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# Phase segmentation of concrete x-ray tomographic images at meso-scale: validation with neutron tomography

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**Abstract**

This work makes the link between the experimental technique of x-ray tomography and the reliable representation of the heterogeneities of a cementitious material at the meso-scale (aggregates, mortar matrix and macro-porosity). An image analysis procedure and its validation are presented. Images coming from x-rays scans are treated to finally obtain a trinary 3D image, where each phase of the material's meso-structure is separated. The separation of the aggregates from the mortar matrix is the technical challenge, due to the physics of x-ray interaction with matter, addressed on this work. Validation of the proposed method is made by comparing the grain size distribution curves computed from images of the same set of aggregates coming from x-rays and neutron scans. The reliably obtained morphology can be used as a basis for direct physical simulations, as well as data to improve morphological models of any type.

*Keywords:* x-ray tomography, neutron tomography, cementitious materials, concrete, aggregates, porosity, morphological description, image analysis tools, phase segmentation

## 1. Introduction

At centimeter (meso-) scale, concrete can be considered as a three-phase geomaterial constituted of aggregates and macro-pores (entrapped air porosity) embedded within a mortar matrix. The mechanical behaviour of concrete is the result of the mechanical and morphological properties of these three components and their interfaces ([1], [20], [8]). At the meso-scale, aggregates and macro-pores define a key scale of interest for percolating cracks that greatly increase permeability (and therefore degradation), as well as macro-failure. Therefore, in recent years, numerical models that explicitly represent the meso-scale have been developed.

One important part of these models is the morphological description of the phases. The most common approach is the use of morphological models (for example, packing of ideal geometrical objects such as spheres ([6], [16], [2], [18]) or excursions of correlated Random Fields [12]) to generate morphologies that can then be used for multi-physics simulation. These approaches currently face problems regarding the representativeness of the generated morphology, which has dire consequences on the physical response of the model. Often, a volume fraction can be targeted, but global descriptors such as surface areas, mean curvature or topology can be very far from realistic. For this reason, this paper proposes a method for obtaining meso-morphologies from real specimens of concrete, providing a basis for direct physical simulations, as well as data to improve morphological models of any type (with a measurement of real global descriptors, for example).

Real meso-morphologies are obtained by taking advantage of recent advances in non-destructive 3D imaging (in this case x-ray and neutron tomography [11], [14], [9], [10], [4], [15], combined with image analysis. Isolating phases from an x-ray image is challenging when phases have similar x-ray attenuation coefficients. This unfortunately happens to be the case of concrete's meso-structure (aggregates embedded into mortar matrix) adding considerable

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