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Investigation on Influence of Halloysite Nanoclay and Carbon Nanotubes on Cement Nano Composites- A Critical Review

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Abstract This paper aims to provide an insight into the various developments that have taken place since the introduction of nano materials into cement mortar. Earlier, cement and sand with aggregates were the basic materials used for construction. But as time passed by, there have been considerable advancements and many other materials whose structural stability have been studied upon as a means to move away from the conventional form and improve the performance of cement composites at the same time. It all began with the inclusion of plasticisers and then in present times, we have moved on to the use of nano materials as a substitute for strength gain. In this paper, various experiments conducted with the use of nano materials, especially halloysite nano clay and Multiwalled carbon nanotubes have been highlighted in order to provide an in depth knowledge of CNT and their individual effects on the strength of cement mortar.

Keywords MWCNT, HNC, Compressive strength, Strength gain

1. Introduction

Nanomaterials is the recent advancement in science and technology. The versatility of their use as well as their minimal quality is what makes these materials the most sought out ones in any industry. Although certain nanomaterials such as CNT's have found to have an adverse effect on the environment yet some other materials such as HNC seem more eco-friendly. While CNTs need to be manufactured, HNC is a naturally occurring nanomaterial in the form of kaolinite. Apart from the general view, these nano materials are found to be the excellent addition to enhance the performance of concrete. The demand for structural stability has gone up since the standard of construction is raised from mere bricks and cement into composite buildings, due to which, there arises a need for multifunctional materials that appeal to both structural and functional aspects of construction. It is a well-known fact that the properties of cement are in direct correlation with the pore structure of the cement matrix which in turn depends on the materials used. Therefore, it clearly implies that more the material is advanced, more will be the strength of the cement matrix. This is achieved by the introduction of ultra-fine particles on the nano scale which fill the voids of CSH structure and provide uniform distribution of hydrated products. Carbon Nanotubes (CNT) are defined as tube like structures constructed of one or more layers of graphite sheets. When carbon atoms join in a hexagonal pattern, Graphite is formed. CNT's are basically classified into single-walled CNT's (SWCNT) and Multiwalled CNT's (MWCNT). SWCNT's have diameter of 1 to 3 nm, while MWCNT's have a diameter somewhere between 10 to 100 nm. The length of both CNT's varies from 0.5μm to 50 μm. CNT's have small diameters and high aspect ratios that range from 1,000:1 to 2,500:1. CNT's make for excellent reinforcements in cementitious composites due to their excellent mechanical properties and aspect ratio. Compared to traditional reinforcing fibers, CNT's can be dispersed in the cement matrix at a much finer scale due to their Nano dimensions. [4] The advent of CNTs have paved way for their application as reinforcing agents. Because of their high strength, low density, high aspect ratio, they are much suitable in structural applications. They produce noticeable stronger composites than their other counterparts such as glass fibres. Due to their fineness, they provide efficient crack bridging at the earliest stages of crack formation. Coming to Halloysite nanoclay, the greatest advantage of HNC is the fact that it is naturally occurring thereby eliminating the need for manufacture which is the cause for its cost effectiveness. Halloysite Nanoclay (HNC) is an Aluminosilicate clay $Al_2Si_2O_5(OH)_4.H_2O$) with Nano

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tubular and hollow micro structure. Its theoretical composition is of 13.96% H_2O, 39.5% Al_2O_3 and 46.54% SiO_2. HNT's have an outer diameter of 10-15nm and inner diameter of 5-10 nm with 2-40 mm in length. [19] They are non toxic in nature and hence eco-friendly. Their usage as reinforcing material is considerably new, but they are considered the next best thing apart from nano silica. The main difference between use of nano silica and HNC lies in quantity. A small quantity of HNC provides a better performing cement composite. In terms of aspect ratio, CNT is similar to HNC but HNC has more advantages in terms of availability, cost and safety.

2. Materials and Methods

A study conducted by Simone Musso [1] et al in 2009 on influence of carbon nanotubes structure on the mechanical behaviour of cement composites, used 0.5wt% of MWCNT in plain cement mortar to study the physical and chemical properties of nanotubes on the mechanical behaviour of cement composite. Three point bending tests were conducted on prism of length 100mm and compression tests were conducted on specimens of dimensions 40x40x60mm with load applied uniaxially at the rate of 0.1mm/min for both tests. The results obtained were compared with the compressive and flexural strength of unreinforced cement mortar. Further, characterization of composites was done using Thermo Gravimetric Analysis coupled with mass spectroscopy and minerology and microstructure characterization took place by means of R-ray diffractometer and Scanning Electron Microscopy. Similar tests were conducted using functionalized MWCNT's.

