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MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Preface to Mechanics of granular materials in engineering and Earth sciences. A Discussion Meeting held at the Royal Society on 28 and 29 January 1998.

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Preface

The papers that follow were presented at a two-day Discussion Meeting held at the Royal Society in January 1998. The Meeting was attended by some 200 people from diverse backgrounds across science and engineering: mathematicians, physicists, geophysicists, geologists, process engineers, structural engineers, geotechnical engineers, chemical engineers, mechanical engineers. The wide range of interest of the audience reflected the interdisciplinary relevance of the mechanics of granular, or, more generally, particulate materials and the animated discussion reflected the value of the cross-disciplinary communication.

For many years, studies of the mechanics of granular materials have been concerned with the behaviour of these materials at a macroscopic level and in engineering or other applications. Extrapolation beyond the observation in one type of test or boundary-value problem to the behaviour to be expected in a different situation has generally been based on models that treat the granular materials as continua, starting from an assumption that continuum concepts such as stress and density are useful simplifications at the scale of modelling. Such an approach is adopted in many of the papers. Geotechnical engineers need to identify the material properties that govern both failure and deformability; earth scientists wish to understand flows in nature and the processes that produce distinctive characteristics in the resulting sediments; the engineering of silos to resist the loads imposed by their contents requires understanding of the flows and structures that develop during filling and emptying; physicists have exploited insights derived from kinetic theory of gases to explore the behaviour of low-density collisional flows.

Whether the materials display strong interparticle contacts, or flow as suspensions in water or air with weak intergranular interactions, modelling has tended to make little reference to their particulate nature. A particulate mechanics of granular media is, however, being promoted through two developments. Physicists have become intrigued by the structures that develop as piles of particles form or rearrange in a state of self-organized criticality, which has its own implications for the way in which loads can be carried through the mass of material and the ways in which the material may have to deform to support new loads. The increasing power of computers has enabled modelling of the behaviour of larger and larger assemblies of discrete particles having more or less realistic, three-dimensional shapes and physical interactions. At the macroscopic scale, it is perhaps inevitable that behaviour must be modelled as a continuum, but understanding the phenomena that have their origin at the particulate level provides inspiration for the continuum descriptions.

There is a challenging agenda for future research.

1. What structures develop as particulate materials come together to form macroscopic assemblies (continua?) capable of supporting external loads? The study of behaviour of particulate materials in silos reveals the extreme sensitivity of particle packings to the details of the process of filling. In geotechnical engineering, fills are created by tipping, rolling and compacting: consequent structures retain some memory for this history. In natural sediments transported by air,

water or ice, complex interactions at the particle level, and the evolution of load-bearing networks, determine the structure and fabric of the resulting sediment, which in turn determine its behaviour and stability as an engineering material.

2. Under what conditions do particulate materials begin to flow and what particulate arrangements are associated with the process of flow? Understanding the damage that can be done by pyroclastic flows, rock avalanches, natural slope failures, and earthquake-induced liquefaction, requires knowledge of the mechanics of the flowing material. The contents of silos have to flow in order to discharge, and the stresses for which the structure of the silo has to be designed depend critically on the nature of the flow. Flow-promotion techniques for silos, such as aeration, air cannons and vibratory devices, produce phenomena similar to those observed in geological systems.

3. Under what conditions does the continuum approach break down? In between the two extremes of stasis and flow for which a macroscopic continuum approach may seem reasonable is the phenomenon of localization. This may manifest itself as the formation of a failure surface or as a more subtle heterogeneity within the granular material. There are also problems associated with particle breakage, which the discrete-particle modellers are only beginning to address. However, understanding the mechanics of materials composed of particles which break apart or crush at asperities when the contact stresses become too high has a ring of necessary truth to it if the macroscopic response is to be computed reliably.

Throughout, there is a recognition that, whatever simplification is made in order that prediction of response may be possible, many mysteries remain on which the sharing of interdisciplinary approaches may help to throw light. There is a limited set of common underlying processes, which it is in all our interests to understand. The conceptual toolkits developed by different groups, often in isolation from each other, are of great mutual interest and it is thus vital to maintain interaction across the range of disciplines represented at the Discussion Meeting.

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