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# Investigation of Electromagnetic Wave Absorber Based on Carbon Fiber Reinforced Aerated Concrete Using Time-Domain Method

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The electromagnetic wave absorbers prepared from autoclaved aerated concrete containing carbon fibers as additions in the shape of slabs with pyramids cut on one plane of these slabs were tested using dc microwave source and the time-domain method. It was demonstrated that autoclaved aerated concrete allows one to fabricate electromagnetic wave absorbers which have a reflection coefficient up to -30 dB in the frequency range from 2 GHz to 18 GHz.

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## 1. Introduction

The addition of carbon fibers to autoclaved aerated concrete (AAC) gives it a new property — the ability to absorb electromagnetic waves [1]. This additive also positively affects some other characteristics of AAC by increasing its mass plastic strength, the compression and flexural strength, as well as the durability of aerated concrete products [2]. The additive considered does not affect phase composition of calcium-silicates-hydrate, the coating of the fibers ensures firm bond to aerated concrete, thus increasing its strength and durability. In general, the effectiveness of AAC as electromagnetic waves absorber is tested using continuous waves of fixed frequency. In this paper we present the new results obtained using time domain method (TDM) when a wide-band pulse propagating in the free space impinges

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against AAC. Changing the density of the carbon fibres it is possible to tune the absorber characteristics, for this reason the AAC can be used as a model for study of various non-homogeneous environments, such as high resistivity semiconductors containing low resistance inclusions.

## 2. Experimental

The radio frequency absorbing material was made from quarry quartz sand, Portland cement of CEM I 42,5 R grade, calcite ground lime, Al powder as a pore former and carbon fibers. The mineralogical composition of the clinker was 63.63%, 10.55%, 6.47%, and 12.22% for  $3\text{CaO}\cdot\text{SiO}_2$ ,  $2\text{CaO}\cdot\text{SiO}_2$ ,  $3\text{CaO}\cdot\text{Al}_2\text{O}_3$ , and  $\text{Al}_2\text{O}_3\cdot\text{Fe}_2\text{O}_3$ , respectively. Carbon fibers of non-ideal cylindrical form having 10 cm length and 0.4–1  $\mu\text{m}$  cavities on the surface were used as inclusions for electromagnetic wave absorbing. The diameter of the fibers varied from 4.6 to 7.7  $\mu\text{m}$ , its tensile strength being 450 N/mm<sup>2</sup>.

Test samples were made in the shape of slabs [3], one side of which had mechanically cut out truncated pyramids. Two sizes of slabs, with dimensions  $440 \times 440 \times 80$  mm and  $440 \times 440 \times 140$  mm were produced. The base and height of the pyramids were 35 mm and 45 mm for the  $440 \times 440 \times 80$  mm dimension slab, respectively. The base of a single pyramid of this slab was 40 mm. The  $440 \times 440 \times 140$  mm dimension slab had pyramids with 60 mm base and 80 mm height. The base of a single pyramid in this case was 57 mm. The pyramids were cut in planes parallel to the base plane producing a  $10 \times 10$  mm area on the top of these pyramids.

In the TDM, the attenuation of the absorber was measured by using ps duration electrical pulses generated at a 100 kHz repetition rate. The frequency range of the measurement (0.85–18 GHz) was limited by the band width of the receiving antenna. The experimental setup used for these measurements operated in the following way. The electrical pulses, having amplitude 30 V and duration 30 ps, were generated by means of a short pulse generator containing a pulse-sharpening circuit based on a backward diode. The pulses were fed through a directional coupler to a transmitting antenna and input of the sampling head of the sampling converter. After reflection from the object under test, the transmitted pulse was recorded by a receiving antenna and transmitted to the input of the sampling head of the sampling converter. The spectrum of the pulse was calculated by using the Fourier transform. In order to obtain the reflection coefficient, the spectrum of the signal reflected from the investigated object and the spectrum of the signal reflected from the metallic plate with the same dimensions as the slab was used.

## 3. Results and discussion

Primarily the investigation of the slab's ability to absorb continuous electromagnetic irradiation was made. It was obtained that  $440 \times 440 \times 80$  mm slab

absorption of 0.8–10 cm waves is  $-20$  dB. However, in the 10–15 cm wavelength range, the absorption ability decreases up to  $-15$  dB. The  $440 \times 440 \times 140$  mm slab exhibited better absorption characteristics in the 0.8–15 cm wavelength range (not less than  $-20$  dB). Stronger absorption of 0.8–3 mm waves ( $-30$  dB) is a result of the thicker slab base (60 mm), while the increase in absorption of 3–15 cm wavelength waves is due to the increase in pyramid height.

