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PREDOMINANT FREQUENCIES OF REINFORCED CONCRETE ELEMENTS SUBJECTED TO THE IMPACT-ECHO METHOD TESTS

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Abstract: *The paper deals with studying predominant frequencies of the Impact-echo response from reinforced concrete beams. Predominant frequencies of the specimen response as determined by the Fast Fourier Transform (FFT) will be the main criterion for assessing the reinforced concrete armature corrosion.*

Key words*: predominant frequencies, acoustic emission, corrosion, reinforced concrete*

1. Introduction

The steel armature corrosion makes one of the most important problems related to the reinforced concrete structures. The steel armature condition affects, above all, the properties of horizontal structures. It is to be noted that the corrosion process itself may not be observable from the outside in many cases. This is why studies of non-destructive methods allowing the researchers to detect the degree of corrosion for the built-in armatures are being paid much attention currently.

The armature corrosion is particularly dangerous in the cases where the concrete cover layer is not disintegrated. This corrosion type is not due to the concrete being attacked by its environment, but, rather, to the concrete – in a modified chemical form – having attacked the steel armature. Whereas the strength of concrete increases in time, its ability to protect the armature, based on a process called the concrete passivation, decreases in time. The reduction of the concrete protecting capacity is connected with the natural carbonation of insufficiently dense concrete, in consequence of atmospheric carbon dioxide absorption. Featuring the capacity to increase the concrete strength and corrosion resistance, the carbonation bereaves – at the same time – the concrete of its capacity to protect the steel armature.

The acoustic emission method, providing for a continuous internal structure damage evolution and degree detection, appears to be a convenient method to monitor the internal building structure condition.

2. Principle of the Impact-echo method

The principle of the method consists in the following: A short-time mechanical impulse (a hammer blow) is applied to the specimen under test, the response being detected by means of piezoelectric sensors placed on the specimen surface Thus generated impulse is reflected by the surface but also by micro-cracks and defects being present in the specimen under investigation. The resulting resonance frequency is determined by means of frequency analysis. Significant frequencies of the response spectrum can be determined by means of Fourier transform.

3. Objective of the study

The present research aimed at studying the response signal predominant frequencies which were expected to serve as a tool to detect the reinforced concrete steel armature corrosion. The experiments focused on the effect of the hammer blow application point position, the sensor position and, last but not least, the experiment result stability.
Four configurations have been tested:
- the sensor at the beam centre, the blow at the armature end
- the sensor at the armature end, the blow at the armature end
- the sensor at the beam centre, the blow at the opposite beam centre
- the sensor at the armature end, the blow at the beam centre

4. Measuring procedure

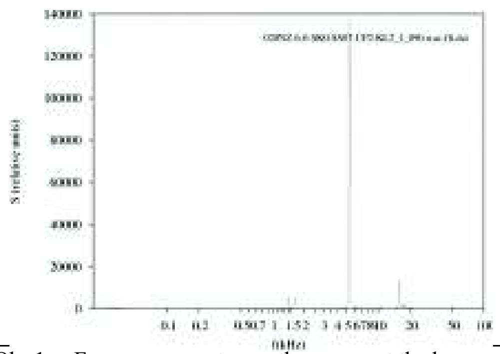
Reinforced concrete beams of dimensions 50 x 50 x 360 mm with centrally embedded 8 mm steel armature have been studied. To generate the exciting impulse, a steel hammer hit the specimen surface. An S3 piezoelectric sensor was used to pick up the response, the respective impulses being fed into the input of a Yokogawa 1540-CL four-channel, eight-bit digital oscilloscope. Having been recorded by the oscilloscope, the response impulses were subsequently analyzed by means of an SW package called AE-proc. A special smoothing algorithm was subsequently applied to determine 5 predominant frequencies from each output signal. Ten measurement series have been processed in one run.

5. Measurement results

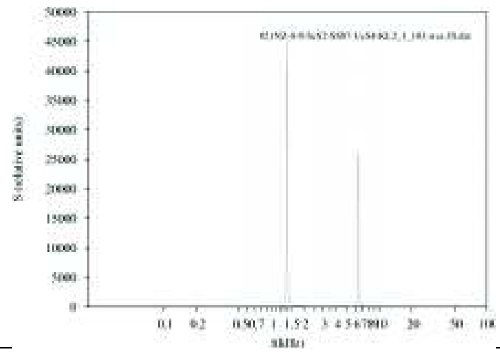
Fig. 1 shows a frequency spectrum record for the sensor at the beam centre and the blow at the armature end. A 10 measurement record is presented in Table 1. The mean predominant frequency is 5250 Hz. For the armature length in the reinforced concrete specimen, the corresponding wave propagation speed should be 4200 ms^{-1}. Longitudinal waves propagate in the rod at a speed of about 5100 $m\ s^{-1}$ to continue propagating through the beam towards the sensor.

The spectrum shown in Fig. 2 corresponds the sensor being placed at the beam centre and the blow being applied at the centre of the beam opposite face. Two kinds of waves are generated here: travelling waves in the beam which pass over into the armature, and transversal oscillations of the steel armature,

The latter in turn influence the concrete beam oscillations. Surface Rayleigh waves are likely to propagate along the beam surface. The frequency spectrum, as observed in this case, is the result of a superposition of the two mentioned waves. Two predominant frequencies, namely, 1339 Hz and 6691 Hz, have been observed.



