Study on the improvement of mechanical properties of cement based composites using carbon nanotubes

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Abstract. Using ultrasonic method to uniformly disperse carbon nanotubes into cement materials to prepare corresponding cement based composites using carbon nanotubes as raw materials, and focusing on the improvement of their mechanical properties. The research shows that adding carbon nanotubes can greatly improve the mechanical properties of cement based composites, with an optimal amount of 0.10 wt%. At this time, The mechanical properties of cement based composites have the best improvement effect. SEM microscopic analysis shows that the addition of carbon nanotubes can play a pull-out and bridging effect, significantly increasing the ability of cement based materials to resist damage.

Keywords: carbon nanotubes; Cement based composite materials; mechanical property.

1. Introduction

Cement concrete, as the most widely used building material in the construction industry with the largest demand, has become increasingly demanding with the rapid development of modern society. Traditional cement materials are far from meeting the material performance requirements for special occasions such as earthquakes, thermal stress effects in dams, and how to improve the corresponding mechanical properties of cement concrete, Then, how to effectively test has become a hot topic and focus in the current scientific community［1］.

According to relevant literature research [2], adding an appropriate amount of carbon materials in cement based materials can achieve good crack resistance and mechanical properties, and can also make cement based materials have excellent piezoresistive properties. Carbon nanotubes (CNTs) are tubular nano carbon materials, which have a graphite crystal structure, and their mechanical properties are nearly perfect compared to traditional carbon fiber materials, It is one of the fiber materials with the best comprehensive properties, especially mechanical properties, discovered by scientists so far. Referring to the different layers of carbon atoms in carbon nanotubes, it can be divided into single-walled carbon nanotubes and multi-walled carbon nanotubes, namely, SWCNTs and MWC NTs. SWCNTs are particularly expensive and can only be used in fields such as sensors with high cost performance. However, MWCNTs are relatively inexpensive, and currently relevant companies have reached large-scale production, Moreover, it has a relatively high degree of application and can be widely used in scientific research in the field of reinforced composite materials. The matrix materials that have been extensively studied in the scientific community mainly include polymer based, ceramic based, and metal based materials. Morsy et al. [3] found that adding 0.02% multi walled carbon nanotubes into cement can improve its compressive strength. There is very little research on related aspects of cement based composite materials, and research on it is currently in the initial stage, Therefore, the research is of great significance.

For scientists engaged in material research, actively studying the incorporation of carbon nanotubes into cement based materials has become a top priority. After the research, it is still necessary to promote and apply it as soon as possible. This is a technological revolution that requires investment of funds and energy. Once achievements are achieved, it will inevitably lead to a new understanding of nanotechnology in the academic community, and it will also lead to the vigorous development of related high-tech industries, leading to a technological revolution in new materials, It will certainly provide space for the entire society to create enormous benefits

Through mechanical tests on carbon nanotube cement paste composite materials, this article obtains data on the impact of different carbon nanotube content and different age on the compressive strength and flexural strength of the material, based on which the optimal carbon nanotube content value is obtained. Finally, the mechanism of carbon nanotube incorporation on the mechanical properties of cement based composite materials is studied, analyzed, and tested.

2. Experimental Study

2.1 Raw Material

Carbon nanotubes were purchased from a Jiangsu nanomaterials Co., Ltd. and prepared by catalytic pyrolysis (CVD). The relevant parameters of carbon nanotubes are shown in Table 1, and the structural diagram is shown in Figure 1. P • O42. Grade 5 ordinary Portland cement is purchased from Nantong, Jiangsu Province. The mineral composition and related physical properties of the cement are shown in Table 2; The material of cetyltrimethylammonium bromide is a pure white powder with simple processing; The polycarboxylic acid water reducing agent purchased from a Jiangsu New Material Co., Ltd. has a corresponding solid content of 25% and a water reducing rate of 35%.