Bryan M. Tyson, [2] in 2011 used untreated and treated CNT's and CNF's for their study of carbon nanotubes and carbon nanofibers for enhancing the mechanical properties of nanocomposite cementitious materials in the proportions of 0.1wt% and 0.2wt% each, added to cement matrix. W/c ratio of 0.4 and a plasticizer to cement ratio of 0.005 was adopted. Five batches of cement paste were produced of which two batches had added CNT, two batches had added CNF and one batch had plain cement mortar. The specimens of size 6.5x6.5mm c/s area were tested at 7, 14 and 21 days for flexure using three point bending tests to determine the Young's modulus, flexural strength, ultimate strain capacity and fracture toughness. SEM was conducted to detect the difference between crack bridging and fibre pull-out.

In order to investigate the effect of carbon nanotubes and carbon fibres on the behaviour of plain cement mortar composite round bars under direct tension, A. M. Hunashyal [3] and his team in 2011 used reinforced cement composite with 0.5wt% MWCNT and 2.25wt% CF (carbon fibres) to determine ultimate load, deflection and stress-strain behaviour. The results were compared with that of plain cement round bars. The w/c ratio was fixed at 0.4% which was acceptable for mixing and workability of the mortar including the introduction of fibres. UTM was used to perform the tensile tests and the ultimate load and maximum deflection were noted down.

Another similar experiments by A.M Hunashyal [4] on experimental investigation on the effect of multiwalled carbon nanotubes and nano-SiO2 addition on mechanical properties of hardened cement paste in 2014 revolved around the behaviour of hardened cement paste reinforced with 0.75wt% of MWCNT and 0.5wt% Nano-SiO2 (NS). Specimens of size 20mmx20mmx80mm were tested under a load frame of capacity 10kN at the loading rate of 0.1kN/s after 28 days curing. For uniform distribution of load, specimen was sandwiched between two steel plates of 5mm thickness. The tests were conducted to determine the mechanical properties such as compressive strength, flexural strength, toughness and ductility. The results were then compared with plain cement mortar beams. SEM was conducted to study the relation between MWCNT and cement matrix.

The properties of MWCNT used by Sanjeev Kumar [5], et al is as shown in table (1).

Table (1). Properties of MWCNT

Property	Values
Carbon content (%)	> 95
Outer diameter (nm)	60–100
Inner diameter (nm)	5–10
Length (μm)	0.5–50
BET surface area (m2=g)	40–300
Melting point (°C)	3,652–3,697
Density (gm=mL at 25°C)	~2:1

0.5, 0.75, 1.0 wt% of MWCNT were used to determine the effect of multiwalled carbon nanotubes on mechanical strength of cement paste by means of cylindrical specimens of 15.8mmx31.6mm. The specimens were cured and tested for compression and split tensile at 7, 28, 60, 90 and 180 days. An electromechanical machine with a capacity of 30 kN was used to perform compression and splitting tensile strength test. The machine was connected to computer to record the data automatically. For compressive strength the load was applied at the rate of 0.127mm/min which is about 0.5% of the height of specimen. For splitting tensile strength the loading rate was 0.0127 mm/min.

A study conducted by Oscar Galao, [6] et al. in 2014 on the mechanical properties of cement mortar with the addition of CNT in 0.05%, 0.10%, 0.25%, and 0.5% of cement mass and plasticizers in quantities 0.4%, 0.5%, 0.9% and 2.2% are studied. The w/c ratio was fixed at 0.5 and c/s ratio was fixed at 1/3. The specimens of the said proportions were used to study bending strength, compression strength, porosity and density of mortar by subjecting them to compressive and bending tests. CNT cement paste specimens were exposed to carbonation and chloride attacks for corrosion rate test, and results determined if steel corrosion rate were related to CNT dosages. The increase in CNT content showed no significant variations of mechanical properties but higher steel corrosion intensities were observed. Prismatic specimens of 4 × 4 × 16 cm^3 were used for mechanical testing. They were tested after 7 and 28 days curing age and prism specimens of 80 × 55 × 20 mm^3 were prepared for corrosion rate tests. Each one contained two 8 mm diameter cylindrical steel electrodes and a graphite counter electrode in the middle.

Along the same lines, Parang Sabdonoa, [7] et al, in 2014 studied the effect of nano-cement percentage in the mortar mix by substitution method. The ratio in weight of the nano-cement with respect to the normal cement ranged from 0%, 20%, 40%, 60%, 80%, to 100%. The specimens sized 50 × 50 × 50 mm were tested at the age of 28 days to obtain their compression strength with the loading of 400 N/s. The cement-to-sand proportion was 1 to 2.75, while a water-cement-ratio of 0.485 was maintained throughout the experiments. Two cement types, PCC (Portland Composite Cement) and PPC (Portland Pozzolane Cement) were used. The setting time of the original cements were tested by the Vicat method.

