

Research of Electrical Response Communication Parameters on the Pulse Mechanical Impact with the Stress-Strain State of Concrete Under Uniaxial Compression

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Abstract. The article presents the results of research of the electrical response on elastic impact excitation of heavy concrete samples under uniaxial compression. In this paper we recorded and analyzed electrical responses during uniaxial compression of concrete samples with a constant velocity. Studies have shown that in the process of uniaxial compression of concrete samples, the transformation of amplitude-frequency characteristics of the electrical response is observed. The stage of elastic deformation of concrete samples is characterized by a centershift of gravity of the spectrum of the electrical response towards lower frequencies. Dramatic centershift of gravity of the spectrum of the electrical response to the high frequency region characterizes the beginning of fracturing.

1.Introduction

Concrete is commonly used in power constructions where it is exposed to high mechanical loads. In operation, the construction has to withstand operational loading without causing residual deformation and fracture. Therefore there is a need for concrete constructions monitoring during the operation in order to determine the stage of stress-strain state. For determining the onset of fracture processes in materials and products, methods based on recording and analysis of acoustic and electromagnetic emissions are being developed. Papers [1, 2] present the results of researches on the use of acoustic emission to determine the start time of cracks formation in concrete. Also researches of electromagnetic emission in the process of cracks germination in various materials such as rocks [3-8], cement mortar [9-10], ice [11] and etc. are being conducted. The main drawback of emission methods lies in the fact that they can only be used for continuous monitoring of constructions during their operation. A possible solution to the problem of determining the technical state of the construction is the use of the method based on the phenomenon of mechanolectrical transformations in low impact action [12]. In this case there is no need for continuous monitoring; control can be carried out periodically.

The purpose of this work is to find informative evaluation criteria for the stress-strain state of concrete by the parameters of the electrical response to elastic impact excitation.

2.Experimental techniques

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The essence of the phenomenon of alternating electromagnetic fields generating in concretes under the shock excitation pulse is that the impact of acoustic waves on the sources of mechano-electrical transformations leads to the formation of an alternating electric field. Acoustic waves are generated in the sample of finite dimensions under its impact excitation. The electric field is generated due to the charges on the faces of piezoelectric quartz contained in fine and coarse aggregate (bank sand and gravel), under its deformation due to these charges displacement and charges of electrical double layers located at the boundaries of cement matrix and inert aggregate with respect to the electrical receiver. Electrical measuring receiver is located in the immediate vicinity of a sample and in the coverage of this field. Therefore, the parameters of the electrical response are determined by elastic characteristics of the research object and securely reflect interprocesses of acoustic waves with internal structural inhomogeneous defects.

The researches were performed using the laboratory complex allowing to produce pulsed mechanical excitation of materials and register the electrical signal.

Figure 1 shows a photograph of a portable laboratory hardware-software complex which consists of an external measure probe, portable power supply, input-output board and a laptop computer.

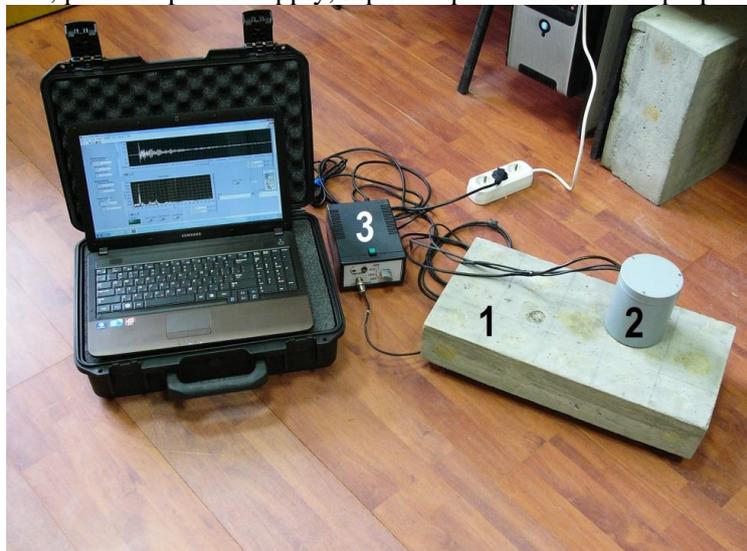


Figure 1. Laboratory complex: 1 – sample, 2 – external measure probe, 3 – portable power supply.

External measure probe is a metal cup; an impact device is located inside the cup allowing to make a single impact and a differential electrical sensor. The methodology of measuring the electrical response to impact excitation is described in further detail here [12].

Loading on the compression of samples was performed using a computerized press SP-500 with a constant rate of 0.2 kN/s. In the process of loading, the registration load and discrete displacement equal to 1s was made with the help of a special program.

The measurements were performed in the following way. Measure probe with the help of rubber bands was attached to a side surface of the sample. Then the concrete sample with the probe was mounted on the bottom plate of the press, loading was done until damage. External measure probe is equipped with long wires that allowed the probe to be laid inside the press, and the power supply and the laptop computer were placed at a considerable distance from the press. Impact excitation and recording of electrical responses were performed every 10 kN.

