Analysis of Acoustic Emission Signals Generated by Cracks during Three-point Bending Test

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Abstract: The method of acoustic emission is an experimental tool well suited for monitoring fracture processes in a material. The typical parameters of acoustic emission signals were identified from the acoustic emission records for different alkali mixtures to further describe the under the stress behaviour and failure development. Alkali-activated slag is a material which has great potential for use in building industry. An understanding of micro structure-performance relationships during stress situation is the key to true understanding of material behaviour.

Keywords: acoustic emission method; three-point bending test; energy of acoustic emission signal, the crack initiation.

1 Introduction

The Acoustic Emission Method (AEM) is an experimental tool well suited for monitoring fracture processes. The AEM can monitor changes in materials behaviour over a long time and without moving one of its components i.e. sensors. This makes the technique quite unique along with the ability to detect crack propagation occurring not only on the surface but also deep inside the material. The AEM is considered to be a "passive" non-destructive technique because usually identifies defects which they develop during the test [1].

Fracture in a material takes place with the release of stored strain energy which is consumed by nucleating new external surfaces (cracks) and emitting elastic waves which are defined as acoustic emission (AE) waves. The elastic waves propagate inside a material and are detected by an AE sensor [2]. Except for contactless sensors, AE sensors are directly attached to the surface. AE signals (Fig. 1) are detected as dynamic motions at the surface of a material are converted into electric signals [3]. Then signals are amplified and filtered. The final goal of monitoring AE phenomena is to provide beneficial information to prevent fatal fracture by correlating detected AE signals with growing fracture process or deterioration [4]. AEM is often used to detect a failure at a very early stage of damage long before a structure completely fails.

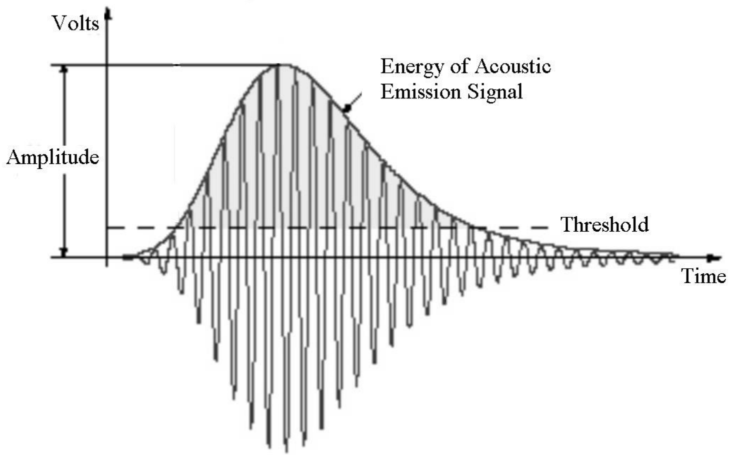

Fig. 1: Typical AE signal

Acoustic emission activity is attributed to the rapid release of energy in a material, the energy content of the acoustic emission signal can be related to this energy release. The true energy is directly proportional to the area under the acoustic emission waveform [5]:

$$\text{AE energy}_i = \int_{t0}^{t1} V_i(t)^2 dt \qquad (1)$$

i = the recorded voltage transient V(t) of a channel
t_0 = the starting time of the voltage transient record
t_1 = the ending time of the voltage transient record

Natural graphite is a versatile material with a unique structure and many different properties. Therefore, it is not only an essential component in applications such as pencils and refractory products but it is also a high-performance raw material for the plastics industry. Being a natural crystalline graphite grade, "COND" still exceeds the conventional graphite grades in terms of electrical conductivity about 10 times. Nevertheless, the COND grades possess other typical quality characteristics of natural graphite-like lubrication, thermal conductivity, and chemical stability. An enormous advantage of the COND grades are that both thermal conductivity and especially high electrical conductivity are combined in this product.

