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DETECTION OF THE REINFORCEMENT CORROSION IN PRESTRESSED CONCRETE GIRDERS

M. Korenska[1], L. Pazdera[1], K. Pospisil[2], J. Stryk[2], P. Vyroubal[1]

[1]Brno University of Technology, Fac. of Civil Eng., Dept. of Physics
Zizkova 17, 602 00, Brno, CZ,
E-mails: korenska.m@fce.vutbr.cz, pazdera.l@fce.vutbr.cz, vyroubal.p@fce.vutbr.cz

[2]Transport Research Centre, Dept. of Infrastructure
Lisenska 33a, 636 00, Brno, CZ,
E-mails: pospisil@cdv.cz, stryk@cdv.cz

ABSTRACT

Prestressed reinforcement is a basic element of the structural stability in a great amount of concrete structures. The corrosion of reinforcement is a major cause of a failure of such structures. Therefore it is very important to find relatively inexpensive and adequately reliable non-destructive method that would be capable to determine prestressed reinforcement conditions. The paper deals with the usage of the acoustic emission method to testing of prestressed concrete girders from corrosive damage point of view. The results of testing and analyses show a correlation with corrosive damage of prestressed reinforcement.
The experimental test investigated acoustic emission method to evaluation of deterioration of prestressed reinforced concrete girders during flexural tests under loadings. The girders were deteriorated due to accelerated corrosion of prestressed reinforcement. The tests demonstrated that acoustic emission is very sensitive to detect the initiation of tensile microcracks, main tensile cracks and internal cracks generated near the interface between the prestressed reinforcement and concrete. They were revealed that the deteriorated girders exhibit different acoustic emission behaviour, depending on the different damage levels induced by the corrosion of the prestressed reinforcement. Acoustic emission parameters analysis showed that they are a very effective criterion to measure the severity of damage induced in the prestressed reinforced concrete girders.

***Keywords**:* Prestressed reinforcement, Corrosive damage, Acoustic emission.

1. Introduction

Based on a foreign literature search as well as our experience gained in the acoustic emission application to concrete specimens, we have extended the scope of our research to assess this method's potential of detecting the corrosion of reinforced structure steel reinforcement. The acoustic emission method was first applied in laboratory environment, where the comparison between the actually measured parameters and those obtained for reference specimens, and also with the actual condition of specimens loaded until destruction, could be carried out. The laboratory measurements have proved to constitute an important starting point for specifying the measurement method for real structures in situ.

2. Description of specimens

Pre-stressed railway sleepers, made by Železniční průmyslová stavební výroba Uherský Ostroh, a.s., were provided for testing. A total of 8 sleepers of B-91S type were manufactured. Out of this number, five contained a certain amount of corroded reinforcement bars. The remaining three ones, being intact, served as reference samples - reference standards. The B-91S type sleepers are 2.6 m long and are reinforced by ten reinforcement bars of a diameter of 6 mm, constituting the pre-stressing reinforcement. Prior to the tests, selected bars were exposed to 35 % hydrochloric acid attack for two months. The HCl wrapping envelopes were applied to one, two and four bars of the upper reinforcement and four bars of the bottom reinforcement. In this way, the corrosion process was accelerated and the bar cross-sectional area was thinned, locally by up to 1 millimetre. The corroded reinforcement layout in the different elements is shown in Fig. 1.

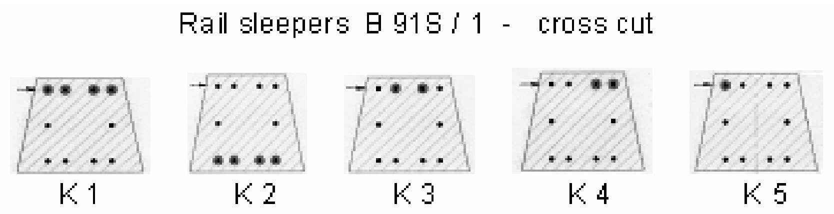

Fig. 1: Corroded reinforcement bar numbers and layout.

3. Experiment set-up

After a two-months period of ripening, the sleepers were loaded in a static load capacity measuring press (flexural tensile stress). All sensors were spaced on a straight line at the centre of the sleeper span. The straight line is indicated by an arrow in Fig. 1. The acoustic emission signals were recorded throughout the loading process, till the first visible crack appeared. Signal recording, processing and evaluation were carried out by LOCAN 320 acoustic emission analyser (four sensors), and Yokogawa DL1540CL oscilloscope (two sensors).

