

Influence of cyclic freeze-thaw on the parameters of the electric response to the pulse mechanical excitation of concrete reinforced by glass fibre reinforced polymer bars

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Abstract. Studies of the influence of cyclic freeze-thaw on the parameters of electric response from samples of concrete reinforced by glass fibre reinforced polymer (GFRP) bars were conducted. It is found that an increase in the number of freeze-thaw cycles increases the attenuation coefficient of energy of electric responses and moves the centre of gravity of spectrum to the low-frequency area. The results can be used to develop a method of non-destructive testing of reinforced concrete.

1. Introduction

In the operation of structures of reinforced concrete in the natural conditions under the influence of seasonal temperature and humidity a gradual destruction is occurring. Concrete damage caused by freeze-thaw is a major problem in cold climates. Concrete reinforced by GFRP bars is increasingly used as an alternative to steel reinforced concrete structures.

Currently, there are not enough simple and reliable methods for determining damages in the construction of reinforced concrete. Therefore, it's necessary to develop methods of control to ensure the safe operation of engineering structures and buildings. Currently, acoustic methods [1-4] are mostly used to control defects in concrete. To solve this problem the non-destructive testing method, based on the phenomenon of mechanoelectric transformations under the pulsed mechanical excitation of heterogeneous non-metallic materials [5] may be used.

This paper is devoted to study changes in the parameters of the electric response of concrete reinforced by GFRP bars under conditions of cyclic freeze-thaw.

2. Experimental procedures

Experimental studies were carried out using the hardware and software complex which allows producing a single normalized by force impact on the object of study and recording the electrical response resulting from the impact.

Figure 1 shows a photo demonstrating the process of measurement of electrical response from the concrete sample.



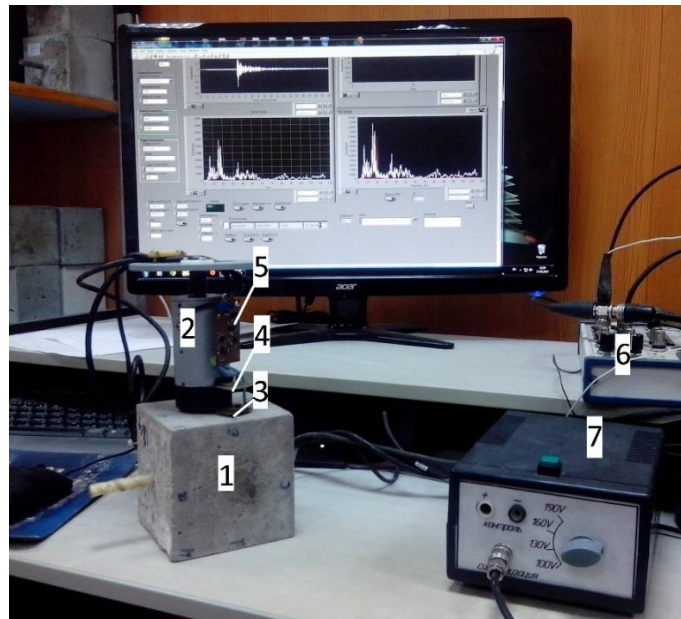


Figure 1. The measuring system photo: 1 – sample; 2 – electromechanical impact device; 3 – measuring receiver; 4 – compensating receiver; 5 – differential amplifier; 6 – NI board terminal block; 7 – power supply.

The technique of measurement of the electric response to mechanical excitation is described in more detail in [6].

For the processing of received data used the program Origin and special programs, developed in environment LabView.

3. Experimental procedures

For this research the laboratory models of concrete, reinforced by GFRP bars were made. The models were represented by the heavy concrete samples sized of 100x100x100 mm. One GFRP bar with diameter of 10 mm and length of 150 mm was placed in each sample during its forming.

Studies were conducted on the batch of models of reinforced concrete, consisting of 12 samples. Before performing the climatic test the samples were soaked in water. There were performed 8, 14 and 20 cycles of freeze-thaw. Freezing was carried out in a climatic chamber at a temperature of minus 400 °C, and thawing in a universal test chamber at a temperature of (20 ± 5) °C and 95% humidity. Three samples were not subjected to climatic test and stored in room conditions for a comparative analysis.

