WATER QUALITY ANALYSIS REPORT

3.6 SURFACTANT:

TRITON X 100 was used as surfactant to disperse the carbon nanotubes. It makes hydrogen bonding with water even at room temperature ($25^{o}C$) due to its hydrophilic nature and can attract hydrophobic CNT's. It is a liquid like water but relatively Q.

Fig.3.5 Triton X 100

CHAPTER – 4

MIX DESIGN

4.1 CONCRETE MIX DESIGN:

CONCRETE MIX DESIGN					
INPUT PARAMETERS:					
S.NO	PARAMETER	CEMENT	COARSE AGGREGATE	FINE AGGREGATE	CONCRETE
1	BULK SPECIFIC GRAVITY	3.15	2.79	2.637	-
2	DRY RODDED UNIT WT	-	95.7	-	-
3	FINENESS MODULUS	-	-	2.52	-
4	ABSORPTION %	-	0.667	1.36	-
5	MOISTURE CONTENT %	-	0.167	0.53	-
6	WEIGHT OF FRESH CONCRETE (ACI TABLE 6.3.7.1)	-	-	-	4010.00
7	COARSE AGGREGATE CONTENT (ACI TABLE 6.3.6)	-	0.698	-	-
8	SLUMP SIZE (INCHES)				3 - 4
9	NOMINAL MAXIMUM SIZE OF COARSE AGGREGATE		1		

Table 4.1: Concrete mix design

OUTPUT RESULTS:

MIXING WATER = 325 LBS/YD^3 (ACI TABLE 6.3.3)	325
W/C RATIO	0.68
F'C (PSI)	3000
CEMENT (LBS/YD3)	477.94
COARSE AGGREGATE (LBS/YD3)	1803.56
FINE AGGREGATE (LBS/YD3)	1403.5
WET WEIGHT OF COARSE & FINE AGGREGATE	
C/AGG (LBS/YD3)	1806.57
F/AGG (LBS/YD3)	1410.94
NET WATER REQUIRED (ADJUSTING M.C)	
WATER REQUIRED (LBS/YD3)	345.67

Table 4.2: Output results

4.1.2 CONCRETE MIX DESIGN FOR 0.05% CNTS CONCRETE:

1 BATCH	VOLUME / SPECIMEN	TOTAL VOLUME (cu-ft)	TOTAL VOLUME (cu-yd)
3 Small Cylinders	0.058	0.174	0.006
1 Prism	0.148	0.148	0.005
1 Large Cylinder	0.196	0.196	0.007
Total volume		0.519	0.019

Table 4.3: Concrete mix design for 0.05% CNT's concrete

APPROPRIATE SURFACTANT CALCULATION

CNT'S	3.5 gm
SURFACTANT	14 ml
% OF SURFACTANT	0.2 %

Table 4.4: Surfactant Calculation

CNT CONCENTRATION CALCULATION

1 SAMPLE OF CNT'S	1000 ml
CNT'S CONCENTRATION	0.5 %
NO. OF GRAMS IN 1 SAMPLE	5 gm
CONCENTRATION OF CNT'S TO BE USED	0.05 %
WEIGHT OF CEMENT USED	7 kg
NO. OF GRAMS OF CNT'S REQUIRED	3.5 gm
VOLUME OF SOLUTION REQUIRED	700 ml

Table 4.5: CNT's concentration calculation

QUANTITIES	1 BATCH
CEMENT	7.00 kg
COARSE AGGREGATE	25.00 kg
FINE AGGREGATE	19.00 kg
WATER	4.00 lit
CNT's	3.5 gm
CNT's SOLUTION (0.5%)	0.7 lit
SURFACTANT	14 gm

Table 4.6: Quantity of materials used

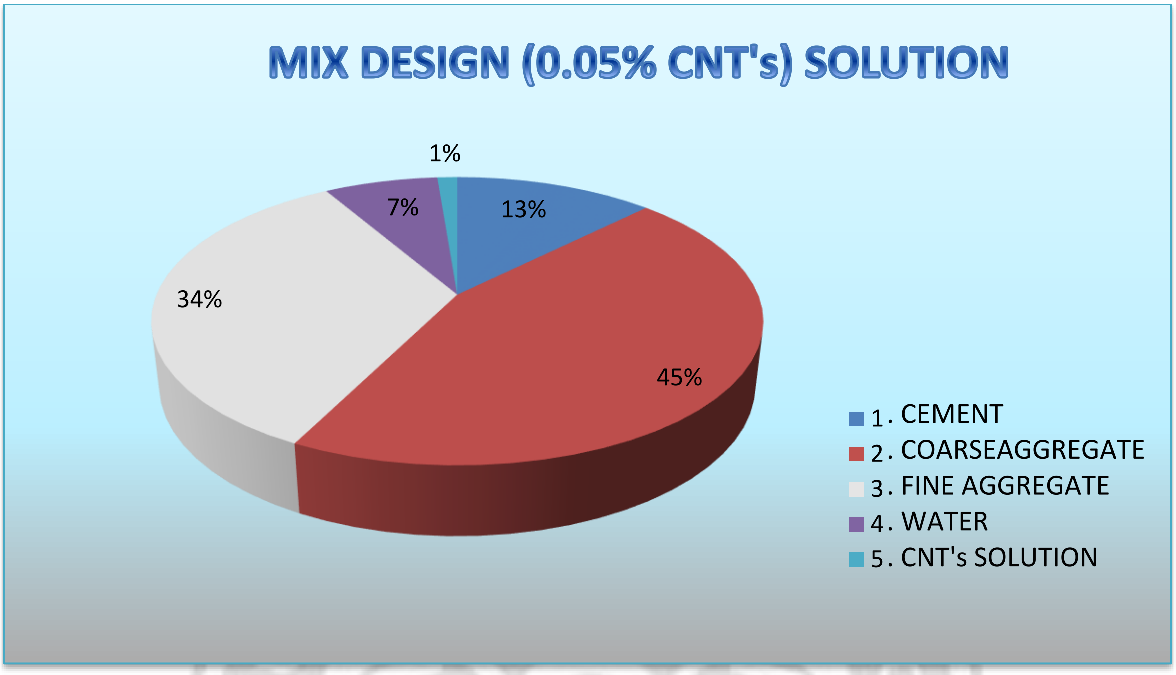


Fig.4.1 %Quantity of materials used for 0.05% CNT's Concrete

4.1.3 CONCRETE MIX DESIGN FOR 0.1% CNT's CONCRETE:

APPROPRIATE SURFACTANT CALCULATION	
CNT'S	7gm
SURFACTANT	28 ml
% OF SURFACTANT	0.4 %

Table 4.7: Surfactant calculation

1 BATCH	VOLUME/SPECIMEN	TOTAL VOL. (cu-ft)	TOTAL VOL. (cu-yd)
2 SMALL CYLINDERS	0.058	0.116	0.004
1 PRISM	0.148	0.148	0.005
TOTAL VOL		0.264	0.010

Table 4.8: Design volume of concrete for 0.1% CNT's concrete

CNT's CONCENTRATION CALCULATION	
1 SAMPLE OF CNT'S	1000 lit
CNT'S CONCENTRATION	0.3
NO. OF GRAMS IN 1 SAMPLE	3 gm
CONCENTRATION OF CNT'S TO BE USED	0.1 %
WEIGHT OF CEMENT USED	7000 kg
NO. OF GRAMS OF CNT'S REQUIRED	7 gm
VOLUME OF SOLUTION REQUIRED	2333.33 ml

Table 4.9 CNT's concentration calculation

QUANTITIES	1 BATCH	1 PRISM 2 CYLINDER
CEMENT	7.00 kg	3.03 kg
COARSE AGGREGATE	25.00 kg	10.83 kg
FINE AGGREGATE	19.00 kg	8.23 kg
WATER	2.37 lit	1.03 lit
CNT'S (0.1%)	7 gm	3.03 gm
CNT'S SOLUTION (0.1%)	2.3333 lit	1.01 lit
SURFACTANT	28 ml	12.13 ml