Obr.1 Frequency spectrum: the sensor at the beam centre, the blow at the armature end



Obr.2 Frequency spectrum: the sensor at the beam centre, the blow at the beam opposite face

Tab.1 Predominant frequencies: The sensor at the beam centre, the blow at the armature end (frequencies in Hz)

Configuration type and No.	f1(Hz)
001NZ-8-1-ScS2-SS07-UP0-KL2_4_008.wav	5249
001NZ-8-1-ScS2-SS07-UP0-KL2_4_003.wav	5255
001NZ-8-1-ScS2-SS07-UP0-KL2_4_005.wav	5249
001NZ-8-1-ScS2-SS07-UP0-KL2_4_007.wav	5247
001NZ-8-1-ScS2-SS07-UP0-KL2_4_010.wav	5253
001NZ-8-1-ScS2-SS07-UP0-KL2_4_002.wav	5245
001NZ-8-1-ScS2-SS07-UP0-KL2_4_006.wav	5247
001NZ-8-1-ScS2-SS07-UP0-KL2_4_004.wav	5251
001NZ-8-1-ScS2-SS07-UP0-KL2_4_009.wav	5251
001NZ-8-1-ScS2-SS07-UP0-KL2_4_001.wav	5249
Predominant frequency mean value	5250

Tab.2 Predominant frequencies: The sensor at the beam centre, the blow at the centre of the beam opposite face (Hz)

Configuration type and No.	f1(Hz)	f5(Hz)
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_005.wav	1339	6698
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_004.wav	1339	6700
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_009.wav	1339	6700
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_008.wav	1339	6696
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_006.wav	1339	6696
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_007.wav	1339	6698
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_003.wav	1339	6700
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_001.wav	1339	6624
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_002.wav	1339	6698
001NZ-8-1-ScS2-SS07-UcS4-KL2_4_010.wav	1337	6700
Predominant frequency mean value	1339	6691

Tab.3 Predominant frequencies: The sensor at the armature end, the blow at the armature end (Hz)

Configuration type and No.	f1(Hz)	f2(Hz)	f3(Hz)
001NZ-8-1-SK0-SS07-UP0-KL2_4_006.wav	3496	5364	6216
001NZ-8-1-SK0-SS07-UP0-KL2_4_010.wav	3492	5364	6233
001NZ-8-1-SK0-SS07-UP0-KL2_4_007.wav	3494	5364	6228
001NZ-8-1-SK0-SS07-UP0-KL2_4_004.wav	3502	5364	6291
001NZ-8-1-SK0-SS07-UP0-KL2_4_003.wav	3490	5360	6225
001NZ-8-1-SK0-SS07-UP0-KL2_4_002.wav	3488	5364	6208
001NZ-8-1-SK0-SS07-UP0-KL2_4_009.wav	3488	5366	6325
001NZ-8-1-SK0-SS07-UP0-KL2_4_005.wav	3500	5362	6248
001NZ-8-1-SK0-SS07-UP0-KL2_4_001.wav	3500	5364	6312
001NZ-8-1-SK0-SS07-UP0-KL2_4_008.wav	3489	5368	6278
Predominant frequency mean value	3494	5364	6256

Tab.4 Predominant frequencies: The sensor at the armature end, the blow at the beam centre

Configuration type and No.	f1(Hz)	f4(Hz)	f5(Hz)
001NZ-8-1-SK0-SS07-UcS4-KL2_4_003.wav	1363	2372	5488
001NZ-8-1-SK0-SS07-UcS4-KL2_4_009.wav	1363	2386	5486
001NZ-8-1-SK0-SS07-UcS4-KL2_4_005.wav	1363	2372	5422
001NZ-8-1-SK0-SS07-UcS4-KL2_4_002.wav	1361	2342	5436
001NZ-8-1-SK0-SS07-UcS4-KL2_4_008.wav	1363	2386	5486
001NZ-8-1-SK0-SS07-UcS4-KL2_4_010.wav	1363	2396	5444
001NZ-8-1-SK0-SS07-UcS4-KL2_4_007.wav	1363	2386	5512
001NZ-8-1-SK0-SS07-UcS4-KL2_4_001.wav	1363	2340	5488
001NZ-8-1-SK0-SS07-UcS4-KL2_4_006.wav	1363	2370	5490
001NZ-8-1-SK0-SS07-UcS4-KL2_4_004.wav	1363	2370	5490
Predominant frequency mean value	1363	2372	5472

6. Conclusion

It follows from the measurements having been carried out until now that several predominant frequencies arise in the specimens under test. The respective amplitudes of the mentioned signals may exceed each other in a different way in repeated measurements of the same specimen. This fact is to be taken into account when evaluating the predominant frequencies obtained from intact and corroded specimens.

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References

[1] Skala J., Chobola Z.: *Frekvency inspection as a tool to assess the armature corrosion.* Workshop NDT 2005 by Brno University of Technology 31. 11. 2005, 159-161, ISBN 80-7204-420-6.

[2] KOŘENSKÁ, M., CHOBOLA, Z., MIKULKOVÁ, P., MARTINEK, J., On the application of impact-echo method to assess the quality of ceramic roofing tiles. In: *Proceedings of IV. Conference MATBUD`2003*`, 2003, Krakow 2003, pp. - 239 – 244.