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Multi-scale 3D pore network characterization of building materials

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Three-dimensional (3D) analyses of the pore structure of building materials are becoming progressively more important in recent years in order to get more accurate interpretations and simulations of moisture and heat transfer properties. These characteristics are a major determinant for the durability and sustainability of structures as well as for the health and comfort of the building occupants. Building materials are characterized by a large variety in pore radii (e.g., nanometer to millimeter scale) that influence these characteristics. The problem of constructing a pore level model at the representative scale, must be solved by including information from each length scale of this multi-scale system.
Two different imaging techniques are used to visualize the pore structure at different scales. On a micrometer scale computed tomography (CT) has proven to be an excellent and versatile tool to perform these analyses non-destructively. To visualize even smaller pore structures of building materials on the nanoscale, scanning electron microscopy combined with focused ion beam (FIB-SEM) is used. Post processing of the 2 dimensional FIB-SEM images results in a reconstruction of the 3D pore space. Both techniques allow calculating relevant parameters such as pore size, shape and orientation in 3D. Additionally, the pore network is also indirectly characterized by mercury intrusion porosimetry (MIP), resulting in a validation of the results of the direct imaging techniques with a multi scale MIP analysis.
Moreover, building materials are often non-granular in nature, resulting in pore networks comprising of complex pore shapes. Hence, these materials are ideal test cases for pore-shape analysis. We will look at different shape descriptors using the ratios of the longest, intermediate, shortest dimensions and compactness of the pore shapes, based on an approximating ellipsoid, in order to obtain a thorough and objective description of pore shapes as well as their orientation.
Also the study of the Representative Elementary Volume (REV) of these different parameters is nessecary to assess the quality of the model. Because the used datasets transient different length scales, the results of the REV analysis will be compared to the observations of Norris et al. (1991) and Nordahl and Ringrose (2008) for geological samples. They both suggested the existence of different REV sizes at different scales which has major implications when determining a relevant upscaling strategy.

References:
Nordahl, K. & Ringrose, P. S. 2008. Identifying the Representative Elementary Volume for permeability in heterolithic deposits using numerical rock models. Mathematical Geosciences, 40, 753-771.
Norris, R., Lewis, J. & Heriot-Watt, U. 1991. The geological modeling of effective permeability in complex heterolithic facies. Paper SPE 22692 presented at the 66th Annual SPE Technical Conference and Exhibition, Dallas, TX, 1991. 6-9.

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