After the climatic tests, the electric response to impact excitation was measured. Figure 2 shows the electrical responses from the samples after different cycles of freeze-thaw.

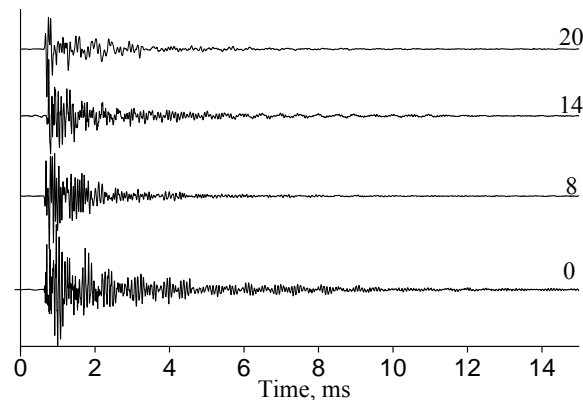


Figure 2. Typical electric responses from reinforced concrete samples that have passed different number of cycles of freeze-thaw (numerals indicate the number of cycles).

As shown in Figure 2 with increasing the number of cycles of freeze-thaw, a change of character of attenuation of electrical responses is observed. The attenuation coefficients of energy of the electric response from samples that have passed different number of cycles of freeze-thaw were calculated using the time-frequency analysis [7-8]. Figure 3 is a graph showing the variation of attenuation coefficient in the process of climatic tests.

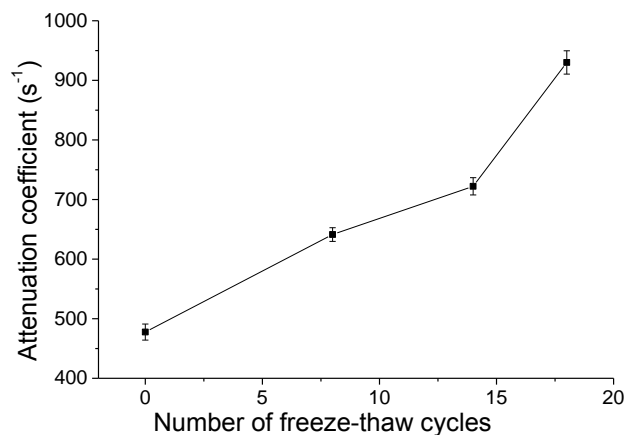


Figure 3. The dependence of the attenuation coefficient of energy of electric response on the number of cycles of freeze-thaw.

As seen in Figure 3 with an increase the number of cycles of freeze-thaw consistent increase in the attenuation coefficient of energy of electric response is observed. Figure 4 shows the spectra of the electric signals detected from the samples subjected to the climate testing.

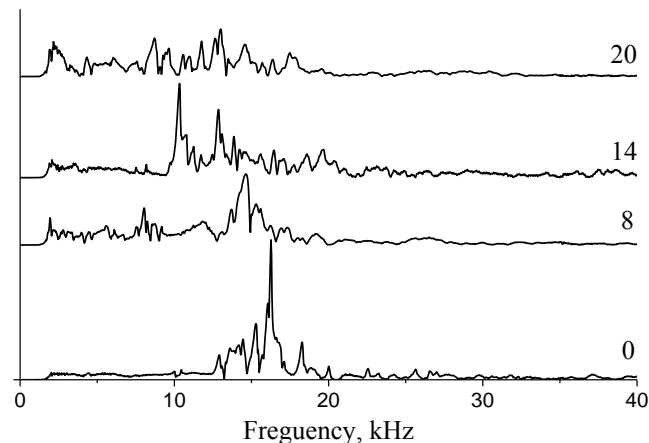


Figure 4. Typical frequency response of electrical responses from the samples of reinforced concrete, subjected to different number of cycles of freeze-thaw (numerals indicate the number of cycles).

As can be seen in figure with an increase the number of freeze-thaw cycles the spectral composition of electrical responses is changed and the spectrum is moved to the low-frequency region. Frequencies of the center of gravity of the spectrum after a different number of freeze-thaw cycles were determined using the special program developed in environment LabView.

