World Academy of Science, Engineering and Technology
International Journal of Civil and Architectural Engineering
Vol:12, No:05, 2018

Strength Evaluation by Finite Element Analysis of Mesoscale Concrete Models Developed from CT Scan Images of Concrete Cube

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Abstract : Concrete is a non-homogeneous mix of coarse aggregates, sand, cement, air-voids and interfacial transition zone (ITZ) around aggregates. Adoption of these complex structures and material properties in numerical simulation would lead us to better understanding and design of concrete. In this work, the mesoscale model of concrete has been prepared from X-ray computerized tomography (CT) image. These images are converted into computer model and numerically simulated using commercially available finite element software. The mesoscale models are simulated under the influence of compressive displacement. The effect of shape and distribution of aggregates, continuous and discrete ITZ thickness, voids, and variation of mortar strength has been investigated. The CT scan of concrete cube consists of series of two dimensional slices. Total 49 slices are obtained from a cube of 150mm and the interval of slices comes approximately 3mm. In CT scan images, the same cube can be CT scanned in a non-destructive manner and later the compression test can be carried out in a universal testing machine (UTM) for finding its strength. The image processing and extraction of mortar and aggregates from CT scan slices are performed by programming in Python. The digital colour image consists of red, green and blue (RGB) pixels. The conversion of RGB image to black and white image (BW) is carried out, and identification of mesoscale constituents is made by putting value between 0-255. The pixel matrix is created for modeling of mortar, aggregates, and ITZ. Pixels are normalized to 0-9 scale considering the relative strength. Here, zero is assigned to voids, 4-6 for mortar and 7-9 for aggregates. The value between 1-3 identifies boundary between aggregates and mortar. In the next step, triangular and quadrilateral elements for plane stress and plane strain models are generated depending on option given. Properties of materials, boundary conditions, and analysis scheme are specified in this module. The responses like displacement, stresses, and damages are evaluated by ABAQUS importing the input file. This simulation evaluates compressive strengths of 49 slices of the cube. The model is meshed with more than sixty thousand elements. The effect of shape and distribution of aggregates, inclusion of voids and variation of thickness of ITZ layer with relation to load carrying capacity, stress-strain response and strain localizations of concrete have been studied. The plane strain condition carried more load than plane stress condition due to confinement. The CT scan technique can be used to get slices from concrete cores taken from the actual structure, and the digital image processing can be used for finding the shape and contents of aggregates in concrete. This may be further compared with test results of concrete cores and can be used as an important tool for strength evaluation of concrete.

Keywords : concrete, image processing, plane strain, interfacial transition zone
Conference Title : ICCEA 2018 : International Conference on Civil Engineering and Architecture
Conference Location : Berlin, Germany
Conference Dates : May 21-22, 2018