

Microwave Absorbing Property of the Nanoparticle Concrete

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Abstract. Nano concrete samples with different sizes were prepared by incorporating particles of Nano ferric oxide, Nano silicon dioxide and Nano alumina with good dispersion. The compressive strength, flexural strength and radar reflected wave were tested. Mechanism of Nano concrete enhancement and mechanism of Nano concrete wave elimination were discussed. Result showed that Nano particles of iron oxide and alumina on the compressive strength of concrete had a different degree of resistance increase. The compressive strength of Nano alumina (NA) concrete was the highest, which was increased by 44.4% compared with that of ordinary concrete (PC). The flexural strength of Nano iron oxide (NF) concrete was the highest, which was 44.4% higher than that of ordinary concrete. As for the radar wave reflectivity, different Nano materials on the radar wave reflection effect were different. The full reflectivity of NSF compounded two kinds of Nano particles was lower than -8dB. With the increase of the content of Nano iron oxide particles, the reflectivity of radar wave decreases gradually. The minimum reflectivity of -16.7dB was achieved at 2.5GHz.

1. Introduction

With the continuous improvement of radar technology, radar stealth technology was also in constant development. A large number of structure materials and stealth coating constantly come out, which was low reflection and high absorption to radar wave. Stealth fighter warships continue to innovate. And to important ground of facilities, underground works et al belong the radar stealth design did not catch up with the pace of the times. With the universal application of wireless communication technology as well as the convenience of life, people are also facing the problem of communication security, electromagnetic radiation pollution, signal interference and other issues, and some even threaten the health of people. However hospitals, research institutes, communications relay and scheduling and other unites are facing the greatest threat. So it was an important research direction to study the wave absorbing of radar wave in the field of building materials.

Most of the research was mainly carbon black, ferrites, carbon fiber, steel fiber and other traditional wave absorbing agent in cement-based materials. Their properties of microwave-absorbing was good [1-3], but they often have a narrow absorption band, severe reduction in strength or other serious shortcomings. Nano concrete has excellent performance in many ways [4-5], but people never learned much about the absorption propertied of Nano concrete [6-7]. In theory, the application of Nano materials should have great development potential in the field of concrete absorbing. In this paper, a variety of Nano concrete specimens were prepared by using well dispersed Nano silica and alumina particles. Mechanical properties of the sample and the radar reflectivity were tested and the



strengthening mechanism and wave absorbing mechanism were discussed. The research and application of Nano concrete wave absorbing will have a certain role in the future.

2. Experiment method

2.1 Test materials

The cement used was Portland cement (P•O32.5R) of Qinling Brand (Shaanxi China), main properties are shown in Table 1; Low calcium fly ash of Hancheng Power Plant; limestone Rubble (5 to 10 mm, 15%; 10 to 20 mm, 85%), river sand (bulk density of 1500 kg/m^3 with a fineness modulus of 2.78 and mud content was 1.1%). Superplasticizer liquor (Solid content of 40%) was from Zhongyi Chemical Plant (Shaanxi, China), as Nano-materials dispersant and concrete water reducing agent. Nano-SiO₂, Nano-Fe₂O₃ and Nano-Al₂O₃ were obtained from Veking New Material Co. Ltd (Zhejiang, China), appearance as shown in Figure 1, main properties are shown in Table 1.