Potential of carbon nanotube reinforced cement composites as concrete repair material was discovered by Tanvir Manzur, [8] in 2016 by carrying out the following tasks:

(i) Effect of MWNT addition on setting time as investigated.
(ii) Effect of MWNT addition on bleeding as investigated.
(iii) Bond strength between the repair materials (MWCNT cement composite, normal cement mortar, and epoxy resin) and concrete substrate was investigated through slant shear tests.

The moulded samples used 0.1, 0.2 and 0.3% MWCNT by weight of cement. Samples were made using different mix proportions having w/c (water to cement) ratios of 0.50 and 0.60 and plasticizer proportions of 0.005 and 0.008. Setting time testing was done using Vicat's apparatus. Initially the readings were recorded at every 30 seconds till the needle failed to touch the bottom of the mould, thereafter, readings were recorded at every 10 minutes until a reading of 10mm or less was obtained. Cylinders with 75 mm x 150mm dimensions were casted for slant shear test. Slant shear tests were carried out at 3, 7, and 28 days. Composites samples were made with 0.1% and 0.3% dosage rate of MWNT with plasticizer proportion of 0.008. The w/c ratio was kept at 0.50. There was no bleeding observed in the composite mix leading to believe that nanotubes do not affect the stability of the cement mix.

Recent study on Halloysite Nanoclay was done by M.T Albdiry and B. F Yousif [9] in 2013 to determine the role of silanized nanotubes on structural, mechanical properties and fracture toughness of thermoset nanocomposites. Due to the hydrophilic feature of HNCs, silanization is done to obtain better bonding and to improve interfacial adhesion with polymer molecules, better uniform distribution and better alignment of the particles. Silanized clay particles was found to improve mechanical properties of epoxy nanocomposites compared to non-silanized clay nanocomposites. Various loadings (1-9%) of HNC and s-HNC were added into neat UPE resin to produce UPE nanocomposites. The mixture was cast into pre-designed moulds of required dimensions. The samples were cured at 24°C for 24 hrs and post cured at 60°C for 2 hrs followed by 2 hr at 90°C in an oven to ensure full polymerisation.

Mechanical properties were tested using Instron Alliance RT/10 MTS machine connected to computerised data acquisition system. The sample was crosshead at a speed of 1mm.min. Young's modulus and strain at break were determined using laser extensometer. Flexural strengths were carried out using three point bending test on samples of 52x12x6mm^3 with a 40mm bending span at a rate of 1mm/min. The crack length to width ratio was limited to 0.5 and a loading rate of 5mm/min.

Under the guidance of Dr. N S Kumar, two studies were conducted on CNTs and HNC. Firstly, Vindhya C.R and Hafeez Khan [10] studied the experimental investigation on halloysite nano composite infilled steel hollow tubes under monotonic loading in 2014. The objective was to study the behavior of HNC's as an infill to concrete and Study the effect of Diameter ((D), Change in steel tube length (l), and Strength of infill (f_{CK}) and to determine the ultimate load (P_{ult}) in HNC's composite steel hollow tubes under monotonic loading. Mild Steel Tubes, with yield strength of 310Mpa are used.These tubes are seam welded. Circular Steel tubes diameters 34mm with Thickness 3.0mm,lengths (50mm, 75mm, 100mm, 125mm, 150mm, 175mm and 200mm), and l/d ratio (2-7) are selected for testing. Experiment were carried out on six different specimens with four variations in each specimen, which varies in length 50mm, 75mm, 100mm, 125mm, 150mm and 200mm with constant diameter 34mm. and mixed with Cement, Sand & HNC's (1%, 2%, 3% and 4%). Universal Testing Machine was used to carry out the compression tests.

Second study by Ghazala Anjum [11] on influence of carbon nanotubes & halloysite nanoclay on strength of cement mortar was done in 2016 where MWCNT and HNC in percentages of 0.5, 0.75, and 1 by weight of cement were used to determine the compressive and split tensile strength of cement mortar reinforced with the said nanomaterials in comparison with plain cement paste. The study aimed to determine the optimum dosage of nano material for higher compressive and split tensile strength, stiffness, strain energy and modulus of toughness. And also to study the morphology of the failed specimens using SEM (scanning electron microscope) and Energy-dispersive X-ray spectroscopy (EDX) for specimens before and after testing. Cylindrical specimens of 20mm dia and 40 mm length were used for both the tests. w/c ratio was maintained constant at 0.45. The tests were conducted at 7, 14 and 28 day curing stages on MULTITEST 25-i NANO UNIVERSAL TESTING MACHINE with inbuilt data acquisition system EMPEROR™.

3. Results

1. The studies by Simone Musso revealed that the mechanical strength of cement composite was greatly affected due to the presence of MWCNTs'. The comparison of the results between the two showed that f-MWCNT were hydrophilic leading to a faulty hydration product, however there was considerable increase in strength of cement composite with both functional and pristine MWCNT. However, by increasing the w/c ratio from 0.4 to 0.56, suitable hydration of the products could be obtained. Although, a more favourable dispersion of CNT is preferable to lower the degree of interference with surrounding CNT.

