Pressure Stimulated Current (PSC) recordings on cement mortar and marble.

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Abstract: -The electrical and mechanical behaviours of marble and cement mortar samples and the differences between them were studied by subjecting them to uniaxial compression. The Pressure Stimulated Current (PSC) technique was applied to measure the charge released by uniaxially compressed samples under constant stress rate up to their failure. As far as the PSC emission is concerned in both marble and cement mortar samples, similar behaviours are observed. They only differ quantitatively, cement mortar giving higher pressure stimulated current density values.

Key-Words: - Pressure Stimulated Currents, PSC, marble, cement mortar, fracture, microcracks.

1 Introduction

Marble belongs to the class of metamorphic rocks. Its structural inhomogeneities are due to either natural or man-made causes like the application of mechanical or chemical processing. On the other hand Portland cement is a widely used material because of its ease of preparation, molding and its low cost.

Since transient electric phenomena are often related to mechanical effects taking place while solid material samples are under stress [1,2] a series of experiments of uniaxial compression both of marble and of hardened cement mortar samples were carried out in order to investigate probable electrical phenomena.

The technique used to exhibit the weak current emitted from hardened cement mortar and marble sample, while applying stress at various rates is referred to as Pressure Stimulated Current (PSC) technique [3-6].

From the microphysical point of view it is noted that in the non-linear deformation range micro structural changes occur within the samples depending on the stress magnitude [7,8]. They constitute the dominant form of all heterogeneities that determine the process of eventual failure. In particular, in the cement mortar there is a transition zone [9,10] between the aggregate and the hydrated cement paste which constitutes a region of relative weakness containing a number of microcracks even before loading. The increasing number of microcracks at the lateral edges of shear cracks reaches a minimum critical distance with respect to each other and begin to merge. In this experiment hardened cement mortar sample and marble sample were subjected to a time varying uniaxial compressional stress at constant stress rates, up to fracture. At the same time the emitted PSC's were recorded for both cases.

2 Sample characteristics and experiment description

The marble samples were cubes of 5 cm side collected from Mt. Penteli, Attica. Marble is mainly composed of calcite (98%) and other minerals, such as muscovite, sericite and chlorite. Its content in quartz is very low (0.2%), while its density is 2.7gr/cm3 and its porosity is approximately 0.40%. Calcite crystals are polygonic, mainly equisized sometimes exhibiting twinning and their texture may be characterized as quasi-homoblastic. The rock is white with a few thin parallel ash-green coloured veins containing silver–shaded areas due to the existence of chlorite and muscovite. Matrix rocks were intentionally selected to be quasi single grained.

The cement samples used were also cubes of 5 cm side. The mortar was composed of Portland type cement (i.e. OPC), sand (SiO_2), and water at a ratio 1:3:0.5 respectively. The final sample consisted of $3CaO.SiO_2$ (54%, C_3S), $3CaO.AI_2O_3$ (19%, C_3A), $2CaO.SiO_2$ (17%, C_2S) and $4CaO.Al_2Oi.Fe_2O$, (9%, C_4AF). The samples were utilized 3 months after their construction in order to get aged properly and achieve an approximate 95% of their maximum strength. The diameter of the sand grains of the composition varied between 0.08mm and 2mm. Its density was $2.2gr/cm^3$ and its porosity was approximately 8%.

The experimental apparatus and technique have been duly described in previous works. [3,5].

The stressing system comprised a uniaxial hydraulic load machine (Enerpac-RC106) that applied compressional stress to the cement mortar and marble samples. The values of the externally applied stress were measured using a load cell. A pair of copper electrodes was attached to each sample. The electrodes were attached in a direction perpendicular to the axis of the applied stress.

The electrodes area was $16cm^2$ for marble and $18cm^3$ for cement mortar. For electrical measurements a sensitive programmable electrometer Keithley 617 has been used. All the recordings originating from the load cell and the electrometer were stored in a PC through a GPIB interface.

The stress-strain curves of the used marble and cement mortar samples are depicted in normalized stress axes in figures 1 and 2 respectively. The stress-strain curves indicate that when the normalized stress exceeds 0.70 the materials enter the non-linear range where the Young's moduli decrease progressively at increasing stress values.

The stress rate for the marble sample was 0.69MPa/s and for the cement mortar sample was 0.71MPa/s. The marble failed when the stress was 62MPa while the cement mortar failed at 55MPa.

3 Experimental results and discussion

PSC recordings were conducted under uniaxial compressional stress for both marble and cement mortar samples.

The diagram of Fig.3 is a dual representation of stress and the emitted pressure stimulated current density, J, as a function of time for both marble and cement mortar. Eq.1 gives the expression relating J with electric current I.

$$J = \frac{I}{A} \qquad (1)$$

where A denotes the electrode area.

PSC density, J, was preferred over current I in order to represent in a more general and comparable way all variations with respect to the applied stress. In the diagram one may observe the linear variation of the applied stress under slightly different constant rates for the two materials.