4. Measurement results

Sleepers labelled 3A, 1K, 3K, 5K have been selected for the measurement and comparison, the respective loading force growth rates as well as the maximum forces attained being comparable. Figures 2 to 5 show aggregate measurement results for all four channels of LOCAN 320 measuring system. The diagrams shown in Fig. 2 illustrate the overshoot counts versus time plots as measured on the sleepers during the load application. It is seen that the highest overshoot counts have been obtained when measuring the 1K sleeper, on the surface of which the sensors were placed closest to the corroded bars. The second-highest overshoot count was recorded when measuring the 5K sleeper. One corroded bar was situated in the same distance from the sensors. The next is the 3K sleeper, showing the internal reinforcement corrosion. The lowest overshoot count was recorded in the case of the 3A sleeper, whose reinforcement was intact by corrosion. The 1K and 5K couple sleepers, which only differ in the number of corroded bars, show a comparable exponential growth of the cumulative curves. In the case of the second sleeper couple, 3K - internal bar corrosion, and 3A – no reinforcement corrosion, the cumulative curves can be divided into three linear sections.

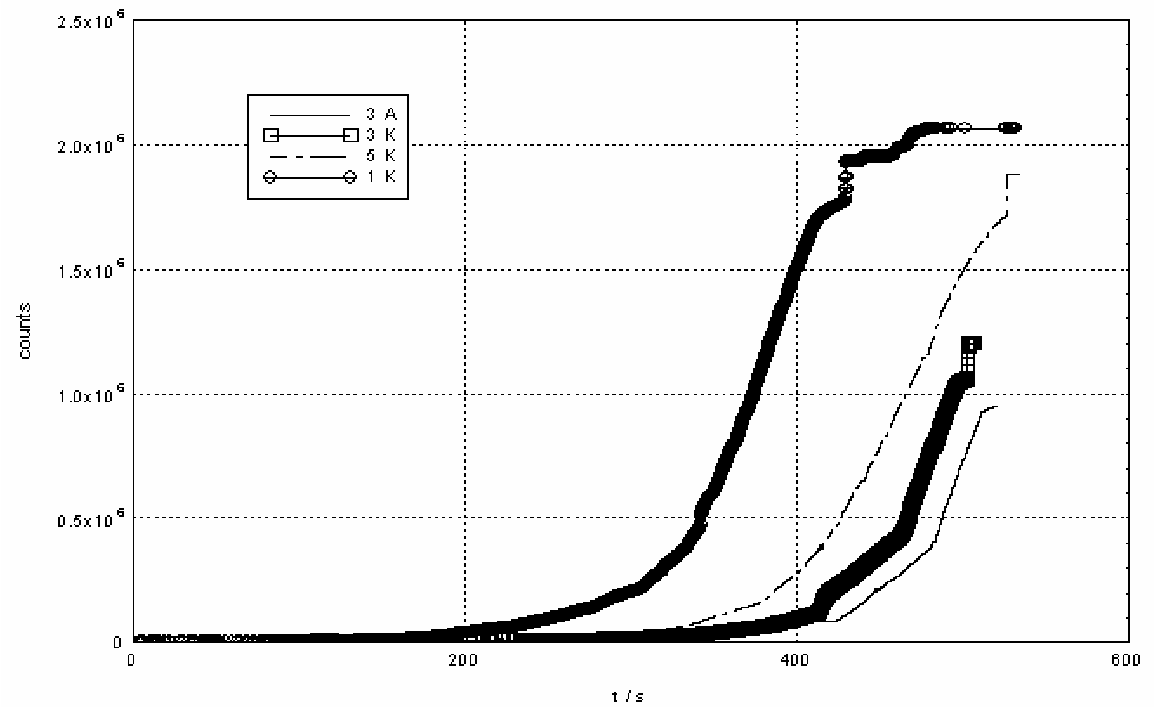

Fig. 2: Recorded overshoot count versus time plot.