It was found that the properties of cement paste can be increased by adding small amounts of CNT or CNF. [1]

2. Bryan M. Tyson's study of untreated and treated CNT's and CNF's for enhancing the mechanical properties of nanocomposite yielded the following graphs.

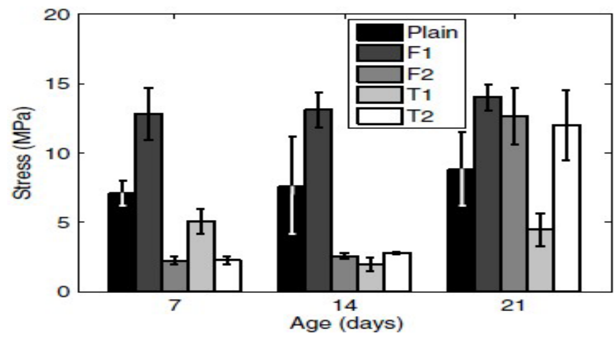

Figure (1). Stress variation

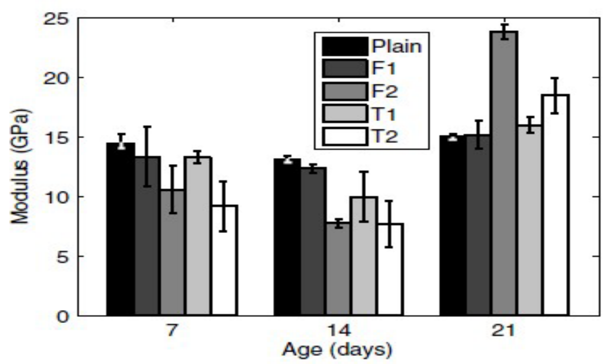

Figure (2). Variation of modulus

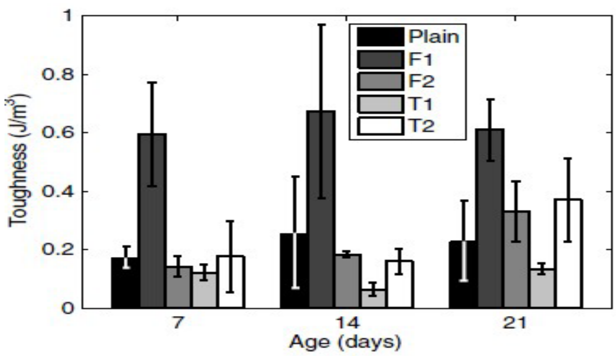

Figure (3). Toughness variation

The above figures demonstrate the variation of stress, modulus and toughness of plain cement mortar with CNT (0.1 & 0.2wt%), CNF (0.1 & 0.2wt%), tested at 7, 14 and 21 days. For the early ages, 7 and 14 days, negative effects for the flexural strength, Young's modulus, and fracture toughness were observed; however, at 28 days, these properties increased beyond the plain cement. [2]

3. The tensile strength with MWCNT and CF is more as compared to plain cement as shown in graphs below. The results obtained from A. M. Hunashyal indicated that specimens with CF showed 38% and specimens with MWCNT showed 19% and specimens with both CF and MWCNT showed 53.28% increase in tensile strength than plain cement mortar. This can be attributed to the interfacial bonding between the fibres and matrix which caused efficient stress transfer when subjected to tensile forces. [3]

