Geophysical Research Abstracts, Vol. 7, 09345, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09345
© European Geosciences Union 2005

Micromechanical investigations of the hydro-mechanical behaviour of shale rocks by means of optical full field strain measurement techniques

M. Bornert, F. Valès and J.C. Eytard

Laboratoire de Mécanique des Solides, Ecole polytechnique, F-91128 Palaiseau
(bornert@lms.polytechnique.fr/Fax +33 1 69 33 30 26)

Micromechanical investigations aim at detecting the actual physical deformation and damage mechanism active at a microscopic scale, the complex averaged interactions of which determine the macroscopic behaviour of materials. They allow a physically based extrapolation of experimental data to situations not accessible to experiment, by means of adequate scale transition models. Such an approach might be very useful for the determination of the long term hydro-mechanical behaviour of shale rocks, for instance in the context of nuclear waste repositories. Qualitative observations of the micromechanisms by means of mechanical tests inside the chamber of a scanning electron microscope, as those used for years for the analysis of metals and composites, can however not be transposed directly to geomaterials, for two main reasons. First, the exposition of the samples to vacuum may noticeably modify the physical properties of the rocks, the behaviour of which being very sensitive to water content, and, second, the levels of deformation are in general too low (below a few percent) for efficient direct observation.

To circumvent these difficulties, direct optical observations, by means of specifically designed optical microscopes and appropriate lighting devices, of samples with controlled degrees of saturation and mechanically loaded on conventional testing machines, have been preferred and combined with efficient digital image correlation techniques, able to detect very small evolutions of the microstructures.

More precisely, images of cylindrical samples (36 or 24 mm in diameter, 50 to 70 mm height) of shale rocks from the underground laboratory of Bures (France) have been recorded by means of digital cameras (2Kx2Kx12bits pixels or 1,3Kx1Kx8bits pixels)

at two different scales and for different hydro-mechanical configurations. Typical areas of 1,5x1,5 mm^2 with a pixel size of 0,7μm have been considered at the microscale, at which the composite nature of the rock made of a clay matrix with other mineral inclusions is revealed. Macroscopic areas with centimetric sizes (pixel sizes of about 10μm) have also been considered in order to characterise the overall response of the samples. The image analysis technique leads to an accuracy better than 10^{-3} at the local scale, for a typical gage length of 20μm (which corresponds to an accuracy on relative displacements of about 20nm), and 10^{-5} at the global scale.

The comparisons of images taken before and after the imposition of controlled suctions reveal the opening or closing of both macro and microcracks, that would have very hardly been detected by conventional observations. The analysis of movies of the samples under uniaxial compression tests reveals the strong heterogeneity of the strain at the local scale. No only it is confirmed that the clay matrix deforms much more than the other mineral inclusions, but it also appears that the deformation is very inhomogeneous in the matrix, with some areas being almost not deformed, while in others the strain is more than twice the overall load, depending on the local distribution of the inclusions. Heterogeneities are also detected at the scale of the sample and can be correlated with fluctuations of the rock composition. Correlations between the evolution of the degree of heterogeneity at both the local and global scales and the nonlinearity of the mechanical behaviour, and in particular its damage, as well as the influence of the degree of saturation on the local strain field, are also investigated.

The development of the presented methods has been funded by ANDRA and CNRS.