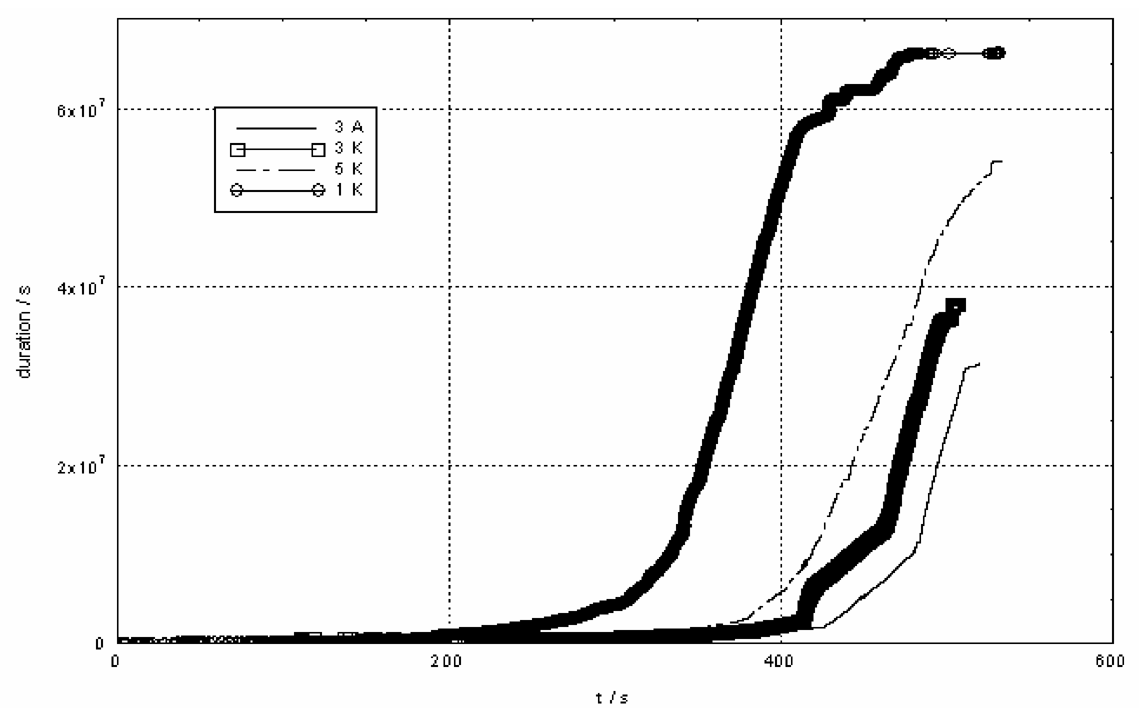

Fig. 3: Emission event duration versus time plots.

Similar results are shown in Fig. 3, where the duration of the various emission events is depicted. The next Figure 4 compares the recorded signal amplitudes. In this case a smooth exponential growth of the cumulative curves is shown by all three sleepers (1K, 5K, 3K), containing corroded reinforcement bars. The reinforcement corrosion-intact 3A sleeper's cumulative curve may be characterized by three linear sections.

