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Electromagnetic wave absorption properties of cement-based composites filled with graphene nano-platelets and hollow glass microspheres

Xingjun Lv [a,b,*], Yuping Duan [b,*], Guoqing Chen [b]

[a] School of Civil Engineering, Dalian University of Technology, Dalian 116085, PR China
[b] Key Laboratory of Solidification Control and Digital Preparation Technology (Liaoning Province), School of Materials Science and Engineering, Dalian University of Technology, Dalian 116085, PR China

HIGHLIGHTS

- Absorbing properties of cement composites were improved after doping GN and HGM.
- The composites include GN(0.2%) and HGM (40vol%) have the best absorbing properties.

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ABSTRACT

The cement-based composites made from graphene nano-platelets (GN) and hollow glass microspheres (HGM) were prepared and its electromagnetic waves absorbing properties were researched in this work. Results show that the absorbing properties were improved after the combination of GN and HGM. As the filling ratio of glass microspheres increases, the value of absorption peak and the bandwidth below −5 dB increases at first and decreases afterwards. In addition, several sharp peaks were obtained and the values tend to appear at high frequency. With further increase of GN, the value at absorbing peak decreases and the curves become relatively flatter. When GN is 0.2%, HGM is 40% (vol/vol) and the thickness is 20 mm, materials have the excellent absorbing properties with the average reflectivity loss being −8.2 dB in the range of 2–18 GHz and the bandwidth was 4.4 GHz below −5 dB. The thickness of sample has a significant influence on the absorbing properties. The optimal thickness is 20–30 mm with 40% (vol/vol) HGM and 0.2% (wt/vol) GN combine together.

1. Introduction

As the electromagnetic environment of urban space deteriorates, many measures have been taken to reduce potential hazards to human bodies and electronic equipments. Electromagnetic shielding is the most commonly used one among these. However, electromagnetic shielding cannot get at the root of electromagnetic interference (EMI) problems as the reflection caused by shielding materials is prone to cause secondary pollution. Therefore, taking measures from buildings to make them have the electromagnetic wave (EMW) absorbing functions has a very important practical significance. In the military dimension, the ground protection engineering under the information warfare conditions not only needs higher antiknock capability, but also needs stealth and electromagnetic immunity functions to improve their ability for resist detection and electromagnetic immunity.

Cement is one of the most widely used building materials. After tailoring, it can be rendered electromagnetic functions. However, the EMW absorbing properties of cement materials mainly come from the metal oxides in cement matrix; Moreover, the compact structure of the hydrated cement paste also hinders the incident electromagnetic wave transmission in the interior of the cement composite. This leads to a poor electromagnetic absorption properties of cement paste. To improve its EMW absorption, conductive or magnetic fillers must be introduced as functional inclusions to improve the electromagnetic properties of the cement pastes. Recently, researchers added porous aggregate, such as EPS [1–4], pumice [5], gelatin powder [8,9], fly ash [10] and glass [11] into cement matrix and found that porous aggregate and other wave-transparent particles with low dielectric constant can reduce the

* Corresponding authors at: School of Civil Engineering, Dalian University of Technology, Dalian 116085, PR China (X. Lv).
E-mail addresses: xingjun@dlut.edu.cn (X. Lv), duanyp@dlut.edu.cn (Y. Duan).

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effective dielectric constant of cement composite and thus reduce the reflection of electromagnetic wave on the surface. This will lead the incident electromagnetic wave into the materials and increase the valid transmission distance. The published reports all show that the introduction of porous particulates have ameliorated the EMW absorption performance of the cement pastes.

Hollow glass microspheres (HGM) are commonly used as a kind of filler due to its merits such as high temperature resistance, high corrosion resistance, light quality, high chemical resistance and excellent mechanical and physical properties [6,7,22]. Graphene, as a new type of carbon materials, has the two-dimensional structure made up of carbon atoms with hybrid sp^2 orbital. With its high specific area, high chemical stability and high conductivity, graphene has been acted as an ideal microwave absorbing material [12–21]. These research substantiate that GN could accelerate the cement hydration and enhance strength of cement-based composite materials. In this paper, a light cement matrix absorbing plates were prepared with graphene nano-platelets as the EMW absorbent and hollow glass microspheres as the filler. Both its absorbing properties and microstructures were investigated through theoretical research and experimental examination.

2. Experimentation

2.1. Materials

(1) Cement: ordinary Portland cement P.O42.5R, produced by Dalian Onoda Cement Co., LTD. Its chemical composition is shown in Table 1.
(2) HGM: Type T32, produced by Sino Steel Maanshan Mining Research Institute Co., LTD. Its particle size, true density and compressive strength are shown in Tables 2 and 3.
(3) Graphene nano-platelets (GN), produced by American Cheap Tubes Inc. through chemical vapor deposition method. Its average thickness, diameter and specific surface areas are about 8–10 nm, 2 μm and 600–750 m^2/g, respectively. Its morphology is shown in Fig. 1.