2 Experimental setup

Alkali-activated slug slurry was cast into prismatic moulds (40×40×160 mm) to set and after 20 h the samples were demoulded and immersed in water for another 27 days before testing. Prior to testing of fracture properties, the specimens were pulled out from water immersion and stored in the air at laboratory conditions (20 ± 1 °C, RH 45 ± 5 %). The three-point bending fracture tests were conducted on beam specimens with central edge notch. The initial notch was made before testing with a diamond blade saw. The depth of the notches was approximately 30 % of the depth of the specimen. The span length was equal to 120 mm. The specimens were tested at the age of 28 days. Fracture tests were carried out using a LabTest 6.1000 electromechanical testing machine within the range of 0–100 kN at a laboratory of the AdMaS Centre (Advanced Materials, Structures and Technologies), Faculty of Civil Engineering, Brno University of Technology.

Tab. 1: Composition of alkali-activated slag mixtures.

Component	**REF**	**COND 10**
Slag [g]	450	450
Water glass [g]	90	90
Quartz sand [g]	1350	1350
Water [ml]	180	135
COND 8 96 [g]	-	45
0.5% Triton X-100 [ml]	-	120
1.0% Lukosan S [ml]	-	20

During the experiment, an acoustic emission activity was recorded. The guard sensor eliminated mechanical and electrical noise. Four acoustic emission sensors were attached to the surface of the specimen with beeswax (Fig. 2). Acoustic emission signals were recorded by DAKEL XEDO measuring equipment with four IDK-09 acoustic emission sensors with a 35 dB preamplifier.

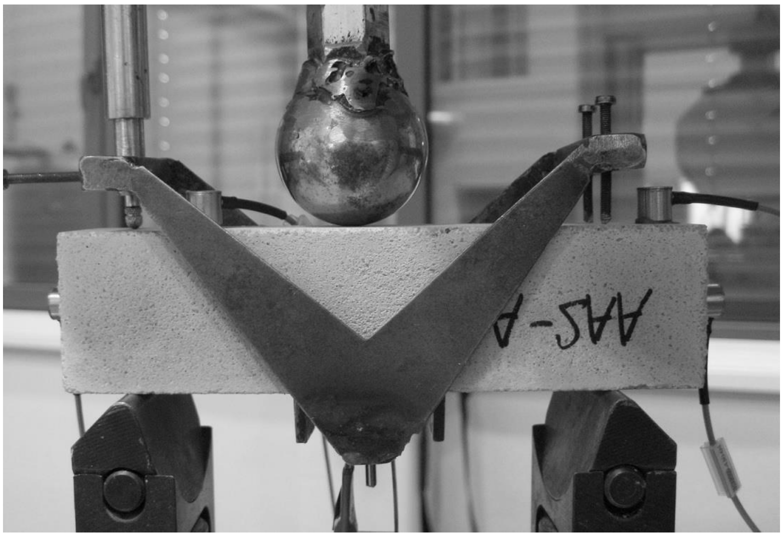

Fig. 2: Photography of experiment

3 Results

To assess the nature of the cracks, we used AE energy. For example on the Fig. 3 is relative cumulative energy AE signal and the relative load versus time. The AE energy of the signal is directly proportional to the area under the acoustic emission waveform. Fig. 3 shows that energy of AE signals starting to evolve before maximum load. That means the crack initiation and thus, release energy began at about 75% of a maximum of graphite powder COND 10. Fig. 4 shows that maximum load. The release of AE energy changed after add energy of AE signals starting to evolve while maximum load.

