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Full-field Characterisation of Strain and Damage in Porous Granular Rocks

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1. Overview

The primary objective of this work is to measure simultaneously in a full-field sense, the evolution of grain/cement strains (at different scales), elastic properties and damage in granular (clastic) rocks. This will be accomplished by combining certain advanced "full-field" experimental measurement approaches (Digital Image Correlation <DIC>, Ultrasonic Tomography, Neutron Diffraction and X-Ray Tomography and Diffraction) that will be used during mechanical loading of both real and artificial rocks (quartz rich sandstones and grains & cement, respectively), under plane strain conditions. The experimental data will then be exploited to develop and calibrate a continuum model that incorporates grain scale processes of (localised) strain, degradation and associated evolution of mechanical properties (pre- and post-failure).

2. General Experimental Approach

The mechanical loading of the samples for all the types of the experiments will be realised in a prototype device that is being designed for the purposes of this project (Section 4).

By the use of the full-field experimental techniques, either individually or in combination, new data on the mechanical evolution of granular rocks under load will be acquired. More specifically, the standard macro-scale measurements will be enhanced by the full-field measurements that are listed in Figure 1.

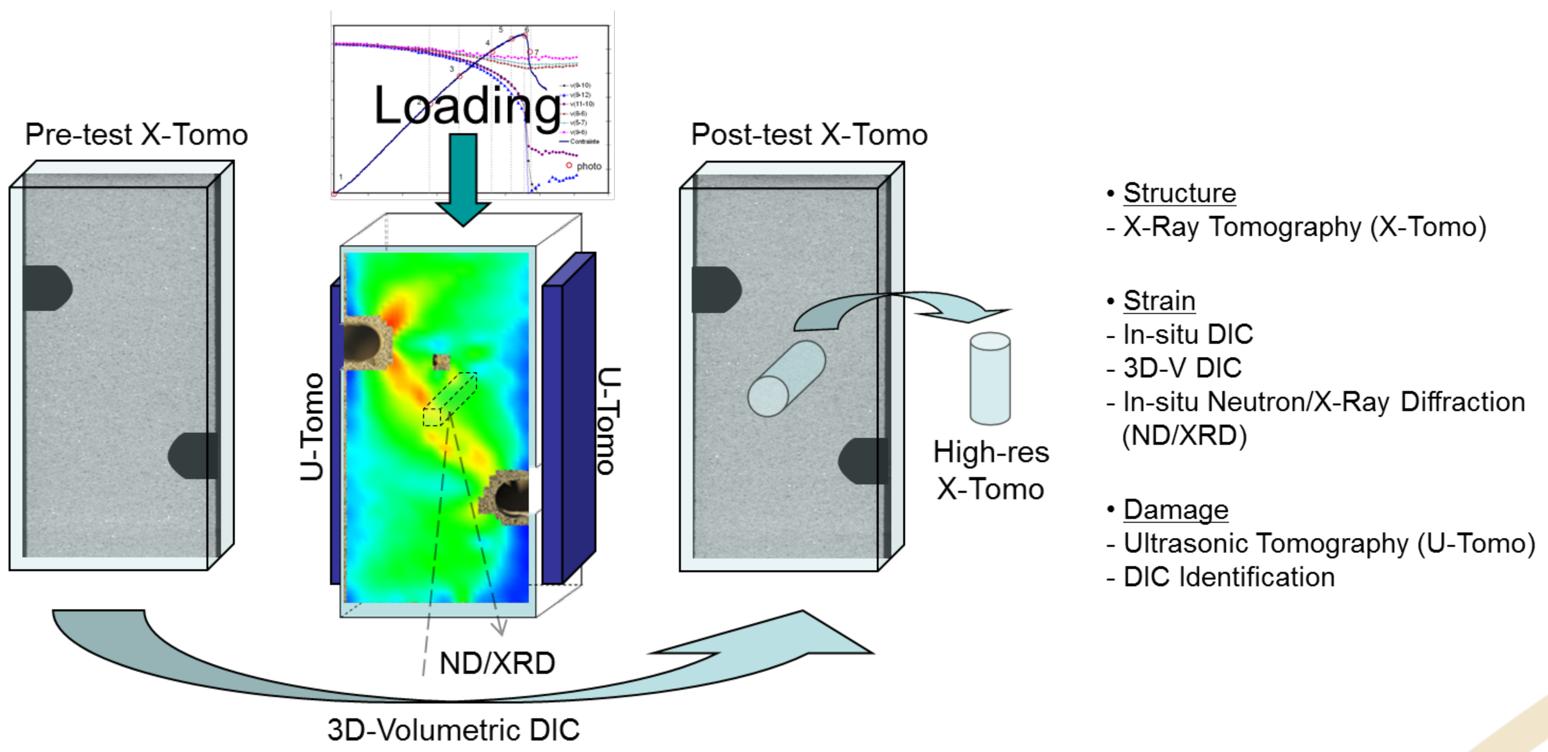
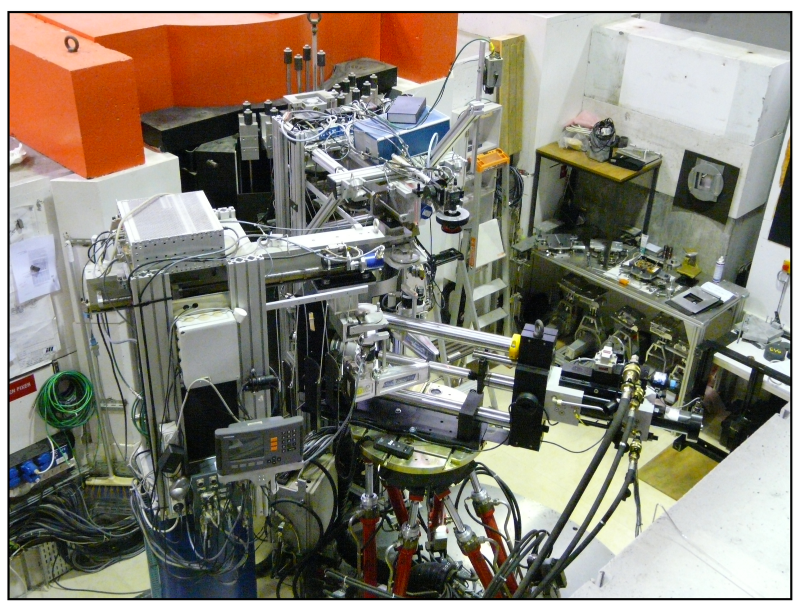


