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Impact-Echo Method Used to Testing of High Temperature Degraded Concrete Composite of Portland Cement CEM I 42.5 R and Gravel Aggregate 8/16

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Abstract. In this article, we showed possibility to use Impact-echo acoustic method to testing concrete degraded by high temperature. The results are compared with traditional parameter such as flexural bending strength. We observed longitudinal waves.

Introduction

The present paper examines the potential applicability of the Impact-echo method for analyzing the specimens made from a concrete composite material, which were intentionally degraded by high-temperature treatment to1200 °C.

Acoustic techniques are very often used to evaluate concrete [1, 2]. The impact-echo method is based on the application of a short-duration stress pulse on the concrete surface by a mechanical impact. Then follows analyzing an elastic-impulse-induced mechanical wave [3]. A short-time mechanical impulse, which is induced by a steel spherical body tapping the test specimen surface, gives rise to a low-frequency pressure wave. Thus generated wave propagates throughout the specimen structure being rebounded by defects located in the specimen bulk or in the surface. The time difference between the emitted wave and the rebounded one is captured by a sensor, which shows the signal waveform [4, 5]. This signal describes transient local vibrations, which are caused by the mechanical wave multiple reflection inside the structure.

The dominant frequencies of these vibrations give an account of the condition of the structure, at which the waves are rebounded [6]. As a rule, the signal is digitized by means of a data processing system to be transferred into a computer memory. The signal is further processed to gibe rise, for example, to a frequency spectrum. Peaks in this spectrum represent resonance frequencies in the curve and can be used for assessing the condition of the structure under investigation.

The Specimens

For our research we have prepared concrete samples with dimensions of 0.1 m x 0.1 m x 0.4 m. Specimens type A were prepared according to the following mix design (for 1m3): 345 kg Portland cement CEM I 42.5 R Mokrá, 848 kg quartz sand 0/4 mm Zabcice, 980 kg gravel aggregate 8/16 Olbramovice, 2.8 kg super-plasticizer Sika Viscocrete 2030 and 160 kg water. Consistency F4 (Flow, 550 mm). Samples were compacted in form for 10 second on a vibrating table a frequency of 30 Hz. The specimens were manufactured by prof. Hela in Institute of Technology of Building Materials and Components. The specimens were 28 days soaked in water and then dried at first in the laboratory temperature and then 48 hours in a ceramic furnace at temperature 110 °C. The concrete specimens were heated in programmable laboratory furnace Rhode KE 130B at the heating rate of 5 °C/min (Fig. 1). Selected temperature T= 200 °C, 400 °C, 600 °C, 800 °C, 1000 °C and 1200 °C were maintained for 60 minutes.

Experiment

To generate the signal, a hammer of a mass of 70.5 g, originally suspended from a hanger, was released to fall on the specimen from a height of 4 cm. The response was picked up by an S3 type piezoelectric sensor whose output voltage was fed into Yokogawa 1540-CL four-channel, digital, eight-bit oscilloscope (Fig. 2). Being processed and displayed by the oscilloscope, the signal was evaluated by means of AE-proc package [7].

Fig. 1 Programmable furnace Rhode KE 130B.

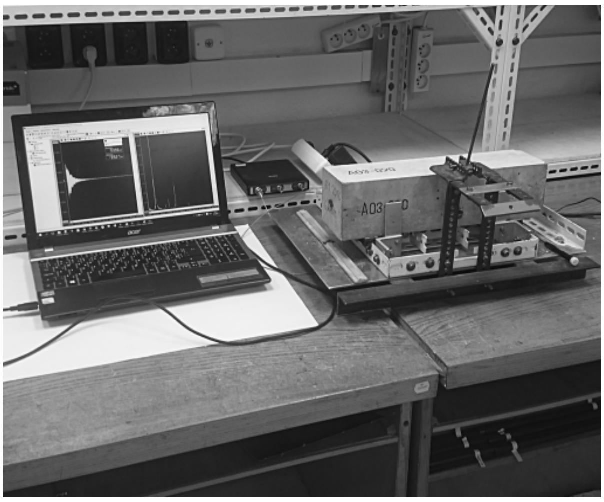

Fig. 2 The arrangement of experiment.