Figure 5 is a graph showing the nature of the displacement of signal spectra from the reinforced concrete under cyclic freeze-thaw conditions.

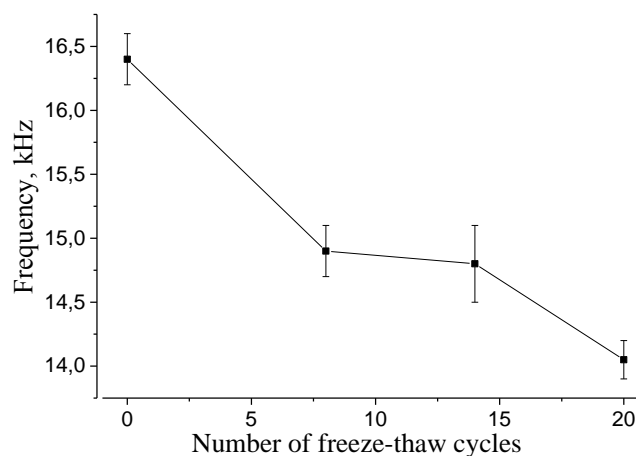


Figure 5. The dependence of frequency of center of gravity of the electric signals on the number of freeze-thaw cycles.

As shown in Figure 5 an increase the number of freeze-thaw cycles leads to moving of the center of gravity of the spectrum of electrical response to the low frequency region.

4. Conclusions

The purpose of the present work was to study the parameters of the electric response from concrete reinforced by GFRP bars under the cyclic freeze-thaw conditions. Visual observations showed that

appearance of surface cracks is not observed up to 20 cycles during the climatic test of reinforced concrete.

Absence of surface cracks indicates that the change in the characteristics of electric signals during the freeze-thaw is associated with the internal structural damages, including the contact failure of GFRP bar with concrete.

Studies have shown that in the process of increasing the number of freeze-thaw cycles the parameters of electric response are changed in time and frequency domain. It was found that with increasing number of freeze-thaw cycles an increase in the attenuation coefficient of energy of electric response and spectrum of signals moves to the low frequency region.

Therefore, the parameters of electrical response to impact excitation are sensitive to changes in the quality of the contact of the GFRP bar with concrete and it can be used for the development of nondestructive testing of reinforced materials.

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References

- [1] Aggelis D G, Mpalaskas A C and Matikas T E 2013 Investigation of different fracture modes in cement-based materials by acoustic emission *Cement and Concrete Research*. **48** 1–8
- [2] Liu Pei-Ling and Yeh Po-Liang 2011 Spectral tomography of concrete structures based on impact echo depth spectra *NDT & E International* **44** (Is. 8) 692–702
- [3] Antonaci P, Bruno C L E, Gliozzi A S and Scalerandi M 2010 Monitoring evolution of compressive damage in concrete with linear and nonlinear ultrasonic methods *Cem. Concr. Res.* **40** 1106–13
- [4] Bui D, Kodjo S A, Rivard P and Fournier B 2013 Evaluation of concrete distributed cracks by ultrasonic travel time shift under an external mechanical perturbation: study of indirect and semi-direct transmission configurations *J. Nondestruct. Eval.* **32** 25–36
- [5] Fursa T V, Surzhikov A P and Osipov K Yu 2007 Development of an acoustoelectric method for determining the porosity of dielectric materials *Russian Journal of Nondestructive Testing* **43** (No. 2) 95–9
- [6] Fursa T V, Osipov K Yu, Lyukshin B A and Utsyn G E 2014 The development of a method for crack-depth estimation in concrete by the electric response parameters to pulse mechanical excitation *Meas. Sci. Technol.* **25** 10
- [7] Quiviger A, Payan C, Chaix J F, Garnier V and Salin J 2012 Effect of the presence and size of a real macro-crack on diffuse ultrasound in concrete *NDT&E International* **45** 128–32
- [8] Osipov K Yu and Fursa T V 2013 Evaluating the depth of open cracks in concrete from parameters of electric response to elastic impact excitation *Technical Physics Letters* **39** 481–3