Acoustic Emission Method as a Diagnostic Tool for Corrosion Cracking in Reinforced Concrete Beams

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Abstract

The paper deals with acoustic emission evaluation of deterioration of reinforced concrete beams during flexural tests under repeated loadings. The beams were deteriorated due to accelerated corrosion of 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 reinforcement and concrete. They were revealed that the deteriorated beams exhibit different acoustic emission behaviour, depending on the different damage levels induced by the corrosion of the reinforcement. Acoustic emission parameter analysis showed that a Felicity ratio, the ratio of the load at onset of acoustic emission and the maximum prior load, is a very effective criterion to measure the severity of damage induced in the reinforced concrete beams. High acoustic emission activity during unloading was also shown to be an effective index to estimate the deterioration of reinforced concrete beams due to corrosion of reinforcement.

Introduction

Reinforced concrete structure condition has become a hot issue during last ten years. Most reinforced concrete structures and constructions exhibit quite a good endurance, showing that reinforced concrete is a stable building material. On the other hand, it is well known that, under certain circumstances, there arise serious faults in some structure parts, or, that a total destruction of the reinforced concrete structures or buildings may even take place. Rehabilitation techniques have been developing in foreign countries for several decades. In this field, rapid development has also begun in this country during last period. Thanks to a number of renowned experts as well as professional societies, which had established around them, our civil engineering managed to keep pace with the foreign countries' research. A problem which proves to persist, however, consists in the lack of non-destructive methods to be applied in the defectoscopy of inhomogeneous materials and complex form bodies (which are typical of the building industry), by means of which the internal structure of constructions and their static reliability could be assessed and their service life estimated. The absence of such methods appears to be most severe in the cases of building structure breakdown.

The acoustic emission based method appears to be very well suited for this purpose, because it can detect easily the emerging and developing processes, of which concrete cracks or armature corrosion are good examples undoubtedly. It may therefore be assumed that, based on the ongoing application of new developments, the acoustic emission method will gradually become one of the promising non-destructive diagnostic methods for reinforced concrete and pre-stressed concrete bridge structures.

Experiment

Our experiments have been designed to study the response of standard reinforced concrete joists to bending stress in compliance with ČSN EN 12390-5, see Fig. 1. The specimens to be stressed were prepared in the laboratories of CDV Tišnov. They were 10 cm x 10 cm x 40 cm in size. The specimen set consisted of specimens having a dia. 8 mm armature, a portion of the specimen set being subject to accelerated corrosion tests, and, further, several plain-concrete specimens.
The stressing consisted in three stress cycles, with maximum stress forces of 3 kN, 6 kN and 10 kN. The specimen stress versus time plot is shown in Fig. 2. Acoustic emission impulse counts were registered during the stress cycles. [1]

