Mechanical Strength Simulation of Concrete Samples Using COMSOL Multiphysics® Software with 3D Mesh Generated By Industrial Tomography System

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Abstract

Analysis of concrete structures is usually carry out by destructive methods. The internal volume flaws directly influence the concrete properties. Such inclusions are empty or even resulting from manufacture process or degradation by percolation leaching, dissolution and chemical reactions between its constituent. Industrial tomography system (ITS), has proven to be a powerful tool for analyzing and determining the internal volume of the objects. In this context, this work aims to show that it is possible to generate representative triangular meshes from real samples of concrete from data obtained with 3D ITS and use them to simulate mechanical properties. The results of these simulations can be used to compare them with the results of mechanical strength obtained in the laboratory. Thus, the acquisition of 3D tomography of a sample of concrete cylindrical with dimensions of 10 cm by 5 cm diameter using the ITS from Institutos Lactec in Curitiba (Figure 1) was performed. Then, data preprocessing was carried out from STL data scanner software in MeshLab Open Software (Figure 2). The preprocessing was required to reduce the set of data that make possible the simulation, but without losing the mechanical and morphological properties of the concrete sample. The studies were applied to COMSOL Multiphysics® software equivalent to laboratory compression tests of concrete samples. These samples have, in addition to concrete, aggregates and as rock and sand are taken from varying depths, with different states of compression, so that when tested to provide information on the state of the dam. Simulation consisted in keeping the base fixed of sample cylindrical and apply compressive force distributed over the entire area of the top of the cylinder. This happens until there is a rupture of the sample. In actual tests, it is possible see that the breaks occur in regions of interface between concrete and aggregate, indicating that these are the weakest points of the sample. In mechanical simulations using COMSOL was possible to verify that the interface regions have higher concentrations of stress (Figure 3). Figures 3 and 4 show the results obtained for the concrete sample studied. Due to limitations in computational cost, it was possible to reduce the number of granites. In this work only cement and 4 granite was defined to simulation. Figure 3 shows the distortion map due to the applied load and the

distribution of stresses applied to the sample. The computer simulation of the concrete behavior subjected to mechanical stress enables the prediction of catastrophic events in the dams, reducing laboratory costs and reducing the time trials. The results obtained here are not definitive, but may be the considered for future studies if performed procedures with mesh data from 3D tomography and simulation using finite elements that allow process all sample data and compare them with mechanical tests laboratory.

Reference

Erdem Coleri and John T. Harvey, A fully heterogeneous viscoelastic finite element model for full-scale accelerated pavement testing, Construction and Building Materials, vol.43, p. 14-30(2013).

Erdem Coleri et al., Development of a micromechanical finite element model from computed tomography images for shear modulus simulation of asphalt mixtures,Construction and Building Materials, v.30,p. 783-793 (2012).

Roberto Mendes et al., Determination of crushed stone volume in concrete cores from hydroelectric power plant dams by three-dimensional tomography, Insight (Northampton), v. 51, p. 654-659 (2009).

Roberto Mendes, A Tomografia Computadorizada de Raios X como Método Não Destrutivo de Análise Volumétrica de Concreto: Estudo de Caso em Testemunho de Concreto da Usina Hidrelétrica Mourão, Dissertação de Mestrado, Universidade Federal do Paraná, Curitiba, 2010 (in Portuguese).

Rosimery C Fagundes et al., Simulation of Electric Field Distribution in Polymeric Insulators. In: COMPUMAG, 2009, Florianópolis. Proceedings of the 17th Conference on the Computation of Eletromagnetic Fields, p. 875-876(2009).

Sebastião J Ribeiro et al., Analysis of dielectric breakdown in power cables using 2D and 3D tomography. Insight (Northampton), v. 53, p. 557-561 (2011).

Thomas de Larrarda et al.,Influence of aggregate shapes on drying and carbonation phenomena in 3D concrete numerical samples, Computational Materials Science
Vol. 72, p. 1–14(2013).