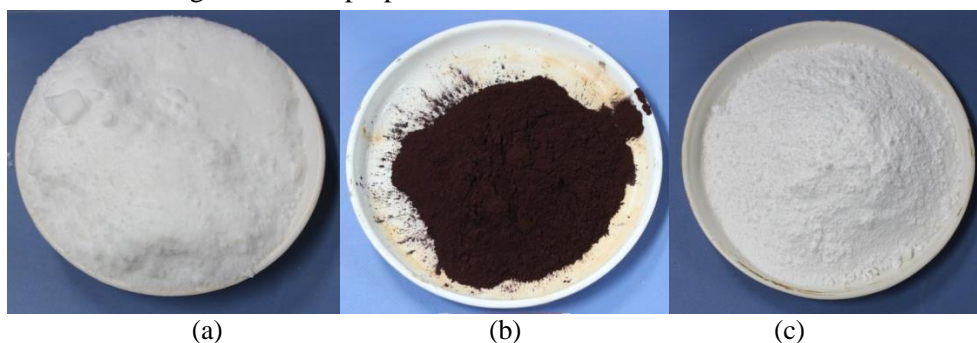


Figure 1. Particles of Nano ferric oxide, Nano silicon dioxide and Nano alumina

Table 1. Properties of Nano particles

Item	Model	Appearance	Purity/%	Surface-volume Ratio(m^2/g)	Diameter/nm	Water%
SiO ₂	VK-SP15	White powder	≥ 99.8	250 ± 30	15 ± 5	≤ 0.1
Fe ₂ O ₃	VK-E01	Cinnamon	≥ 99.8	80-90	50	≤ 0.1
Al ₂ O ₃	VK-L20Y	White powder	≥ 99.9	150-200	10~20	≤ 0.01

2.2 Test technique

Quasi static mechanical test refer to "ordinary concrete mechanics performance test method standard" (GB / T50081. 2002) in the provisions of the method. The polycarboxylate superplasticizer with 3/4 water were stirred into the solution, then adding Nano-particles in solution and stirring 30 s at a low velocity and stirring 30 s at high velocity, which were scattered for 15 minutes by using the ultrasonic dispersion method to ensure Nano particles dispersed evenly. Concrete prepared by "wrapped sand method", the specific process was as follows: Firstly, adding fly ash and half of the cement and mixing together into a mixing ash (30 s); secondly, adding Nano mixture and mixing into mortar (30 s); thirdly, adding to the sand and beat up (30 s); and then putting in the stones and stirring (30 s); lastly, adding 1/4 water washing container and the residual cement and stirring (120 s). A mixture of fresh concrete was uniform.

The radar reflectivity measured by sweep frequency measurement system arc method, as shown in Figure 2, whose testing standards are in line with the "radar reflectivity test method" (GJB2038A). The test frequency was in the range of 2GHz~18GHz and the test results take of 3 specimens of group average. The specimen of Radar absorbing material reflectivity test cast by wood formwork whose size was 200 mm x 200 mm x 100 mm. After pouring the specimens were covered with plastic film to prevent excessive evaporation of water. After standing the room for 24 h, the mold was carried out. Then put the test-pieces in the standard curing room for 28 d, which was in the temperature of $20 \pm 2^\circ\text{C}$ and whose relative humidity was more than 95%. It was polished accurately using a SHM-200 type

double section grinding machine, whose surface irregularities must be controlled in the 0.1 mm.



Figure 2. H62 brass pulse shapers

3 Experimental results and analysis

3.1 physical and mechanical properties

The physical and mechanical properties of Nano concrete is shown in Table 2. The water cement ratio of all samples was 0.36. Polycarboxylate superplasticizer was used as Nano-particles dispersing agent and water reducing agent, ensuring that the Nano-particles were uniformly dispersed in the concrete and keep the concrete working better than concrete in low water cement.

Table 2. Physical and mechanical properties of Nano concrete

Specimens	Nano materials	Volume of Nano concrete/%	Volume of superplasticizer/%	Strength of 28 d/MPa	
				Compression	Flexural
PC	0	0	0.4	34.2	4.3
NA	Al_2O_3	2.0	0.4	49.4	4.9
NS	SiO_2	2.0	1	33.8	3.6
NF-a		1.0		38.3	4.8
NF-b(NF)	Fe_2O_3	2.0	0.4	42.4	5.2
NF-c		5.0		40.5	4.7
NSF	$\text{Fe}_2\text{O}_3, \text{SiO}_2$	2.0	1	40.2	5.1

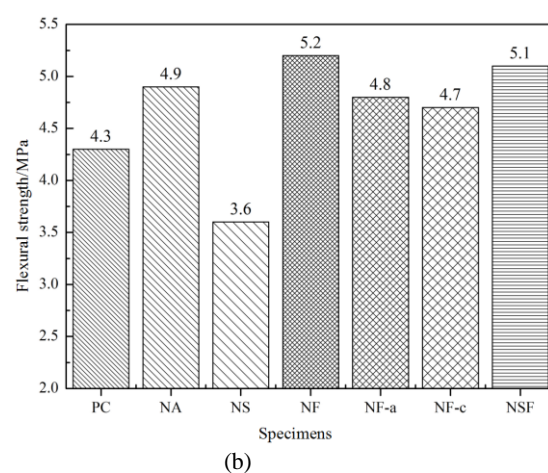
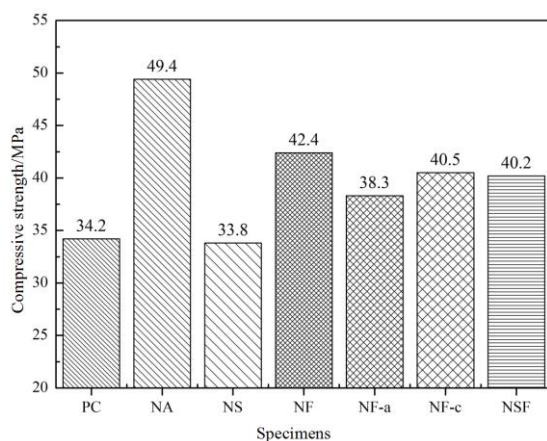


