Usage of Carbon nanotubes and nano fibers in cement and concrete: A review

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***Abstract*- Carbon Nanotubes (CNTs) are basic carbon consisting of curved graphene layer which consists of a single layer of atoms in a combined hexagonal structure. After plenty of years several characterization of the carbon Nanotubes has become very popular in various applications in civil engineering. Carbon Nanotubes shows good results in terms of mechanical properties of cement mortar when added to it. Literature has showed that carbon Nanotubes can be used in the manufacture of the concrete and the cement pastes. This paper represents the summary of the various research works on the usage of the carbon nanotubes in cement paste, mortars and concrete.**

Keywords- Carbon Nanotubes (CNTs), graphene layer, hexagonal structure Carbon, cement paste, mortars, concrete

I. INTRODUCTION

Lijma and his group discovered the carbon Nanotubes in the year of 1991 there after growing the special interest in the CNTs [1].CNTs are available in the form of hollow tubular channels, and also formed either by Single-walled Carbon Nanotubes (SWCNTs) and multi-walled Carbon Nanotubes (MWCNTs) of rolled graphene sheet [2, 3].Most of the researchers and industrial persons show their special interest because of their extraordinary physical properties as well as chemical properties. These properties will be useful in different applications from existing matter in to Nano sized meter composites [4, 5].Carbon Nanotubes are circulated in a finer scale when compared to Carbon Nanofibers, Carbon Nanotubes depends on the parameters, and the nature of the synthesis method that is arc discharge methodology [6], Laser ablation [7] and chemical vapour deposition (CVD) [7,8].Carbon Nanotubes were used for numerous composite applications showing the outstanding physical properties and mechanically they will exhibit elastic modulus in terms of TPa range [9]. CNTs have theoretical strength of 100 times than that of steel [10], although the exact magnitude of the value depends upon only on the diameter and chirality, Single-walled carbon Nanotubes and multi- walled carbon Nanotubes has high strength of 60 GPa and 6% for ultimate strain which have been reported [11, 12]. In CNTs/Alumina matrix the strength will be three times the toughness [13]. The single-walled carbon Nanotubes will shows the electric properties which will have a semi conducting or metallic character and also depends upon their chirality. Where as in the multi-walled carbon Nanotubes shows the metallic character and it is having the electrical conductivities in the range of 10^5-10^6 s/cm that have been reported for MWCNTs [14]. The plain concrete have low tensile strength and is quasi-brittle which is vulnerable to the uncontrolled propagation of cracks; to overcome this advantage, a new concept of introducing additional material at the millimetres to Nano meter scale has been realized in recent years. Fibers at the millimetres, micro scale are a commonly used materials [15].Advanced technology with in this field of Nano materials, such as Carbon Nanotubes (CNTs), Nano silica, Nano TiO_2, Nano Fe_2O_3, and Nano Al_2O_3 has recent focused on the reinforcement of the cement motor. Carbon Nanotubes (CNTs) are available in two forms one is Single-walled carbon Nanotubes (SWCNTs) and the one is Multi-walled carbon Nanotubes (MWCNTs), it depends on the number of concentric tubes [16-18].The researchers has been worked on determining the performance index with in the field of mechanics, electricity and thermology [19-24].Carbon Nanotubes will have the outstanding mechanical, thermal and electrical properties. The MWCNTs will have range from 1.4nm to 100nm, whereas their lengths range from 0.1 to 100 micro meters [25-28].

In the SWCNTs the dimensions will starts from 0.4nm to 3nm where as in their lengths the dimensions will starts from 1 to 50 micro meters [25, 28]. But in the aspect ratio it is approximately 1000 times in general exceeding 10^7 at its limit [25, 28, and 29].The carbon atoms will have a chemical bonding atoms composed entirely of sp^2 bonds, similar to those of graphite and strengthen than sp^3 bonds, making the carbon Nanotubes will be high in both modulus and strength. In SWCNTs tensile strength will reach up to 500 GPA, where the MWCNTs can reach only 10 GPA-63 GPA [24, 30]. The young's modulus of SWCNTs and MWCNTs are approximately 1 TPA and 0.21TPA respectively [28, 31]. The yield strain will be more than 10% [32]. When compared to capped one the open ended CNTs will have the higher chemical reaction [33].In the CNTs the

elastic modulus and the tensile strength are very less because of having the larger c-c bond compared to graphite [34].Carbon Nano tubes are made with length to diameter ratio of up to 1, 32,000,000:1. It's larger than the other material.Which are valuable for engineering, optics, electronics and Nano technology [35, 36, and 37]. Carbon Nano tubes with all the above said properties will be used as additives to the structural materials.