Table1 Basic Physical Parameters of MWNT

Purity/%	Outer diameter/nm	Length/ μm	Specific surface area/(m2/g)	Ash content/%	Conductivity/(s/cm)	- COOH content/%
＞ 95	15 ～ 20	15 ～ 30	50 ～ 300	＜ 1．6	100 ～ 1 000	2．00

Table 2 Physical Properties and Mineral Composition of Cement

Specific surface area/(m2/Kg)	Setting time/min		Stability	Bending strength/MPa		Compressive strength/MPa		Mineral composition/%				
	Initial coagulation	Final coagulation		3d	28d	3d	28d	C3S	C2S	C3A	C4AF	SO3
350	194	239	qualified	5.5	8.4	33.8	64.1	49.32	25.14	9.92	10.84	2.24

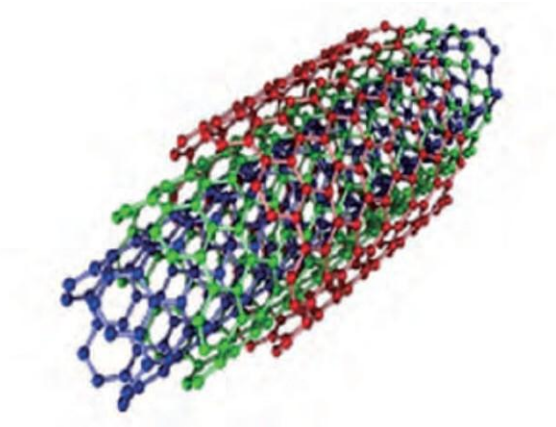

Figure 1 Structural Diagram of Carbon Nanotubes

2.2 Specimen Forming and Testing

Add well-weighed carbon nanotubes to the aqueous solution of cetyltrimethylammonium bromide. The corresponding mass ratio of cetyltrimethylammonium bromide to carbon nanotubes is 9:1. Firstly, disperse them (using ultrasound), and continue for 80 minutes to ensure that carbon nanotubes are very reliably and uniformly dispersed in the aqueous solution, Then, a carbon nanotube suspension is generated. Then, the newly generated carbon nanotube suspension and Portland cement are placed in a cement mixer for uniform mixing, with a water cement ratio of 0.4. The mixing time is controlled at about 7 minutes, with a low speed mixing interval and a high speed mixing interval, with a time ratio of 3:1. After mixing, immediately pour the net slurry in the mixer into 40 mm × 40 mm × 160 mm and 40 mm × 40 mm × The 40 mm test mold is vibrated, compacted, and cured. According to the curing standards, the mold is removed after 24 hours of curing. The test pieces are labeled and placed in water at a temperature of 20 ℃ before curing until their age is reached [5]. The mix ratio and carbon nanotube content of all test pieces are shown in Table 3, and the microstructure of partial samples is shown in Figure 2 .

Table3 Mix ratio of carbon nanotube cement based composite materials

sample	Water cement ratio	Mix ratio/%		
	（W/C）	Multi walled nanotubes	Single walled nanotubes	Water reducing agent
No1	0．30	0	0	0．1
No2	0．30	0．06	0．6	0．1
No3	0．30	0．11	1．1	0．1
No4	0．30	0．16	1．6	0．1
No5	0．30	0．22	2．1	0．1
No6	0．30	0．26	2．6	0．1

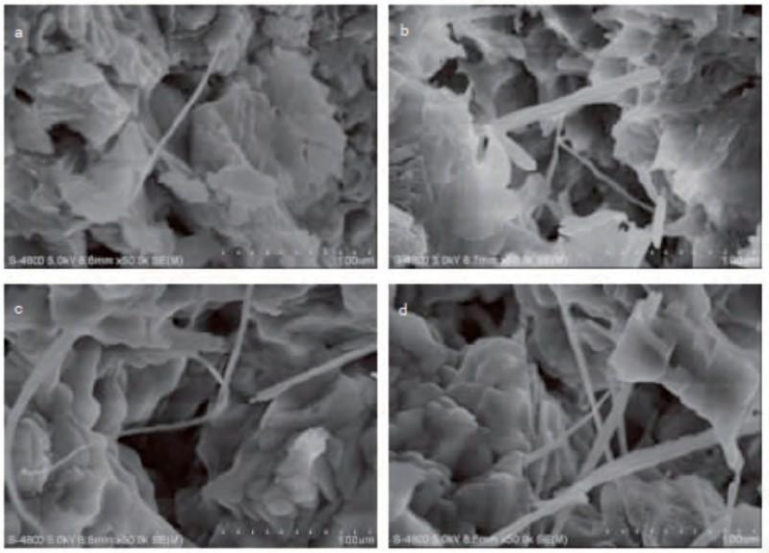

Figure 2 Microstructure of the sample

2.3 Test process

According to GB/T17617-1999 Test Method for Strength of Cement Mortar, the impact of carbon nanotubes on the flexural strength of cement based composites was tested using a DKZ-5000 type flexural testing machine, and its compressive strength was tested using a WHY type fully automatic press, The effect of carbon nanotube incorporation on the compressive strength

of cement based composites was analyzed. The morphology of each fracture of multi walled nanotube cement based composites was observed using SU-80 thermal field emission scanning electron microscopy. Finally, the mechanism of carbon nanotube and cement was explored and analyzed.

