FAILURE DETECTION IN CEMENTITIOUS COMPOSITES BY THE ELECTROMAGNETIC AND ACOUSTIC EMISSION

Tomáš Trčka

Doctoral Degree Programme (4), FEEC BUT

E-mail:xtrcka03@stud.feec.vutbr.cz

Supervised by: Pavel Koktavý

E-mail: koktavy@feec.vutbr.cz

Abstract: This paper is focused on the failure detection in cementitious composites under mechanical loading. Our diagnostic method is based on the measurement of electromagnetic and acoustic emission signals, which occur when the solid dielectric materials are mechanically stressed. This contribution describes our measurement system developed in the UFYZ FAST laboratory and also includes the first experimental results of one cementitious specimen during linearly increasing uniaxial compression.

Keywords: electromagnetic and acoustic emission, failure detection, cementitious composites.

1. INTRODUCTION

Electromagnetic emission (EME) and acoustic emission (AE) methods are promising methods to study the generation and behavior of cracks. EME and AE signals appear during cracks generation when a solid is exposed to mechanical loading (tensile, compressive, shear, torsion etc.). Generation of electromagnetic emission is related to electric charge redistribution during cracks creation and development and it is in the frequency range from tenths of Hz up to the gamma radiation. For the time being, the EME method is the only method suited to study the time development of the crack growth (crack propagation speed, crack face movement speed, crack length and size, etc.) [1]. Acoustic emission appears due to release of elastic energy during this process and it is in frequency range of ultrasonic waves. Application of the EME and AE methods to studying the material and structure behavior provides valuable information on other physical and technological parameters (porosity, rigidity, inhomogeneiety, occurrence. etc.), which in turn contributes a great deal to a further development of the non-destructive testing methods [2].

The main advantage of EME and AE is their ability to be detected already in stressed stage, which prevents the macroscopic dislocation in solids. Suitably designed methodology of EME and AE signals measurement, processing and evaluation allows observing the response of stressed materials on applied mechanical load continuously and also allows obtaining the useful information about the processes taking place in the cracks formation in solids.

2. MEASUREMENT SYSTEM

A fully automated measurement set-up was developed for EME and AE measurement (Fig. 1). The main part of the measurement system is the adjustable hydraulic press which provides mechanical load of a sample in the range from 10 kN up to 100 kN. The press is controlled by computer via voltage that is set by card NI PCI-6014. This card also acquires the output voltage of Wheatstone bridge with a sensitive load cell which measures the mechanical load. A change of the sample length is stored from the deformation meter to computer by the RS-232 port. Both signals of EME and AE are sampled by NI PCI 6111 card (for two-channel measurement) or PXI 5105 Digitizer (allows up to eight channels data acquisition) and transferred to the PC, where further processing is carried out. Detailed description of developed measurement system is in [3].

The press is electrically controlled by computer and it offers the continual measurement of both signals for various loading conditions. Further improvement is the deformation meter which is used for the sample contraction measuring during compressive stress application. This makes it possible to observe the curve of mechanical load versus sample deformation (contraction) during the sample mechanical loading.