Table 4.10: Quantity of materials used for 1% CNT's Concrete

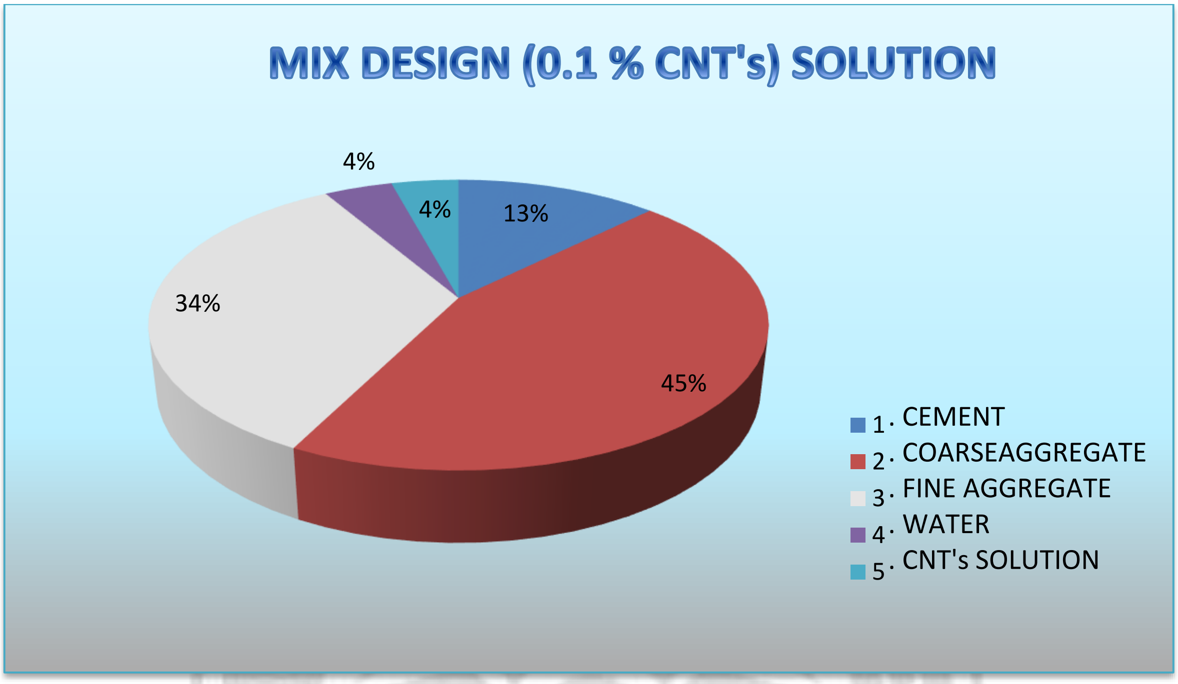


Fig.4.2 %Quantity of materials used for 1% CNT's Concrete

4.1.4 CONCRETE MIX DESIGN FOR SURFACTANT IN HIGHER CONCENTRATION:

CNT's CONCENTRATION CALCULATION

1 SAMPLE OF CNT'S	1000 ml
CNT'S CONCENTRATION	0.5 %
NO. OF GRAMS IN 1 SAMPLE	5 gm
CONCENTRATION OF CNT'S TO BE USED	0.05 %
WEIGHT OF CEMENT USED	7 kg
NO. OF GRAMS OF CNT'S REQUIRED	3.5 gm
VOLUME OF SOLUTION REQUIRED	700 ml

Table 4.11: CNT's concentration calculation

HIGHLY SURFACTANT CALCULATION	
CNT's	3.5gm
SURFACTANT	70 ml
% of surfactant	1 %

Table 4.12: highly surfactant calculation

1 BATCH	VOLUME/ SPECIMEN	TOTAL VOLUME (cu-yd)	TOTAL VOLUME (cu-ft)
1 SMALL CYLINDERS	0.058	0.058	0.002
1 PRISM	0.148	0.148	0.005
TOTAL VOL		0.206	0.008

Table 4.13: Volume

QUANTITIES		1 PRISM 1 CYLINDER
CEMENT	7.00	2.33 kg
COARSE AGGREGATE	25.00	8.33 kg
FINE AGGREGATE	19.00	6.33 kg
WATER	4.00	1.33 lit
CNT'S	3.5	1.17gm
CNT'S SOLUTION	0.7	0.23lit
SURFACTANT	70	23.33 mg

Table 4.14: Quantity of Materials used

4.1.1 CONCRETE MIXES FOR NORMALCONCRETE:

IN KILOGRAMS (Kg/yd^3)		1 BATCH	APPROXIMATELY (Kg)
CEMENT	216.80	6.50	7
COARSE AGGREGATE	819.49	24.58	25
FINE AGGREGATE	640.03	19.20	19
WATER	156.80	4.70	4.7

Table 4.15: Quantity of materials used for concrete mix for normal concrete

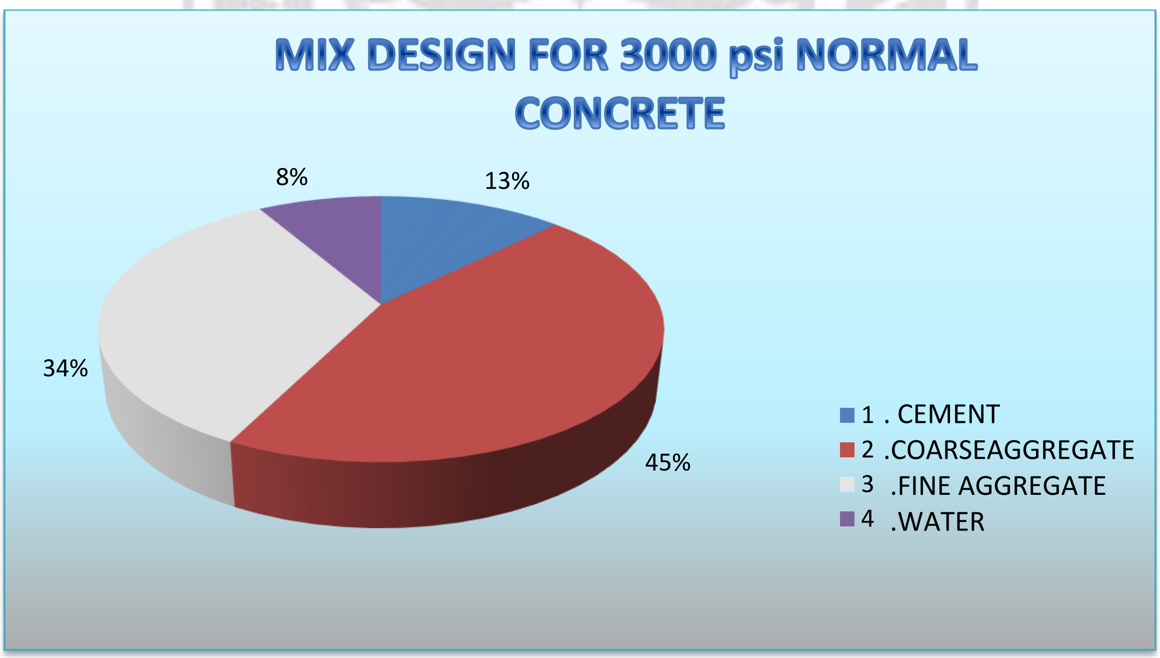


Fig.4.3 %Quantity of materials used for normal Concrete

CHAPTER – 5
TESTING AND RESULTS

5.1 WHY NOT DRY MIXING:

Carbon nanotubes are used within solution form for mixing because due to dusty nature of carbon nanotubes and toxicity, it can't be used in dry form. As it is in very minute product and just like dust particles, stay suspended in air and one can inhale these particles. Health problems may arise after inhaling.

Fig 5.1 Dry CNT's

5.2 Preparation of Moulds and Compaction:

Properly lubricated steel moulds were used as per ASTM standards for the casting of concrete specimen. Mechanical Vibrating machine was operated for the compaction of concrete. We avoided the risk of segregation and over finishing as far as possible.

5.3 Remolding and Curing of Specimen:

All the specimens were remolded after 24 hours of casting and were ready for curing period for specified time interval. Each sample was designated with an identification number with a permanent marker.

“Risalpur” water was used for curing of concrete specimens, here in the water report is also dispatched. Finally the samples were tested after they had reached the calculated time for curing.

5.4 DENSITY AND SLUMP OF CONCRETE:

5.4.1 DENSITY:

Mass of concrete per unit volume is density. Density of mixes is presented in Table 5.1 and graph 5.1. Density is decreasing as solution of CNT’s is added. Though it should be increasing by addition as microspores are filled due to nanomaterial making it denser but presence of surfactant makes air pockets which contributes in decrease in density.

5.4.2 SLUMP:

Slump is the measure of uniformity of the mix. Slump of mixes is presented in Table 5.1 and graph 5.2. For the same gradation it depends upon the moisture content. Increase in slump is also because of the surfactant; here it behaves as lubricant and increased the value of slump.