Measurements Results

Fig. 3 shows a record of the frequency spectrum measurement taken for a specimen by temperature of 20 °C (this specimen has not been subjected to any elevated-temperature load test). The sensor was placed at the center of the specimen shorter side. The hammer tapped the specimen at the opposite side in the longitudinal center line direction. The measurement run was labelled UB0. We measured the longitudinal waves. We observed dominant frequency f = 5220 Hz. Considering the length of sample, we get the wave propagation velocity to equal 4176 ms^{-1}.

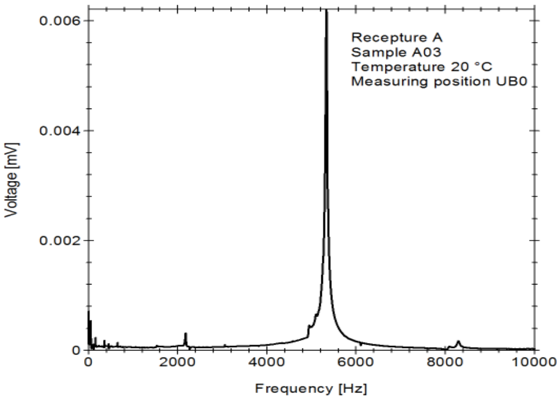

Fig. 3 Frequency spectrum of Sample A03, temperature 20 ºC.

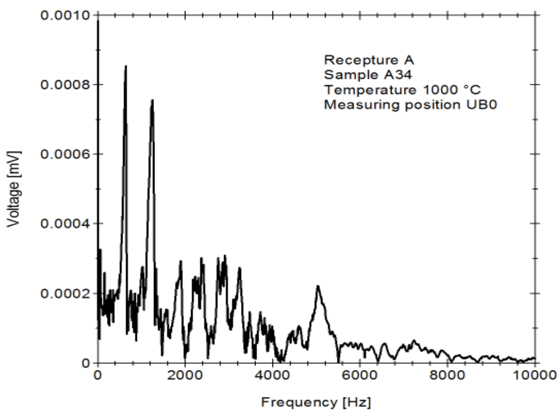

Fig. 4 Frequency spectrum of Sample A34, after degradation by temperature 1000 ºC.

Fig. 4 shows a frequency spectrum record for the specimen which underwent thermal stressing at a temperature of 1000 °C. It is seen that the predominant frequencies shifted down towards the lower frequency region, namely, to f = 890 Hz.

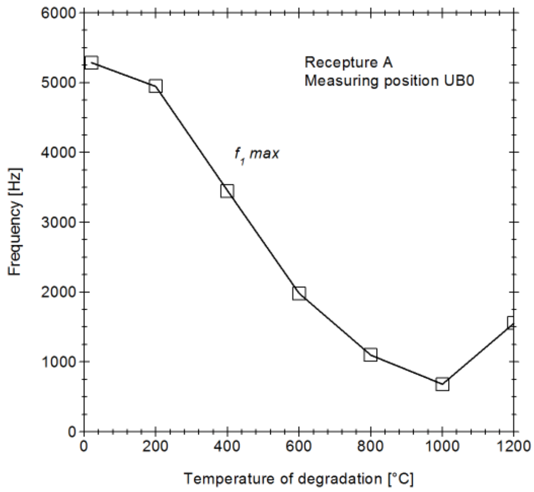

Fig. 5 Shift of dominant frequencies due to degradation by high temperature.

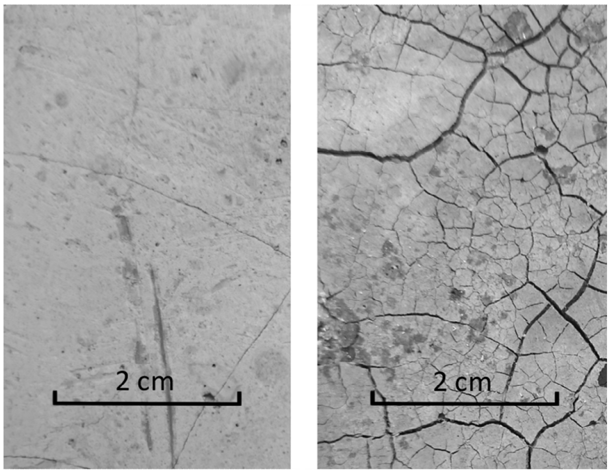

Fig. 6 Specimen surface before and after temperature degradation at 1200 ºC (on the right).