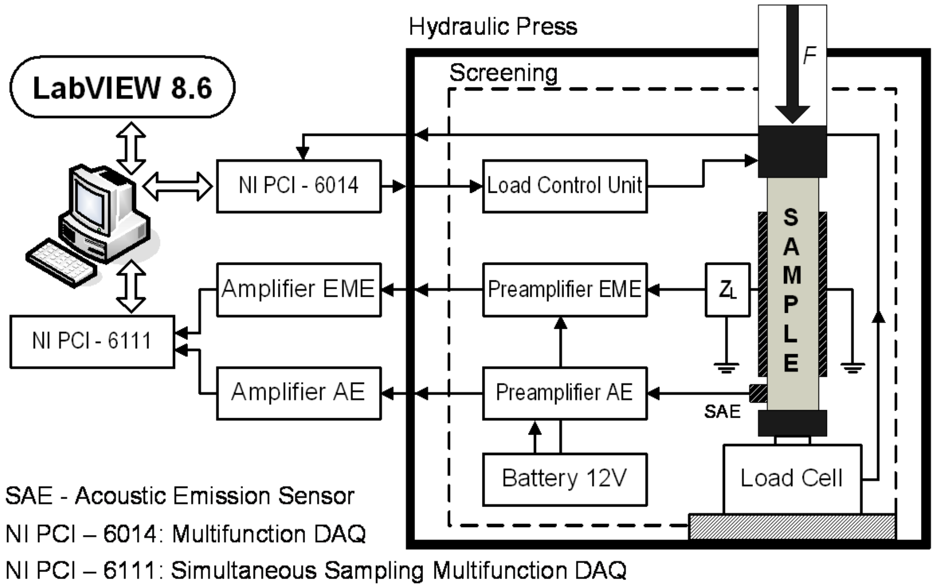

Figure 1: Experimental set-up

3. EXPERIMENTAL RESULTS

Study in this paper is focused on cementitious composites. Several groups of concrete samples with various concrete composition formulas have been prepared for two-channel (EME and AE) measurement on our experimental set-up. The measured specimens were concrete blocks of overall dimensions 100 mm × 100 mm × 80 mm. Each of these concrete blocks can be measure for defined loading conditions.

Linearly increasing uniaxial compression up to the load of 80 kN with a rate of 11 N/s was applied on the sample R5F with the following manufacturing formula: sand (0-4) mm, grit (4-16) mm. The curve of applied mechanical load and the histogram describing the distribution of the fracture events (triggered by the AE signals) in time is shown in Fig. 2. Each bar in this chart describes number of AE events during the time interval of 60 s. Number of fracture events in individual time intervals is almost constant below the applied load of approximately 60 kN. The number of fracture events exponentially increases above this load level. The peek with the maximum value corresponds to the start of the whole sample destruction.

The curve of applied force versus sample deformation (contraction) is in both figures, Fig. 3 and Fig. 4. The histogram in Figure 3 illustrates the distribution of AE fracture events depending on the increasing sample contraction. A significant increase of detected AE events started from the mechanical load of 60 kN, which corresponds to the 0.33 mm contraction of the loaded sample. The total number of detected AE events was 8144. Figure 4 shows the similar histogram of detected EME event. In this case, the significant increase of detected EME events begins later (from the mechanical load of approximately 65 kN and sample contraction of 0.38 mm). The total number of 856 EME events was detected during the entire measurement.

Figure 5 shows the example of measured signals which contain only separated EME and AE events. Formation of the continuous EME and AE signals (see Fig. 6) occurs just before the total destruction of the whole sample. In the case of R5F sample, the maximum load (before the sample destruction) was approximately 77 kN.

