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Particle Placement Strategies for Lattice Discrete Particle Models

J. Vorel[1], J. Vozáb[1], M. Marcon[2], J. Podroužek[3] and R. Wan-Wendner[4]

[1]Faculty of Civil Engineering, Czech Technical University in Prague, Czech Republic
[2]Christian Doppler Laboratory LiCRoFast, Department of Civil Engineering and Natural Hazards, University of Natural Resources and Life Sciences (BOKU), Austrian University of Ostend, Belgium
[3]Faculty of Civil Engineering, Brno University of Technology, Czech Republic
[4]Laboratory for concrete research, Ghent University, Belgium

Abstract

The paper aims at characterizing the influence of particle placement and clustering in lattice discrete particle models (LDPM) on structural response. More specifically, the meso-structural features are mimicked by the proposed particle placement schemes for LDPM, which are no longer independent and random but are correlated to prescribed fields.

Keywords: Lattice Discrete Particle Model, structural response, Monte Carlo, particle placement.

1 Introduction

The Lattice Discrete Particle Model (LDPM) is well established numerical model used to simulate the behaviour of concrete structures [1] and other quasi-brittle materials, e.g. polymers. It simulates the mesostructure of material by a three-dimensional (3D) assemblage of particles generated randomly according to a given grain size distribution (Fuller curve) [2]. Therefore, the LDPM material model response is dependent on particle distribution, and thus multiple simulations are needed to provide credible results. This variability is often considered similar to experimental scatter. However, the numerical model scatter is usually much smaller than the experimentally observed. Therefore, the particle placement influence and its effect on the response scatter is investigated in the paper.

2 Methods

In this paper, the material model formulated in [1,2] is utilized to study the influence of particle placement on the model response. As already mentioned above, the material's internal structure is modelled through discrete elements to capture the fundamental aspects of heterogeneity. Essential inputs for the models are the maximum and minimum aggregate sizes which are used for the particle size generation based on the classical Fuller curve. A statistically isotropic random distribution is employed in the original formulation presented in [2]. In the first step, particles represented by spheres are generated following the defined concrete granulometric distribution. The main difference between the standard and the new procedure lies in the particle placement strategy. The particle centres are positioned throughout the specimen volume one by one (from the largest to the smallest). For the random placement strategy, the particle's position is generated before the placement, and the overlapping is controlled. If there is a conflict between the new and already positioned particles, the new position is generated. On the contrary, in the new placement strategy, the particle positions are generated first and ordered according to the intensity of the underlying field. This approach allows us to place larger particles into the preferred locations, i.e., the largest particle is placed at the position with the highest intensity.

3 Results

The numerical models of classical concrete experiments are introduced, i.e. cubes and cylinders loaded in compression and unnotched beams loaded in three-point bending. Along with simulations in which the particle generation is governed by a field (PGGF), the independent and random particle placement simulations (IRPP) were run for direct comparison. In all cases, 20 repetitions per specimen configuration were run. The results reveal only a slight change in the results and scatter compared to IRPP if the PGGF based generation is utilized.

4 Conclusions and Contributions

The presented study is the initial phase of a more extensive investigation. Modelling concepts for different sources of spatial variability in materials are being investigated, including spatially variable material property fields. In order to study the pure effects of the particle generation process governed by random or prescribed fields, the material properties have been kept constant for all of the presented analyses. Based on the presented results, the following conclusions can be drawn:

1) Directional effects, mimicking production processes (casting direction, etc.) and represented by gradient-based fields, may slightly affect both the mean values of force at peak, displacement at peak, and their respective coefficients of variation of the response;

2) Correlated spatial variability models (random fields) governing the particle generation process moderately influence the COV of the response compared to the independent and random generation of particles;

3) The investigated particle placement schemes with constant material and composition properties enhance the realism of the simulations but are insufficient to reproduce the experimental scatter.

Acknowledgements

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