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# *Grain crushing in a porous granular material studied by X-ray tomography*

Giulia Guida*[1], Edward Andò†[2], Francesca Casini[3], Gioacchino Viggiani[2], and Giulia M.B. Viggiani[3]

[1]University "Niccolò Cusano", via Don Carlo Gnocchi 3, Roma 00166, Italy
[2]Univ. Grenoble Alpes, CNRS, Grenoble INP, Institute of Engineering Univ. Grenoble Alpes, 3SR, F-38000 Grenoble, France
[3]Dipartimento di Ingegneria Civile e Ingegneria Informatica, Università degli Studi di Roma Tor Vergata, Rome, Italy

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**Summary:** this work presents some results of an experimental programme consisting in oedometer tests on an artificial granular material made of crushed expanded clay pellets. The tests are sperformed *in-situ* inside an x-ray micro-tomography setup, in order to study the particle breakage. 3D images at 10 different levels of stress are analysed to characterize the material and to study the evolution and the micro-mechanics of grain crushing.

## 1. Introduction

Loading of geotechnical structures may result in particle breakage of the constituent granular materials when the stress imposed on the particles exceeds their strength. Significant amounts of crushing are observed in nature in faults and glacial deposits, characterized by high stress concentrations along particular planes and internal instability are consequential. However, systematic experimental investigation of grain crushing for natural materials is often difficult due to the relatively high stress required to crush the grains and the variability and heterogeneity of natural deposits, which makes it difficult to obtain repeatable results. For these reasons the experimental work has been carried out on an artificial granular material consisting of crushed expanded clay pellets, whose grains break at relatively low stress, under one-dimensional loading. This artificial material, commercially available for civil engineering applications under the acronym LECA (Light Expanded Clay Aggregate), is characterized by a very low unit weight due to the presence of a second order of porosity inside the grains, that makes it lighter and more crushable [1, 2]. The tests have been performed using x-ray micro-tomography setup in Laboratoire 3SR in Grenoble. This represents a powerful tool in geomechanics due to its ability to acquire images with a resolution of tens of microns allowing the grain-scale to be accessed, and the grain crushing to be characterised at this scale. In this work the particle breakage phenomena will be studied through the technique of particle tracking using Digital Image Correlation.

## 2. Mechanical Experiments

A one dimensional compression test was performed inside the tomography apparatus in order to make scans of the sample, at 10 different levels of vertical stress up to 36 MPa, and to observe the internal evolution of the granular configuration and of the breakage phenomena. The sample is composed of 1g of LECA particles with sizes ranging from 1,19 mm to 1,7 mm, inside an oedometer with diameter of 15 mm, made of PEEK (Fig. 1 (a)), that facilitates x-ray imaging. At the end of each loading step the loading system is stopped, and the sample is scanned. Such a test results in mechanical data throughout loading (forces and displacements) but also the series of 3D images acquired at the different stress levels. Fig. 1(b) shows the compressibility curve, defined in the semi-logarithmic plane vertical stress  void ratio. Fig. 1 (c), (d), (e) report the vertical slice images corresponding to three specific stages of the test: the initial configuration, in which no load is applied,

*giulia.guida@unicusano.it
†edward.ando@3sr-grenoble.fr

the yield stress, at which the phenomenon of breakage starts, and the final step in which the maximum stress is reached and a large amount of finer is created.

## 3. Quantitative Image Analysis

The analysis aims to make two principal measurements:

1. Accurate image segmentation of the initial step to study the physical properties of the grains, such as dimension, morphology, distribution of the intra - pores size, *etc.* and to investigate the initial particles configuration through an analysis of the neighbors and of the contacts with the surrounding particles, in order to understand why some of the particles survive at high stress.

2. Tracking of particles through different stress levels in order to follow the evolution of breakage. Starting from the objects segmented on initial image, the particles are recognized at the following stress step levels trough an Digital Image Correlation. The particles crushed may be detected imposing a threshold to the correlation coefficient (CC) Furthermore all the fragments of the broken particle may be detected around the last position that their parent particle occupied.