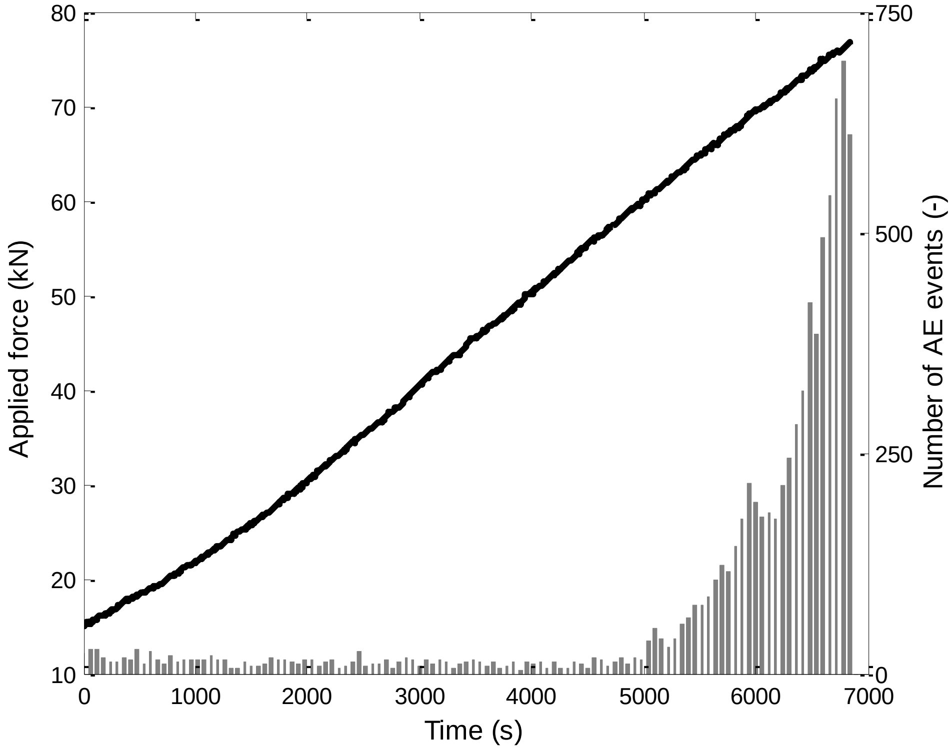

Figure 2: Applied mechanical load and the distribution of the fracture events (triggered by the AE signals) in time

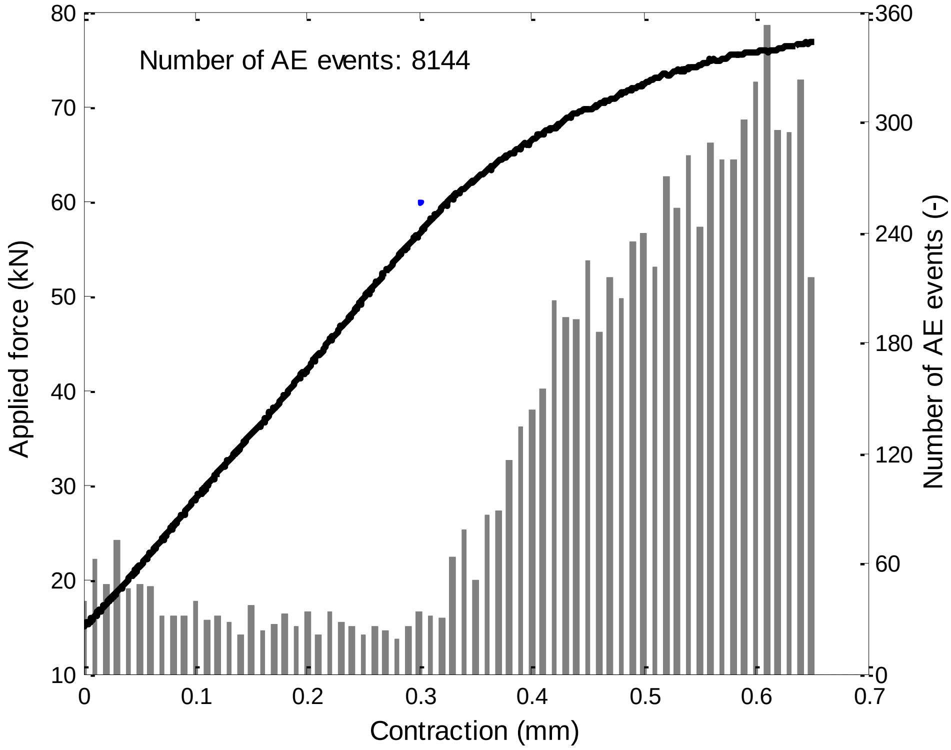

Figure 3: Applied force versus sample contraction and the distribution of AE fracture events depending on the increasing sample contraction