MIX	FRESH CONCRETE DENSITY (kg/m³)	SLUMP (mm)
NORMAL CONCRETE	2256	63
0.05% CNT's CONCRETE	2190	75
0.1% CNT's CONCRETE	2188	91

Table 5.1: Slump test& concrete density

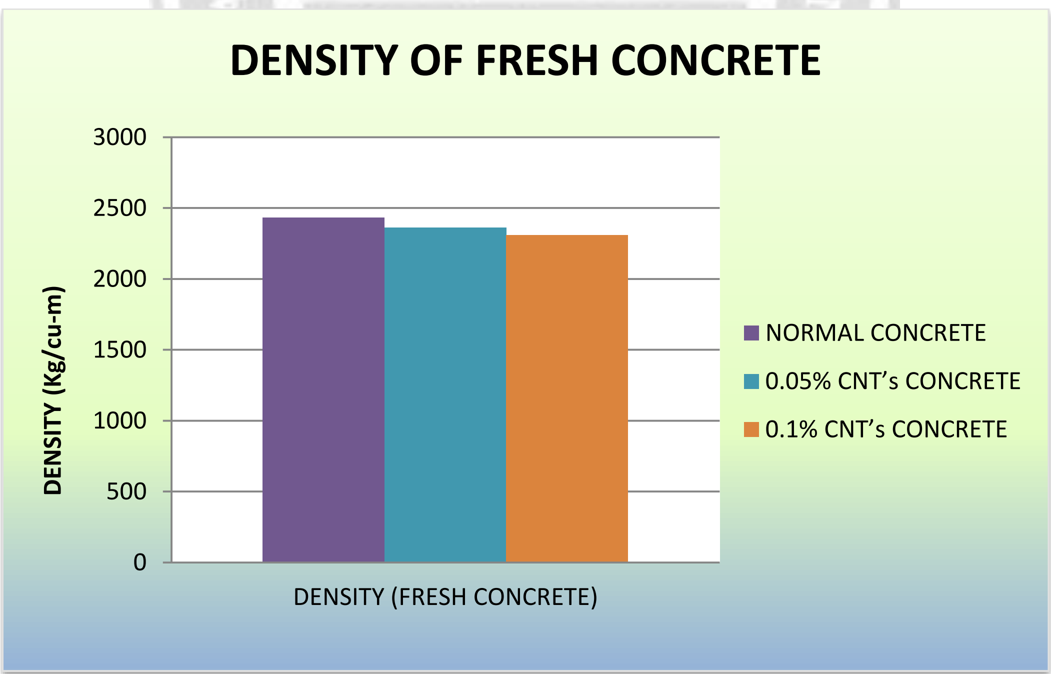


Fig.5.2 Density of fresh concrete

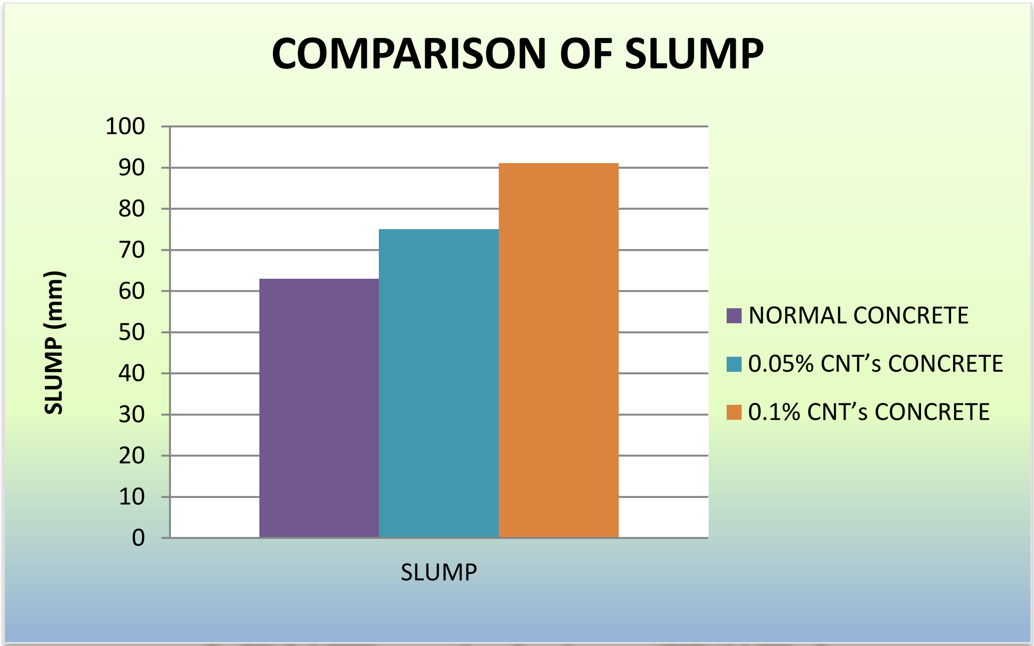


Fig. 5.3 Comparison of slump

Results:

Density of concrete decreased as CNT's concentration increased. This was actually not due to addition of CNT's but addition of surfactant for CNT's dispersion increased the air content in concrete mix.

Slump increased, that is also due to lubricant action of surfactant.

5.5 COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMEN:

This ASTM test covers the compressive strength determination of concrete cylinders. This method demonstrates the application of compressive axial load to the molded concrete cylinders at specified strain rate by Hydraulic Compaction Testing Machine.

Test was conducted according to ASTM designation C 192/C 192M – 02 on 4” x 8” cylinders.

COMPRESSIVE STRENGTH OF NORMAL CONCRETE

DAYS	S1		S2		MEAN
	KN	psi	KN	psi	
7	112	1997	124	2211	2104
14	162	2889	158	2818	2854
28	178	3175	167	2978	3076

Table 5.2: Compressive strength of normal concrete

COMPRESSIVE STRENGTH OF CNT CONCRETE (0.05%)
SURFACTANT/CNT'S RATIO = 4

DAYS	KN	psi
7	104	1855
14	192	3424
28	260	4637

Table 5.3: Compressive strength of CNT’s concrete (0.05%)

COMPRESSIVE STRENGTH OF CNT CONCRETE (0.1%) SURFACTANT/CNT'S RATIO = 4		
DAYS	KN	psi
7	98	1748
28	210	3745

Table 5.4: Compressive strength of CNT's concrete (0.1%)