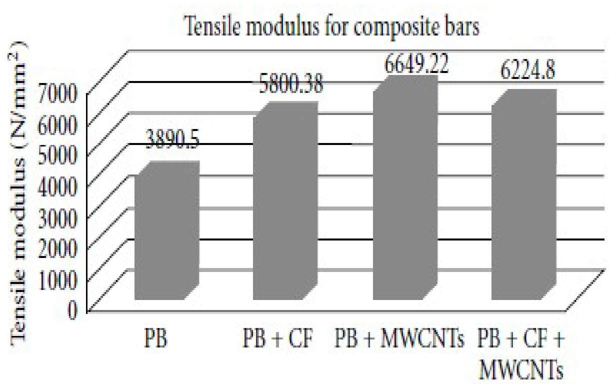

Figure (4). Variation of tensile modulus

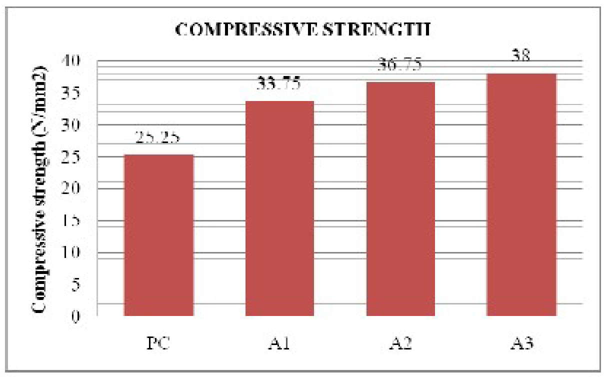

Figure (5). Compressive strength

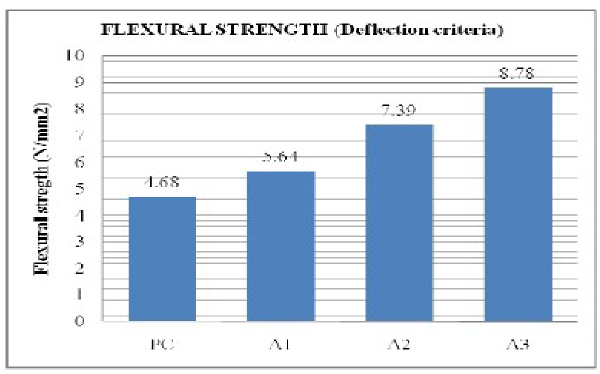

Figure (6). Flexural strength

The second study by A. M. Hunashyal on effect of MWCNT and nano-SiO2 addition yielded the following charts.

The samples of plain cement(PC), PC+0.75%MWCNT (A1), PC+0.5%NS (A2), PC+A1+A2 (A3) as in the above charts show highest increase in both compressive and flexural strength in the hybrid specimen A3 as compared to other specimens. The study also determined that the load carrying capacity increased and in turn increased the deflection in the order PC>A1>A2>A3. The proportion of A3 showed highest increase in toughness, amounting to 153% increase as compared to PC.

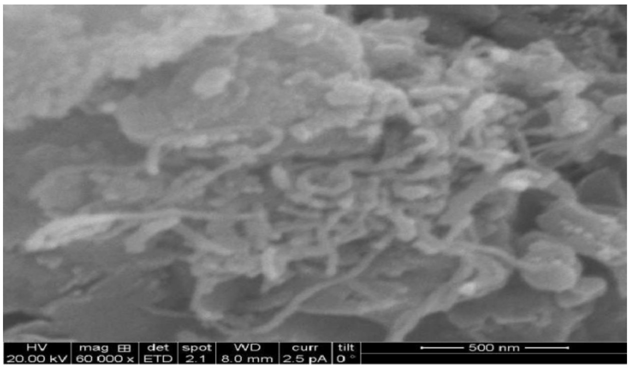

Figure (7). SEM image of hybrid composite with MWCNT and nanosilica

The SEM image from above show clustering of MWCNT and NS in the hybrid composite while the clustering was small to nil in the other proportions. A physical bond between cement matrix and MWCNT was also visible. [4]

5. **Sanjeev Kumar** in his study inferred that there was 15% increase in compressive strength and 36% increase in compressive strength with respect to plain cement at 28 days curing stage for 0.4% of CNT. Above 0.5% CNT, the compressive and split tensile strength appeared to be decreasing. [5] This is explained in the form of graphs as shown below.

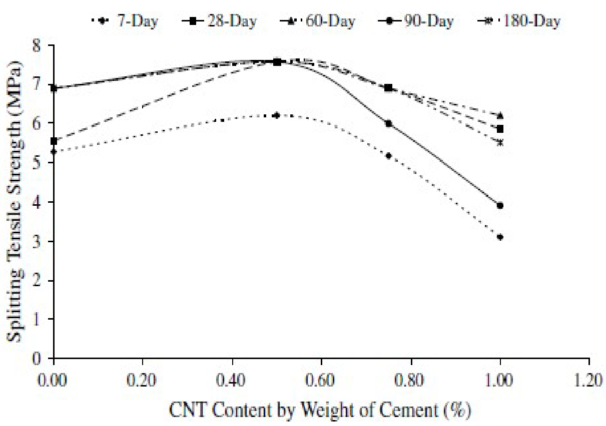

Figure (8). Splitting tensile strength

6. Separate experiments of Oscar Galao w.r.t the use of CNT in normal cement mortar showed that the bending and compressive strengths for each CNT dosage of cement cured and tested at 7 and 28 days showed lower strength than the control samples, without CNT, for a 7 days curing time. The increase in CNT dosage did not significantly affect bending strength after a 28-days curing age. [6] Whereas as per Parang Sabdonoa, it was observed that higher the nano cement ratio, greater was the strength. There was 37% and 30% in strength gain for PCC and PPC respectively at 100% substitution of nano cement at 28 days. The strength gain was more for PCC at the initial stages, whereas PPC showed improvement at 40% substitution. The strength gain was equal for both the cement mixes at 80% substitution. [7]

7. Tanvir Manzur demonstrated that for CNT composite to act as a repair material, it should have greater strength and smaller setting time as compared to normal cement mix. The following graphs are obtained from the study.