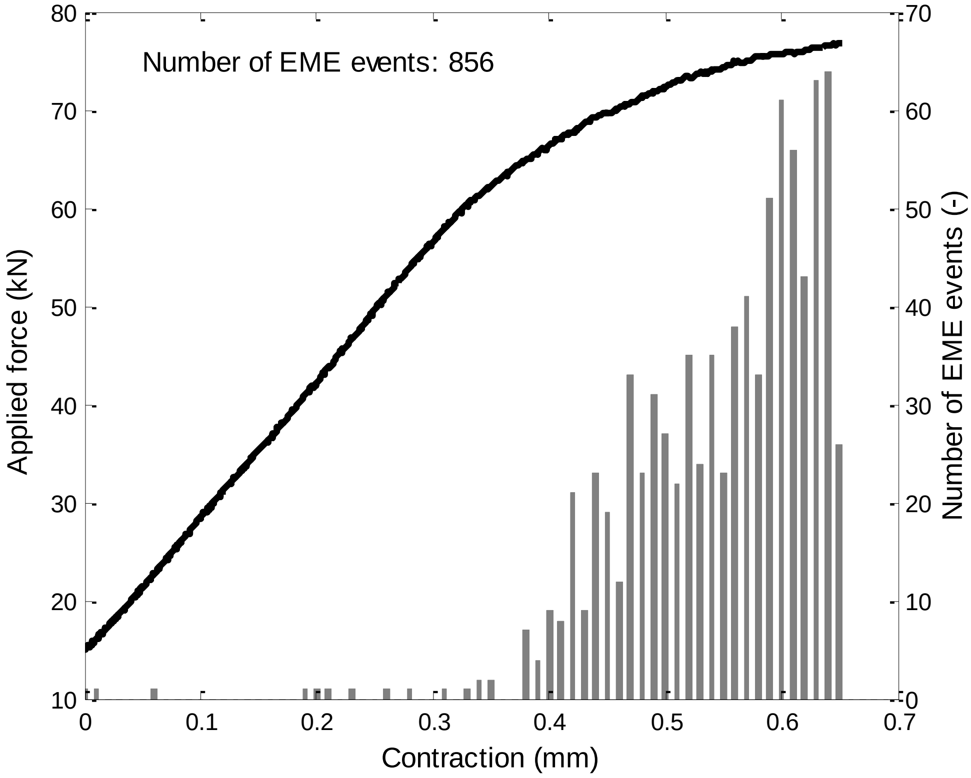

Figure 4: Applied force versus sample contraction and the distribution of EME fracture events depending on the increasing sample contraction