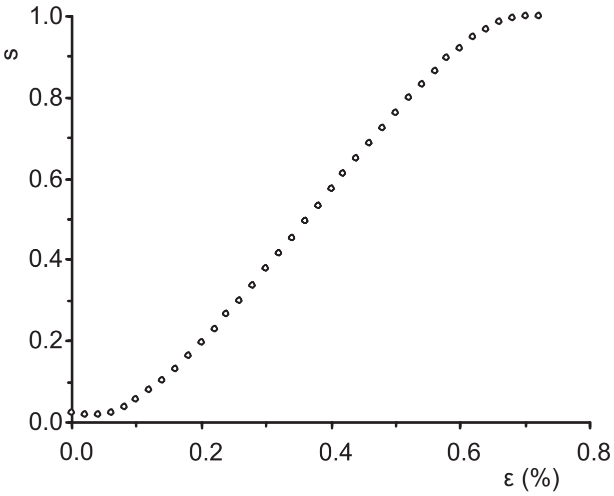

Fig. 1: Normalized stress-strain diagram of the used cement mortar sample.

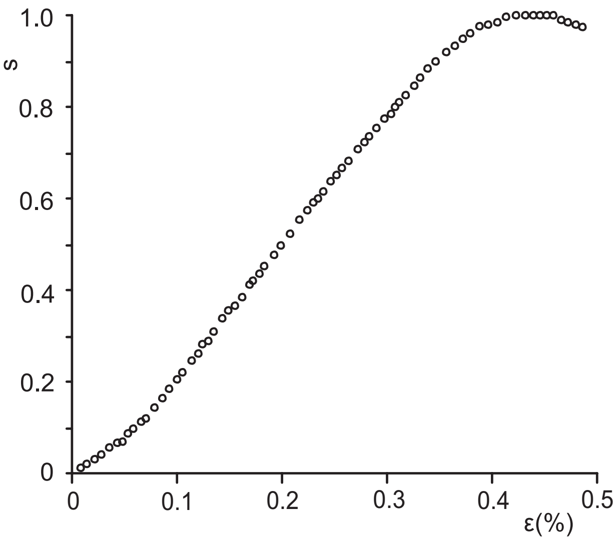

Fig.2: Normalized stress-strain diagram of the used marble sample.

In the same diagram, the pressure stimulated current density appears approximately 55s after the beginning of compression upon both samples, which corresponds to a region between 0.70 and 0.75 of the normalized stress.

The fact that the PSC appears after 0.70 combined with the fact that beyond 0.70 both materials practically start deviating from the linear behaviour range suggests that PSC appears as a result of microcracks.
The greater the applied stress the larger the PSC density up to a maximum value slightly before sample failure.
In an effort to compare the PSC densities emitted by the two material samples, one can observe that the PSC emissions begin practically for equal normalized stress values but although they vary similarly with respect to time, the corresponding

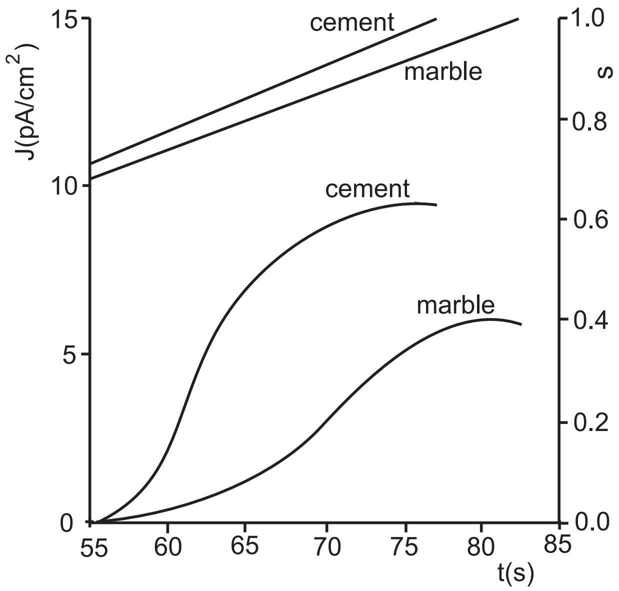

Fig.3: Temporal representation of the normalized stress upon cement mortar and marble samples and the corresponding variation of pressure stimulated current densities.

PSC magnitudes differ significantly. In particular the cement PSC curve attains larger values than those of the marble sample. This can be interpreted in terms of the different microstructures of the two materials.
More analytically, the chemical bonds of calcite are stronger and more cohesive than those of cement mortar which is made of cement, sand and water establishing a much more porous solid.
As a result, the latter has a great probability to form more microcracks. Moreover, the pre-existing microcracks in the aggregate transition zone increase in length and width resulting in a progressively increasing contribution to the overall strain. Thus, new microcracks appear corresponding to more released electric charge and consequently to a larger PSC magnitude up to fracture limit of the material sample.

4 Conclusions

A comparison of marble and cement mortar PSC emissions was made. Both materials were found to respond to uniaxial compressional stress emitting pressure stimulated currents.
Although both materials started deviating from linearity at approximately equal relative stresses, cement mortar exhibited a higher sensitivity emitting PSC of approximately double as large density as compared to marble during uniaxial stress and while both samples were slightly before failure. A possible interpretation of this difference may be attributed to the way in which cement solidifies establishing relatively large pores with air inclusions. Cement mortars also include potential damage generators like microcracks due to drying originated shrinkage. Such damage generators are non-existent in unstressed marble and must play a role of critical importance in the differentiation between the two materials with respect to PSC emission.

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