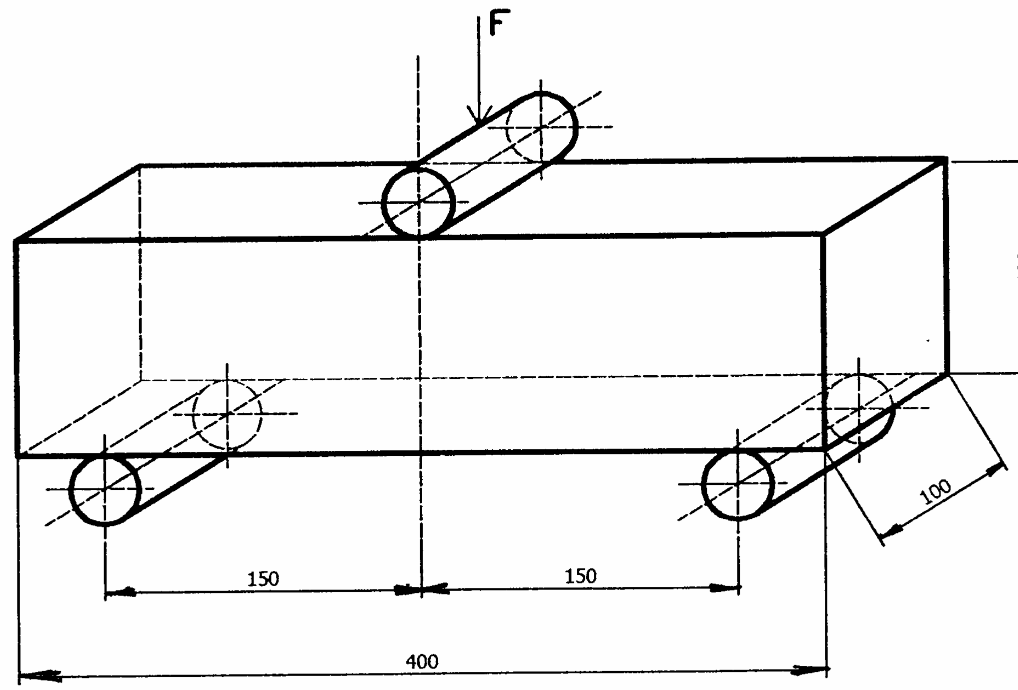

Fig. 1 Specimen stress test layout

The parameter to be monitored during the cyclic stress tests was the acoustic emission impulse frequency. Cumulative counts of the acoustic emission induced impulses versus specimen stress plots are shown in Fig. 3 to 5. Fig. 3 shows the cumulative frequency of acoustic emission impulses for plain concrete specimen stressing. It is evident from the chart that irreversible structure defects took place already during the first stress cycle – the so-called Felicity effect. Fig. 4 shows the measurement results for a dia. 8 mm armature specimen which has not been subject to forced corrosion. Fig. 5 displays the measurement results for a forcedly corroded specimen. The non-corroded specimen behaviour demonstrates the Kaiser effect. The impulse count growth is rather gradual, being linear between 3 MPa and ~ 5 MPa. An abrupt growth appears above ~ 5 MPa. Fig. 5 shows the behaviour of a forcedly corroded armature specimen. Felicity effect is apparent between the second and the third stress cycle. An exponential growth in the impulse count is evident for stresses exceeding 3 MPa.