Fig. 5 illustrates the change in predominant frequencies versus the specimen stressing temperatures. Dominant frequencies are shifting towards to the lower frequency range during the degradation. The decrease is rather slow at temperatures of up to 600 °C, to speed up above this temperature. This is due to the phase transformation of quartz at 573 °C. The predominant frequencies are growing up at temperatures above 1000 °C. This is due to the specimen structural changes, because new crystalline phases are arising.

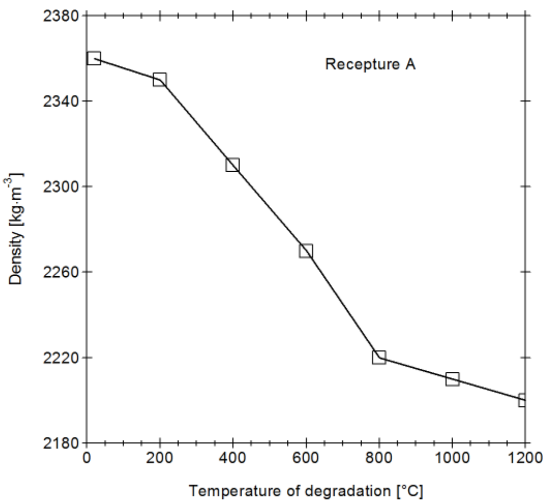

Fig. 7 The effect of a temperature on density of hardened concrete.

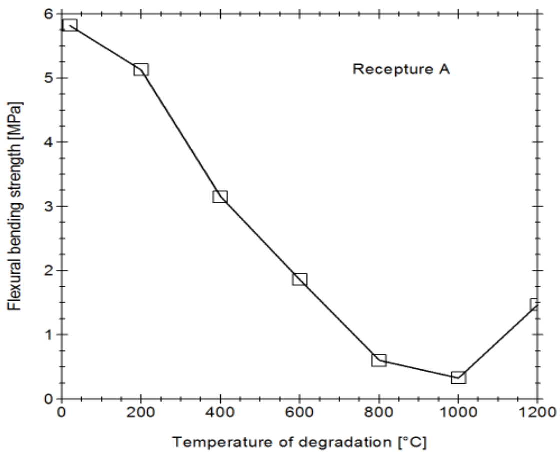

Fig. 8 The effect of a temperature on flexural bending strength.

Concrete is a composite material. The main parts represent aggregates and cement matrix. An increasing temperature influences both the aggregate and the cement matrix. During heating the aggregates expand in volume, while the cement matrix shrinkages. These facts lead to formation of micro-cracks in the transition zone aggregate-cement paste. During heating of cement paste physically and chemically bound water is released, and cement hydration products is dehydrated (decomposition C-S-H gel, and portlandite). These processes contribute to an increase of porosity in the cement matrix and result in decreasing the density of the concrete (see Fig. 7). Increasing porosity, cracks in transition zone aggregate –cement paste, and decomposition hydration products leads to decreasing the mechanical properties of concrete [8] (see Fig. 8). It should be noted that the concrete samples were dried before heating. Therefore, there was no apparent significant decrease of concrete density at 200 °C, and no spalling occurred during heating.

Conclusion

The paper deals with analyzing the feasibility of concrete composite material of Portland Cement CEM I 42.5 R and gravel aggregate 8/16 testing by means of Impact-echo acoustic method. The specimens were intentionally degraded by application of elevated temperatures to 1200 °C. A shift of the predominant frequencies was observed to occur during the degradation process.

Thus obtained results were compared with the changes in the bulk density and flexural bending strength of these specimens.

A strong correlation, which was disclosed between thus obtained results shows that the frequency inspection carried out by means of the Impact-echo method makes a convenient tool to assess the quality and life of these composite materials when exposed to elevated temperature.

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