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The Application Impact-Echo Method to Detect Corrosion of Steel Reinforcement Due to Carbonation of Concrete

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Abstract: The corrosion of steel elements in reinforced concrete structures has an influence on lifetime of structures and adversely affects their properties. The steel in concrete structures is protected against corrosion by properties of concrete such as high pH or impermeability, but if the concrete is of poor quality and his protective properties are insufficient, then the corrosion may occur. Problem is caused by action of carbon dioxide which has the effect of lowering the pH below the critical value and thereby accelerating the corrosion. This article reports the use of Impact-echo method as a tool for monitoring of influence carbonation concrete and corrosion of steel reinforcement. For research were used beams made of concrete with steel rod diameter of 10 mm. Non-destructive methods such as Impact-echo method offer the possibility of easy and quick detection of initial damage of structure and thus can prevent the occurrence of permanent damage to the whole construction.

Keywords: Impact-Echo Method; Non Destructive Acoustic Method; Carbonation Concrete; Corrosion; Steel Reinforcement.

1 Introduction

Steel reinforcement is protected against corrosion if the concrete is healthy and it has a high value of pH. However carbonated concrete has pH value below the critical value 9.6 and it results in corrosion of the reinforcement [1,2].

Non-destructive method such as Impact-echo is based on the acoustic properties of the material which are dependent on its condition [3–5]. It allows to study development of micro-defects in the structure of the material. This acoustic method allows to identify and to locate defects and thus is suitable for monitoring the building structure condition [6–8]. The early identification and localization of the defect the structural damage can be minimized and prevention is more efficient [9–11]. The signal analysis from the impact-echo method is the most frequent performed by frequency spectra obtained from the fast Fourier transform. The changes of dominant frequency are the main parameter to assess of the condition of structure and they are a tool to determine the degree of damage of the observed material structure [12]. Application of this method is wide, it can be used in mechanical engineering, power engineering and in many industries as well as in construction [13].

2 Experimental Setup

For research were used beams made from concrete mixture in composition 300 kg of cement CEM II/B – S 32.5 and 1350 kg of sand with fraction of aggregate 0 – 4 mm and 225 l of water. These beams of dimensions 50 × 50 × 340 mm were reinforced with one steel reinforcement diameter of 10 mm and length 400 mm passing through the center of the beam. After 28 days of concrete curing, these samples were exposed to 20 % carbon dioxide and then they were exposed to accelerated degradation by chlorides, when the specimens were immersed into a 5 % water solution of NaCl for 16 hours and then subsequently placed into a drying oven with temperature of air 40 °C, for 8 hours. The measurement was carried out before carbonation of concrete, after it, and then after every 20 cycles of accelerated degradation by chlorides. The measurements were made on two sets of sample. The first set of samples was only exposed to 20 % carbon dioxide and for the second set of samples was also exposed to 20 % carbon dioxide and then was carried out accelerated degradation by chlorides.

Impact-echo uses a short-time mechanical impulse (a hammer blow) which is applied to the one surface of the test sample and is detected by means of piezoelectric sensors placed on the opposite surface of sample. The impulse is reflected by the surface but also by micro-cracks and defects of the specimen under investigation. From shuch obtained signal is determined the frequency spectrum and is found the dominant resonance frequency by using Fourier transformation.

For inducing a mechanical impulse was used hanging hammer weighing 12 g and the hammer hit was carried out on the centre of longitudinal side of the concrete beam in the direction of the transverse axis. The signal response was taken by a piezoelectric sensor MIDI placed on surface concrete beam on the centre of longitudinal side and was fed to the input of an oscilloscope TiePie engineering Handyscope HS3 two-channel with resolution 16 bits. In Fig. 1 is shown used measuring equipment.

Fig. 1: Measuring equipment.

3 Result and Discussion

In Fig. 2 are frequency spectrums for the degraded sample No. 233 for the first measurement before degradation and for the last measurement after four sets cycles when each set is composed of 20 cycles of accelerated degradation by chlorides. From these graphs the significant change of the dominant frequency is evident. The dominant frequency which is at the position 6.18 kHz moved on the position 5.10 kHz which is a change about 1.08 kHz.

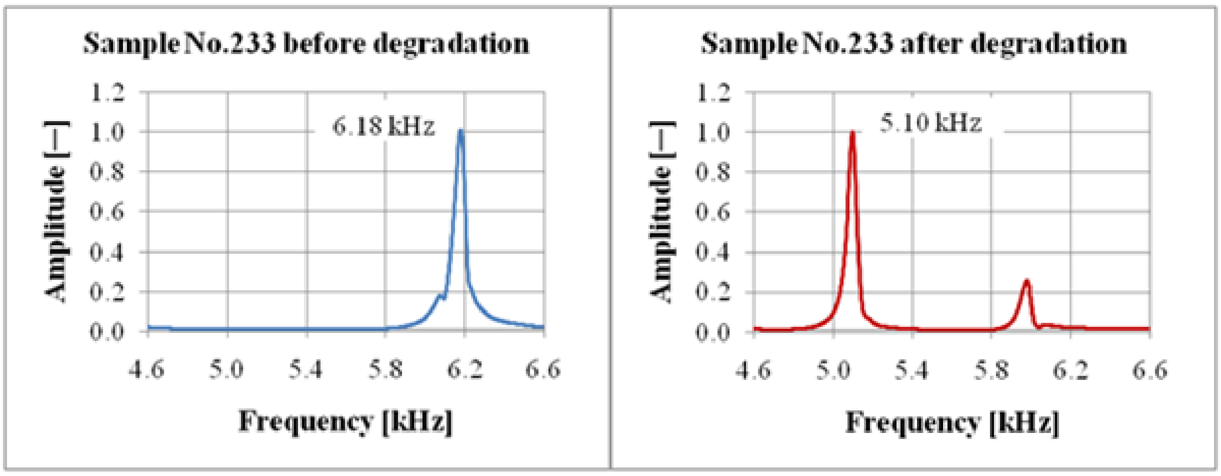

Fig. 2: The frequency spectrum for sample No. 233.