Figure 3. Mechanical properties of Nano concrete

The 28 d compressive strength and flexural strength of Nano concrete in each group samples were shown in Figure 3. All groups except NS of Nano concrete compressive, flexural strength had different

degrees of improvement compared with the blank group PC. NA compressive strength was highest and increased by 44.4% compared with PC among them. NF-b flexural strength was (the same ratio of NF) highest and more 20.9% than PC. However, the NS doped with Nano-SiO₂ has no advantage and even weakened compared with PC in compressive strength and flexural strength, which should be noticed in the following research. The NSF doped with two kinds of Nano materials has a certain advantage compared with PC in the two aspects of compression and bending, increased respectively by a factor of 17.6% and 18.6% and was basically the same as that of the NF. The compressive strength and flexural strength of NF-b was the highest in the NF group, explaining that the compressive and flexural strength had a first increased and then decreased in the 0~5.0% content range of Nano particles. So there should be the best volume to make the concrete strength reaches the maximum.

The different Nano particles had different effects on the strength of concrete. The formation of hydrated calcium silicate was due to the reaction of Nano-SiO₂ and Ca(OH)₂ in the early hydration of cement, which reduced the calcium hydroxide crystals. But with the increase of strength, a large number of Nano SiO₂ was in the reaction and water consumption. The cement hydration reaction was not sufficient, affecting the further development of NS late strength. Therefore, NS strength was weakened compared with PC [8]. When Nano-Al₂O₃ is in concrete, the process of concrete hydration was greatly promoted due to the great surface area and surface polarity charge. A part of Nano Al₂O₃ reacts with the alkaline substance in concrete in order to reduce the aggregation of harmful crystal. The other part filled in concrete pores in the form of decreasing the harmful hole, which had an influence on the strength of NA [9]. Nano-Fe₂O₃ particles dispersed uniformly were added into the concrete. On the one hand, due to the nucleation effect, hydration reaction takes Nano-Fe₂O₃ particles as the core and strengthens gradually for getting more uniform crystal. On the other hand, new three dimensional crystal structure produced by reaction continue to improve the strength of test-pieces owing to the original three-dimensional structure of cement stone [10]. Different Nano materials have different reaction mechanism, and the reaction activity of cement stone was different. So the influence on the macro mechanical properties of concrete was quite different.

3.2 effect of different Nano materials

Different Nano particles were added into the concrete, which has different effects on the radar reflectivity of the sample. The measured results were shown in Figure 4. NS, NF and NA were respectively on behalf of Nano-SiO₂, Nano-Fe₂O₃ and Nano-Al₂O₃ concrete, the sample's thickness was all 50 mm.

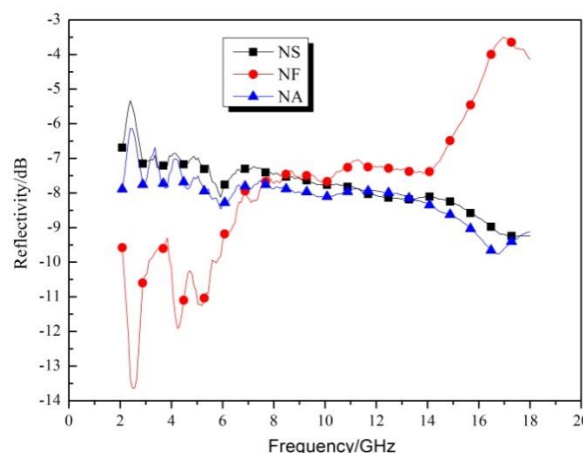


Figure 4. Stress versus strain curves by

The results of three kinds of sample had significant difference. The radar reflectivity of NF was smaller in the lower frequency range, larger in higher frequency range. NA and NS were opposite of NF. The reflectivity was larger in the low frequency range but lower in the high frequency range. NA's reflectivity was less than NS as a whole. The minimum of NF was -13.56dB near the 2.56GHz radar

frequency. When the wave frequency was 2GHz~7GHz Radar reflectivity were all less than -8dB. When the frequency is above 10GHz, NA and NS show more obvious advantages. The frequency was near 14.2GHz or better and the radar reflectivity would be less than -8dB.