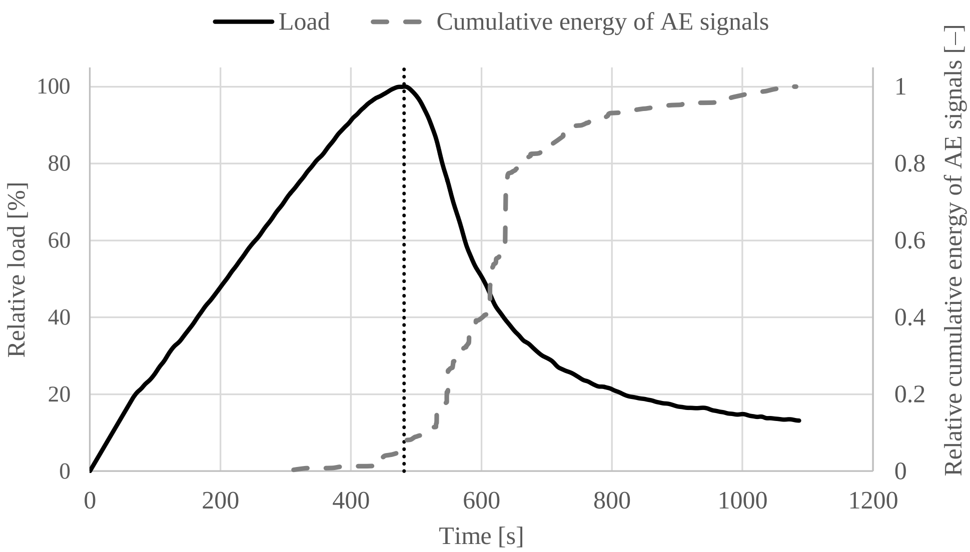

Fig. 3: Dependence of relative cumulative energy of AE signal and the relative load on time. (REF sample)

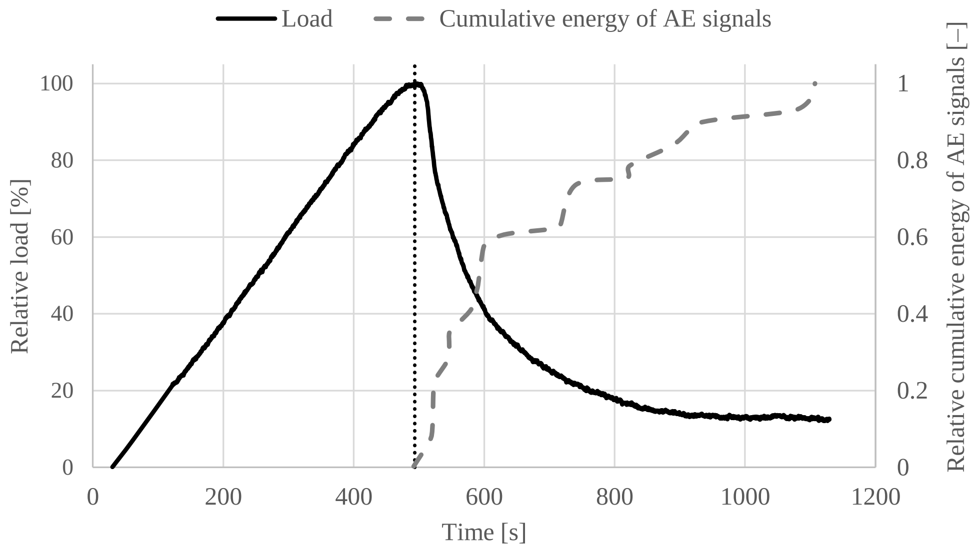

Fig. 4: Dependence of relative cumulative energy of AE signal and the relative load on time. (COND 10 sample)

4 Conclusion

The fracture properties of alkali-activated slag composites have been investigated. The acoustic emission method appears to be a suitable tool for determining the behaviour of alkali activated slag mortar specimens during stable crack propagation from an initial crack/notch. Stable crack propagation is followed by a number of AE signals until fracture takes place. The addition of graphite powder has a significant influence on the evolution of energy of acoustic emission signals. Application of acoustic emission method during the three-point bending test of alkali-activated slag mortar can help to obtain their better properties. The properties of the emerging micro cracks can ultimately be linked to the overall fracture behaviour of the materials.

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