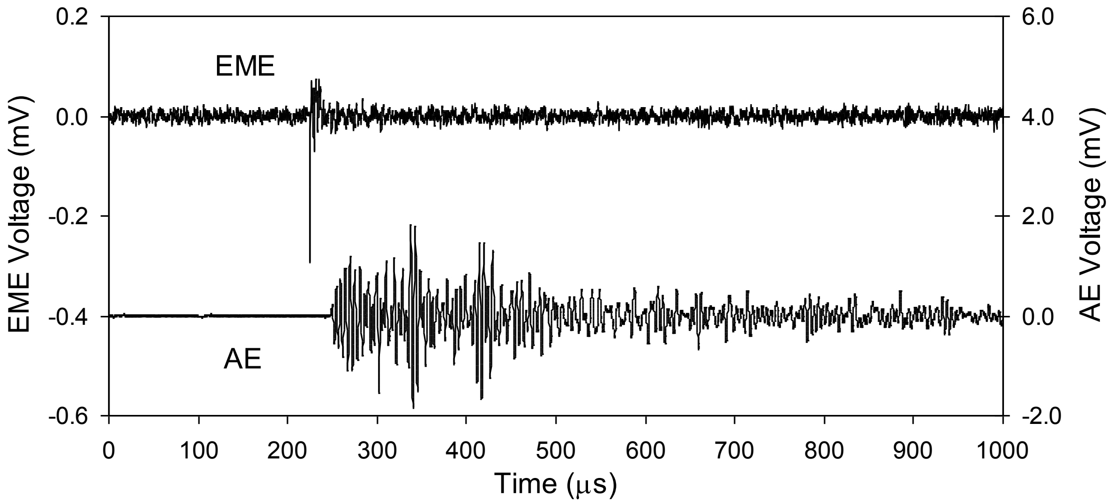

Figure 5: Separated EME and AE events, mechanical load 66.4 kN, sample R5F

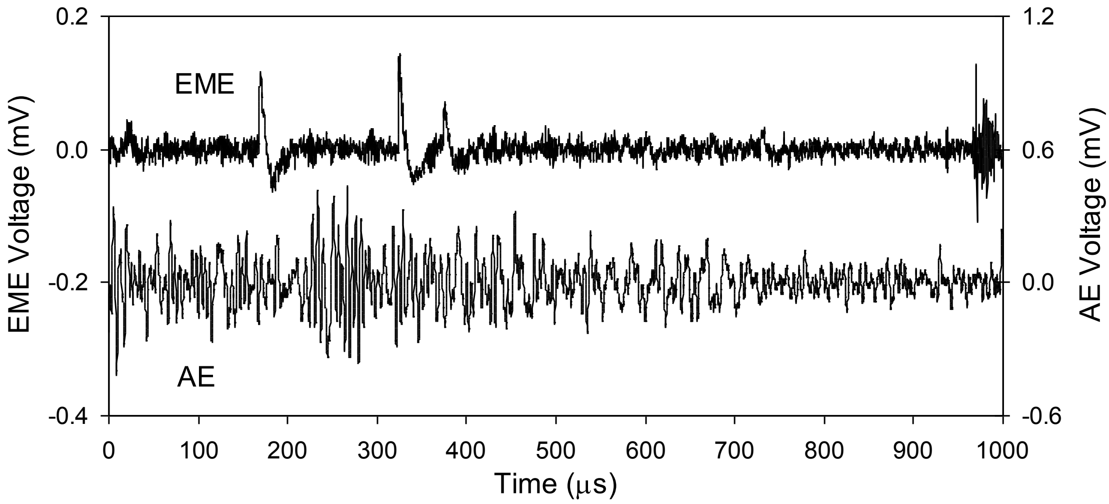

Figure 6: Continuous EME and AE events, mechanical load 76.8 kN, sample R5F

4. CONCLUSION

The R5F concrete sample was mechanically stressed by defined way (linearly increasing uniaxial compression with a constant rate of 11 N/s). The active cracks generated during the mechanical loading were monitored by detected acoustic and electromagnetic emission signals. The capacitance sensor is commonly used to EME capture. In our case, the capacitance sensor is formed by the specially made adjustable bracket with two electrodes, into which we can easily insert the rectangular samples. The piezoelectric sensors with frequency band at least up to 1 MHz are used for AE monitoring.

Obtained experimental results allow us to study the dependence of the AE and EME events intensity during specific stages of the curve of mechanical load versus sample deformation. The significant increase of detected EME events corresponds with the beginning of the stressed sample plastic deformation (see Fig. 4). In the case of R5F sample, the plastic deformation begins from the mechanical load of approximately 65 kN and sample contraction of 0.38 mm. The formation of plastic deformation is also accompanied by increasing activity of detected AE events, which can be seen in Figure 3.

ACKNOWLEDGEMENTS

This research has been supported by the Brno BUT Specific Research, by the Grant Agency of the Czech Republic within the framework of the projects GACR 102/09/H074 and GAP 104/11/0734. This support is gratefully acknowledged.

REFERENCES

[1] Koktavý, P.: Experimental study of electromagnetic emission signals generated by crack generation in composite materials. *Measurement Science and Technology.* 2008. 20(1). p. 0-7. ISSN 0957-0233.

[2] Koktavý, P., Trčka, T., Koktavý, B.: Noise diagnostics of advanced composite materials for structural applications. In *21st International Conference on Noise and Fluctuations ICNF 2011*. 1. Toronto, Kanada, IEEE. 2011. p. 88 - 91. ISBN 978-1-4577-0191-7.

[3] Trčka, T.: Continual measurement of electromagnetic and acoustic emission signals for various loading conditions. In *Proceedings of the 17th Conference STUDENT EEICT 2011*. Brno, NOVPRESS s.r.o. 2011. p. 391 - 395. ISBN 978-80-214-4273-3.