CONTACT TRANSFORMATIONS IN GRANULAR ASSEMBLIES OF 2D NON-CONVEX GRAINS

Krzysztof Szarf[1]

[1]*Chair of Geotechnics, Geology and Marine Civil Engineering, Faculty of Civil and Environmental Engineering, Gdansk University of Technology, Gdansk, Poland*
e-mail: krzszarf@pg.edu.pl

1. Context of the Study

Numerical modelling of granular materials as discrete particles becomes more common, especially with increasing computational power available. The default tactic of many researchers is to increase the overall complexity of the simulation but to save on computational power by oversimplifying important aspects of the medium itself, namely the form of the particles used. Most of Discrete Element Method simulations incorporate the simplest particle shapes possible: discs in 2D and spheres in 3D. The well-known pathological effects of such assemblies (e.g. low shear resistance, small changes of volume in shearing) are remediated with various numerical features, such as additional contact laws [4, 5], restrictions on degrees of freedom [2], etc. Such approaches, however effective, can be regarded as controversial because of dubious values of the multiple numerical parameters needed.
Other simulations incorporate complex particle shapes, but without full understanding of the underlying physics. Detailed studies focused on the grain shape influence have been performed [1, 3, 7], but the problem remains open to further investigations.

2. Overview of the Study

A family of non-convex 2D particles (clumps) with three axes of symmetry was chosen to form multiple polydisperse assemblies simulated in the framework of Molecular Dynamics in PFC^{2D}. The particles, each made of three discs, were described with a single low-order shape parameter α. The samples were carefully prepared so as to ensure homogeneity of the initial assemblies in terms of contact directions, spatial distribution of porosity, distribution of the coordination number, etc. The numerical parameters of the simulations were chosen with respect to certain dimensionless characteristic numbers [6] to assure quasi-static loading conditions. Each sample consisted of 5000 identical particles of different sizes, initially loaded isotropically in a square box, and later biaxially compressed ($\dot{\varepsilon}_1 = const$; $\sigma_3 = const$) up to a critical state, where $\frac{p}{q} = \frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3} \cong const$ and $\varepsilon_{vol} \cong const$. Four comparable but random samples of each particle shape type were prepared in parallel in order to enable statistical analysis of the results. Although the results of such simulations were investigated macroscopically in the past [8], their microscale studies leave a lot of room for further research.

Because of the complex shapes of the clumps, much more complicated contacts were possible between any two particles (contacts between two neighbouring clumps via two, three or four discs), unlike in assemblies made of separate discs, where only a singular point of contact is possible. The focus of this research was to observe the transitions of contact types in different phases of the biaxial compression test, contact point (area) transformations, location of certain contacts in the force chain network, and to examine the findings in the context of contact force magnitudes and the shapes of the particles.

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