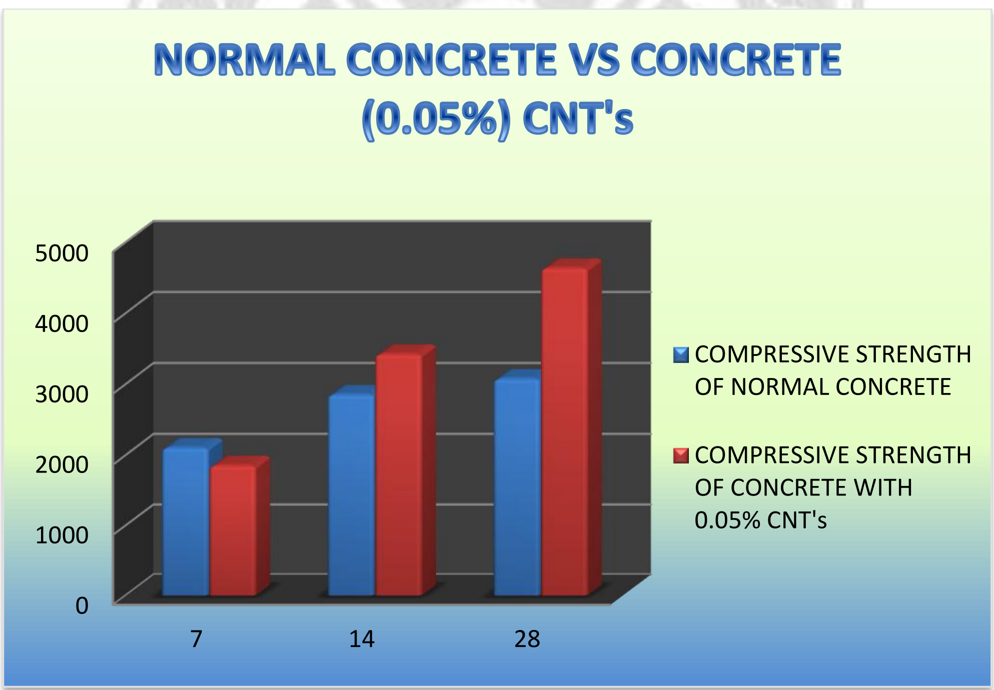


Fig. 5.4 Comparison of normal concrete with CNT's (0.05%) concrete

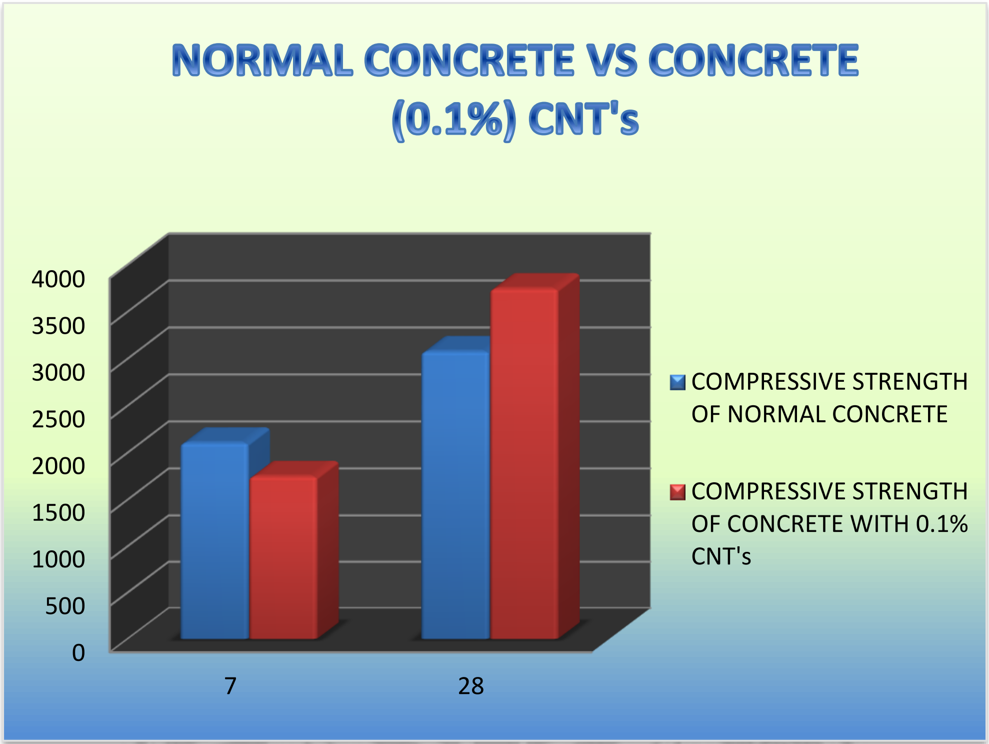


Fig. 5.5 Comparison of normal concrete with CNT's (0.1%) concrete

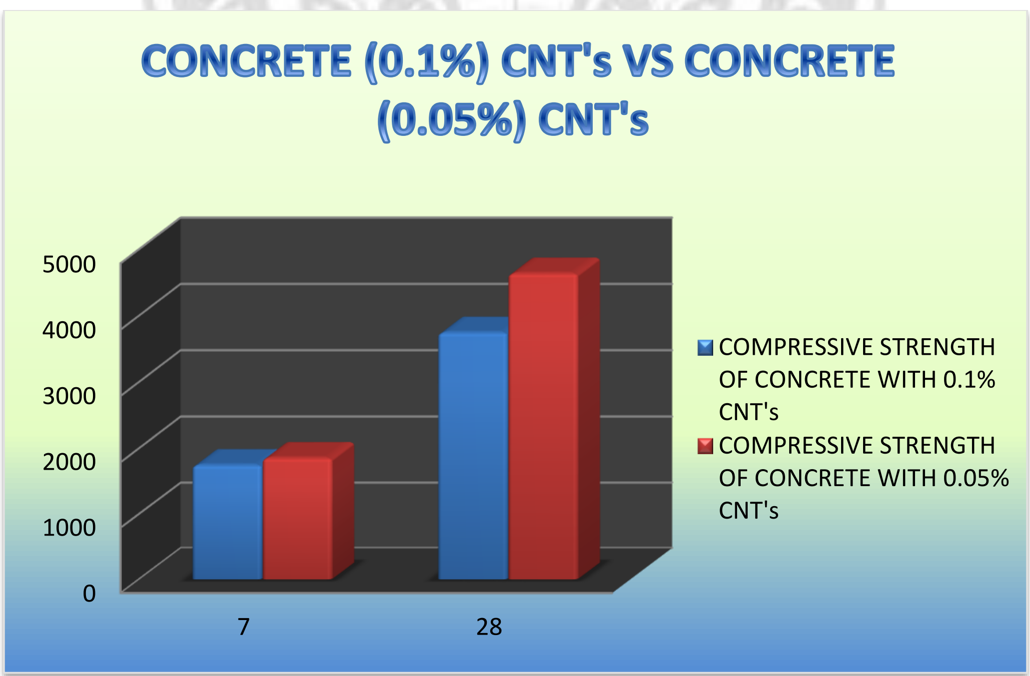


Fig. 5.6 Comparison of CNT's (0.1%) concrete with CNT's (0.05%) concrete

COMPRESSIVE STRENGTH OF CNT CONCRETE (0.05%) WITH SURFACTANT/CNT'SRATIO = 20					
DAYS	S1		S2		MEAN
	KN	psi	KN	psi	
28	142	2532	130	2318	2425

Table 5.5: Compressive strength of CNT's concrete (0.05%)

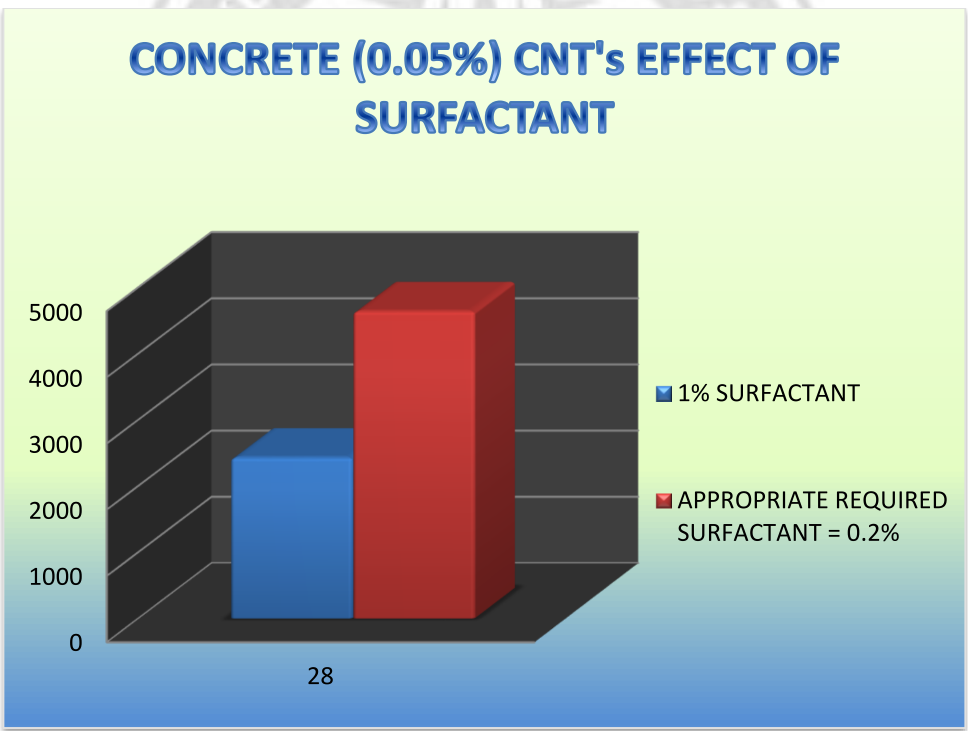


Fig. 5.7 Effect of concentration of surfactant on strength of CNT's (0.05%)

RESULTS:

- Compressive strength of CNT's modified concrete for 0.05% concentration increased by 50.74% with respect to normal concrete.
- Compressive strength of CNT's modified concrete for 0.1% concentration increased by 21.74% with respect to normal concrete.
- So, good results for compression were obtained at 0.05% concentration.
- Increased compressive strength was found for CNT's modified concrete at 0.05% concentration by 23.8% with respect to CNT's modified concrete at 0.1% concentration.
- Compressive strength decreased for CNT's modified concrete at 0.05% concentration but with higher % of surfactant by 21.16% with respect to normal concrete.
- In compression CNT's particles buckles due to huge aspect ratio.

5.6 FLEXURE TEST ON PRISMATIC CONCRETE:

This ASTM test covers the resolution of flexural strength of concrete beam sample loaded at 2 points. Modulus of rupture was calculated by the results.