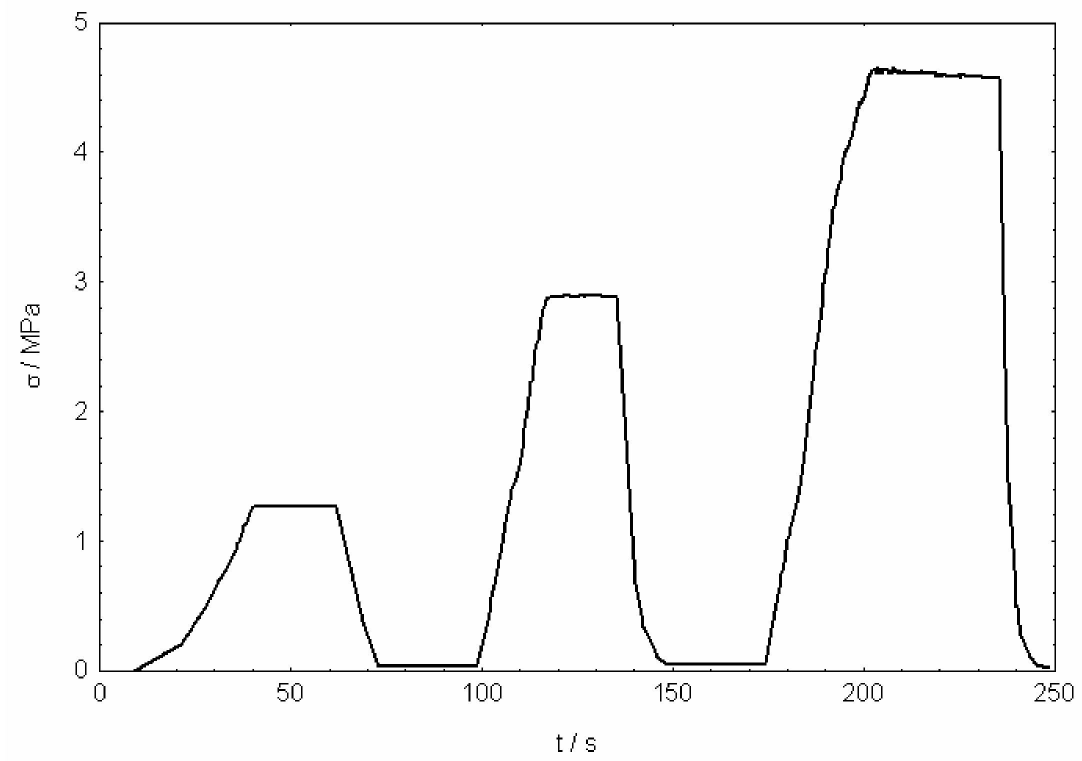

Fig. 2 Specimen stress versus time plot

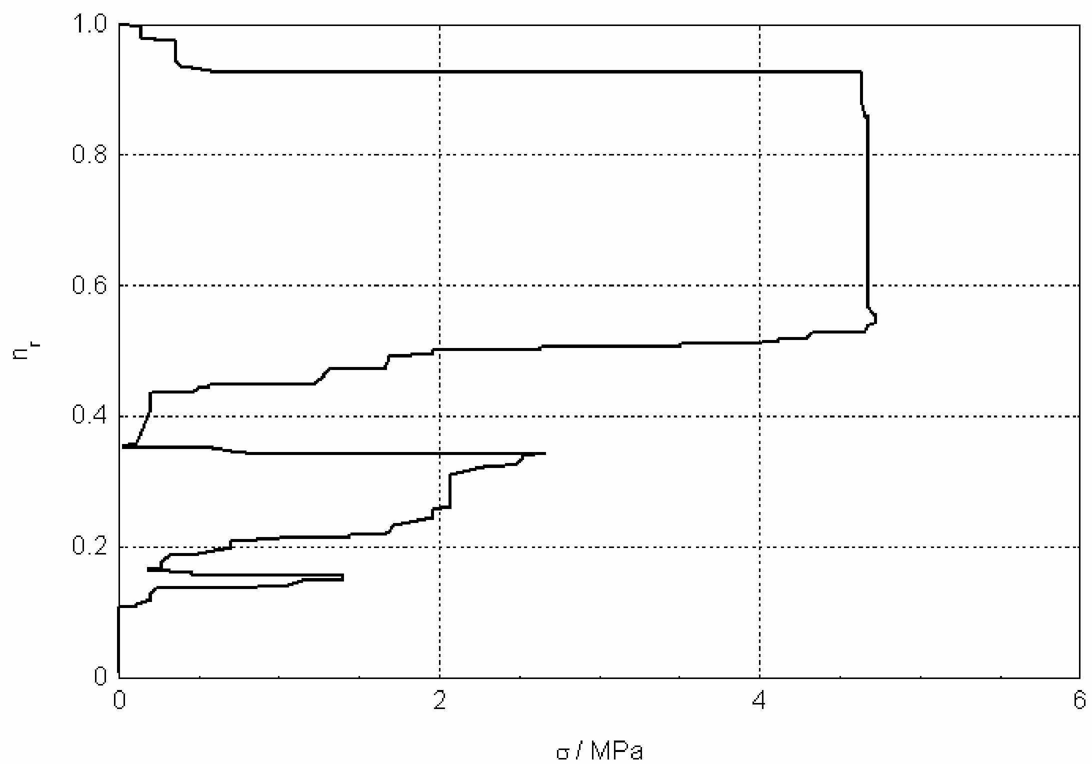

Fig. 3 Acoustic emission impulse cumulative frequency - plain concrete specimen

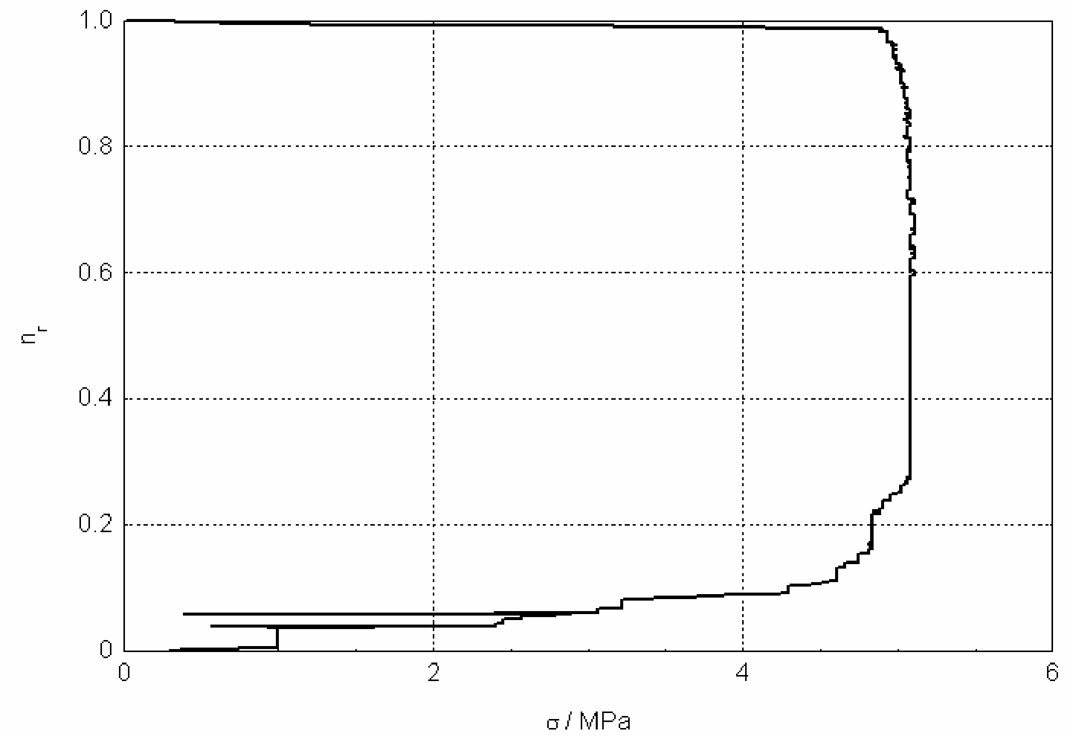

Fig. 4 Acoustic emission impulse cumulative frequency - non-corroded, dia. 8 mm armature specimen

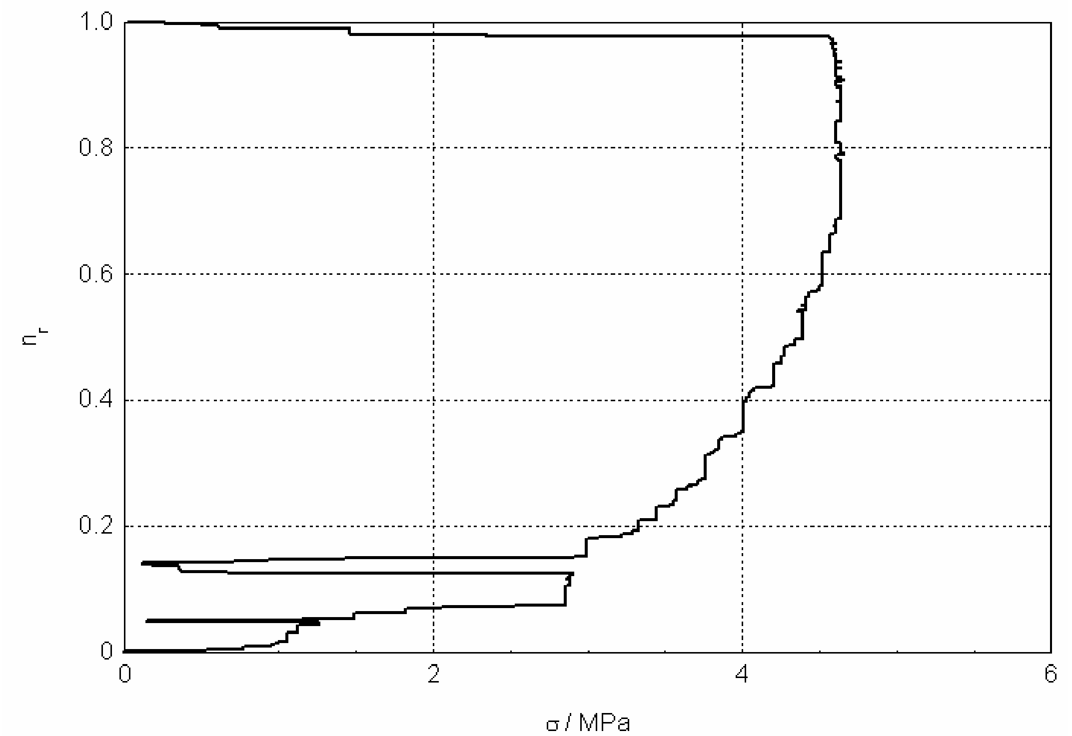

Fig. 5 Acoustic emission impulse cumulative frequency - corroded, dia. 8 mm armature specimen

Conclusion

The parameter under investigation – the acoustic emission impulse cumulative frequency – showed the Felicity effect during the stress tests, thus providing information on the generation of irreversible structure defects. In the case of plain concrete specimens (Fig. 3), the Felicity effect was registered between all stress cycles. For reinforced concrete specimens, the impulse cumulative frequency curves provide information on the acoustic emission impulse counts for various specimen stress magnitudes. In the corroded specimen case (Fig. 5), showing also the Felicity effect between the first and second cycle, the source of these signals consisted obviously in microcracks arising in the binder in the armature neighbourhood, in consequence of the incipient armature corrosion. It is thus confirmed [2] that the occurrence of the Felicity effect during the cyclic stressing tests gives evidence of irreversible structure defects taking place in the material. These defects may be due to both lower specimen strength (plain concrete) and deterioration of the armature-to-concrete bonds in consequence of the incipient armature corrosion.

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