It is difficult to achieve the dual requirements of impedance matching and strong absorption, for a single absorption complex. Composite material was conducive to improve electromagnetic loss ability as well as complementary electromagnetic parameters. So we can imagine mixing two kinds of Nano material, so that the sample achieved the purpose of low reflectivity in a wider frequency range

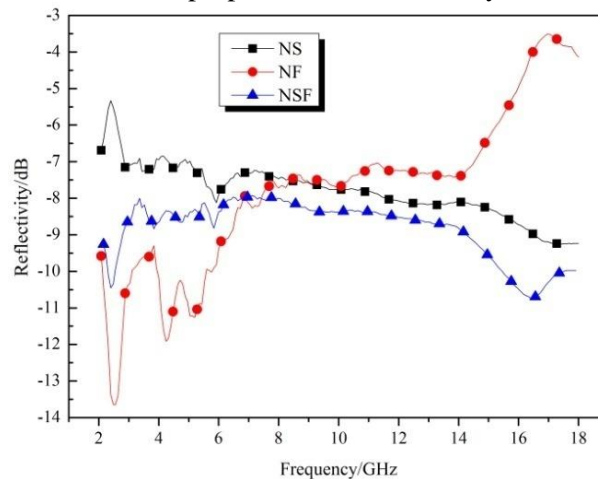


Figure 5. Stress versus strain curves

NSF was the Results of radar reflectivity that shown in Figure 5, which indicated that Nano-SiO₂ particles were added into concrete together with Nano-Fe₂O₃ particles. The figure shows that NSF can be seized of the common advantages of NS and NF. Radar reflectivity was almost less than -8dB in the full band range (2GHz~18GHz), but its effect was not a single linear superposition of them. The lowest reflectivity of NSF appeared near 2.56GHz and was consistent with the lowest frequency of NF whose reflectivity was -10.48dB. The second was near 16.42GHz and also synchronous with the lowest point of NS. Thus, it was feasible to use multiple absorbing materials to complement each other within a certain range.

3.3 The influence of different proportion

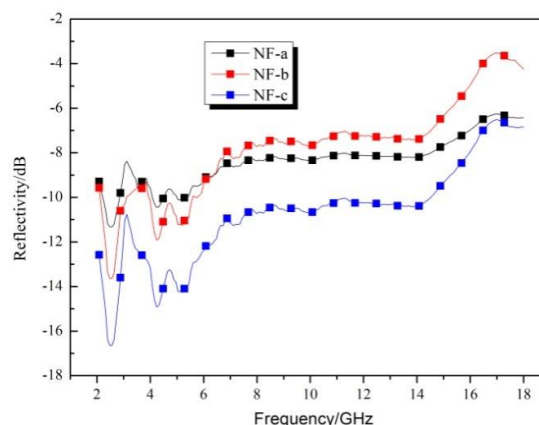


Figure 6. Stress versus strain curves

As shown in Figure 6, the reflectivity of concrete slab was under three kinds of different Nano-Fe₂O₃ content, including NF-a, NF-b and NF-c. And the mix proportion was respectively corresponding to the 3, 4 and 5 group in the table 2. The content of Nano-Fe₂O₃ respectively was 1%, 2% and 5% of cement content. It shows obvious regularity that three sets of curves were consistent

with each other among the range of whole full frequency. This might be interpreted that the peaks and troughs of reflectivity curve keep synchronized. The three groups of curves reached the minimum at the frequency of 2.56GHz, which were respectively -11.2dB, -13.6dB and -16.7dB. Therefore, in the range of 1% to 5%, the larger the amount of Nano-Fe₂O₃ was, the smaller the radar reflectivity of concrete slab was. And the reflectivity got smaller at lower frequencies.

At present, great progress has been made in the research of novel Nano absorbing materials, but its mechanism has not yet formed a unified conclusion. Nanoparticles have the quantum size effect and macroscopic quantum tunneling effect because of extremely small size, which were not available in general materials. So it was difficult to explain with conventional macro mechanism.

