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# VIRTUAL TESTING AND COMPUTATIONAL HOMOGENIZATION OF GEOMATERIALS

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## ABSTRACT

Geomaterials such as sands, clay, rock, and concrete are involved in a very large number of engineering applications (geotechnical, structural, petroleum, environmental, etc) and have for this reason been the subject of much research. Common to all geomaterials is their porous structure comprising a solid (often called the matrix) permeated by a network of pores which may be filled with a fluid (liquid or gas). The properties of interest usually revolve around their response to mechanical loading and their ability to conduct fluids. Other important aspects include heat conduction, wave propagation and the diffusion of various substances through the pore network.

The traditional approach to the modeling of geo- and other porous materials is to replace the actual inhomogeneous material by an equivalent homogeneous one. The material parameters that define the effective constitutive model are then determined experimentally. Alternatively, it is in principle possible to derive the effective material parameters on the basis of the properties of the individual phases and the morphology (shape and structure) of the material. Obviously, the motivation for this fictitious porous medium approach above is that the actual morphology of most materials traditionally has been very difficult to assess. Moreover, in cases where detailed information has been available, the adequate processing of this information has been hampered by limited computational resources. In recent years, however, significant developments on both fronts have made it feasible to, first of all, obtain detailed information about the microstructure of a given material and, secondly, to use this information to solve the relevant large-scale problems necessary to derive effective material properties of interest. The first component is addressed by micro-computed tomography (micro-CT) which has now evolved to an extent where 3D digital images with a resolution of 1 μm or less can be readily obtained. The second component, which we will refer to as *Virtual Testing*, makes use of state-of-the-art numerical methods and grid computing tools. By combining these technologies it is envisioned that a range of important engineering properties of *real* materials can be determined non-destructively in a fraction of the time and for a fraction of the cost of the alternative physical experiments. Moreover, valuable information about the variability of the effective properties is obtained as a natural part of the process. In the paper a number of new methodologies for extracting effective

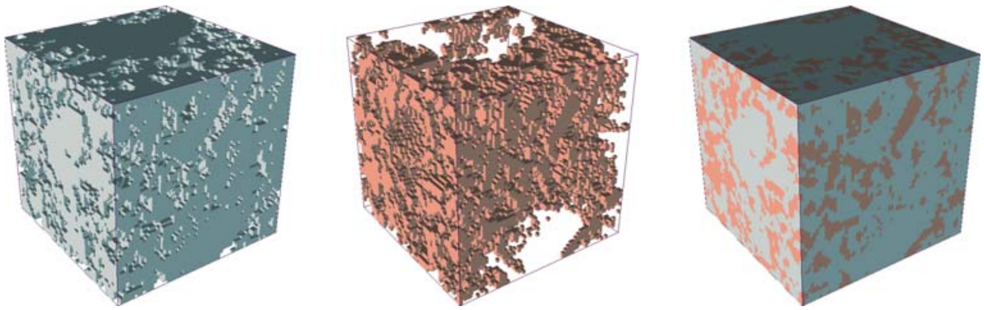

**Figure 1: Three-dimensional reconstruction of the cement paste: solid phase (left), pore space (center), and combined solid/pore phases (right). The volumes consist of $64^3$ = 262,144 voxels, each of which is represented by an 8-node finite element.**

properties of interest are presented along with application examples involving common porous materials such as cement pastes, sands, and sandstones.

Secondly, we consider the application of the framework to the problem of copper ore agglomeration. The efficient extraction of valuable metals from mined ore can be considered as a problem of global concern as the world's reserves of such metals quickly diminish. For low grade copper ore, heap leaching has long been recognized as the most efficient mineral recovery procedure. By applying X-ray microtomography and micromechanical modelling to quantify the critical leaching properties of ore agglomerates, optimal heap leaching strategies can be formulated.

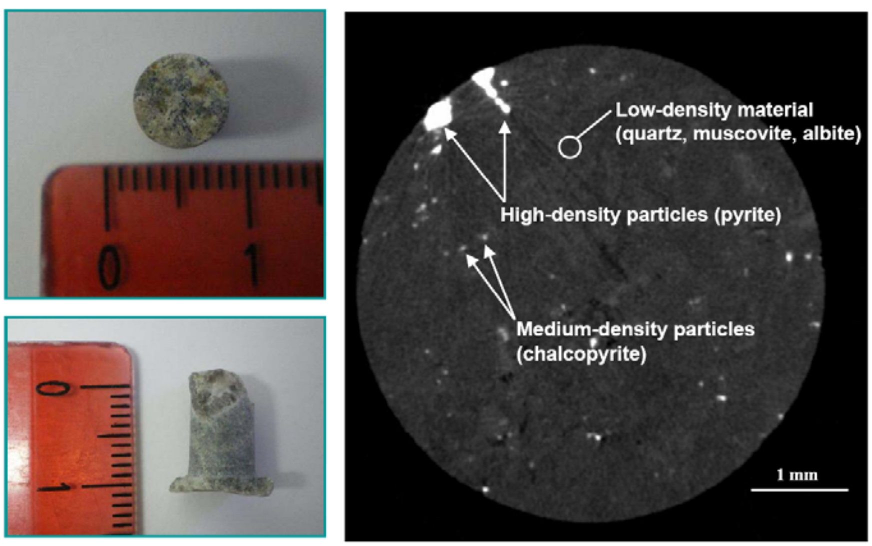


**Figure 2: Copper ore agglomerate cores and cross section from XMT (after Karipidis 2007).**

## REFERENCES

[1] Karipidis, T (2007). Analysis of mineral characteristics and porosity during chalcopyrite heap leaching using micro-CT, Technical Report, BHP Billiton/University of Sydney.

[2] Krabbenhoft K, Hain M, Wriggers P (2007). Computation of effective cement paste diffusivities from microtomographic images, In: Kompis V (ed): Composites with Micro-and Nano-Structure, Springer-Verlag.