3. Experimental results and their considerations

The measurements of electrical response to impact excitation from the samples of heavy concrete with the size of 100x100x100 mm³ were made. For this research the samples of heavy concrete were made. Ratio of cement, sand and coarse aggregate was 1:2:4. Water-cement ratio was 0.35. We used two

types of samples. After the process of hardening one part of the samples was polished on the grinding machine for the removal of weak surface layer. The second part of the samples was not subjected to any treatment.

A typical load curve of concrete which was not subjected to grinding is shown in Figure 2.

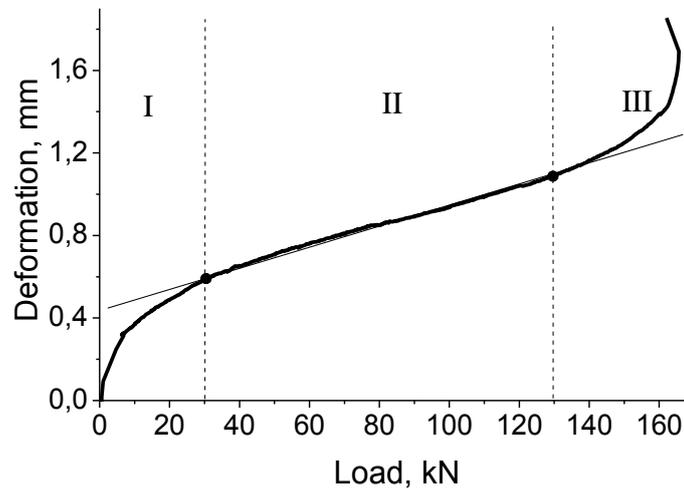


Figure 2. Dependence of concrete deformation on the magnitude of external mechanical load.

As shown in Figure 2 the strain dependence for concrete at a constant rate of loading is characterized by three stages.

The presence of the first nonlinear plot (I) occurs due to the surface compression of the sample which has a lower hardness and was not specially polished before testing. Then the plot (II) of linear anelastic deformation comes. Plot (III) is characterized by sharply nonlinear deformation associated with the process of crack initiation and penetration.

Figure 3 shows the amplitude-frequency characteristics of electrical responses to the impact excitation of the concrete sample during uniaxial compression.

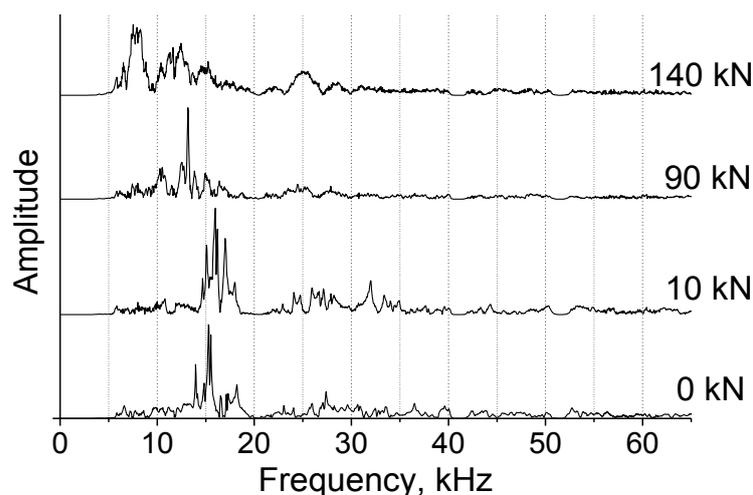


Figure 3. Change of the amplitude-frequency characteristics of the electrical response depending on the magnitude of the external load.

As shown in Figure 3 the bulk of high-amplitude spectral components for the unloaded sample is concentrated in the frequency range from 13 to 18 kHz. The dominant peak is at 15.8 KHz frequency. In the early stage, corresponding to the sealing area of the sample's surface layer, a slight shift of the dominant peak to the high frequency region and occurrence of significant peaks in the frequency range from 23 to 35 kHz appear. These changes of spectral distribution may be a consequence of surface disfunction in setting the shape of sample. Previously, it was shown on laboratory models of concrete that a change in artificial surface cracks concentration leads to the shift of electrical signal spectrum to the high frequency domain [13]. This shift may be due to the processes of reflection of acoustic wave excitation from surface cracks. With further loading (section II), there appears a successive shift of the dominant peak and the entire spectrum in the low frequency region. During intense fracturing at the late stage of loading (section III) the formation and development of deep cracks occur. Appearance and increase of low-frequency spectral components of the electrical signal may be due to rounding processes of deep cracks by acoustic waves. Spectrum shift of the electrical response in the low frequency region was observed earlier in the process of cracking caused by cyclic freezing and thawing of concrete [14]. As a criterion of changes of the spectral distribution of electrical responses occurring during loading, it is possible to suggest the use of the centershift of gravity of the spectrum. Using special software program in LabVIEW programming environment, frequencies of center of gravity of the spectrum at different stages of deformation were identified. The analyzed signal spectrum is sent to the entry point. In signal spectrum using cursors, we choose the desired frequency band for the analysis. The program consistently calculates the integral of two parts of specified spectrum region and determines the frequency at which they are equal; this frequency is the center of gravity of the defined spectrum. Figure 4 shows the dependency graph connecting the center of gravity of the spectrum of electrical response to the magnitude of an external mechanical load for a normal sample of concrete.