Test was conducted according to ASTM designation C 78 – 94on 4" x 4" x 16" prisms.

FLEXTURE STRENGTH OF NORMAL CONCRETE

DAYS	S1		S2		MEAN
	KN	psi	KN	psi	
28	10	490	11	539	514.5

Table 5.6: Flexure strength of normal concrete

FLEXTURE STRENGTH OF CNT CONCRETE (0.05%)
SURFACTANT/CNT'SRATIO = 4

DAYS	KN	psi
28	25	1225

Table 5.7: Flexure strength of CNT's concrete (0.05%)

FLEXTURE STRENGTH OF CNT CONCRETE (0.1%)
SURFACTANT/CNT'SRATIO = 4

DAYS	KN	psi
28	17	833

Table 5.8: Flexure strength of CNT's concrete (0.1%)

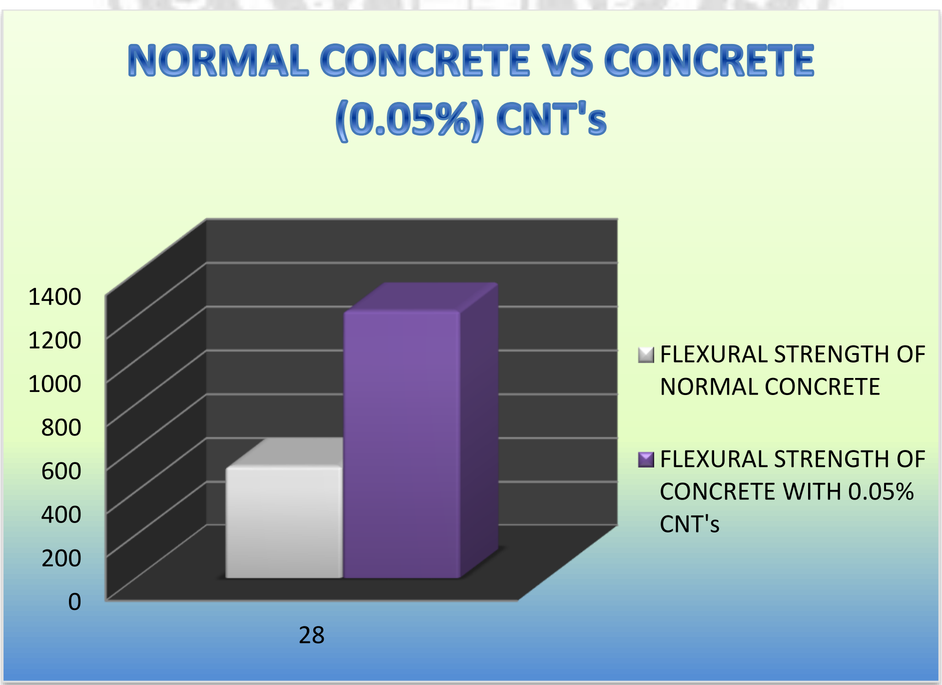


Fig. 5.8 Comparison of normal concrete with CNT's (0.05%) concrete

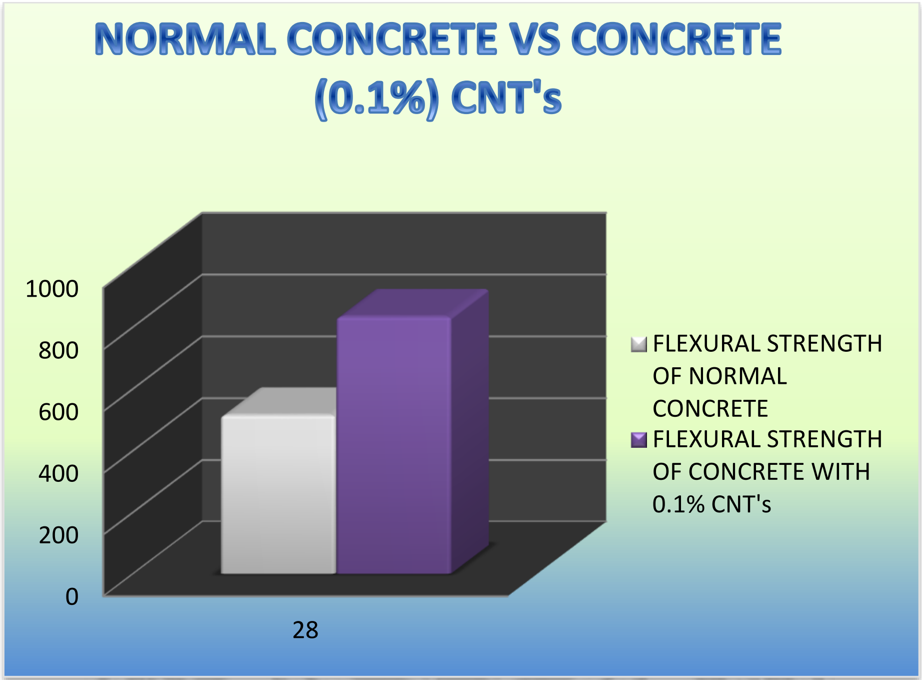


Fig. 5.9 Comparison of normal concrete with CNT's (0.1%) concrete

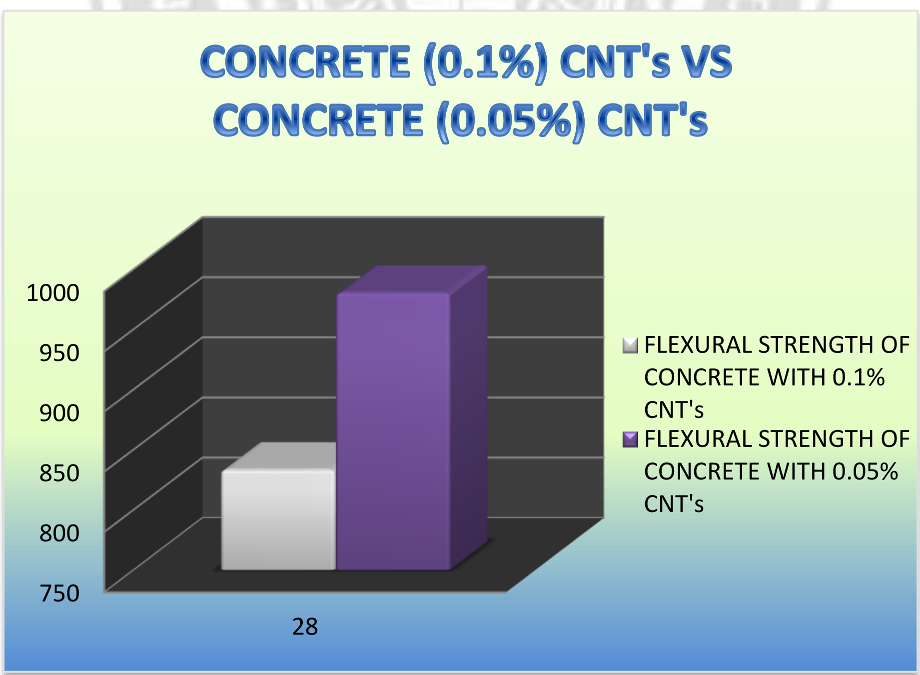


Fig. 5.10 Comparison of flexure strength CNT's (0.1%) concrete with CNT's (0.05%) concrete

FLEXTURE STRENGTH OF CNT CONCRETE (0.05%) SURFACTANT/CNT'SRATIO = 20		
DAYS	KN	psi
28	20	980

Table 5.9 Flexure strength of CNT's concrete (0.05%)