## References

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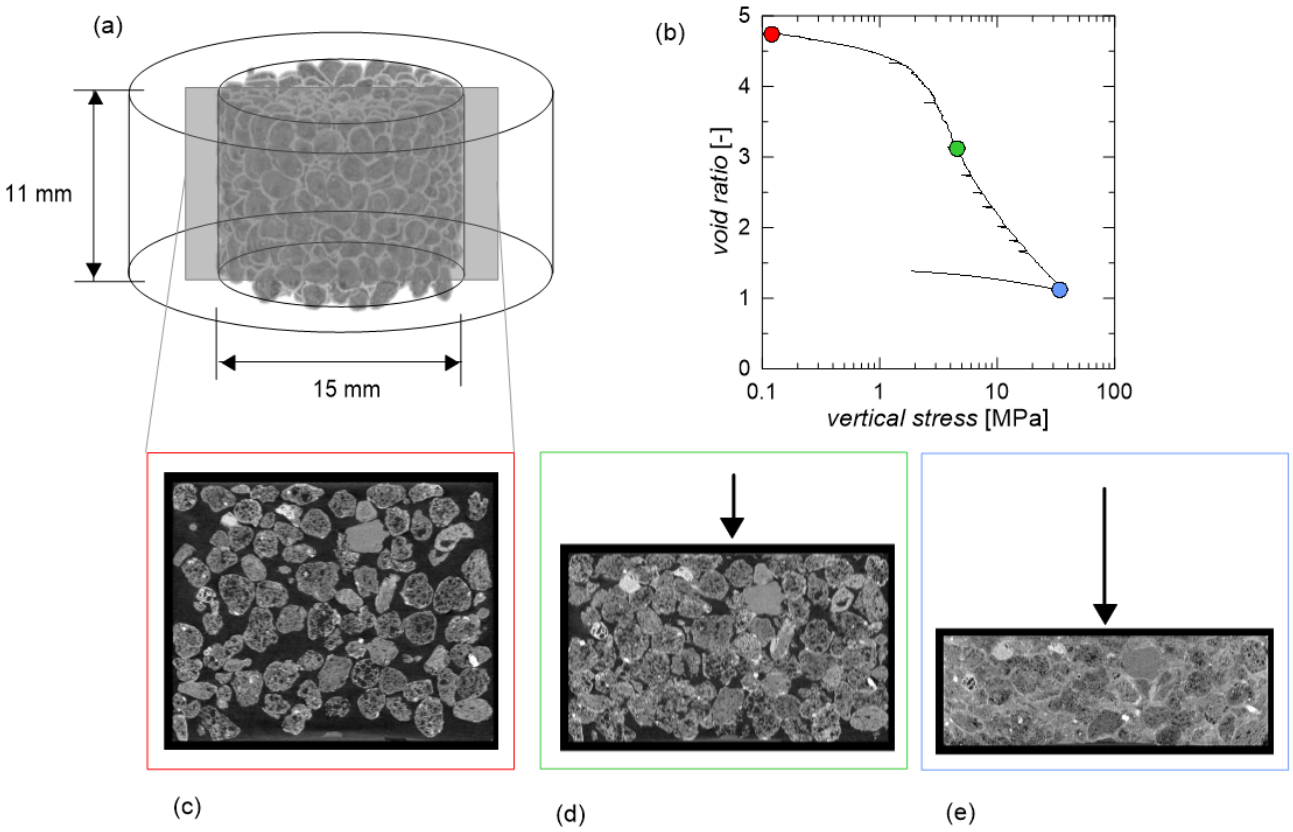


**Figure 1:** (a) 3D image of LECA sample. (b) Compressibility curve. (c), (d), (e) Vertical sample slices images at different load steps: 0.1 MPa, 4.5 MPa and 36.0 MPa, respectively..