W.C. Godoi et al., Volume and surface measurements of flaws in polymeric insulators using X-ray computed tomography, Insight (Northampton), v. 50, p. 554-559 (2008).
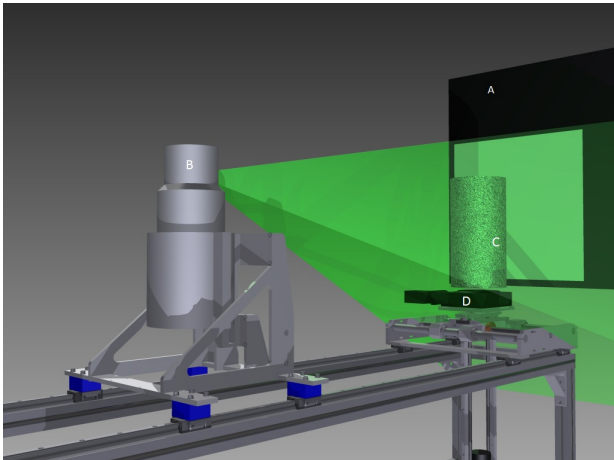
Figures used in the abstract

Figure 1: Illustrative of the industrial tomography acquisition system used for STL mesh generated shown in Figure 2: A- Flat panel (direct radiography acquisition), B- X-Ray source, C-concrete sample, D – rotatory support.
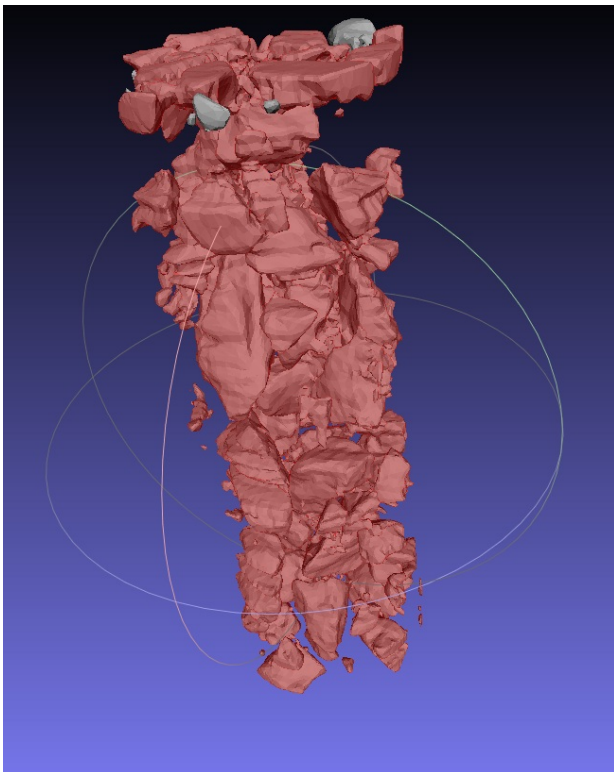

Figure 2: 3D image of the 3D mesh of concrete sample generated in the scanner software showing only the aggregates (granites) displayed on MeshLab. Pink color is the data reduction, i.e., excluding the granites were not be used in the COMSOL simulation.
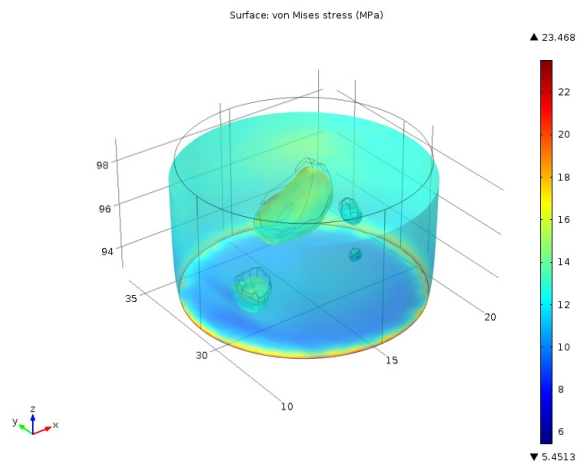
Surface: von Mises stress (MPa)

Figure 3: Mechanical Simulation using von Mises stress method from COMSOL: deformation of the concrete sample.
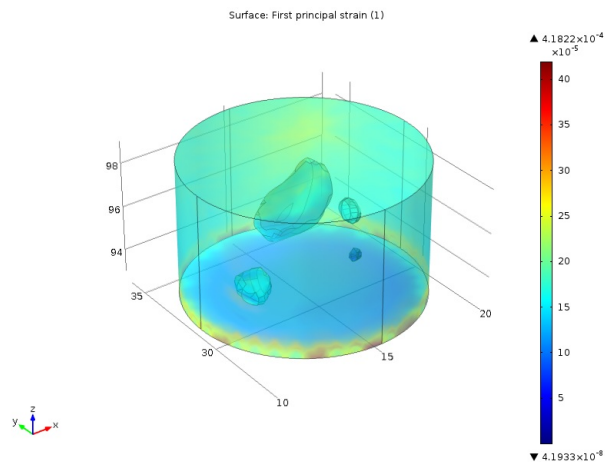

Surface: First principal strain (1)

Figure 4: Mechanical Simulation using COMSOL: distribution of stresses applied in the sample (arbitrary units) map.