Figure 1. Schematic of the experimental set up and the full-field measurements to be used.

3. Combining Neutron Diffraction-based Experiments with Ultrasonic Tomography and DIC

Neutron Diffraction-based full-field strain scanning measurements, over gauge volumes (that include grains and cement) will be realised in a set up similar to Figure 2, using the device outline in Figure 4. The set up that will be actually used (ENGIN-X at ISIS) provides the opportunity of measuring simultaneously two directions of strain (Fig.3).

The ND scannings will be eventually realised simultaneously with DIC and U-Tomo (Fig.3) in order to aid in the better understanding of the source of ultrasonic velocity variations with loading and of the exact mechanisms that cause strain.



* Hall et al., 2011, Granular Matter, 13, 251-254

Figure 2. Neutron instrument SALSA at ILL.

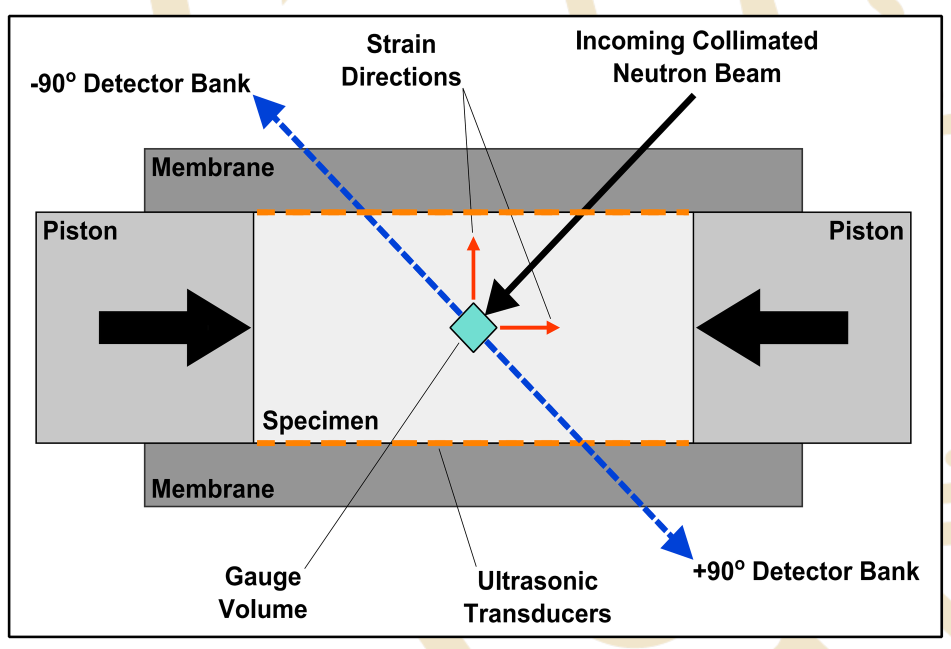


Figure 3. Schematic of the setup of the Neutron Diffraction & Ultrasonic Tomography experiments to be realised.

4. Prototype Device

The prototype device that is currently under design (Fig.4) had to meet certain criteria for each one of the techniques. Some of the most significant parameters that have been taken into account are listed below:

General Features

- Sapphire Glasses and membranes to accomplish plane strain conditions.
- Membranes that act like pressure bags (high tensile strength & elongation ratio).