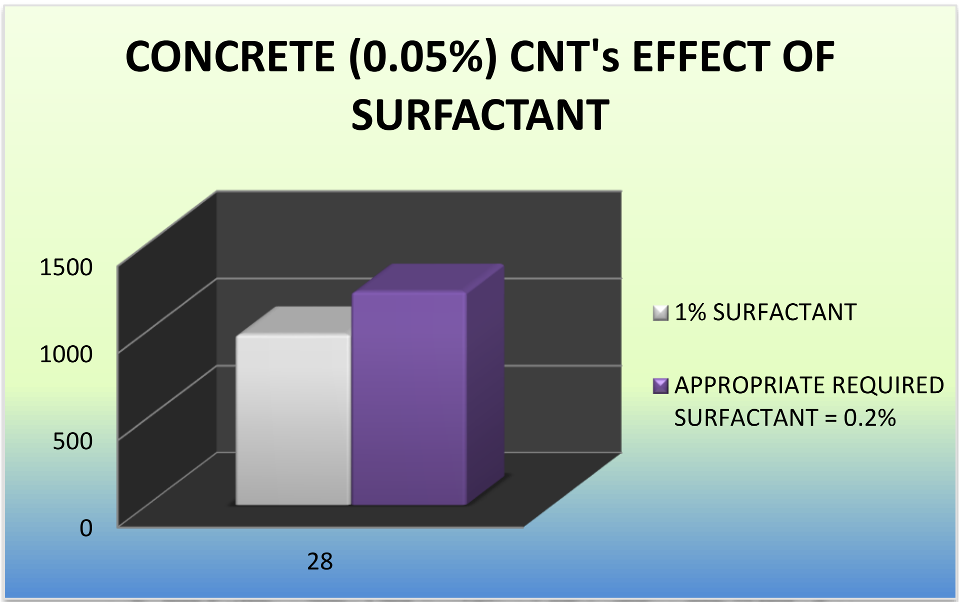


Fig. 5.11 Effect of surfactant on flexure strength of CNTs concrete

RESULTS:

- Flexure strength of CNT's modified concrete at 0.05% concentration increased by 2.38 times the normal concrete.
- Flexure strength of CNT's modified concrete at 0.1% concentration increased by 70% with respect to normal concrete.
- So, good results for flexure were obtained at 0.05% concentration.
- Increased flexure strength was found for CNT's modified concrete at 0.05% concentration by 47% with respect to CNT's modified concrete at 0.1% concentration.
- Flexure strength for CNT's modified concrete at 0.05% concentration but with higher % of surfactant still increased by 90% with respect to normal concrete.

5.7 FAILURE BEHAVIOR OF PRISMS:

During testing prisms showed about 6-7 mm deflection and then suddenly broke.

Fig.5.12 Failure of prisms

The failure suggests that initially CNT's had shown some resistance against flexure but then suddenly failed, inadequate pull out resistance was the only reason for that failure. Researchers are still finding remedy for that; to further increase mechanical properties of nano-reinforced cementitious composites.

5.8 STATIC MODULUS OF ELASTICITY OF CONCRETE IN COMPRESSION:

This test helps to find the modulus of elasticity of the moist cured concrete cylinders. Test was conducted according to ASTM designation C469 on 6" x 12" cylinder.

Modulus is calculated by $I = \sigma_2 - \sigma_1 / \varepsilon_2 - 0.00005$.

σ_2 = Stress corresponding to 40% of applied load

ε_2 = Longitudinal strain for σ_2

σ_1 = Stress corresponding to longitudinal strain of 0.00005.

COMPRESSIVE STRENGTH OF NORMAL CONCRETE = 3012 psi

40% OF COMPRESSIVE STRENGTH OF NORMAL CONCRETE = 1205 psi

5.8.1 STATIC MODULUS OF ELASTICITY OF NORMAL CONCRETE:

MODULUS OF ELASTICITY(NORMAL CONCRETE)					
STRESS	psi	READING	ΔL(mm)	LENGTH(mm)	STRAIN
0	0	0	0	203.2	0
50	396	2	0.02	203.2	9.843E-05
100	793	5	0.05	203.2	2.461E-04
150	1189	11	0.11	203.2	5.413E-04
200	1585	19	0.19	203.2	9.350E-04
250	1982	32	0.32	203.2	1.575E-03
300	2378	45	0.45	203.2	2.215E-03
350	2774	64	0.64	203.2	3.150E-03
380	3012	80	0.8	203.2	3.937E-03

Table 5.9: Static modulus of elasticity of normal concrete

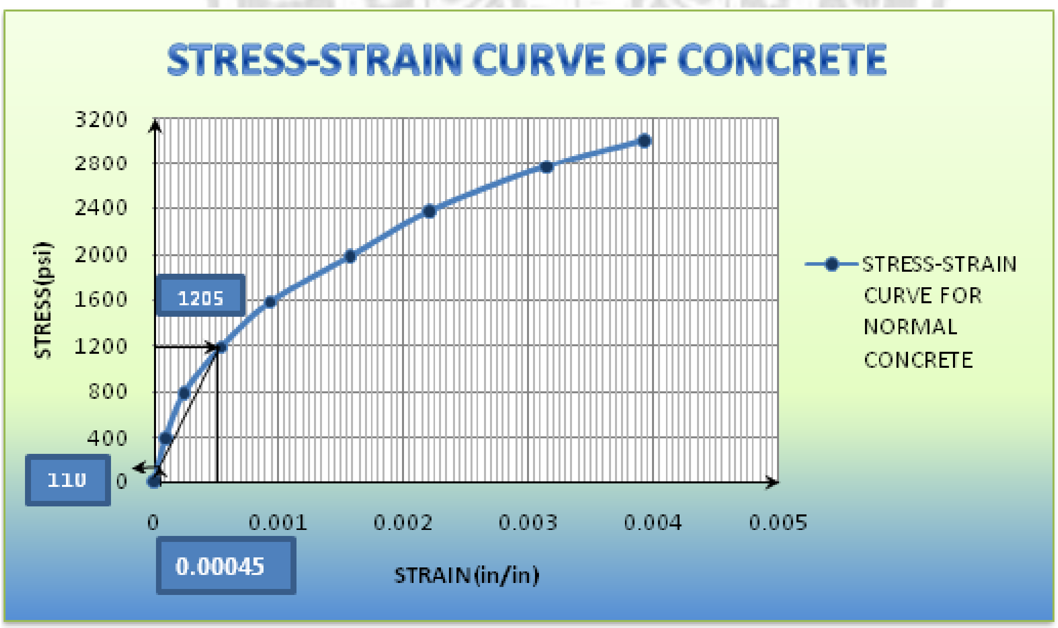


Fig. 5.13 Stress –strain curve of concrete

MODULUS OF ELASTICITY = I $= \sigma_2 - \sigma_1 / \varepsilon_2 - 0.00005$.

σ_2= 1205 psi

σ_1 = 110 psi

ε_2 = 0.00045

MODULUS OF ELASTICITY = $\frac{1205 - 110}{0.00045 - 0.00005}$

MODULUS OF ELASTICITY = 2.73×10^6 psi

BY ACI PROVISIONS:

$E_C = 33 \times w_c^{1.5} \times \sqrt{f'_c}$

$= 33 \times (139)^{1.5} \times \sqrt{3012}$

$= 2.97 \times 10^6$ psi

$E_C = 57000 \times \sqrt{f'_c}$

$= 57000 \times \sqrt{3012}$

$= 3.12 \times 10^6$ psi

RESULTS:

Experimental value of modulus of Elasticity of normal concrete is nearly equals to value in the equation of ACI Code provision.

5.8.2 STATIC MODULUS OF ELASTICITY OF CONCRETE WITH 0.05% CNT's:

COMPRESSIVE STRENGTH OF CNT's CONCRETE = 4121 psi

40% OF COMPRESSIVE STRENGTH OF CNT's CONCRETE = 1648 psi

MODULUS OF ELASTICITY (0.05% CNT's)CONCRETE					
STRESS	psi	READING	ΔL(mm)	LENGTH(mm)	STRAIN
0	0	0	0	203.2	0.00000
50	396	3	0.0325	203.2	0.00016
100	793	5	0.0467	203.2	0.00023
150	1189	7	0.0671	203.2	0.00033
200	1585	13	0.1341	203.2	0.00066
250	1982	17	0.1727	203.2	0.00085
300	2378	23	0.2337	203.2	0.00115
350	2774	43	0.4267	203.2	0.00210
400	3171	48	0.4796	203.2	0.00236
450	3567	85	0.8473	203.2	0.00417
500	3963	112	1.1196	203.2	0.00551
520	4122	120	1.2009	203.2	0.00591

