Chapter 1

Introductory Chapter: A Short Survey of Landmarks

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70337

1. Introduction

Granular materials are a broad category of materials of interest in Civil engineering, Chemical engineering, Mining Industry, Physics, Chemistry, Pharmacy and Agriculture. In engineering, great advances took place recently by the introduction, both, of experimental and computational methods. X-ray tomography revealing the grain materials structure and the distinct elements computational method are two of them. The granular materials may behave as fluids or solids or both. The grains size may span from microscopic to macroscopic scale. From the wet sand effect, Reynolds inspired in 1885 [1] the notion of granular universe introducing the term "dilatancy." In his Rede Lecture in Cambridge [2] entitled *On an Inversion of Ideas as to the Structure of Universe*, he presented an explanation of the cause of electromagnetism giving a physical interpretation of the equations linking electricity with magnetism. In **Figure 1**, the experiment to show the effect of dilatation in the Rede Lecture is presented.

Later on, Lorentz gave the relativistic explanation of the electromagnetic waves. Schofield [3] gives a short account of Reynolds' ideas. In 1930, Casagrande introduced the concept of critical voids ratio to explain the liquefaction phenomenon. Donald Taylor in 1948 used the concept of dilatancy to explain the friction as result of the interlocking of grains. Later on in 1960, Cambridge soil mechanics group [4] introduced the models of Cam-Clay and Granta-Gravel to explain the plastic behavior of soil. On the other hand, researchers from Mathematics and Physics like Bak et al. [5] and Bak [6] used the sand pile as a representative model of complex systems (**Figure 2**).

Many researchers continue developing the concept of self-organized criticality to explain physical phenomena like earthquakes, landslides and avalanches. Werner [7], using notions and principles of Complexity Theory, explains the localization of shear: "…the most rapidly changing parts of the system tend to be localized in space. Familiar examples include localization of shear into narrow bands in turbulent fluids and in solid deformation or fracture. Patterns inherently involve localization because they can be described with fewer spatial dimensions than the space in which they are embedded: lines for two-dimensional patterns and surfaces in three-dimensional patterns."

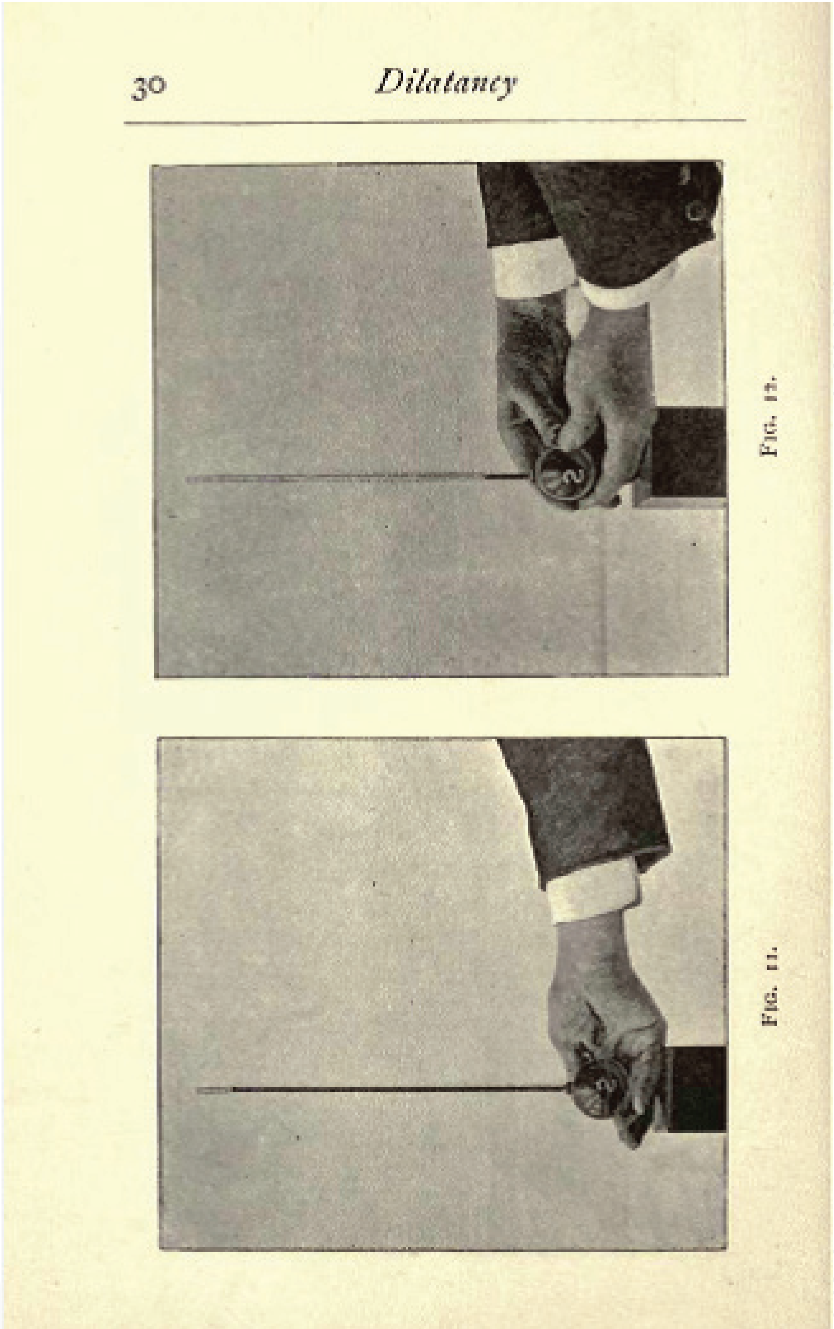

Figure 1. Experiment presented in Reynolds' Rede Lecture to show the dilatancy phenomenon. In Fig. 11 of the original publication, a bag filled with water is shown. After squeezing the bag, the water rises in the tube. In contrary, in Fig. 12, as above, a big filled with small shot and colored water is shown. In this case, the squeezing of the bag caused a drop of the water in the tube resulted from the increase of voids in the coarse material.

