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X-RAY TOMOGRAPHY OF FRACTURED POROUS MEDIA

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Summary: In situ experiments in XRCT provides a tool to measure microstructure properties of porous materials. These properties are used as input parameters of heuristic and rigorous mathematical functions that describe the effective response of such materials. XRCT is a method which lowers the time and costs of material characterization.

1. INTRODUCTION

The study of the mechanical, transport and electrical properties of porous media are of major interest (but not limited) to the geophysics community. The focus of our work is the characterization of fractured rocks using micro-focused X-ray computed tomography (XRCT). Some of the advantages of using this method are that the cost and time are reduced to find the effective properties of rocks. The calculations and characterization techniques can readily be used in other scientific fields like medicine, biology and engineering.

The geometric properties of the fractures in the samples are the aperture, tortuosity, orientation, density (number of fractures per volume unit) and interconnection. In the effective medium scale, these microstructure parameters directly affects the effective measurable properties of the rocks [3, 4].

Some of the challenges present in the study of fractured media resides in the complex multi-scale problem inherent nature of crack initiation and propagation. Challenges also arise in the coupling of physical phenomena (e.g. the deformation of a fluid saturated rock can induce a fluid flow within pores and the pressure elevation also induces a consolidation problem in which fluid flows into the smaller pores in the solid matrix). The combination of in situ experiments in the XRCT system allows us the capture both multiphysics and multiscale phenomena.

2. EXPERIMENTAL METHOD

The first type of samples studied are borosilicate cylindrical rods which are thermally cracked following the sample preparation in [1]. The micro-cracks created in the samples have often an aperture smaller than the maximum resolution of the XRCT system. This makes the segmentation of the cracks not possible. To counter this problem, two additional steps are done in order to enhance the visibility of the cracks. Using an X-ray transparent triaxial cell [2], the pore pressure of the fractures is raised and the apperture of the cracks is visible in some places of the aperture. Furthermore, the porespace of the rock samples are saturated with water with a 1 mol concentration of potassium iodide. The contrast agent added to the water does not react with the borosilicate glass and it creates a high contrast ratio between glass and the porespace.

The second type of samples studied are fractured rocks which have resolvable cracks (aperture larger than the XRCT system's resolution). From this large cracks, smaller cracks are produced which still plays an important role in some of the effective properties of rock. Usually, these smaller cracks are not possible to differentiate from the solid phase due to their small aperture. For this case, the samples are left for a variable time in a 1 mol solution of water and potassium iodide. When the samples are partially saturated with the solution in it's microstructure, a scan is performed. The different saturation times play a role in the size of cracks that can be resolved. If the sample is completely saturated, the smaller samples are again unresolvable.

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3. RESULTS

For the cylindrical borosilicate rods, it is important to notice that the aperture measured after the segmetation process is much higher than the real fracture aperture. Nevertheless, the crack orientation and interconnectivity were measured. These parameters were later compared with the experimental values in the literature and the in situ results of the experiments.

The samples with fractures that have different aperture sizes were studied using the mentioned method. In figure 1a, it is possible to see that part of the fractures could be segmented. The 3-dimensional information is difficult to segment, since the fracture is not visible in several contiguous slices. Here, some fluid flow mechanisms were still possible to calculate from the measured microstructural geometry.

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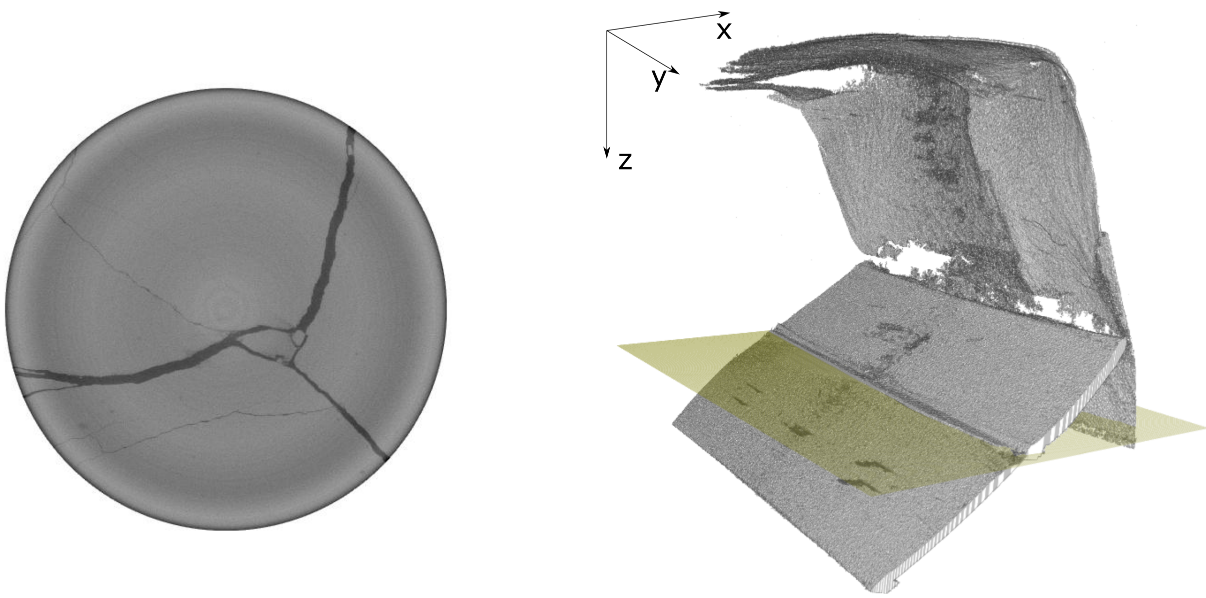

(a) (b)

Figure 1: (a) Limestone sample of 30mm diameter subjected to a 3 point bending experiment. This cross section view is the point where the inner load is applied. (b) Sandstone of 50mm diameter with an artificial initial defect and an experimentally produced wing-crack. The sample is in a confining pressure in the x-y plane and a compressive load is applied in the z direction.