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Comparison of results of impedance spectroscopy methods with results of impact-echo method in investigation of high-temperature-degraded concrete

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Abstract

The growth in the transport industry results in more accidents, which often include fire in locations with the concrete structures, which also effects its lifetime and its functionality. After any case of fire loading it is required to verify structure's condition. One way how to assess the risks connected with further usage of the structures after being exposed to the fire is the non-destructive testing. This paper is dealing with non-destructive measurement of changes of electric parameters of the cement based mortars subjected to the high temperatures. Prismatic samples with dimensions of 40×40×160 mm were prepared from water, Portland cement CEM I 42.5 R and quartz sand (in a ratio 1:3), with water/cement ratio 0.46. Samples were intentionally degraded by high temperature in range of 200–1200 °C (200 °C step) and the changes in bulk density, flexural tensile strength and electric properties (loss factor tan δ (f), the imaginary component impedance ImZ (f) and the real part of component impedance ReZ (f) were monitored. Two methods were used for testing of electric properties – Impedance spectroscopy and Impact-echo method. The obtained results were compared and suitability of used methods was assessed.

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Keywords: Impact-echo method; cement-based composite material; high-temperature degradation; bulk density; flexural tensile strength; impedance spectroscopy; dielectric losses

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1. Introduction

The infrastructure is expanding very quickly in present time and therefore there is a big demand on building materials. The growth within the automobile industry results in more accidents, which often include fire in locations with the concrete structures, which also effects its lifetime and its functionality.

After any case of fire loading it is required to verify structure's condition. The aim of non-destructive testing is to predict lifetime of a structure and assessment of risks connected with its further usage. Great advantage of this method is that after testing the structure remains undamaged.

The impedance spectroscopy is a non-destructive testing method employing the impedance characteristic frequency dependence to analyse the properties of the cement and non-cement materials. The equipment set-up designed to study the system under investigation includes: a metal-material-metal composition, which is relevant for identifying the application limits of the impedance spectroscopy method. The method cannot be applied to thick-layer low-conductivity materials. Reinforced concrete products may serve as an example. The principle of the mentioned method is based on evaluation of the dielectric studying the dielectric losses versus frequency plots. The dielectric losses of composite materials and plastics can assume values which are many times higher than those of the most materials commonly used in the building industry [4].

Analysis of impedance spectra variances in the tan $\delta(f)$ and Im$Z(f)$ or Re$Z(f)$ of the inhomogeneous materials is a part of the impedance spectroscopy which is still waiting for its development. At present, one is not able to determine unambiguously the individual material component contributions to the total electric conductivity and polarization at various frequencies of the exciting field.

Impact-echo is a method for non-destructive evaluation of concrete structures. The principle of the method is based on analysing an elastic impulse-induced mechanical wave [12]. It is a technique for flaw detection in concrete. The method overcomes many of the barriers associated with flaw detection in concrete based on ultrasonic methods. A short-duration mechanical impact produced by tapping a small steel spherical body gives rise to a low-frequency stress waves that propagate into the structure and are reflected by flaws and external surfaces. A transducer records surface displacements caused by reflections of these waves. Classical impact-echo has receiver attached close to impact. Described method has transmitter in different positions. This signal describes transient local vibrations, which are caused by the mechanical wave multiple reflections inside the structure. The dominant frequencies of these vibrations give information about the condition of the structure or to determine the location of flaws, at which the waves are rebounded. As a rule, the signal is digitized by means of a data processing system to be transferred into a computer memory [12].

2. Material used

Mortar samples (of dimensions 40 mm × 40 mm × 160 mm) were produced using CEM I 42,5 R Portland cement (Ceskomoravský Cement-Heidelberg Cement Group), quartz sand from Filtrační písky, s.r.o. (in a ratio of 1 to 3) and water. (water/cement ratio 0.46). In compliance with CSN 721200 standard, the specimens were demolded after 24 hours, then cured in water for 27 days and finally air-cured for 31 days at laboratory temperature (25±2 °C) and relative humidity of 53±5 %. After initial curing; the specimens were dried at a temperature of 60 °C for two days. Subsequently, the specimens were subjected to gradual heating in a furnace at 200 °C, 400 °C, 600 °C, 800 °C, 1 000 °C and 1 200 °C. The temperature increase rate was 5 °C/min. A dwell of 60 minutes at each temperature was provided, in order to find out the effect of the temperature on the specimens. After heat treatment, the specimens were left to cool down spontaneously at laboratory conditions.

3. Experimental setup

At the Department of Physics, Faculty of Civil Engineering, TU Brno, the IS-based measurements have been implemented using following instrumentation: Agilent 33220A generator, Agilent 54645A double-channel oscilloscope, HP 82350 PCI HP-IB Interface card, and a PC. To operate the above mentioned instruments and to process the IS data acquired, a software called IS_alpha has been prepared by the first author of this paper. [2, 3]