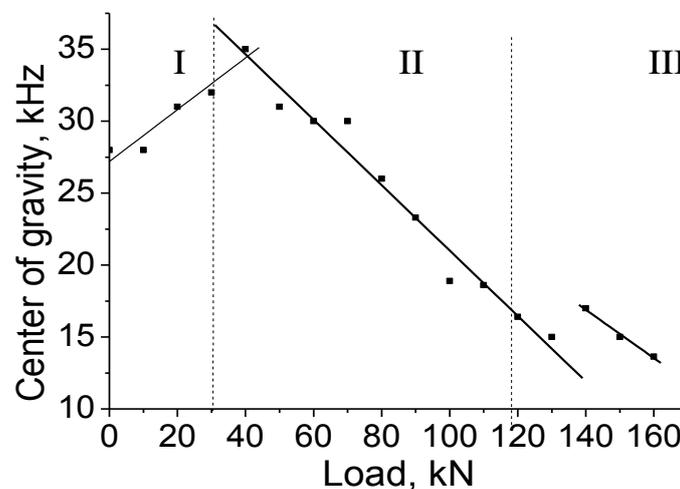


Figure 4. Changing the center of gravity of the spectra of the electric signals from concrete depending on the value of the external load.

As can be seen in figure 4 the stage of surface layer sealing is characterized by a linear increase of the center of gravity of the spectrum; the area of elastic deformation is characterized by linear decrease. The initial section of the transition in the cracks area is characterized by an abrupt increase in frequencies of the center of gravity.

Similar studies were conducted on polished samples of concrete.

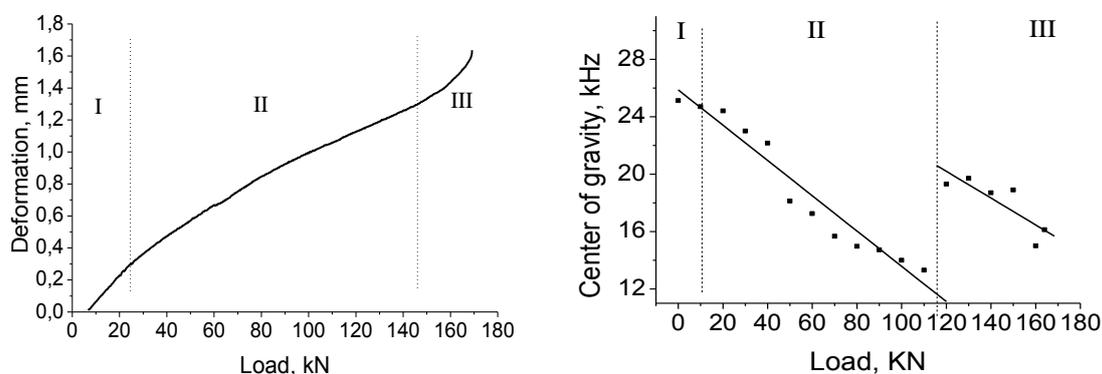


Figure 5. Typical distortion dependence (a) and the center of gravity of the spectrum of the electrical response (b) of the magnitude of an external mechanical load for the polished sample of concrete.

As shown in Figure 5a, the load curve for the polished sample has weakly expressed sealing area of the surface layer (I). As a result, there is no increase in frequencies of the center of gravity of the spectrum in this area (Figure 5b) compared with test results of the unpolished sample (Figure 4). Behaviour change of the center of gravity of the spectra in areas I and II for polished and unpolished samples has common patterns.

4. Conclusion

The purpose of the present research is to develop a non-destructive method for monitoring the stress-strain state of concrete products using the parameters of electrical response to elastic impact excitation.

The changing of the stress-strain state was carried out by uniaxial compression of concrete samples; the stages of the stress-strain state were defined on the basis of load registration and deformation. The process of uniaxial compression of concrete is characterized by three stages: the first – form installation, the second – quasi-elastic deformation and the third – fracturing.

It was established that the stage of form installation is characterized by electrical response of the spectrum shifting to higher frequencies. At the stage of quasi-elastic deformation there occurs a successive shift of the dominant peak and the entire spectrum to the low-frequency side. The initial stage of fracturing is characterized by the appearance of a significant proportion of high-frequency components in the spectrum of response.

Based on these studies it was suggested to use the center of gravity of the spectrum of the electrical response as a criterion for stages evaluating of the stress-strain state in concrete.

The work is done under the State task “Science”.

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