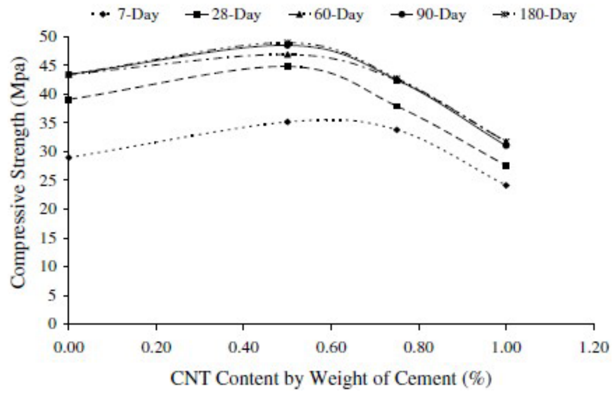

Figure (9). Compressive strength

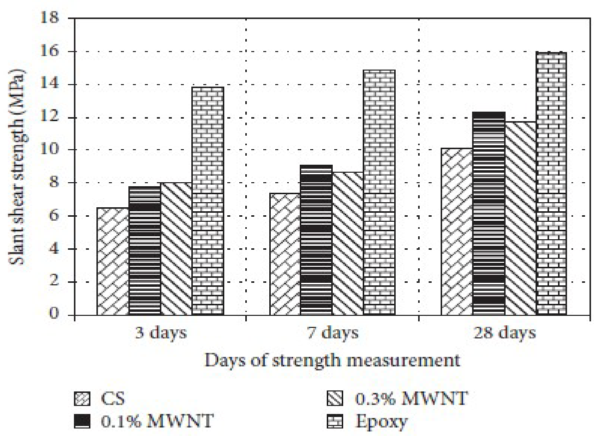

Figure (10). Slant shear strength at various curing days

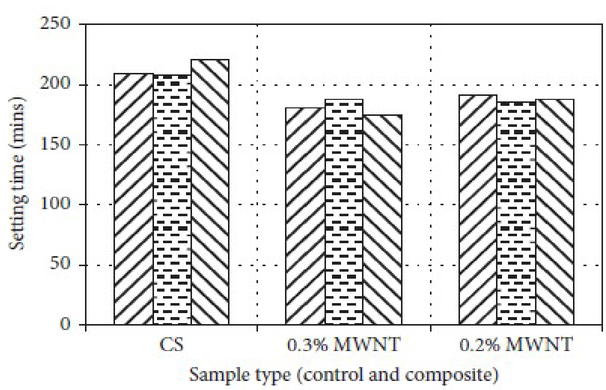

Figure (11). Setting time of control and composites

From the above, it can be noted that at 3, 7 and 28 days, the MWCNT mix yielded 20, 30 and 22% more strength respectively as compared to control samples. However, the same strengths were 44% and 40% less than that of Pro-epoxy 300. It is evident that cement mix reinforced with MWCNT showed greater slant shear strength as compared to control sample at all ages. As far as setting time was concerned, the samples with 0.5 w/c ratio exhibited a setting time of 175 minutes, whereas the MWCNT composites showed setting times as 125 and 135 minutes for MWCNT content of 0.1 and 0.3%. This shows that MWCNT composite required 25% less time to set than normal cement mix. [8]

8. The incorporation of HNC or s-HNC beyond 5 wt% resulted in slight decrease in mechanical properties as per the results obtained in the study of silanized Halloysite by M.T Albdiry and B. F Yousif which can be attributed to the presence of aggregates in the micro structure leading to poor interfacial adhesion and poor stress transfer between the reinforcements and the matrix. Mechanical properties of the nanocomposites are directly affected by their dispersion status which is related to material characteristics. Numerous micro-voids form simultaneously in a brittle material when the applied loads reach a certain level. The distribution of these micro cracks depends essentially on the local stress concentration and the material heterogeneity, where the formation of either micro cracks around the crack tip reduces stress concentration and interferes with the crack propagation. [9]

9. The compression testing of halloysite nano composite infilled (Cement, Sand & HNC's in percentages of 1%, 2%, 3% and 4% by wt of cement) steel hollow tubes of variable diameter under monotonic loading by Vindhya C.R, and Dr. N S kumar [10] indicated the following results:

- The Ultimate load (P_u) decreased for Hollow tubes for 50mm-200mm due to aspect ratio or stiffness.
- The Ultimate load (P_u) increased for Cement only for 50mm-125mm and suddenly decreased for 150mm to 200mm due to decreasing stiffness.
- The Ultimate load (P_u) increased for Sand only for 50mm-125mm and suddenlydecreased for 150mm to 200mm due to self compaction.
- In all cases of CNC (50mm-200mm), the Ultimate load (P_u) is increased from 1% to 2% and suddenly decreased for 3 & 4%.
- In all cases of SNC (50mm-200mm), the Ultimate load (P_u) is increased from 1% to 2% and suddenly decreased for 3 & 4%.
- In all cases CSNC (50mm-200mm), the Ultimate load (P_u) is increased from 1% to 2% and suddenly decreased for 3 & 4%.