Table 5.10: Static modulus of elasticity of concrete with 0.05% CNT's

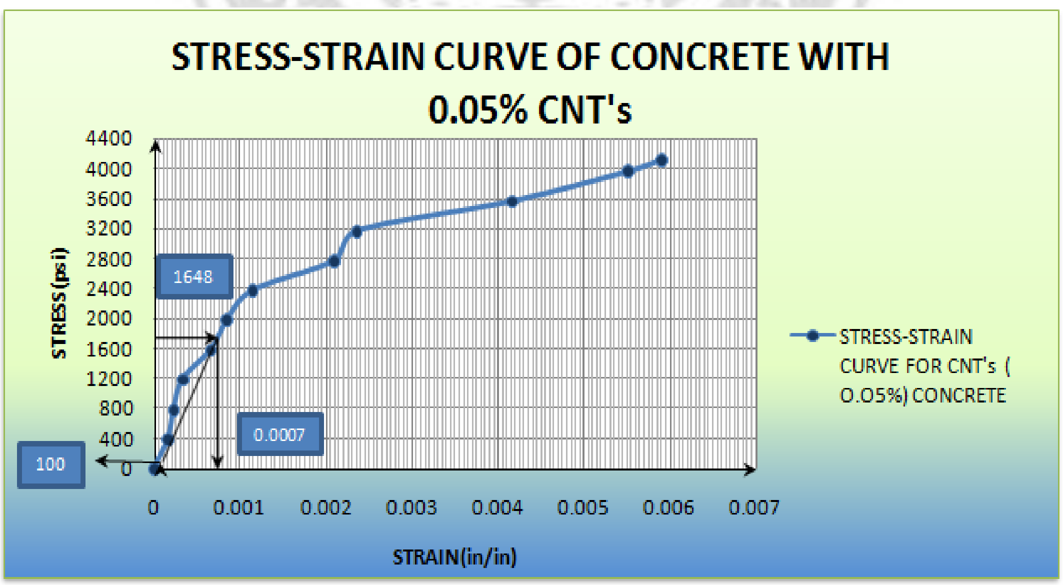


Fig. 5.14 Stress –strain curve of concrete with 0.05% CNT's

MODULUS OF ELASTICITY = $I = \sigma_2 - \sigma_1 / \varepsilon_2 - 0.00005$.

σ_2= 1648 psi

σ_1 = 100 psi

ε_2 = 0.0007

MODULUS OF ELASTICITY = $\dfrac{1648 - 100}{0.0007 - 0.00005}$

MODULUS OF ELASTICITY = 2.38×10^6 psi

By Aci Provisions:

$E_C = 33 \times w_c^{1.5} \times \sqrt{f'_c}$

$= 33 \times (135)^{1.5} \times \sqrt{4121}$

$= 3.32 \times 10^6$ psi

$E_C = 57000 \times \sqrt{f'_c}$

$= 57000 \times \sqrt{4121}$

$= 3.66 \times 10^6$ psi

RESULTS:

Modulus of Elasticity of CNT reinforced concrete is much less (30%) than that of normal concrete; this is mainly due to amount of surfactant used.

5.9 STRENGTH ACTIVITY INDEX TEST:

The strength activity index is the ratio of the compressive strength of nano reinforced cement mortar to the strength of the reference (Ordinary Portland Cement mortar) at same curing time.

Test was conducted in accordance with ASTM C109-04 Cubes test.

QUANTITIES		
CEMENT	1 part	83 g
SAND	2.75 part	230 g
W/C RATIO	0.485	40 ml

Table 5.11: Quantities for one cube

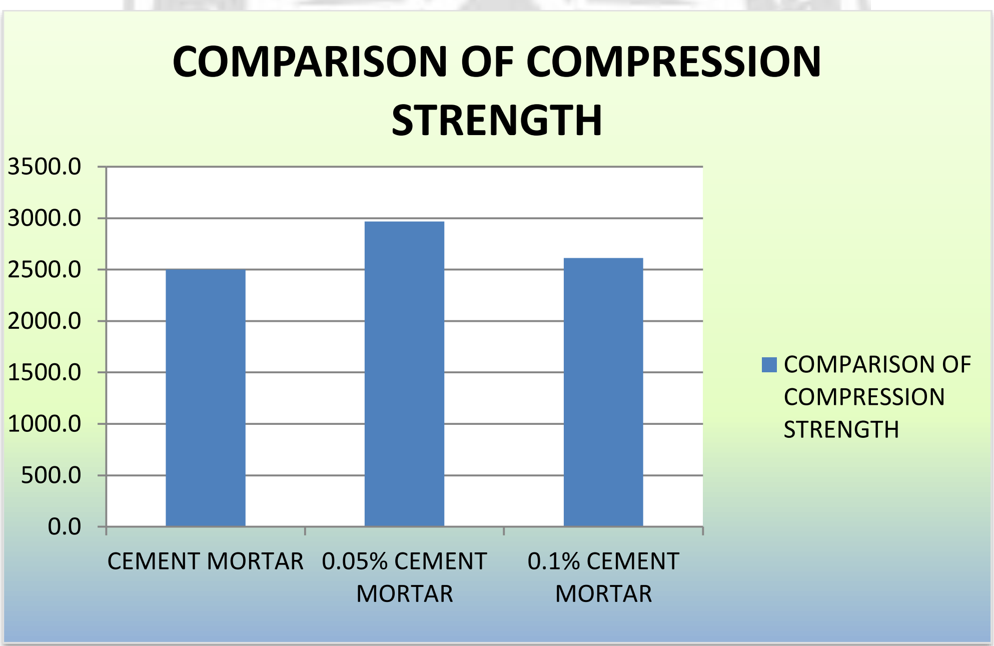


Fig.5.15 Comparison of compression strength

MIX	28 DAYS REACTIVITY INDEX		
	AVERAGE STRENGTH OF 3 SPECIMENS		REACTIVITY INDEX (%)
	Psi	MPa	
CEMENT MORTAR	2501.3	17.3	100.0
0.05% CEMENT MORTAR	2968.0	20.5	118.7
0.1% CEMENT MORTAR	2613.3	18.0	104.5

Table 5.12: Reactivity index of mortar cubes

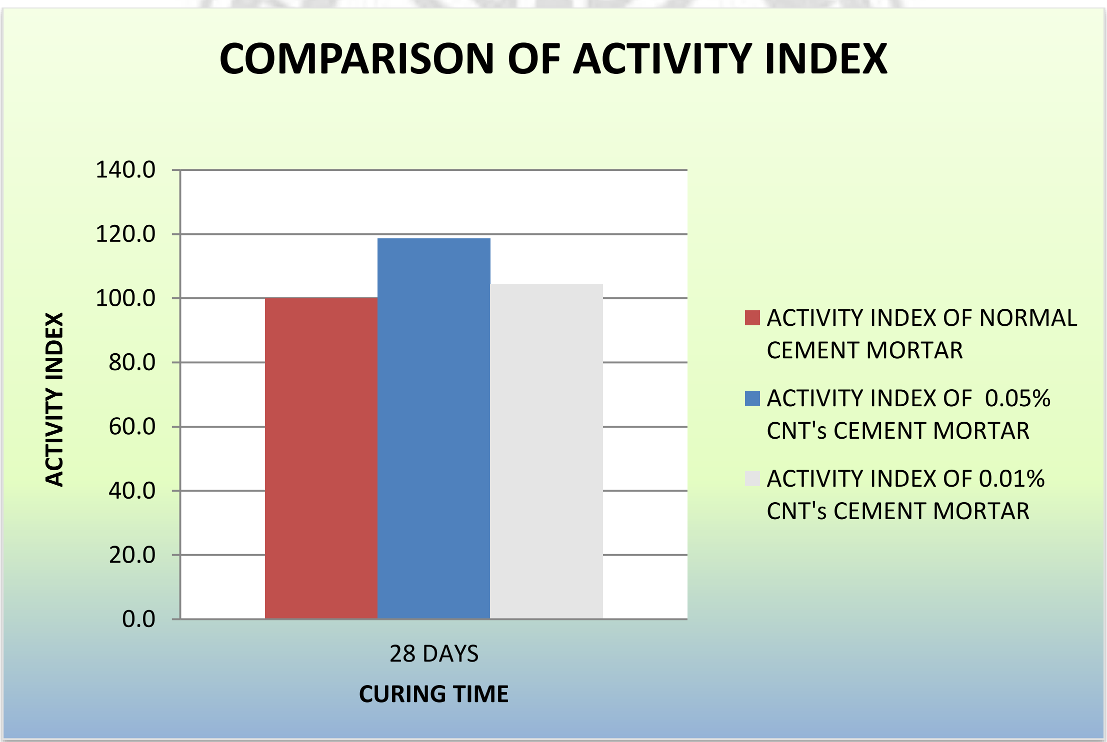


Fig.5.16 Comparison index of activity

5.10 COST:

Cost of carbon nanotubes is very high. Due to newness of carbon nanotubes and procedures to prepare and characterize them is very complex, but their cost is decreasing day by day as techniques of preparation are developing. Cost will further reduced with the development of manufacturing technologies and their large scale production.