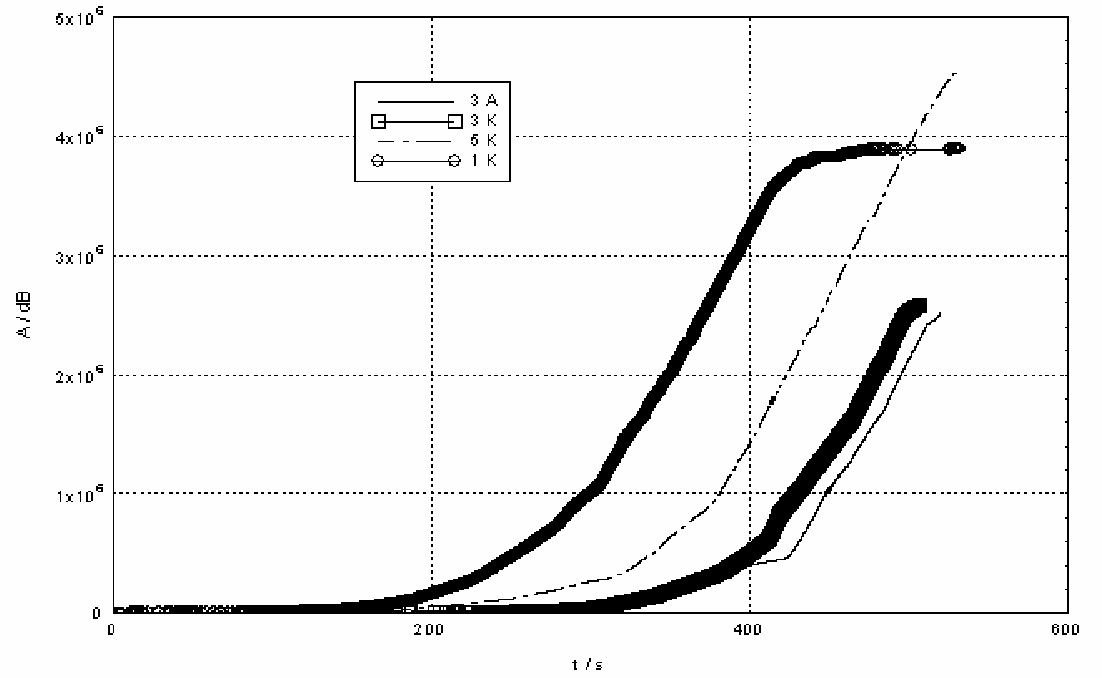

Fig. 4: Amplitude versus time plots.

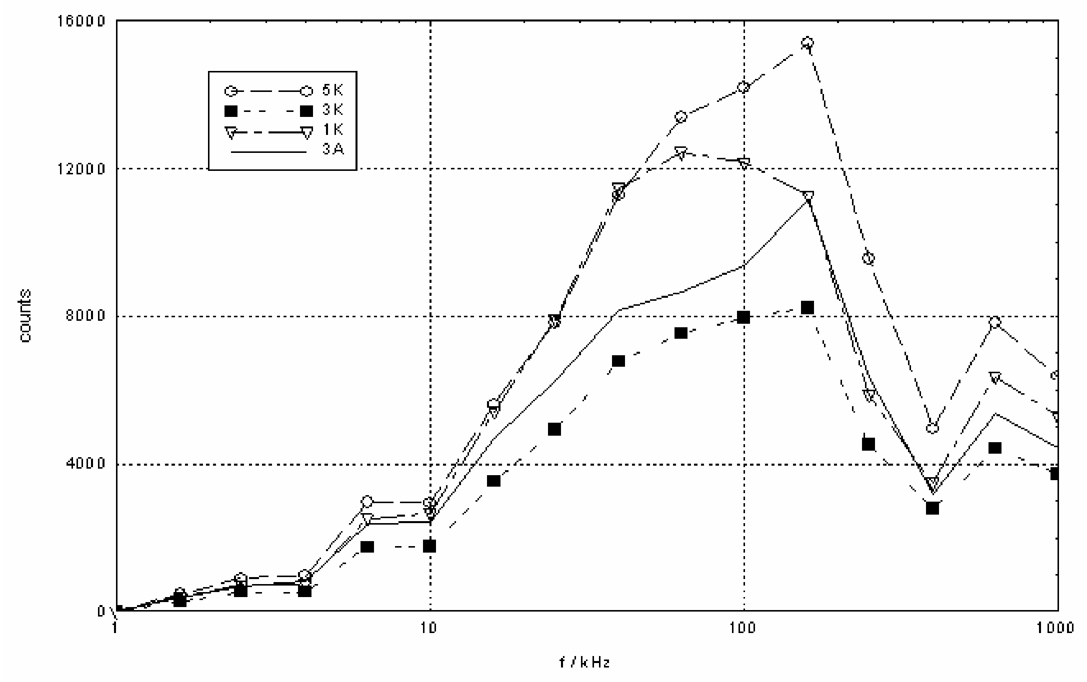

Fig. 5: Average frequencies of AE signals.

The next Fig. 5, shows the acoustic emission pulse average frequencies. In this diagram, two curves, namely, 3A and 5K are worth attention, showing similar maximum counts at frequencies of 100 kHz and 150 kHz. Note that the 5K sleeper's reinforcement is corroded, whereas that of the 3A sleeper is corrosion intact. However, both of these sleepers have one thing in common: after the first crack had been detected, the loading force continued to grow by 8 kN and 7 kN (3A and 5K respectively). The above frequency components are apparently due to the first crack growth and new micro-crack generation. A similar trend is also shown in the 3K curve (internal reinforcement bar corrosion), where the loading force went up by 5 kN after the first crack had

been identified. What the corroded reinforcement sleeper curves have in common is a higher content of the frequency components from 40 to 100 kHz.
Our measurement results, as obtained from Yokogawa DL1540CL digital oscilloscope, are shown in Fig. 6. In this diagram, acoustic emission frequency spectra are compared for identical loading force magnitude. Spectra of corroded reinforcement sleepers (1K, 3K, 5K) show an emphasized occurrence of frequency components from 60 to 400 kHz. The frequency components characteristic of the progressing corrosion consequences are in this frequency band [1, 2].
In the case of the 3A sleeper (intact reinforcement) no pronounced frequency components occur in the mentioned regions.