II. SYNTHESIS OF CARBON NANO TUBES

The MWCNTs were initial known within the arc discharge methodology by Lijma [38]. This methodology will be used in the manufacture process of the carbon Nano fibers and fullerenes. TheSWCNTs took two years forsynthesis Lijma and Ichihashi [39] and Bethune et al [40].The followed method of metal catalysts with in the arc discharge methodology. In the optical devices ablation process will be used to synthesis bundles of aligned SWCNTs with tiny diameter distribution by researchers [41]. Yacaman et al was first to use chemical vapour decomposition (CVD) for catalytic growth of the Carbon Nanotubes. For the synthesis of the Carbon Nanotubes different procedure are followed such as chemical vapour deposition.(CVD)[45], Arc discharge methodology (AD)[43] and Laser ablation (LA)[46]. Chemical vapour deposition (CVD) is the most employed technique [44] because under the particular conditions it will allow the collection of group of Carbon Nanotubes with well aligned structures and with the desired orientation of the layers [47].The different methods of carbon Nanotubes preparation can be consulted through recent reviews by Szaboetal [48] and Praseketal [49].

III. CARBON NANOTUBES ADDITIONS

Carbon Nanotubes and carbon fibers (CNFs) have showed a very good improvement in terms of strength in the cement based composites. Carbon Nanotubes will have the extraordinary properties [63]. Carbon Nanotubes will have excellent young's modulus, elastic behaviour and high tensile strength [64] and extraordinary thermal property [65]. There is no proof of Caron Nanotubes commercially available especially for construction materials [62], some of the trails shown that the significant improvement in hardness, compressive strength and young's modulus. Carbon Nanotubes addition will increases the the compressive strength by 50% [66] almost 600% increase in hardness at the early age of hydration [67] and greater than the 200% increase in young's modulus [68].

IV. CARBON NANO TUBES AND NANO FIBERS

Carbon Nanotubes/Nano fibers were used as the Nano reinforcement in cement based materials.CNTs/CNFs will gives the greater strength in terms of modulus of elasticity (TPA) and the tensile strength (GPA) and it has distinctive chemical and electronic properties [69-71].CNTs/CNFs Nano materials can strengthen the mechanical properties of the cement based materials [72, 73].CNFs,SWCNTs and MWCNTs are highly structured graphene ring based on high aspect ratio (1000 or more)[74] and it is having a high surface areas. CNTs/CNFs were broadly studied in the polymeric composites [75-77].In the present days carbon Nanotubes and carbon fibers were the most extensively used research materials. This area of research gives the surprising results, the researchers focuses on CNTs (Carbon Nanotubes) addition in cement pastes than Carbon Nano fibers (CNFs) [72, 78-82]. Only a small number of investigations [73, 82] have dealt with the incorporating of the CNTs in to the mortar. The main challenge in the carbon Nanotubes /Nano fibers was proper dispersion that will be taken place in the cement paste, partially due to their hydrophobicity and some partially due to strong self attraction incorporating CNTs/CNFs in to the cement composites. The mechanical properties show the mixed results a good interaction bond between the CNTs/CNFs that has been observed.

V. METAL OXIDE NANO PARTICLE ADDITIONS

The main advantage of these Nano materials used in the construction industry was, its capability and good mechanical properties of the cement based structural materials, and the use of these Nano materials has the following advantages.

1. It gives the high strength in concrete for the particular applications.
2. It will cut back the quantity of cement in concrete so as to get similar strength and decreasing the price and therefore creating positive environmental impact on construction materials.
3. Nano materials will increase the strength in concrete within a short curing time and reduces the construction time period.
4. The addition of some of the metal Oxides present in the Nano particles in concrete, can reduces the permeability of concrete into ions. Because of this aspect the concrete will strengthen and there after we can improve the durability aspects.
5. TiO_2, Nano particles [50-52], Al_2O_3 Nano particles [53-55], ZrO_2 Nano particles [55], Fe_2O_3 Nano particle [53, 55-57], SiO_2 Nanoparticle [52, 53, 56-61] and Nano clay [21-24], inclusion in to the cement and concrete specimens shows improved mechanical properties.
6. The metal oxides Nano particles reacts with CaOH increasing the number of calcium silicate hydrate(C-S-H) gel, this produces the leading additional compacted microstructure and thereby decreases the permeability, and also improves the mechanical properties [58] such as flexure, compressive strengths and abrasion resistance [59].

VI. PROPERTIES OF THE CARBON NANO TUBES

A. Mechanical properties

Carbon Nanotubes has high stiffness and axial strength as a result of its carbon-carbon sp^2 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.

B. Thermal properties

Carbon Nanotubes shows that the thermal conduction will be double than that of the diamond. Carbon Nano tubes can have a special property of feeling cold to the bit, like metal, on the sides were the tube ends are exposed. Thermal conductivity and specific heat can be determined by using the phonons. The measurements of the thermo electric property of a Nanotube systems can offer the direct information carriers and therefore for the conduction mechanisms.