SUMMARY

From very beginning of the human life man needed shelter. He used stones, woods to make shelters. Man invented different ways to make improvements in infrastructure with time. Today, with the help of new building materials he is constructing skyscrapers, long span bridges, dams, highways. Cementitious material has been used in construction industry for centuries and still being used. This material with many advantages has some weaknesses e-g. less flexural capacity, cracking etc. Keeping in view the high population growth rate; stronger and more durable materials are needed which can fulfill future needs. New material carbon nanotubes evolved with promising unique mechanical properties which can be used in concrete to enhance its weaknesses.

In this project Multi walled CNT's were used. Concrete and cement mortar samples were prepared with w/c ratio of 0.68 and two different concentrations (0.05% and 0.01%) of CNT's were used. CNT's were dispersed in aqueous solution in the presence of surfactant (triton X 100) in ultrasonic mixer at 60 kHz frequency. Samples were cured in water for specified age. Compression samples were tested after 7, 14, 28 days of curing, while flexural samples were tested after 28 days of curing. Effect of surfactant on mechanical properties of concrete was studied. Tests showed that compression and flexural strength can be improved by very low concentration of CNT's. 0.05% concentration showed 24% better results in compression and 47% in flexural as compared to 0.1% concentration. Use of 5 times more concentration of surfactant showed 21% decrease in compression while in compression it was still better as compared to normal concrete results. Test on compression showed 50% improved results with 0.05% concentration, while test on flexure showed 138% improvement in results with the same concentration as compared to normal concrete.

CONCLUSION

Based upon experiments, following conclusions can be drawn:

- Carbon nanotubes are viable source of increasing tensile strength of concrete.
- Effective dispersion of CNT's is a key factor in controlling the mechanical properties of concrete.
- Effective dispersion can only be achieved by mixing CNT's in ultrasonic mixer in the presence of suitable surfactant.
- Type and amount of surfactant is another important aspect in controlling the mechanical properties.
- Appropriate surfactant is the one which has minimum effects on the hydration process of cement.
- Time and energy required for sonication should be appropriate so that structure of CNT's is not affected.
- Dry CNT' can't be used, because of possibility of suspension in air, as being toxic can cause health hazards.
- To investigate mechanical properties, concrete samples were prepared with 0.05% and 0.1% concentration of CNT's.
- Compression test has shown improvement in strength by 50% for 0.05 wt% concentration and 22% improvement in strength have been found for 0.1% concentration as compared with normal concrete.
- Flexure test has shown improvement in strength by 138% for 0.05 wt% concentration and 47% improvement in strength have been found for 0.1% concentration as compared with normal concrete.
- Modulus of elasticity of normal concrete was more than that of CNT's reinforced concrete that is because of air entrained due to surfactant.

- Decrease in density and increase in slump was also due to surfactant action in making concrete highly air entrained and lubrication effect respectively.
- Cost of CNT’s is high but with the time it is decreasing enormously. According to September 2008 economics report Pakistan is making CNT’s 4 to 6 times cheaper as compared to USA and China.

RECOMMENDATIONS

- Other types of surfactant need to be developed which do not affect the hydration process of cement.
- Dispersion phenomenon of CNT's still need to be studied in detail to make it fully understandable.
- Techniques employed for dispersion have room for development.
- Sonication time and energy required to achieve specific degree of dispersion need to be optimized.

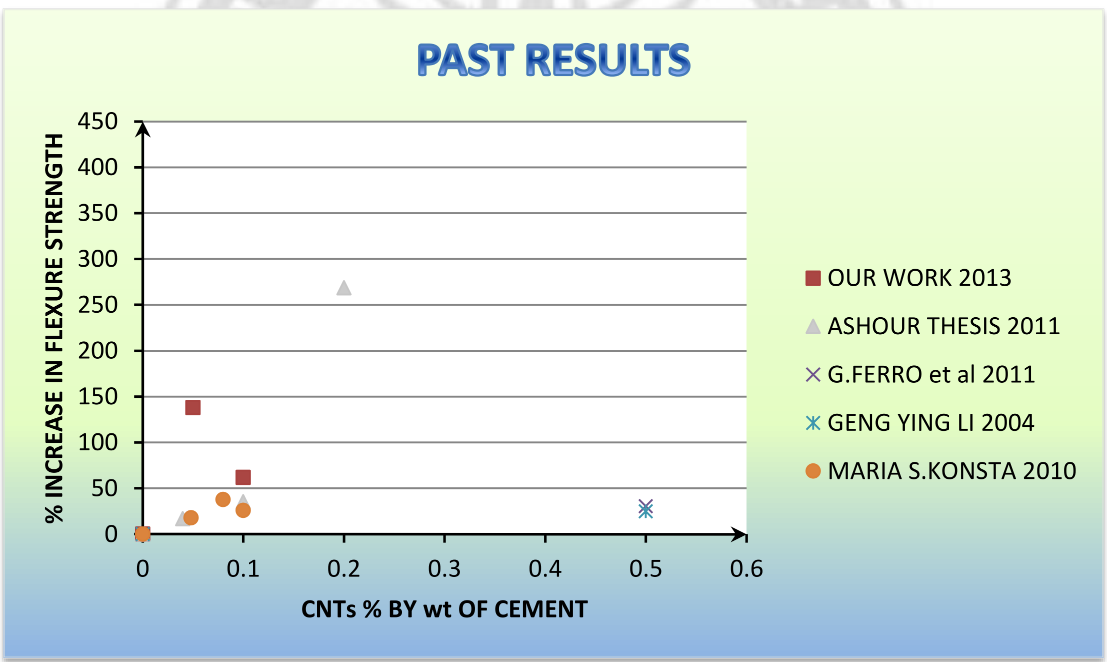


Fig. Rec # 1 Past Results

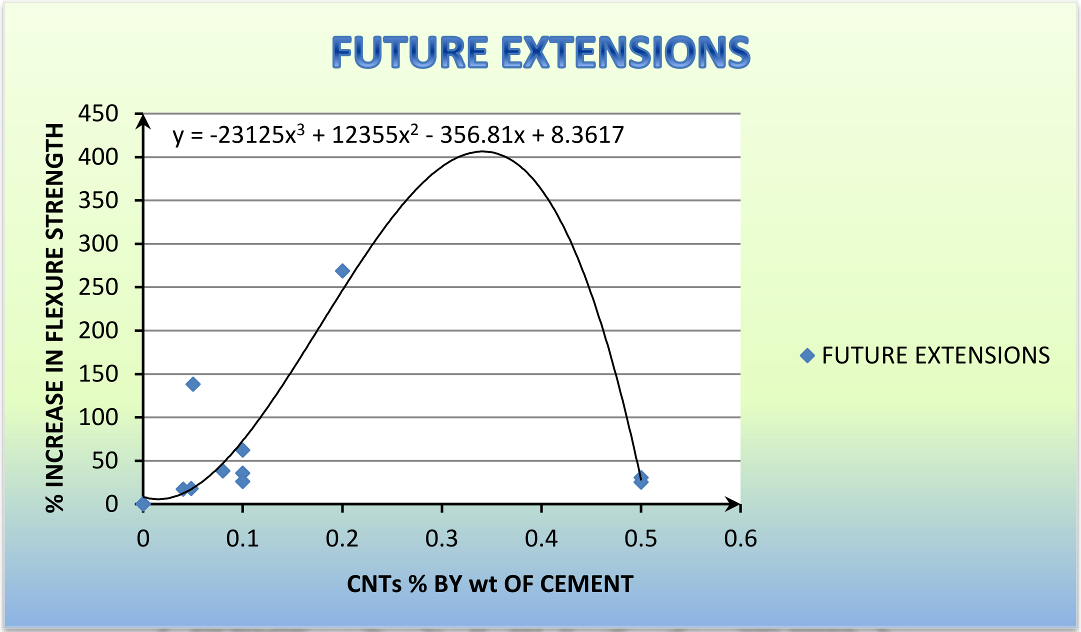


Fig. Rec # 2 Future Extensions

- Some of the results of researches are provided Fig. Rec # 1 and those results are analyzed as shown in Fig. Rec # 2 which shows higher probability of increase in strength at (0.3 - 0.4) %. So in future project can be extended to (0.3-0.4) wt% concentration of CNT's.
- Stress strain behavior should be studied thoroughly.
- To understand the internal mechanism of CNT's cement composites for strengthening of matrix finite element modeling should be performed.
- Research can be carried out on heat accelerated hydration of CNT's cement composites. Just like concrete mix design whole empirical design need to be developed by thorough research and practice.
- Appropriate amount of surfactant is still an ambiguity; techniques need to be employed to determine the specific amount of surfactant for specified amount of CNT's.

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PROJECT GALLARY: