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Cementitious Composites Reinforced with Multiwalled Carbon Nano Tubes Dispersed in Gum Arabic

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Abstract: The current study aims to investigate the effect of multi-walled Carbon Nano Tubes (CNTs) on mortar. In this study, Gum Arabic was used as a surfactant for dispersion of the multi-walled CNTs in an aqueous solution along with sonication. Mortar specimens of 40 x 40 x160 mm are prepared and tested as per EN 196-1. Ordinary Portland land cement of local brand "Fauji" was used. Standard sand of French origin conforming to ASTM Standard C778 was used. The C/s ratio was kept at 1:3 with a W/c of 0.5. Base on trials, 60 seconds sonication regime was selected, and mortar prisms were studied at 3, 7,14, and 28 days. An increase of 10.57 and 20.4% was observed in flexure and compressive strength, respectively. SEM images show many single filaments of CNTs, which is an indication of good dispersion. Results of this research will be beneficial for the use of multi-walled CNTs in cementitious composites.

Keywords: *Component, formatting, style, styling, insert*

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I. INTRODUCTION

The Journey of nanoscience and technology emerges from the lecture of well known Nobel Laureate Richard Feynman in 1959 at the California Institute of Technology saying, "There is plenty of room at the bottom" [1]. A lot of revolutionary changes were brought by nanotechnology in the world. Nanotechnology is basically studied of materials at the nanoscale [2]. Now a day's nanomaterials and science are being frequently used in civil engineering.

Concrete is the most frequently used construction material in the world due to the universal availability of its constituents. Its production exceeds 20 billion tons annually, which is the highest among all the composite materials [3, 4]. Its basic constituents are cement, sand, gravel, and water. Special characteristics can be achieved by using different additives and admixtures [5]. Nanotechnology has a lot of potential use in concrete [6]. Usually, cementitious composites possess very little tensile strength and strain capacity. It leads to cracking and sudden failure with ample warning. To increase the tensile capacity reinforcing bars are added to regions susceptible to tensile stresses and composite material is termed as

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reinforced concrete. Since a few decades, researchers started adding macro and micro-fibers in concrete to control the crack growth and to enhance the tensile strength of concrete [7]. Due to their exceptionally small size of a few nanometers, they can bridge the crack of infinitesimally small size. This effect will delay the crack propagation and enhance the ultimate strength and ductility [8].

TABLE 1
PROPERTIES OF MWCNTS

Purity	>95%
Outer diameter	10-20nm
Inner diameter	5-10nm
Length	20-100μm
Specific Surface Area	180-200m2/g
True density	2.1g/cc
Tap Density	0.27 g/cc
Electrical Conductivity	100 s/cm
Making Method	CVD

CNTs have a modulus of elasticity about 1TPa, tensile strength of 60 GPa and strain capacity of 12%. Modulus of elasticity of CNTs is five times higher than steel; Tensile strength is 100 times and strain capacity 60 time and specific gravity just one-sixth of steel [9]. Multiwalled CNTs used for this study were supplied and manufactured by Soochow Hengqiu Graphene TechnologySuzhou Co.Ltd. Jiangsu China. The properties of CNTs are given in Table 1 below. These extra-ordinary properties of CNTs make them attractive in the design of cementitious composites and other composite materials with different matrices [10]. Some researchers have used CNTs in cementitious composites in the range of 0.5 to 2% by weight of cement [11, 12, 13, 14, 15, 16, 17]. CNTs form bundles or agglomerates, firmly stick with each other due to the way they are produced. The main challenge in the use of CNTs in cementitious composites is poor dispersion. Due to this, it is impossible to achieve desired characteristics [10].

Surfactants are the agents that act as dispersants by lowering the surface tension between any fluid to fluid or fluid to the solid interface. In this study gum Arabic was used as surfactant along with sonication for dispersion of multiwalled carbon nanotubes.

Gum Arabic is gummy excreta obtained from the acacia tree. It is found in arid regions from Senegal to East Africa, Pakistan, and India [18]. It was being used for several purposes for 70,00 years. Gum Arabic is a complex polysaccharide. It consists of 39-42% of galactose, 24-27% of rabinose, 12-6% of rahmose, 15-16% of glucuronic acid, 1.5-2.6% of protein, 0.22-0.39% of nitrogen and 12.5-6% moisture [19]. It is easily soluble in water. Gum Arabic has the ability to adsorb and stabilize gas-liquid, liquid-liquid and solid-liquid interfaces [18]. From previous research it is established that gum Arabic is compatible with OPC and it enhance the properties of mortar and concrete [19, 20, 21, 22]. Furthermore, it is also beneficial for mitigating sulphate attack due to presence of $BaCO_3$ [22]. Above mentioned properties make it suitable as surfactant for dispersion of CNTs.

During this study effect of multiwalled carbon nanotubes was studied at mortar. Multiwalled CNTs were dispersed in Gum Arabic along with sonication by using cleaning bath type sonicator. It is observed that an increase of 18.5% in compressive strength and 5.5% increase in flexural strength is observed. Findings of this study contribute toward enhancing the mechanical properties of cementitious composites. It will promote the use of CNTs in concrete.

II. DISPERSION OF CNTS

As discussed in previous section real challenge with use of CNT in cementitious matrix is dispersion. Dispersion of CNTs is a great challenge. In case of low energy CNTs will not properly disperse and ultra-high energy will break them. In this study Gum Arabic is used as surfactant for dispersion of CNTs. CNTs concentration is kept 0.06% by weight of Cement. Surfactant to CNT ratio was kept 6 as described in literature [23]. Dispersion of CNTs achieved in 03 stages.

A. *Manual Mixing*

1.62 g of gum Arabic is dissolved in 100ml of water in a magnetic stirrer for 10 minutes. Then 0.27 g of CNTs are added and stir for 05 minutes manually in a glass beaker.

B. *Sonication*

Sample prepared in previous step was kept in sonicator. Frequency of sonication was 37 KHz. Temperature of sample Was maintained below 30C0. 03 sonication trials of 15,30 and 60 minutes. During sonication beaker was covered wit an aluminum foil to prevent the loss of water.

Fig. 1. Sonicator

C. Visual Observation

All three samples were observed for reaglomeration by visual inspection. Sample sonicated for 15 minutes started precipitating at bottom just after 01 hours. While Sample sonicated for 30 minutes and 60 minutes take 38 and 90 hrs. respectively. Based on these trials 60 minutes sonication regime was selected for casting specimens.

Fig. 2. CNTs after dispersion

III. MATERIALS AND METHOD

Mortar specimen of size 40 x 40 x160 mm are prepared and tested as per EN 196-1. Ordinary Portland land cement of local brand “Fauji” was used. Standard sand of French origin conforming to ASTM Standard C778 was used. C/s ratio was kept 1:3 with W/c of 0.5.

A. Casting of Specimen

Two types of specimens were prepared. One is controlled with gum Arabic and designated as A0. Other specimens with CNTs designated as A1.03 gang prism molds were used for casting specimen. Mortar is mixed in Hobart mixer following standard mixing regime for mortar as per EN 196-1. Samples were immediately molded after mixing in two layers. Each layer was compacted by 60 jolts of jolting apparatus. Each mold was covered with a glass plate. Now this covered mold was transferred to moist curing cabinet with temperature of 20+1C0 and humidity of 95%. After 24 hours samples were carefully demolded and immediately shifted to curing cabinet up to the age of testing.

B. Testing of Specimen

Specimens were tested in compression and flexure according to EN196-1. Three samples were tested in flexure in MCC8 Machine. Out of 06 broken pieces 05 were tested in compression and one is kept for microstructure.

Fig. 3. Standard sand

Fig. 4. Specimen just after casting

IV. RESULTS AND DISCUSSION

The influence of CNTs on several mechanical properties of cementitious composites like compressive strength and flexure strength were investigated. Three samples in flexure are tested. Out of 6 broken pieces 05 were tested in compression and one was kept for micro structure. The results shown for all tests for each type is the average value which had repeatability.

A. Fresh and SSD Density

Fresh and SSD densities were shown in Table 2. It is evident that sample with cnt has fresher as well as SSD density at 28 days. It shows that Addition of CNTs has increased the packability of matrix by filling infinitesimally small pores. It is also evident from microstructure.

TABLE 2
FRESH AND SSD DENSITY

Sample	Fresh density	SSD at 28 days
Ao	2.23	2.22
A1	2.25	2.24

Furthermore, fresh density is more because during hydration process some of water is utilized and pores are filled with hydration products.

B. *Compressive Strength*

Compressive strength is a significant property of the cementitious composites either paste, mortar or concrete. It reflects the characteristics and excellence of the cementitious composite.

Results for compressive strength at 03, 07, 14 and 28 days for controlled as well as sample with CNTs are shown in Fig. 5 It is evident that strength of sample A1 is greater than the Ao. Strength of A1 is 21.3, 19.6, 13.73, 20.41% more as compare to control specimen at age of 03, 07, 14, 28 days respectively. It indicates that CNTS dispersed in gum Arabic are beneficial in enhancing the compressive strength of cementitious composite. From figure it is evident that gain in compressive for both A0 and A1 follow the same pattern. The gain in compressive strength follows the logarithmic law with R^2 value 0.978 and 0.999 for Ao and A1 respectively.

Fig. 5. Specimen just after casting

C. *Flexure Strength*

As cementitious composites are weak in flexure. Increase in flexure strength of cementitious composites is a matter of interest. In this study MWCNTs dispersed in gum Arabic were used to enhance the flexural strength of the cementitious composite. Results are shown in figure.

Increase in flexural strength in A1 as compare to Ao is 2.2, 5.35, 4.8 and 10.57% at age of 03, 07, 14 and 28 days respectively. Like compressive strength a well-established logarithmic law is followed by A0 and A1 with R^2% value of 0.987 and 0.988 for A0 and A1 respectively. An increase of 10.57% by addition of CNTs is due to well known phenomenon of crack bridging effect of CNTs [6, 10, 23]. Due to their infinitesimally small size CNTs bridge the very small cracks even from a nm to a few micrometer. In this way it prevents the propagation of the crack in turn increase in flexural strength is observed. Microstructure results also confirm crack bridging phenomenon.

Relation between flexural strength and compressive strength is matter of great interest for different stake holders of construction industry such as structural designer, researchers, code forming bodies and constructor. In literature a lot of relationships are proposed. A few of them are adopted by may codes. Relationship between flexure Strength and compressive strength is shown in Fig. 6. It is evident a well-established linear relationship exists between Flexure strength and compressive strength for A0 and A1. R^2 value is 0.989 and 0.987 for A0 and A1 respectively.

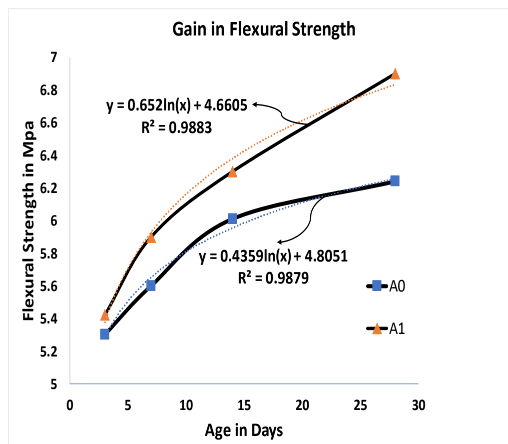

Fig. 6. Gain in flexural strength

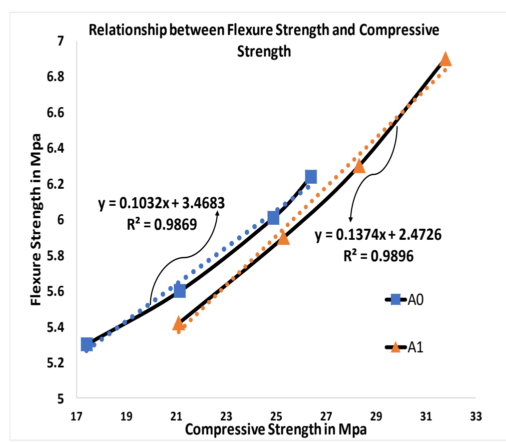

Fig. 7. Relationship between compressive and flexure strength

V. MICROSTRUCTURE

In Fig. 4 SEM images are shown for fractured surface of the specimens in Fig. 8. Well known phenomenon of crack bridging can be observed. A lot of well dispersed

Single CNTs are present Which indicate the effective dispersion. A few Clusters of non-dispersed CNTs are also observed.

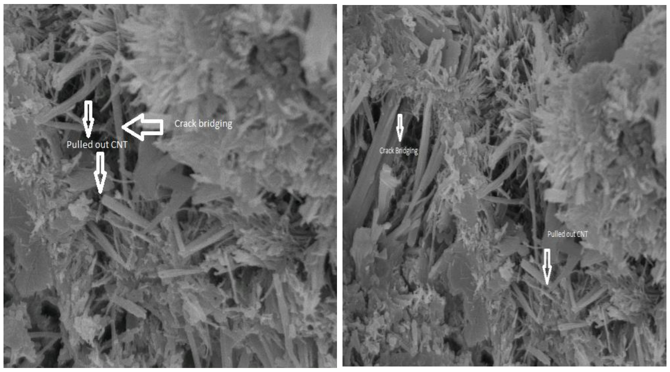

Fig. 8. SEM images

VI. CONCLUSION AND RECOMMENDATIONS

Present study discusses the effect of multiwalled carbon nanotubes on cementitious composite. It is indicated that sonication in a cleaning bath sonicator has dispersed the CNts to large extent. For improving the dispersion probe type sonicator may be used. The influence of CNTs on various mechanical properties like compressive strength and flexure strength are also investigated. There is an increase of 10.57% and 20.4% in flexure and compressive strength observed respectively. Gum Arabic can be used in cementitious composites. Scholars are encouraged to investigate this domain further and enhance the body of knowledge.

Declaration of Conflicting Interests

There are no conflicts of interests.

REFERENCES

[1] R. Feynman, "There is plenty of room at the bottom: An invitation to enter a new field of physics," in *Lecture at American Physical Society Meeting*, Pasadena, CA, 1959.

[2] A. Khitab and M. Tausif Arshad, "Nano construction materials," *Reviews on Advanced Materials Science*, vol. 38, no. 2, pp. 181–189, 2014.

[3] M. A. Broekmans and H. Poellmann, *Applied Mineralogy of Cement & Concrete*. Boston, MA: De Gruyter, 2018.

[4] E. Worrell, L. Price, and M. Ruth, "Policy modeling for energy efficiency improvement in US industry," *Annual Review of Energy and the Environment*, vol. 26, no. 1, pp. 117–143, 2001. doi: https://doi.org/10.1016/s0301-4215(01)00069-6

[5] A. M. Neville, *Properties of concrete*. Dehli, India: Pearson Education India, 1963.

[6] F. Sanchez and K. Sobolev, "Nanotechnology in concrete–a review," *Construction and Building Materials*, vol. 24, no. 11, pp. 2060–2071, 2010. doi: https://doi.org/10.1016/j.conbuildmat.2010.03.014

[7] A. Khitab, M. T. Arshad, N. Hussain, K. Tariq, S. A. Ali, S. Kazmi, and M. Munir, "Concrete reinforced with 0.1 vol% of different synthetic fibers," *Life Science Journal*, vol. 10, pp. 934–939, 2013.

[8] P. J. Bartos, "Nanotechnology in construction: A roadmap for development," in *Nanotechnology in Construction 3*. Berlin, Germany: Springer, 2009, pp. 15–26.

[9] K. L. Scrivener and R. J. Kirkpatrick, "Innovation in use and research on cementitious material," *Cement and Concrete Research*, vol. 38, no. 2, pp. 128–136, 2008. doi: https://doi.org/10.1016/j.cemconres.2007.09.025

[10] A. Sobolkina, V. Mechtcherine, V. Khavrus, D. Maier, M. Mende, M. Ritschel, and A. Leonhardt, "Dispersion of carbon nanotubes and its influence on the mechanical properties of the cement matrix," *Cement and Concrete Composites*, vol. 34, no. 10, pp. 1104–1113, 2012. doi: https://doi.org/10.1016/j.cemconcomp.2012.07.008

[11] M. S. Konsta-Gdoutos, Z. S. Metaxa, and S. P. Shah, "Highly dispersed carbon nanotube reinforced cement based materials," *Cement and Concrete Research*, vol. 40, no. 7, pp. 1052–1059, 2010.

[12] J. Makar, J. Margeson, and J. Luh, "Carbon nanotube/cement composites-early results and potential applications," in *Conference on Construction Materials*, Vancouver, Canada, 2005.

[13] G. Y. Li, P. M. Wang, and X. Zhao, "Mechanical behavior and microstructure of cement composites incorporating surface-treated multi-walled carbon nanotubes," *Carbon*, vol. 43, no. 6, pp. 1239–1245, 2005. doi: https://doi.org/10.1016/j.carbon.2004.12.017

[14] G. Y. Li, P. M. Wang, and X. Zhao, "Pressure-sensitive properties and microstructure of carbon nanotube reinforced cement composites," *Cement and Concrete Composites*, vol. 29, no. 5, pp. 377–382, 2007. doi: https://doi.org/10.1016/j.cemconcomp.2006.12.011

[15] Y. Saez de Ibarra, J. J. Gaitero, E. Erkizia, and I. Campillo, "Atomic force microscopy and nanoindentation of cement pastes with nanotube dispersions," *Physica Status Solidi (a)*, vol. 203, no. 6, pp. 1076–1081, 2006. doi: https://doi.org/10.1002/pssa.200566166

[16] S. Wansom, N. Kidner, L. Woo, and T. Mason, "Ac-impedance response of MWCNTS/cement composites," *Cement and Concrete Composites*, vol. 28, no. 6, pp. 509–519, 2006. doi: https://doi.org/10.1016/j.cemconcomp.2006.01.014

[17] A. Cwirzen, K. Habermehl-Cwirzen, and V. Penttala, "Surface decoration of carbon nanotubes and mechanical properties of cement/carbon nanotube composites," *Advances in Cement Research*, vol. 20, no. 2, pp. 65–73, 2008. doi: https://doi.org/10.1680/adcr.2008.20.2.65

[18] C. Sanchez, M. Nigen, V. M. Tamayo, T. Doco, P. Williams, C. Amine, and D. Renard, "Acacia gum: History of the future," *Food Hydrocolloids*, vol. 78, pp. 140–160, 2018. doi: https://doi.org/10.1016/j.foodhyd.2017.04.008

[19] A. U. Elinwa and M. Umar, "X-ray diffraction and microstructure studies of gum arabic-cement concrete," *Construction and Building Materials*, vol. 156, pp. 632–638, 2017. doi: https://doi.org/10.1016/j.conbuildmat.2017.08.162

[20] Z. C., Z. Q., Z. Y., and Z. M., "Thee effect of gum arabic on dispersion of cement paste," in *Proceedings of the 11th International Congress for Applied Mineralogy (ICAM)*, Cham, Switzerland, 2015.

[21] R. Mbugua, R. Wanjala, and J. Ndambuki, "Influence of gum acacia karroo on some mechanical properties of cement mortars and concrete," *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, vol. 9, no. 11, pp. 1369–1372, 2015.

[22] A. U. Elinwa, G. Abdulbasir, and G. Abdulkadir, "Gum arabic as an admixture for cement concrete production," *Construction and Building Materials*, vol. 176, pp. 201–212, 2018.

[23] B. S. Sindu and S. Sasmal, "Properties of carbon nanotube reinforced cement composite synthesized using different types of surfactants," *Construction and Building Materials*, vol. 155, pp. 389–399, 2017. doi: https://doi.org/10.1016/j.conbuildmat.2017.08.059