QUALITATIVE CORRELATION BETWEEN ACOUSTIC AND ELECTRIC ACTIVITIES IN BRITTLE MATERIALS

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1. Introduction

Low-level electric signals, generated during mechanical loading of specimens made of quasi-brittle materials, provide valuable information about internal damage processes. These signals are the result of formation and growth of micro-cracks [1], which are the origin of electric charges, constituting either electric dipoles or even more complicated electrically charged systems. Indeed, during cracking ionic bonds break, polarising the newly created crack edges, thus creating electric dipoles. These dipoles produce an electric potential across the crack allowing an electric current to flow. This current, denoted as Pressure Stimulated Current (PSC) [2] can be detected and recorded by means of ultra-sensitive electrometers using sensors in the form of pairs of golden electrodes attached on the specimens. In this study an attempt is described to qualitatively correlate the PSC signals with the data provided by another sensing technique, i.e., the Acoustic Emissions (AE) technique, which is worldwide considered as a mature tool for understanding the mechanisms activated before and during failure processes, and also as an efficient Structural Health Monitoring tool [3].

2. The experimental protocol

Prismatic specimens of square cross section, made of either Dionysos marble or cement mortar were subjected to uni-axial compression. The dimensions of their cross section were 50 x 50 mm^2 and their length equal to 100 mm. The experiments were quasi-static under load-control mode. The load was imposed monotonically, until fracture of the speci-mens, at a constant rate (for the whole duration of each experiment) equal to about 0.35 MPa/s.

During loading, the axial force, the axial strain, the PSC signal and the AE data (of amplitude equal or higher of 45 dB) were recorded as functions of time.

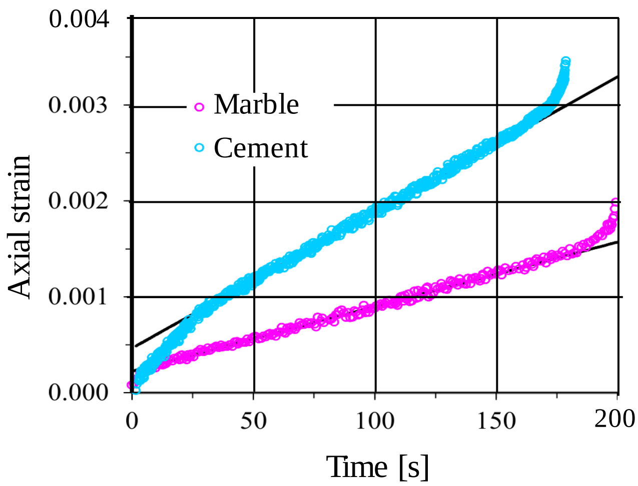

Figure 1: Axial strain vs. time for marble and cement specimens.

In Fig.1 the time evolution of the axial strain for two typical tests is shown. Given that the experiments are load-controlled, these graphs correspond to the stress-strain ones. As it is expected for very brittle materials, both graphs are characterized by almost perfect linearity (excluding an initial region, where bedding errors prevail, and the region very close to the fracture stress, where some non-linearities are expected). The moduli of elasticity determined are equal to about 70 GPa for marble and 20 GPa for cement mortar.

3. Acoustic versus electric activity - The F-function

An alternative method for representing the acoustic emission activity is adopted in the present study, in terms of the F-function, corresponding to the mean frequency of occurrence of AE hits in a time interval, in which n successive hits are recorded. F-function is plotted taking advantage of the interevent times of a sufficient number n of successive hits (it is here assumed that n=50). Each value of the F-function is paired to an average time instant τ of the time instants of the n successive hits used to calculate the specific value of F-function.

The time variation of the F-function and the PSC is plotted in Fig.2, for two characteristic experiments, one for marble (Fig.2a) and one for cement (Fig.2b). The plots are realized against the $(t_f - \tau)$ or the $(t_f - \tau)$ parameters (where t_f is the time instant of final fracture of the specimens) in logarithmic scales, in an attempt to better enlighten processes at the very last loading steps before the specimens' fracture. In the same figures, the respective time variation of the axial strain is plotted, together with its linear fit.