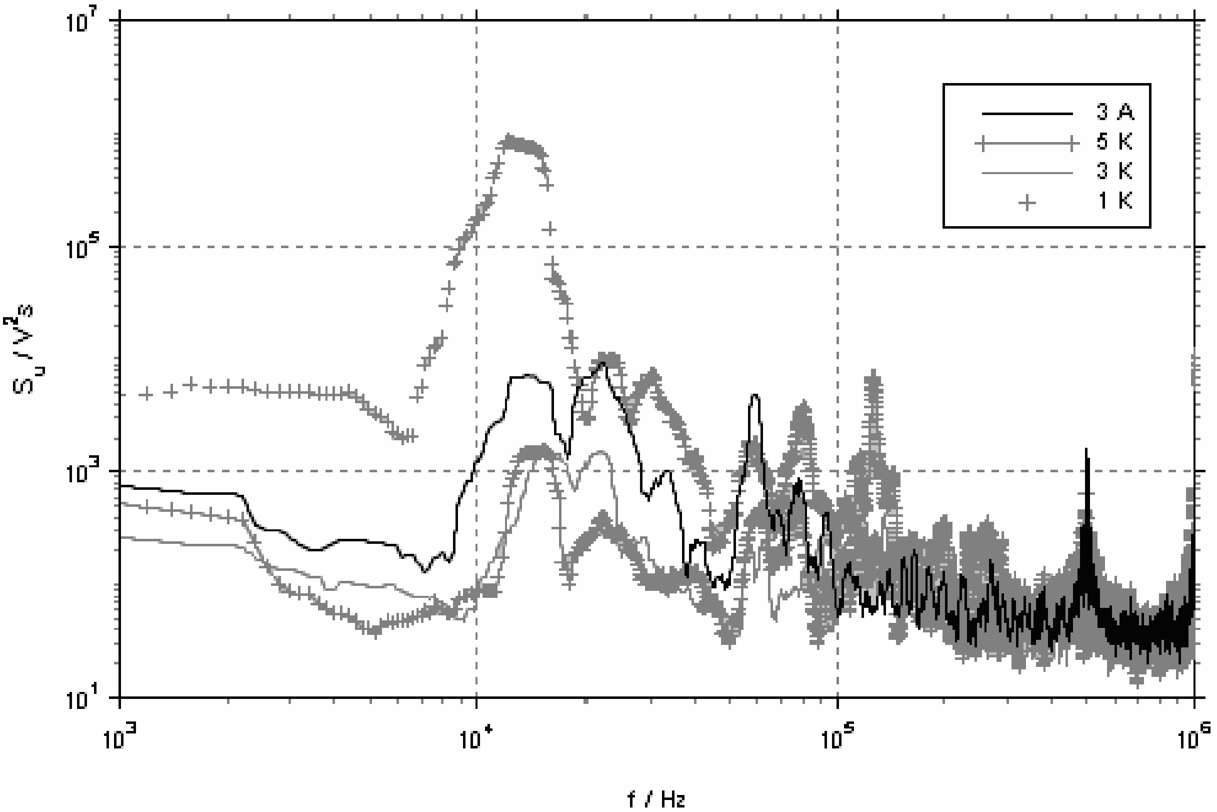

Fig. 6: AE frequency response plots.

5. Conclusions

The AE method has been used as a comparison method. Reference specimens of known characteristics have been available for the determination of the test parameters dividing points. The laboratory test results have shown that the AE signal time behaviour based analysis provides sufficient information on the loading of specimens, girders etc. in presses or similar devices. The reinforcement corrosion can be diagnosed by comparison with the measurement results obtained from reference specimens. However, to find out the emission event causes, a frequency analysis of the AE spectrum must be carried out. In addition, the correlation between the frequency components and the corrosion attack degree has also been used to design a method of in situ measurements, where the current condition of the structure is unknown, no comparison thus being practicable. These measurements should be designed so as to analyse the frequency components related to the reinforcement corrosion and its consequences [1, 2].

Acknowledgements
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