C. Strength

Carbon nanotubes are stiffest and strongest materials. In the year 2000 multi-walled carbon Nanotubes were tested [69] and it achieves a tensile strengthof 63gigapascals (GPa) and later in the year of 2008 it gains a strength of up to 100 GPa [70].But 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[71].Multi-walled carbon Nanotubes the strength will reaches up to 60 GPA [70] and 17 GPA for double walled carbon Nanotubes.

D. Kinetic properties

Multi walled carbon Nanotubes will have the multiple concentric nanotubes with in one another, because of these it exhibit a striking telescope property where as in the inner nanotube will may slide without friction. Outer shell of the nanotube will creates an automatically perfect linear or rotational bearing.

E. Toxicity

The toxicity can play a key role in the field of the nanotechnology. The information are still to be fragmental and subject to criticism owing to the starting results which can highlight the issues with in the evaluating method of the toxicity of the heterogeneous material parameters like surface area, surface charge, surface chemistry, structure, sized distribution, agglomeration. The state of the samples can have bound impact on the carbon nanotubes. But the results show that the carbon nanotubes can cross the membrane barriers. If the raw materials reaches the organs, this will create the harmful effects like inflammatory, fibroticreactions for the human beings [72], if these carbon nanotubes enter into human cells it accumulate in the cytoplasm which will even lead to death [73].

VII. APPLICATIONS OF THE CARBON NANOTUBES

Carbon Nanotubes will have a numerous applications in various application fields like Civil engineering, energy sector, medicine sector, environmental, electronic sector etc. Carbon Nanotubes will have remarkable applications in the concrete structures. Researchers identified that the carbon nanotubes can fill these voids in to the conventional type of concrete. Because of these voids, water can penetrate and it will cause concrete cracks. The filling voids in conventional concrete can reduce the cracks. Carbon Nanotubes and carbon Nano fibers will gives the greater strength with high modulus of elasticity it is represented in terms of TPA and the tensile strength will be represented in the order of GPA and this will have a special chemical properties and electronic properties [74-76].Adding of weight percentage of MWCNTs to the epoxy resin will increase the fracture toughness and stiffness by 23% and 6% respectively. But at the same time carbon nanotubes will be good at enhancing the mechanical properties. These increases will depend upon the diameter, dispersion, alignment, aspect ratio and interfacial interaction with the matrix. According to theoretical aspect SWCNTs will have a young's modulus as high as 1TPA.other enhancements are strength characteristics carbon nanotubes will be good at the mechanical properties, as well as self compacting concrete and resistance to chloride penetration, and because of these properties shrinkage and permeability will be reduced [77, 78].Primarily carbon nanotube will have the mechanical properties of the reinforcement in composite materials. Carbon Nanotubes will behaves in a different way in the response of a load. By using these carbon nanotubes a sensor has been inserted in to the concrete structures as crack indicators. Carbon Nanotubes is facing a major challenge in the availability and the cost aspects. There is no available techniques that can produce a large amount of carbon Nanotubes with pureness and excellence in terms of kilogram amounts. At present the carbon nanotubes price will be very high for commercial applications. In the initial stage carbon Nano fibers/fullerenes were also very high. But the present scenario has been totally changed in the carbon Nanotubes in the last 2-3 years. Several companies came forward to start and manufacture the carbon Nanotubes. If we overcome these challenges in the carbon

Nanotubes aspects, this will become a most innovative and useful material in the construction industry in the concrete structures.

VIII. CONCLUSION

1.Carbon Nanotubes will have the excellent properties in various applications fields like civil engineering, energy sector, medicine sector, environmental ,electronics sector etc. a plenty of research work has been done and the test results shows that the carbon Nano tubes having the excellent potential in various application fields.

2. By adding these carbon Nanotubes in cement and concrete specimens, the results observed shows that the mechanical properties has been increased significantly. Good interaction takes place between the cement paste and the carbon Nanotubes. Carbon Nanotubes are dispersed uniformly throughout the cement mortar without any aggregation of the carbon Nanotubes. Good interaction takes place between the fly ash cement and the carbon Nanotubes composites has been identified through research.

3. Compressive strength will increase with the fly ash mixes. The increase of the carbon nanotubes will give high strength. The specimens with high strain loadings and with optimal addition of the carbon nanotubes, the strength of the composite will be increased.

4. Inclusion of the carbon nanotubes shows the flexural strength will get increased with the high aspect ratios of the carbon nanotubes. In plain cement the strength will be very low. Flexural strength directly depends upon the concentration of the carbon nanotubes. When compared to carbon nanofibers, carbon Nanotubes will give the good flexural strength.

5. When the samples are reinforced with the carbon Nanotubes, young's modulus will be greater than the plain cement composites.

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