Ultrasonic Tomography & DIC Features

- Realisation of DIC through the front sapphire glass
- Prototype, "flexible" ultrasonic transducers that can fit between the specimen and the membranes

Neutron Diffraction Features (Low percentage of Hydrogen)

- The main body is built out of Aluminum.
- The membranes that act like pressure bags are made out of fluoro-polymer.
- The pressure liquid in the membranes will either be fluorinert or heavy water.

Neutron/X-Ray Diffraction Features ("Clear path" for the rays)

- The walls are designed to be as thin as possible.
- The liquid/air tubes are set to be out of the scanning plane.

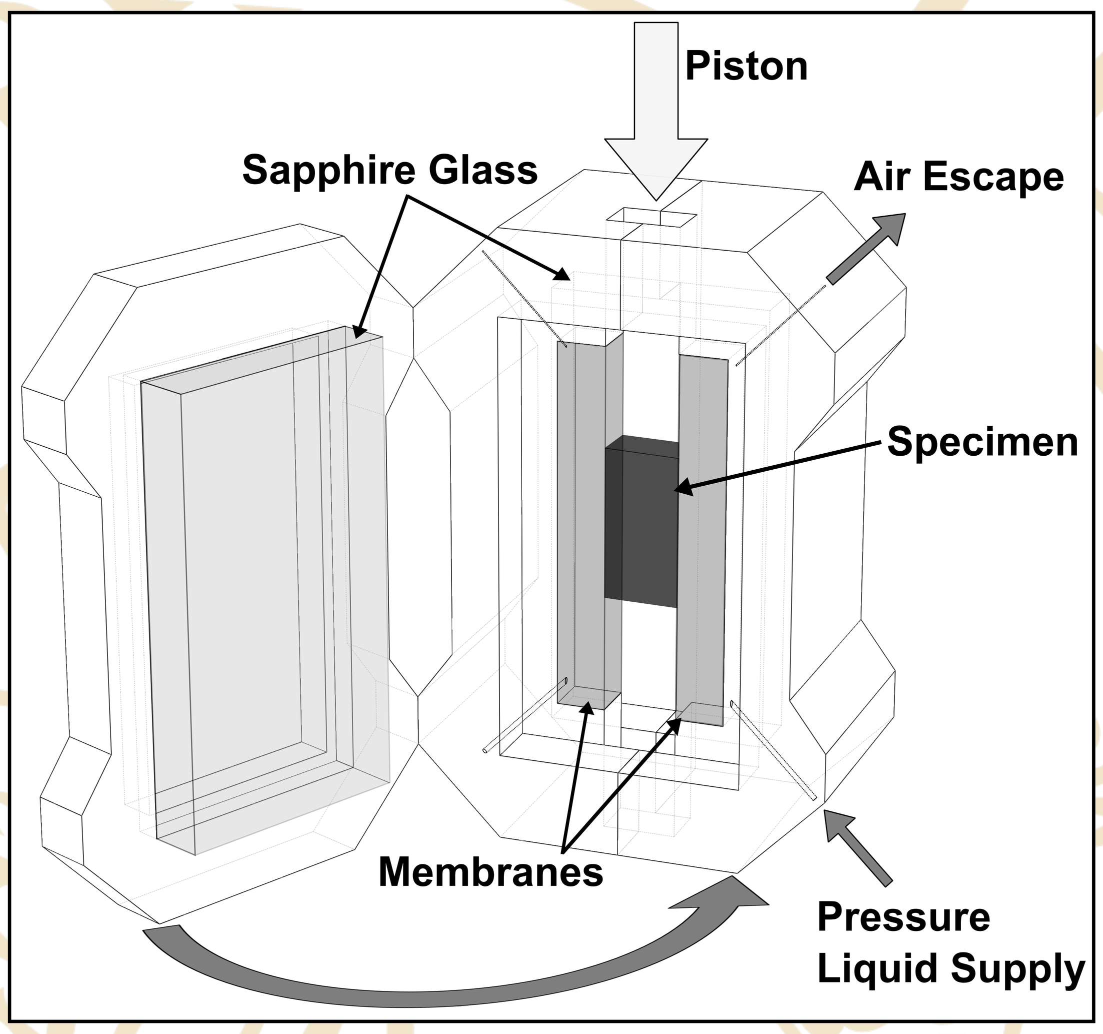


Figure 4. Schematic of the under design prototype plane strain device.

5. Goals and Future Work

After the experimental device is built, a set of test experiments will take place. Due to the fact that the technique of ND has the strongest demands as far as the design details of the device are concerned, it will be the first one to be tested on it. Once the goals of using it individually are accomplished and possible alterations are made to the device, U-Tomo and DIC will be tested in combination with ND.

As far as the significance of this project to the research area is concerned, it aims to contribute to it in three different ways:

- To provide advances to experimental (geo)mechanics methods (using full-field methods, both individually and in combination).
- To deliver new knowledge on the deformation phenomena in cemented granular rocks.
- To enable advances in theoretical modelling and numerical simulation tools through multi-modal-full-field data calibration.