15th World Congress on Computational Mechanics (WCCM-XV)
8th Asian Pacific Congress on Computational Mechanics (APCOM-VIII)
31 July – 5 August 2022, Yokohama, Japan

Assessment of Macro and Micro level Heterogeneities for Characterizing Mechanical Behavior of Sand in Biaxial Test employing DEM

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Key Words: *Macro and micro level, Heterogeneity, Biaxial test, Representative volume element (RVE), Wall-based measurement, Sand*

Discrete element method (DEM) is widely used to examine the mechanical behaviour of granular assemblies, like sand, under various loading conditions by performing numerical simulations replicating different laboratory tests. While simulating various element tests from such particle-based methods, it is often required to estimate magnitudes of field variables, such as stresses and strains, which are essentially defined based on a continuum assumption. In this regard, either a wall-based global estimation or a representative volume element (RVE)-based local assessment is often adopted. Wall-based estimation predicts an overall response of the specimen which takes into account only the particle to wall contacts. As a result, such wall-based estimation of field variables is often influenced by the boundary effects arising due to the concentration of stresses and voids around wall boundaries [1], which can be identified as a source for macro level heterogeneities. On the contrary, RVE is considered to be statistically representative of the specimen under consideration. Further, it must be large enough so that an increase in the size will not change the estimated field variables and should exclude any possible macro level heterogeneities. In addition, an RVE should not be too small such that it starts to depict micro level heterogeneities, such as the development of unrealistic localized zones of various field variables due to consideration of only limited number of particles within the RVE [2]. However, deciding the optimal extent of the RVE to avoid such macro or micro level heterogeneities requires a systematic analysis.
In the present study, biaxial test simulations are performed employing DEM with non-circular particles of realistic particle size distribution [3]. Subsequently, an analysis has been carried out to assess the influence of the aforementioned macro and micro level heterogeneities in reference to the characterization of mechanical behavior of the specimen from a chosen RVE configuration. In this regard, a series of simulations have been carried out by generating various RVE configurations with different diameter and volume coverage over the specimen. It has been observed that the wall-based estimation predicts higher stresses and unrealistically higher volumetric strain, particularly at the larger strain levels, in comparison to the RVE-based estimations. However, it is interesting to note that increasing the volume coverage of RVE can predict stresses in the range of wall-based stress estimates. In order to establish a better mechanical characterisation, it has been proposed that the RVE should evolve with the continued deformation maintaining a constant volume fraction coverage in reference to the deformed configuration of the specimen. Further, it is suggested that the RVE should occupy a maximum of 90% volume of the specimen in order to avoid any possible boundary effects and can still be able to capture its overall mechanical behavior. However, when a local variation of field variables is of interest, RVE of smaller diameters can be employed. In such cases, depending on the average particle size of the granular assembly, the diameter of the RVE should be selected ensuring that it is small enough to aptly capture the local variation of field variables and at the same time, large enough to avoid any micro level heterogeneity.

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