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Micromechanics of granular materials

Foreword

Since several decades now, the constitutive behaviour of materials has been generally described by phenomenological relations built upon the framework of visco-elasto-plasticity. This approach has led to impressive successes: (i) for modelling the behaviour of materials, even in the case of a great complexity like geomaterials (sands, clays, rock, concrete, snow), and their implementation into finite element codes; and (ii) for modelling the behaviour of structures and engineering works.

However, the above phenomenological approach has reached some limits, particularly for geomaterials, when it becomes obvious that for complex loading paths (strongly non-proportional paths, and cyclic loading, among others) a realistic description of material responses requires the introduction of yield surfaces and plastic potentials of non-regular shape (existence of vertices), evolving in an intricate manner (isotropic, kinematic, rotational hardening), and most of all depending on a continually increasing number of ad-hoc parameters.

In such a situation, completely new approaches are necessary and micromechanics is probably today one of the most promising framework within which this question of constructing realistic constitutive relations for geomaterials with only a few physical parameters can be addressed.

Homogenization techniques (linking the particle scale to the representative element volume one) and localization operators (for the inverse change of scales) can now be successfully applied to granular materials, where the local interaction law between the particles can mostly be described in a very simple way. For instance, an intergranular dry friction is just sufficient to simulate qualitatively all the main mechanical properties of a sand.

Interestingly, numerical studies based on discrete element methods coming from molecular dynamics lend support to the above-mentioned analytical-numerical approaches. Indeed for geomaterials as well as for some other materials, the complexity of their behaviour, as observed in the real world, is generally just due to the great number of interacting particles and not to the complexity of the interaction law between the particles.

These fundamentals constitute the common ground of the papers published in the thematic issue "**Micromechanics of granular materials**". Many questions are tackled in this issue, some of them are still being very challenging. The analysis of the microstructure of granular specimens is considered (Tordesillas et al., Goncu et al.), and more specifically its relation to both strain and stress evolution of the specimen. Generally, such issues are approached with spherical particles. As such, the effect of the grain elongation is discussed in (Nouguier-Lehon). Then, some features in relation with the plastic behaviour of granular assemblies are investigated, such as their volumetric behaviour and ratcheting phenomenon (Kruyt, Vincens et al., Calvetti and di Prisco). Finally, an extension toward multiphysical couplings and the treatment of boundary value problems is given in order to bridge the gap between academic issues and practical engineering realities (Scholtes et al., Bourrier et al.).

Some of these papers were included in the invited session "Micromechanics of granular media enlightened by discrete element modelling", of the ECCOMAS thematic conference "Particles 2009", that was held in Barcelona (November 2009). We would like to express our utmost gratitude to Professors D.R.J. Owen and E. Oñate, Conference Chairmen, for having given us the opportunity of organizing this meeting that has inspired this thematic issue.

We hope that this thematic issue will constitute an exciting and stimulating source for ongoing collaborative and fructuous works!

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