The overall qualitative similarity between the time evolution of the PSC signal and the F-function is quite striking for both materials. Moreover, it is worth mentioning, that after the time instant t_y, at which the materials enter the non-linear portion of the respective constitutive law (indicated by the dotted red line in Figs.2(a,b)), the plots of both the PSC and the F-function are perfectly described by a power law of the following form:

$$\text{PSC or } F = A\left(t_f - \tau\right)^m \quad (1)$$

where A and m are numerically determined constants. The values of the constant m, representing the slope of the fitting lines in Figs.2(a,b), vary in a rather narrow interval (from -0.71 s to -0.84 s for marble and from -1.04 s to -1.20 s for cement).

Finally, it is to be mentioned that, for both the PSC signal and the F-function, the time evolution exhibits a clear maximum value, which is attained a few seconds before the final collapse of the specimens.

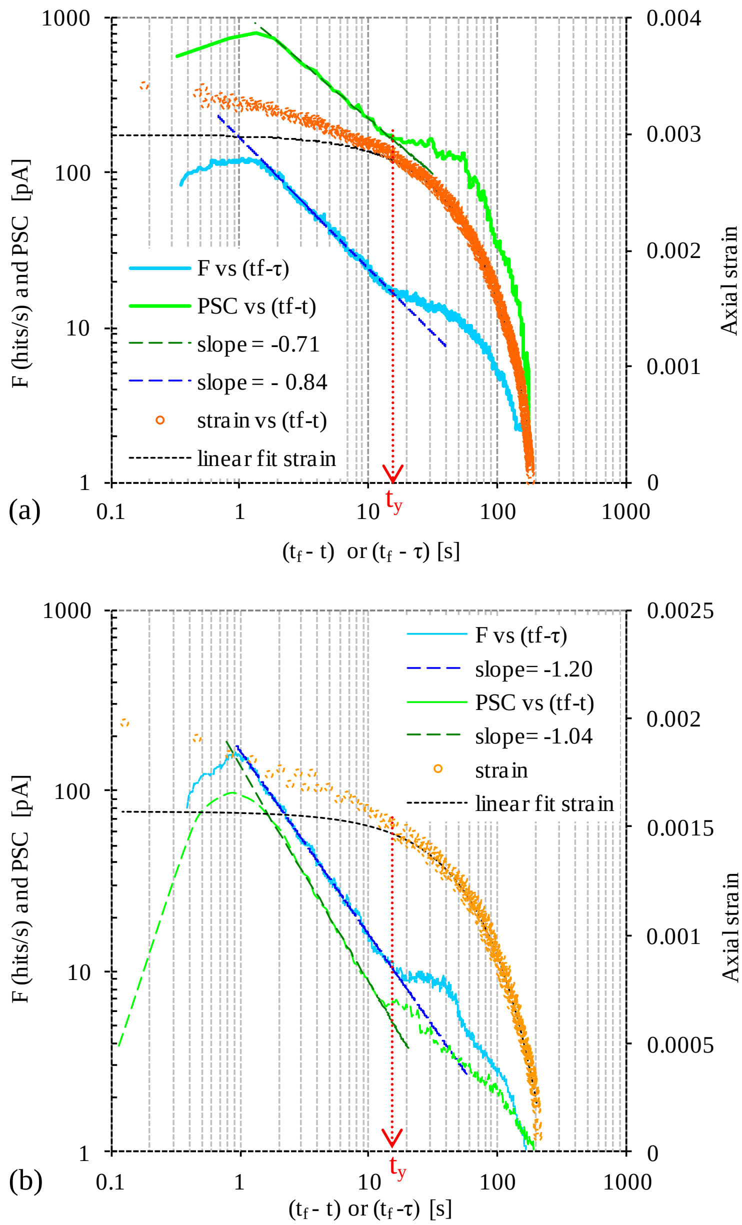

Figure 2: The PSC and the F-function against the $(t_f$-t) or $(t_f$-τ) or parameters, in juxtaposition to the respective variation of the axial strain, for marble (a) and cement (b).

4. Concluding remarks

The time evolution of the PSC recorded during compression of brittle materials and the respective one of the acoustic activity, expressed in terms of the F-function, exhibit common qualitative characteristics. Moreover, they provide clear indications that either the materials abandon linearity, exhibiting increased rate of damage (designated by a power law dependence of PSC and F-function on the $(t_f - \tau)$ parameter) or that fracture is approaching (designated by the attainment of a maximum value a little while before the specimens' collapse).

References

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