The reflection coefficient ( $A$ ) of slabs having different shapes at one surface was investigated using TDM. Four types of slabs were investigated: slabs with large (80 mm height) pyramids, slabs with small (45 mm height) pyramids, uniform slabs and slabs having small ruffles on one surface. Figure 1a demonstrates that slabs

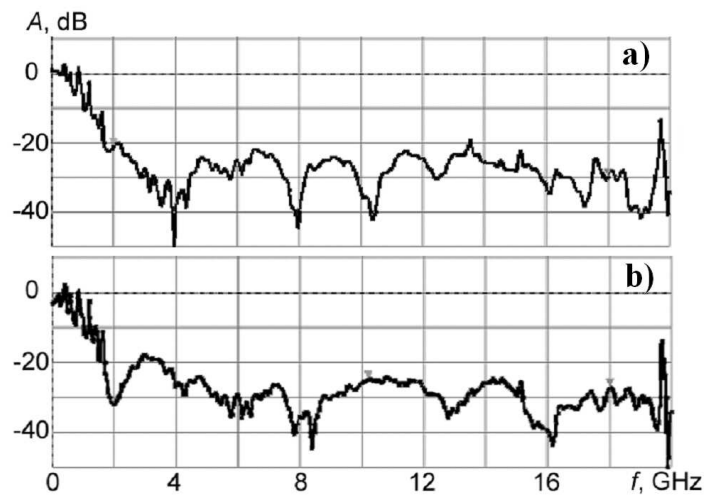


Fig. 1. Reflection coefficient vs. frequency: (a)  $440 \times 440 \times 140$  mm slab; 60 mm base and 80 mm height pyramids (large pyramids); (b)  $440 \times 440 \times 80$  mm slab; 35 mm base and 45 mm height pyramids (small pyramids).

with carbon fibres additions having large pyramids exhibit reflection coefficients ranging from  $-21$  dB to  $-30$  dB at frequencies ranging from 2 GHz to 18 GHz. Slabs with smaller pyramids, in this frequency range, showed smaller absorption. In this case, the reflection coefficient was  $-18$  dB and  $-27$  dB, respectively (Fig. 1b). The reflection coefficient of uniform slabs without carbon fibres inclusions (see Fig. 2a,b) was found to be much smaller,  $-11.15$  dB and  $-13.63$  dB for 2 GHz and 18 GHz, respectively. Small ruffles on one surface of the slab slightly increased the absorption up to  $-17$  dB. Ruffles also induced “waving” of the absorption coefficient vs. frequency dependence. This effect is the result of wave reflection from pyramids or ruffles and for this reason the “wavelength” and “amplitude” of the waving correlates with the dimensions and shape of these non-homogeneous slabs.

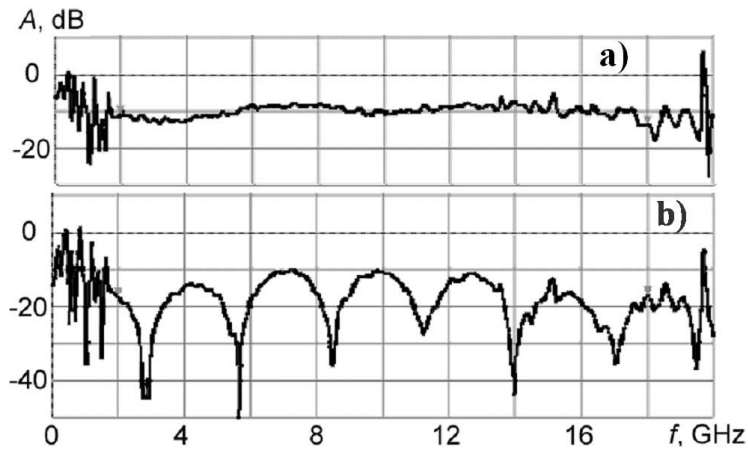


Fig. 2. Reflection coefficient of AAC without carbon fibres additions: (a) slab without ruffles, (b) slab with ruffles.

In conclusion, the ability of AAC to absorb electromagnetic wave in the frequency range from 2 GHz to 18 GHz strongly depends on the presence or absence of carbon fibres and the shaping of one surface of the slabs.

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