3. Result Analysis

3.1 Mechanical Property

The test structure for the mechanical properties of cement based composites doped with carbon nanotubes after 7 days of curing is shown in Figure 3. As can be seen from Figure 3, the flexural and compressive strength of cement based composites doped with carbon nanotubes have significantly improved, with an increase of more than 15%. When the content of multi wall nanotubes is 0.10 wt% of the weight of water mud, its flexural strength increases by 28%, reaching the peak; At the same time, its compressive strength has also increased by 22%, reaching a peak of 41 MPa. The change trend of the folding box compressive strength of the sample is identical

Subsequently, the mechanical properties of 14 and 28 days were tested, and it was found that the situation was the same. Overall, the addition of 0.10% MWC-NTs have the best improvement effect.

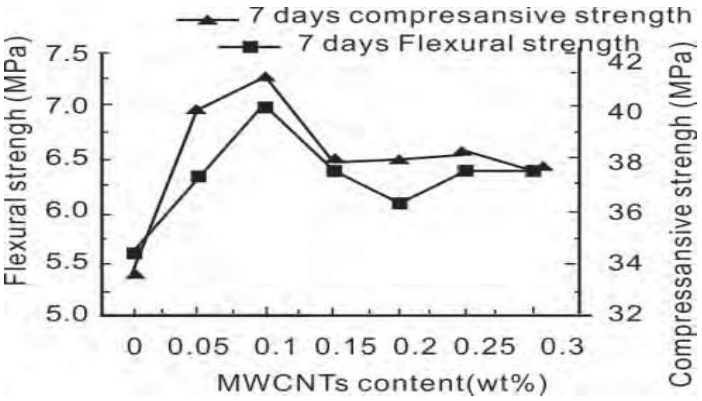

Figure 3 Mechanical Properties of Cement Mortar Specimens with Different MWCNTs Admixtures

4. Sem Analysis

In order to accurately study the formation mechanism of mechanical properties of MWCNTs reinforced cement based composites, the author conducted SEM image analysis of the material's cross-section. The observation results are shown in Figure 4, which clearly shows that MWCNTs have a good bridging effect in the cement matrix. This bridging enables MWCNTs to have a certain external force effect, which can consume external stress damage, greatly prevent the formation and expansion of material cracks, and improve the toughness and strength of the material.

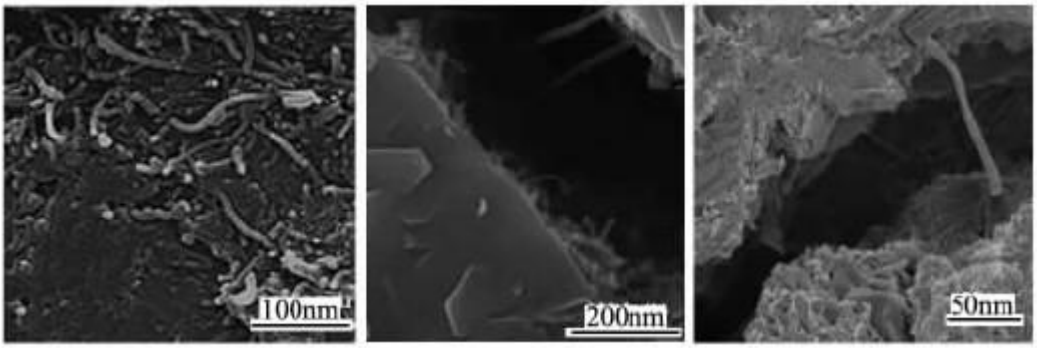

Figure 4 SEM Analysis Results of Carbon Nanotubes

5. Conclusion

The addition of multi walled nanotubes significantly enhances the mechanical properties of cement based composites. According to the 7-day test results, when the content is 0.10 wt%, the effect of improving the mechanical properties is the best; In the analysis of SEM images, carbon nanotubes can have a bridging effect in cement-based materials, enabling MWCNTs to have a certain external force effect, which can consume external stress damage, prevent the formation and expansion of material cracks, and improve the toughness and strength of materials.

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