Nano-Fe₂O₃ was a kind of double loss material with dielectric loss and magnetic loss, whose magnetism was consist of many domains and different from conventional polycrystalline and amorphous materials. The domain wall was in the middle of each domain. Every grain of Nano-Fe₂O₃ was a single magnetic domain. The different magnetic structures make it have new magnetic properties. The Nano-Fe₂O₃ at room temperature has super paramagnetic. There are multiple absorption peaks in the Mossbauer spectrum, which was a kind of reflection on the macroscopic quantum tunneling effect. The difference of this magnetic structure affects the complex permeability of NF when the radar reflectivity was measured. Nano-Fe₂O₃ was used as additives in the experiment of radar reflectivity because of those losses of unique domain wall resonance and natural resonance in an alternative power plant.

Nano-Al₂O₃ particles can be explained in terms of electrical loss mechanism. Dielectric constant can be expressed in the plural.

$$\varepsilon^*(\omega) = \varepsilon'(\omega) - i\varepsilon''(\omega) \quad (1)$$

" ε' " said the real part and " ε'' " said the imaginary part, which respectively said dielectric constant and under electrostatic field and alternating electric field:

$$\tan \theta = \frac{\varepsilon''}{\varepsilon'} \quad (2)$$

This was the dielectric loss. The Phase-angle Difference existed between them, if the response of the electric displacement lagged behind the change of electric field. This was the dielectric loss. And the bigger the Phase-angle was, the more serious the loss was. The response of electric displacement was relative to polarization process. There were a large number of ionic bonds, approximately 63%, in the Nano-Al₂O₃ particles. So the arrangement of atoms in the huge interface was confusing in which Nano particles had many defects such as strong lattice distortion, vacancy and so on. And there are a large number of vacancies of oxygen irons in those Nano particles. The vacancy was equivalent to with positive charge. This kind of positive charge will form inherent electric distance with the negatively charged oxygen ions and turning-direction polarization in foreign electromagnetic field when the direction was changed. Turning-direction polarization was an important factor to Nano-Al₂O₃ with higher dielectric constant.

It can be inferred that the different electromagnetic parameters of different Nano concrete was due to these electromagnetic effects at the micro level and then the radar reflectivity had disparate impact. If the lattice structure and the molecular structure of Nano materials were further explored and to master the action parameters of different Nano materials to the radar wave, composite material can be used to improve and control the electromagnetic parameters. Radar stealth and electromagnetic shielding can be smoothly done or easily solved with the extension of the absorption bandwidth and absorption intensity to electromagnetic wave.

4 Conclusions

Polycarboxylate superplasticizer Liquor was be used as water reducer and the dispersant of Nano particle. Three kinds of Nano-concrete specimens were prepared by high-speed stirring and ultrasonic dispersion. And the static mechanical properties and the radar reflectivity were tested. The conclusion obtained was as follows:

(1) Nano- Al_2O_3 and Nano- Fe_2O_3 particles can significantly improve the compressive strength and flexural strength of concrete at 28 d. The c of NA increased by 44.4% compared with PC. The flexural strength of NF was 20.9% higher than that of PC. The effects of Nano- SiO_2 particles to improve compressive strength and flexural strength on the concrete was not obvious, even a certain weakening effect. The compressive strength and flexural strength of concrete in which Nano- SiO_2 and Nano- Fe_2O_3 particles were mixed was the same as that of NF.

(2) The effect of three kinds of Nano particles on the radar reflectivity of concrete was different. The reflectivity of NF was up to -8dB when wave frequency was in the range of 2GHz to 7GHz and the minimum value was -13.56dB when reflectivity was at 2.56GHz. The reflectivity of NA and NS was smaller in the range of 10GHz to 18GHz and below -8dB when wave frequency was above 14.2GHz. NSF in which Nano- SiO_2 and Nano- Fe_2O_3 were mixed had the advantages of NS and NF combined and the reflectivity of radar wave was all less than -8dB in the full range of frequency.

(3) It was very effective to reduce the radar reflectivity of the sample by adding Nano materials in a certain amount of content. The lowest frequency of NF's radar reflectivity was all near 2.56GHz when the content of Nano- Fe_2O_3 were namely 1%, 2% and 5% and the reflectivity were -11.2 dB, -13.6dB and -16.7dB respectively.

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