In Fig. 3 we can observe the modification of the dominant frequency. The hammer hit was applied to the one surface of the test sample on the centre of longitudinal side of the concrete beam in the direction of the transverse axis and the piezoelectric sensors was placed on the opposite surface of sample on the centre of longitudinal side.

In the first stage for the healthy samples 28 days old was found dominant frequencies around 6.10 kHz. Then all samples were exposed to 20 % carbon dioxide and the dominant frequency has fallen to a value of about 5.50 kHz. Selected samples were further exposed to accelerated degradation by chlorides. After first 20 cycles there was not a fundamental change of monitored frequency, but during the next measurement was recorded significant decrease of frequency to the value of about 4.90 kHz for degraded samples. There was a significant damage and the formation of microcracks. Non-degraded samples did not show major change. Other measurements did not show significant changes dominant frequency for all samples.

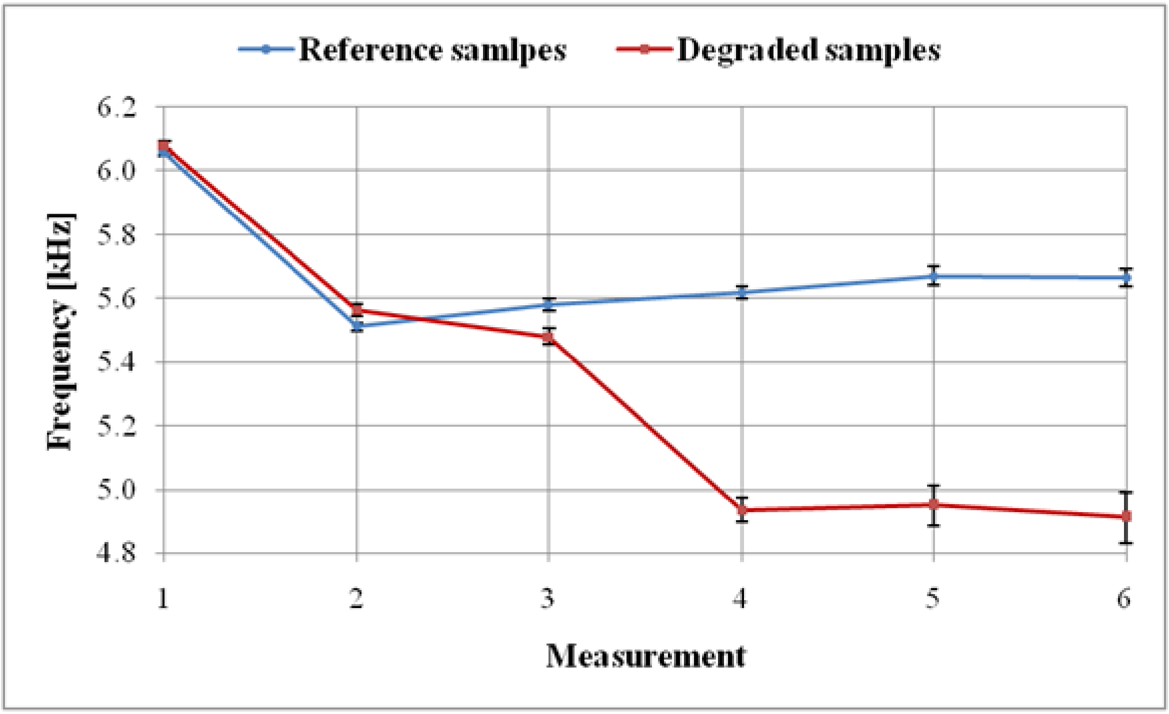

Fig. 3: Change of the dominant frequency during degradation.

The results from frequency analysis of acoustic response signals in Fig. 3 are displayed in the form of arithmetic average (obtained from 3 independent measurements for reference samples and from 6 measurements for degraded samples) and standard deviations as error bars.

4 Conclusion

In this paper we dealt with the study corrosion steel reinforcement and its influence on condition of concrete by using of monitoring changes in frequency spectrum during degradation process.

We used impact-echo and fast Fourier transform to obtain the dominant frequency from which we monitor these changes. Research used two sets of samples. The first set of samples was the reference and the second set was degraded by chlorides, when they were immersed into a 5 % water solution of NaCl.

The most significant change occurred after degradation by carbon dioxide and then between the third and fourth measurement, when creating cracks in structure of concrete due to expansion of the corrosion products which induce mechanical stress. The difference between reference samples and degraded samples by chlorides was 0.76 kHz

Based on the above results Impact-echo method can be evaluated as an effective tool based for assessment of quality of concrete and corrosion of reinforcing steel. The results show a significant decrease in dominant frequency which corresponds to the processes occurring during the degradation of reinforced concrete.

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