FROM IMAGING TO PREDICTION OF CARBONATE SAND BEHAVIOUR

Sadegh Nadimi[*1], Deqiong Kong[†1] & Joana Fonseca[‡1]

[1]City, University of London, London, UK

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Summary: The mechanical response of shelly carbonate sand differs significantly from that of more common silica sand and is yet poorly understood. A series of one-dimensional compression tests was performed on this material inside an x-ray scanner and high resolution computed tomography (μCT) images were used to investigate the evolution of the internal microstructure. In addition, numerical simulations were carried out using a newly developed micro Finite Element (μFE) [1]. The capability of the numerical model to measure the stress within a grain with complex morphology is demonstrated here.

1. INTRODUCTION

Highly conservative methods are commonly used in the design of soil-structure interaction on shelly carbonate soils. Understanding the mechanical behaviour of this material is of great importance for the development of offshore structures (e.g. foundations, pipelines). In particular, understanding the physical phenomena taking place at the microscale has the potential to spur the development of robust computational methods to improve current design approaches. This paper focuses on the experimental and numerical work carried on shelly sand, whereas grain kinematics and intra-granular strains and stresses can be analysed.

2. EXPERIMENTS

The in-situ one dimensional compression tests were performed at the Research Centre at Harwell (RCaH), UK. Two carbonate sands from the Persian Gulf [2], one coarse (median grain size, d_{50}= 2100 μm) and another fine graded (d_{50}=400 μm) were investigated, under both dry and wet conditions (four combinations). The set-up, specially designed for this study, was mounted on the rotating table of the scanner (Figs 1a and 1b). The vertical force was exerted by a micrometre with axial loading capacity of 450 N. The applied force was monitored by a low profile 'pancake type' load cell with 500 N capacity. The sample container was made of Perspex with a 2 mm thickness and had less than 3μm deflection under the maximum loading force. Friction was avoided by including a 1 mm gap between the container and the x-ray window. The soil samples were 13.5 mm in diameter, with aspect ratios (height/diameter) varying from 1.0 to 1.1. The x-ray tomography data was acquired on a Nikon XTH 225 ST machine, operating at an accelerating voltage of 90 kV and 110 kV for the coarse and fine samples, respectively. A total of 3142 projections were collected per scan, with an exposure of 500ms per projection. The spatial resolution of the 3D images was 9.5μm. Five scans were acquired per loading test. A slice through the 3D image of the coarse sample is shown in Fig. 1c.

3. SIMULATIONS & RESULTS

Prior to the numerical simulations, the 3D images were segmented using an adaptive watershed segmentation method developed by Kong & Fonseca [3]. Each individual grain in the image could thus be identified and subsequently meshed in order to create a virtual sample. These data constitute the input for the μFE model, which enables the numerical simulations to be carried out under various loading conditions. Thus far, only single grain testes have been done. Fig. 1d shows a virtualised grain, which was loaded between two flat platens. An important feature of this model is the ability to compute the map of stress distribution inside each grain as shown

* e-mail: sadegh.nadimi-shahraki@city.ac.uk
† e-mail: deqiong.kong@city.ac.uk
‡ e-mail: joana.fonseca.1@city.ac.uk

in the cut view presented in Fig. 1e. Future work will focus on the numerical simulation of the whole assembly under one-dimensional compression to capture the behaviour observed in the experimental tests.

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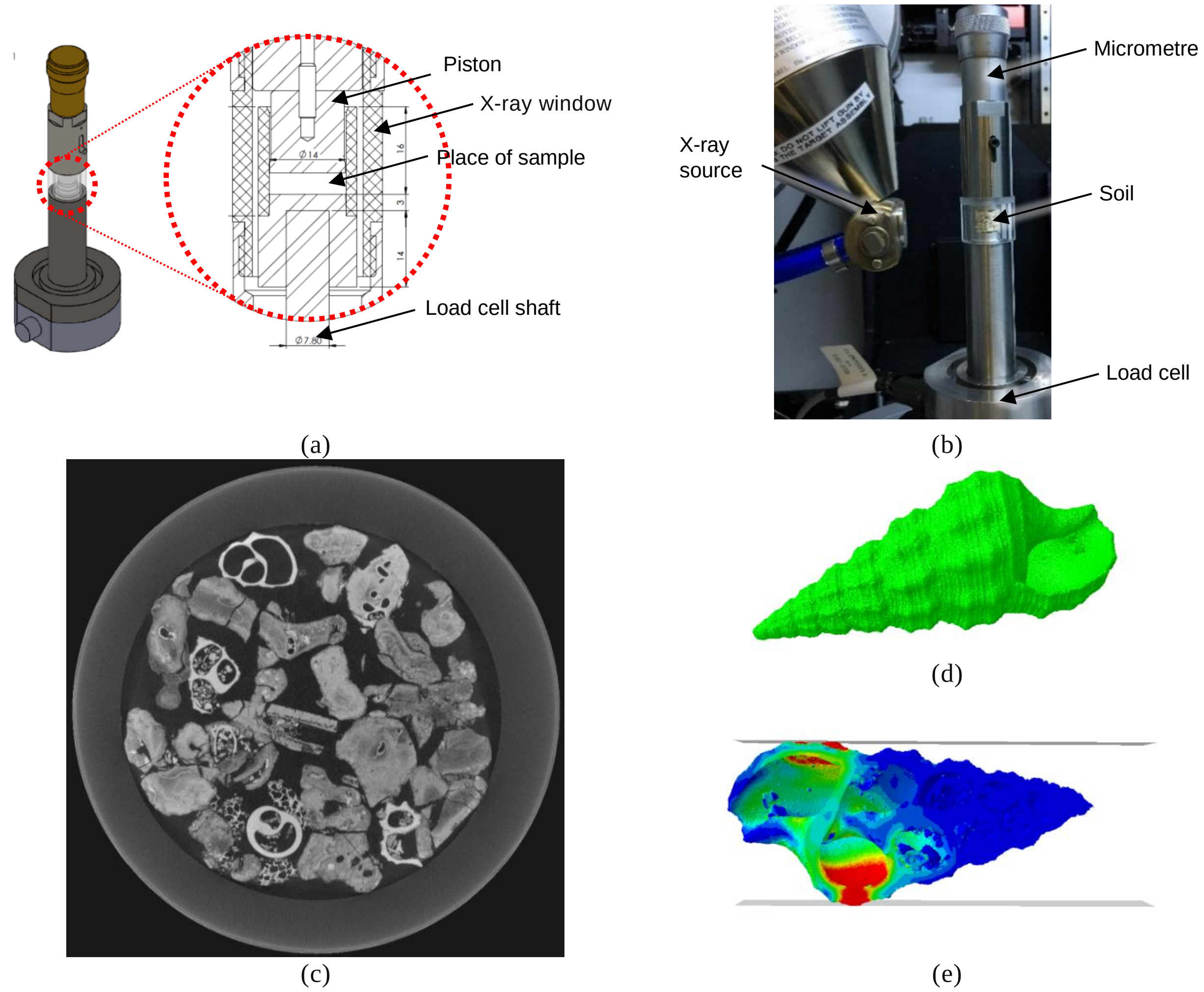

Figure 1: a) Schematics of the loading apparatus; b) x-ray source gun and soil sample; c) slice through the 3D image of the dry coarse sample; d) 3D model of a single grain; e) intra-granular stress distribution for a single grain compressed between two flat platens (cut view).