The second study by Ghazala Anjum and Dr. N S Kumar [11] that included use of HNC and MWCNT in percentages of 0.5, 0.75 and 1.0 w.r.t the weight of cement subjected to compression and splitting tensile tests yielded the following graphs on 28 day curing stage.

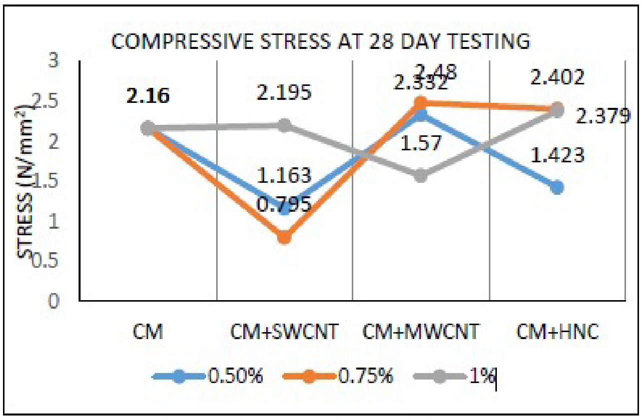

Figure (12). Compressive stress at 28 day

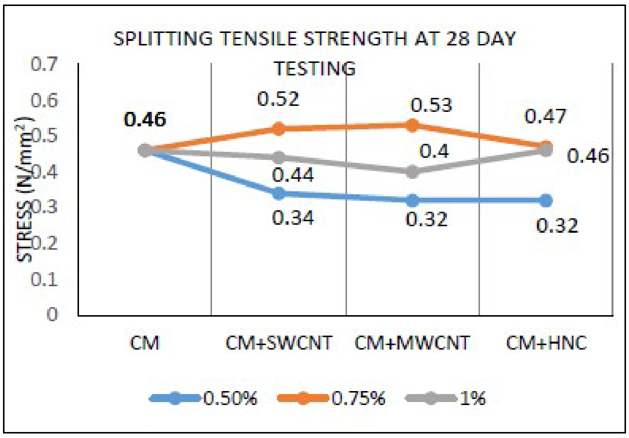

Figure (13). Splitting tensile strength at 28 day

From the above graphs, it can be inferred that at 28 day testing, MWCNT composite and HNC showed 18.2% and 14% greater compressive strength than conventional mix. The 14 day strength was highest for MWCNT at 15.3% followed by HNC at 2.7%. After compression testing, maximum stiffness was seen in samples with 0.75% MWCNT overall but at 28 days, samples with 1% MWCNT showed maximum stiffness. Maximum strain energy absorbed was by samples with 0.5% HNC at 28 day curing stage.

The splitting tensile strength was maximum at 0.75% MWCNT and HNC after which reduction is seen in the strength. MWCNT showed 48% increase and HNC showed 28.6% increase in splitting tensile strength. Maximum stiffness was found at 14 day curing for 0.5% MWCNT. Both stiffness and strain energy absorbed by the specimen increased up to 14 day curing thereafter reduction in same was observed.

SEM images obtained show anchoring of cement compounds by CNT. Beyond 1% reinforcement, nanotubes formed clusters leading to ineffective bonding between cement compounds and nanotubes. Fig (15) shows random dispersion of nano materials in cement mortar but the analysis of failed specimens showed stretching of fibres at the crack portion indicating that the fibre had the ability to arrest micro crack by stretching as in fig (14).