2.2. Preparation

2.2.1. Preparation of GN dispersed suspension

To improve the water solubility of GN and enable them to be dispersed better in water, the GNs was mixed with 300 ml deionized water, and then put in water bath of 30 °C with ultrasonic treatment for 30 min. Then the mixture was dealt with magnetic stirring for 30 min for later use.

Table 1
Chemical composition of the cement matrix.

Component	CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO	Na_2O
Content (wt%)	61.10	21.46	5.25	2.90	2.51	2.08	0.77

Table 2
Chemical composition of HGM.

Component	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	Others
HGM (wt%)	>8.0	>67.0	0.5–2.0	>0.15	>2.5	>14.0	2.0

Table 3
The physical properties of HGM.

Colour	Particle size (μm)	Density (g/cm^3)	Compressive strength (MPa)
White	10–90	0.32	12–15

2.2.2. Preparation of cement-based microwave absorbing composite

The GN and HGM were first mixed in a mixer-agitator with water cement ratio (w/c) of 0.4 and stirred for 1 min. Then the cement was added and stirred for another 4 min. The stirred cement composites were injected into a mould and scraped to make the surface flat. Then the mould was dismantled after they were maintained for 24 h. After moulding, the specimens were conserved in a concrete-curing room for 28 days and then used for electromagnetic and density testing. The size of mould used for absorbing performance test was 200 × 200 mm with a thickness of 10, 20 and 30 mm. Strength test size was 40 × 40 × 160 mm^3. The mix proportions of each sample are listed in Table 4.

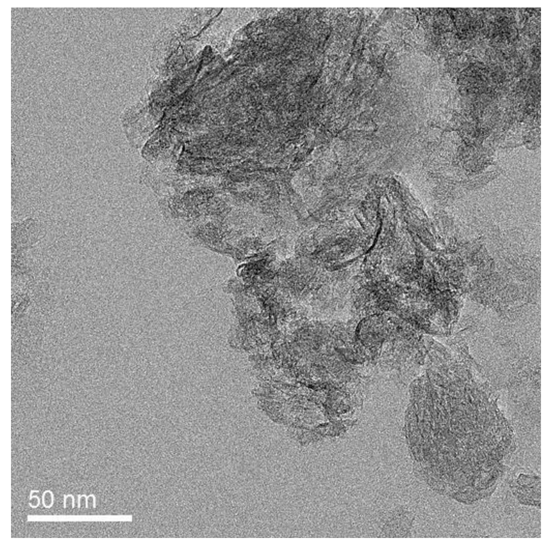

Fig. 1. TEM image of graphene nano-platelets (GNs).

Table 4
Mix proportion and bulk density of each sample.

Sample	HGM (vol%)	GN (wt%)	Thickness (mm)	Bulk density (g/cm^3)
1#	0	0	20 ± 0.1	1.75 ± 0.02
2#	40	0	20 ± 0.1	1.28 ± 0.02
3#	0	0.2	20 ± 0.1	1.70 ± 0.02
4#	20	0.2	20 ± 0.1	1.61 ± 0.02
5#	40	0.2	20 ± 0.1	1.26 ± 0.02
6#	60	0.2	20 ± 0.1	0.97 ± 0.02
7#	40	0.1	20 ± 0.1	1.26 ± 0.02
8#	40	0.3	20 ± 0.1	1.26 ± 0.02
9#	40	0.2	10 ± 0.1	1.26 ± 0.02
10#	40	0.2	30 ± 0.1	1.26 ± 0.02

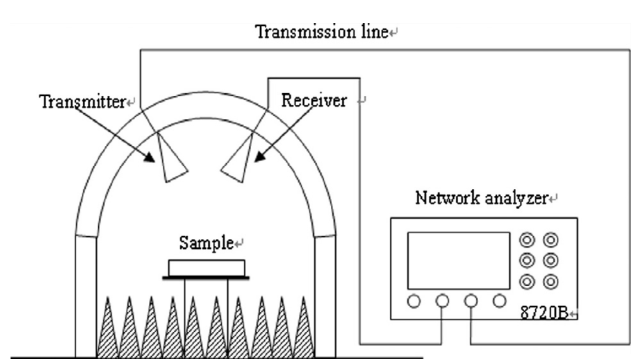

Fig. 2. Schematic of the experimental setup for arched testing in the anechoic chamber.