Composite Materials and Engineering, *Vol. 3, No. 2 (2021) 157-166*
DOI: https://doi.org/10.12989/cme.2021.3.2.157

Sandwich structured lightweight carbon black/cement composites for X-band electromagnetic wave absorption and thermal insulation

Shuai Xie*[1,2], Zhijiang Ji[1,2], Jinjun Zhang[1,2], Yanxin Cao[1,2] and Jing Wang[1,2]

[1]*China Building Materials Academy, Beijing, PR China*
[2]*State Key Laboratory of Green Building Materials, Beijing, PR China*

(Received October 9, 2019, Revised June 23, 2021, Accepted June 29, 2021)

Abstract. In order to develop a lightweight cement based composite with dual-function of EM wave absorption and thermal insulation, sandwich structure was designed to achieve excellent EM absorption capacity, and expanded perlite and carbon black were used as lightweight aggregates and EM absorbent, respectively. The EM absorption properties were studied by arching reflected method, and the results indicate that the sandwich structure design can obviously enhance the EM absorption capacity of cement composites. The sandwich structured composites exhibit better EM absorption properties than the traditional gradient multi-layer structured composites. The reflection loss of three-layer and four-layer sandwich structured composites can be less than -10 dB and -15 dB in the whole X-band. The thermal conductivity test results shows that the developed cement composites possess thermal insulation function.

Keywords: composite materials; layered structure; microwave absorption; sandwich structures; thermal conductivity

1. Introduction

Nowadays, electromagnetic (EM) pollution has been becoming an increasingly serious issue, which can do harm to human health, decrease sensitivity of precision equipment, and even cause information leakage (Gupta and Tai 2019). The application of EM absorbing materials is the most effective method to protect EM pollution, thus the development of EM absorbing materials with high performance has become more and more important and urgent.

Cement-based composite, which exhibits excellent mechanical properties and durability, is commonly used in civil fields and military fortifications. However, its EM absorption capacity is unsatisfactory. In general, introduction of dielectric or magnetic loss fillers is a feasible way to adjust the EM properties and enhance the EM absorption capacity of cement materials, and the most commonly used fillers include carbon black (Dai *et al*. 2010), carbon nano tube (Nam *et al*. 2018), helical carbon fiber (Xie *et al*. 2018), ferrites (He *et al*. 2018), industrial byproduct (Bantsis *et al*. 2012) etc.. But, ideal EM absorption cannot be obtained by adding fillers into cement merely, because of the impedance mismatch.

*Corresponding author, Ph.D., E-mail: xs5649@163.com

 ISSN: 2671-4930 (Print), 2671-5120 (Online)

of cement based composites filled with EPS", *Cement Concrete Comp*., **29**(1), 49-54. https://doi.org/10.1016/j.cemconcomp.2006.08.001.

Gupta, S. and Tai, N.H. (2019), "Carbon materials and their composites for electromagnetic interference shielding effectiveness in X-band", *Carbon*, **152**, 159-187. https://doi.org/10.1016/j.carbon.2019.06.002.

He, Y.J., Lu, L.N., Sun, K.K., Wang, F.Z. and Hu, S.G. (2018), "Electromagnetic wave absorbing cement-based composite using Nano-Fe3O4 magnetic fluid as absorber", *Cement Concrete Comp*., **92**, 1-6. https://doi.org/10.1016/j.cemconcomp.2018.05.004.

Kwak, J.G., Wang, S.J., Yoon, J.S., Lee, D.W., Bae, Y.D., Kim, S.K., Hwang, C.K. and Hong, B.G. (2007), "Enhancement of the rf characteristics of a soda dummy load by reduction of the skin depth effect", *Fusion. Eng. Des*., **82**(5-14), 941-944. https://doi.org/10.1016/j.fusengdes.2007.07.021.

Li, B.Y., Duan, Y.P., Zhang, Y.F. and Liu, S.H. (2011), "Electromagnetic wave absorption properties of cement-based composites filled with porous materials", *Mater. Des*., **32**(5), 3017-3020. https://10.12989/acc.2015.3.2.103 http://doi.org/10.1016/j.matdes.2010.12.017.

Lv, X.J., Cao, M.L., Li, Y., Li, X., Li, Q., Tang, R., Wang, Q. and Duan, Y.P. (2015), "A new absorbing foam concrete: preparation and microwave absorbing properties", *Adv. Concrete Constr*., **3**(2), 103-111. https://doi.org/10.12989/acc.2015.3.2.103.

Lv, X.J., Duan, Y.P. and Chen, G.Q. (2018), "Electromagnetic wave absorption properties of cement-based composites filled with graphene nano-platelets and hollow glass microspheres", *Constr. Build. Mater*., **162**, 280-285. https://doi.org/10.1016/j.conbuildmat.2017.12.047.

Nam, I.W., Choi, J.H., Kim, C.G. and Lee, H.K. (2018), "Fabrication and design of electromagnetic wave absorber composed of carbon nanotube-incorporated cement composites", *Compos. Struct*., **206**, 439-447. https://doi.org/10.1016/j.compstruct.2018.07.058.

Pei, Z., Su, D.L., Dai, F., Liao, Y. and Xu, Y.G. (2018), "Absorbing and shielding properties of a hybrid patterned composite containing CIPs and carbon fiber", *J. Electron. Mater*., **47**(11), 6591-6599. https://doi.org/10.1007/s11664-018-6579-9.

Ren, M.M., Li, F.X., Gao, P., Niu, Y.F., Wei, J.X. and Yu, Q.J. (2020), "Design and preparation of double-layer structured cement-based composite with inspiring microwave absorbing property", *Constr. Build. Mater*., **263**, 120670. https://doi.org/10.1016/j.conbuildmat.2020.120670.

Rusly, S.N.A., Matori, K.A., Ismail, I., Abbas, Z., Awang, Z., Zulkimi, M.M.M., Idris, F.M., Zaid, M.H.M. and Zulfikri, N.D. (2018), "Microwave absorption properties of single- and double-layer coatings based on strontium hexaferrite and graphite nanocomposite", *J. Mater. Sci. Mater. El*., **29**(16), 14031-14045. https://doi.org/10.1007/s10854-018-9535-9.

Xie, S., Ji, Z.J., Yang, Y., Hou, G.Y. and Wang, J. (2016), "Electromagnetic wave absorption enhancement of carbon black/gypsum based composites filled with expanded perlite", *Compos. Part B Eng*., **106**, 10-19. https://10.1016/j.compositesb.2016.09.014.

Xie, S., Ji, Z.J., Li, B., Zhu, L.C. and Wang, J. (2018), "Electromagnetic wave absorption properties of helical carbon fibers and expanded glass beads filled cement-based composites", *Compos. Part A Appl*. S., **114**, 360-367. https://10.1016/j.compositesa.2018.08.034.

Zhang, X.Z. and Sun, W. (2010), "Microwave absorbing properties of double-layer cementitious composites containing Mn-Zn ferrite", *Cement Concrete Comp*., **32**(9), 726-730. https://doi.org/10.1016/j.cemconcomp.2010.07.013.

Zhang, X.Z. and Sun, W. (2012), "Preparation and microwave absorbing properties of three-layered cement-based composites", *Procedia Eng*, **27**, 348-356. https://doi.org/10.1016/j.proeng.2011.12.462.

CC