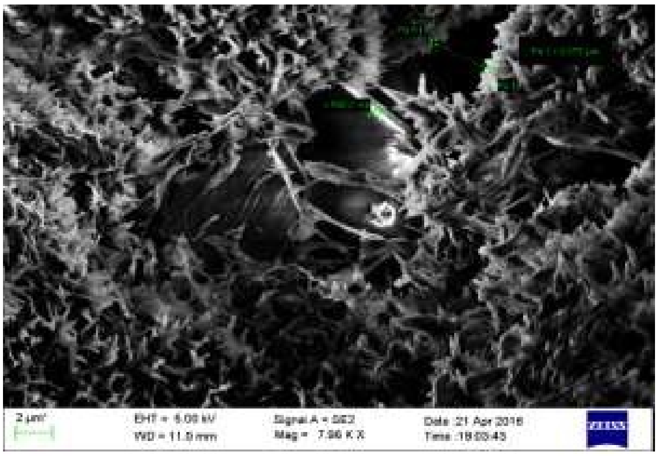

Figure (14). SEM image of MWCNT in cement composite after testing

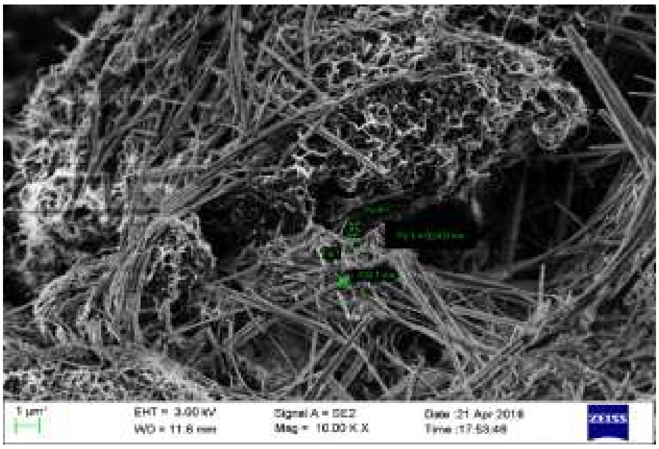

Figure (15). SEM image of MWCNT in cement composite before testing

4. Conclusions

Based on the above results following conclusions could be drawn from each of the studies conducted-

1. The study conducted by Brian M Tyson proved that the addition of CNFs and CNTs increased the strength higher than plain cement paste. The strength, ductility and toughness gain was seen after 14 days and this delay can be attributed to easy separation of nano-filaments at the early stages. However, the bonding seem to harden at later stages which is seen by the increase in strength.
2. CNFs have an improved performance because of their higher aspect ratio than CNTs.
3. The second study of CF's and MWCNT in round cement bars under tension showed that there was 54% increase in load capacity when both the fibres were included. There was also a considerable increase in the tensile modulus values with 0.5wt% MWCNT showing the maximum value of tensile modulus.
4. The addition of nanotubes to the bars, will increase tensile properties in terms of strength, strength to weight ratio. This proves their ability to become an ideal reinforcing material and it can be used for the construction of structures subjected to seismic, impact, dynamic, and so forth, loadings.
5. Increase in compressive and splitting-tensile strength was seen at 0.5wt% CNT by 15% and 36% respectively at 28 days curing. However, at 0.75wt% CNT, the compressive and split tensile strength was almost equal to plain cement mortar. The rate of change of compressive and splitting-tensile of all cement-CNT composites with respect to curing age was seen to be very similar to that of the control mix. This indicates that the strength gain of composites is primarily because of cement hydration and the fact that CNTs are not reacting with cement compounds.
6. The experiments on MWCNT in comparison to nano silica (NS) showed that a mix proportion including both MWCNT and NS was provided optimum strength gain and flexural resistance. MWCNT reinforced the cement matrix on a nanoscale while NS provided the strength gain due to formation of additional CSH gel, almost doubling the flexural strength in comparison to PC.
7. The SEM study by Anand Hunshyal et al. indicated at the non-uniform dispersion of MWCNTs. It was concluded that it is difficult to establish any chemical bond between MWCNT and cement matrix by SEM, the presence of a physical bonding can be verified.
8. From the study of addition of CNT to cement composites with embedded steel bars, it was found that CNT does not significantly affect the bending strength (less than 6%) or the compressive strength (less than 7%), at 28 days curing time.The addition of CNT to the cement matrix could imply the development of higher levels of corrosion in aggressive conditions, such as carbonation and contamination by chloride ions.
9. The nano cement testing involving PPC and the PCC showed that PPC had a moderate increase in strength at the earlier ages with 40% substitution being a turning point for the change in strength gain for both cements. The optimum substitution of nano material content was found to be at 40% to 80%.
10. The use of MWCNT composite as repair material was exhibited by the studies conducted by Tanvir Manzur in which it was concluded that MWCNT composites showed 26%, 21%, 15%, and 14% higher compressive strength at 3, 7, 28, and 100 days respectively.
11. The setting time, bleeding and slant shear tests were conducted showing that MWCNT composite hardened faster than conventional mortar which is an important characteristic of a repair material. Also, it showed no signs of bleeding as bleeding can affect the overall strength and durability of repair material. They also exhibited lower slant shear strength at early ages of 3 and 7 days when compared to epoxy however slant shear strength of MWCNT was more than conventional mortar.

12. The optimum dosage of nanotubes compression testing was found to be 1wt% for HNC and 0.5wt% for both CNT's whereas for splitting tensile strength, optimum dosage was found to be 0.75wt% for all the nanotubes.
13. The SEM and EDX analysis conducted showed that the testing on a specimen with reinforced nanomaterials only change the bonding nature of the materials used by the introduction of a fracture surface. It does not alter the composition of the specimen.
14. From the above survey, it can be concluded that while MWCNT have a greater potential as structural and repair material in cement industry, a lot of tests needs to be conducted in order to determine the inclusion of nano materials on a large scale basis. The use of MWCNT on a large scale is a future dream but use of HNC can be looked forward to as it holds similar properties as MWCNT with an added bonus of being environment friendly and cost effective.

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