This volume presents basic notions and fundamental properties of granular materials covering a wide spectrum of granular material mechanics. In this collection of chapters, granular dynamics, granular flow from dilute to jammed states, dynamics of granular gas in microgravity, particle jetting induced by impulsive loadings, particle migration phenomena in embankment dams and the grading entropy-based criteria of granular materials and filters are presented. The scientific areas of the above are very broad, with applications from earth dams to space flights.

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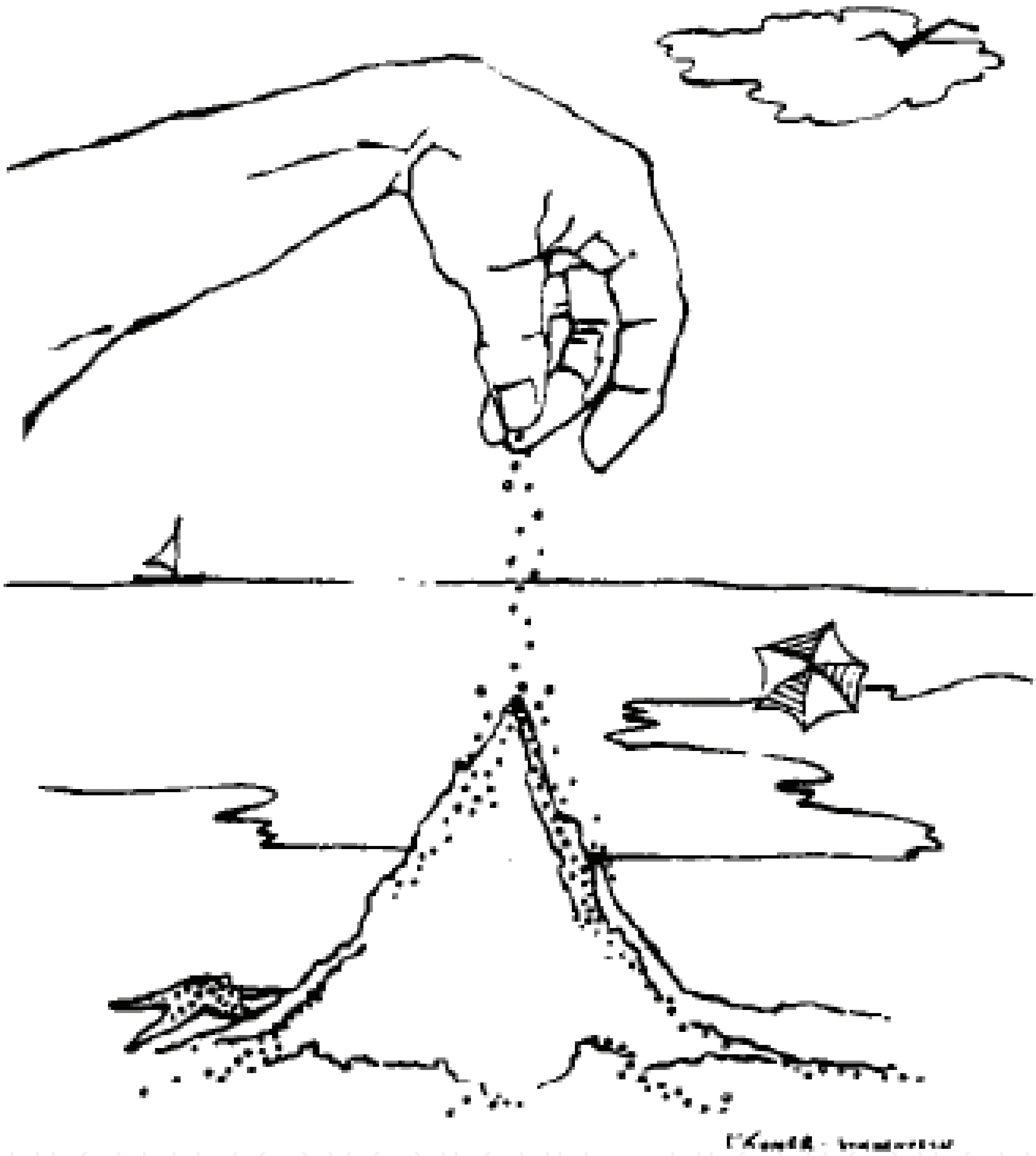

Figure 2. The sand pile as the prototypical example of the self-organized criticality [6].

In the first chapter, a theoretical framework of granular dynamics using a generalized Lagrangian approach is presented, discussing future directions of computational granular dynamics. The second chapter focuses on the mechanical responses of a granular material describing the mechanical behavior of dissipative, deformable particles in different states, from fluid to solid states. The next chapter presents an experimental study of the dynamical behavior of a model granular medium. The model has been submitted to external vibrations under microgravity, the whole process being recorded using high-speed video camera. The fourth chapter is an experimental and numerical study of the particle jetting phenomenon observed in the explosive or shock disposal of particle rings, shells or cylinders. Continuum approach, for the explosive case, and Distinct Element Method for the shock-induced jetting have been adopted. In the following two chapters, important hydraulic properties of earth dams are presented, affecting their structural integrity. First, a numerical procedure has been developed to simulate particle migration phenomena due to seepage resulting erosion. The method has been applied in case studies. The final chapter presents entropy-based criteria to control the internal erosion process in earth dams. According to this procedure, the whole grading curve is used instead of a limited number of points, as is usually adopted.

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