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Vertical structure of high-concentration liquid-granular flows

Abstract

For a substantial part of their behaviour, certain natural debris flows can be idealised as flowing solid-fluid mixtures composed of cohesionless grains of uniform size embedded in a Newtonian liquid (Takahashi 1991). This doctoral thesis addresses the issue of the experimental and theoretical analysis of high concentrated uniform granular flows with water as interstitial fluid, drawing the attention to the relevance of the condition of flow in equilibrium with the bed. Four different flow regimes have been observed: (a) loose bed, immature debris flow; (b) loose bed, mature debris flow; (c) loose bed, "plug" debris flow; (d) rigid bed debris flow.

The study was motivated by the need of a deep comprehension of the general features of the different flow regimes and of the relevant distribution of rheological processes within the flow section.

Deep comprehension of the rheological properties of granular materials, both in presence and absence of water with the role of interstitial fluid, has been an enterprise for scientists during the last fifty years. Many contributions could be cited, but in general what emerges from a review of literature is that detailed experimental measurements in well-controlled flow conditions have been difficult to obtain. The present work seeks to address this problem by resorting to a novel recirculatory flume set-up, in combination with recently developed Voronoï imaging methods, used to obtain a detailed characterisation of the local flow kinematics and of granular concentration, as seen through the flume sidewall.

Looking at the profiles of the variables of interest in the stress formation (velocity, fluctuation energy, and solid concentration), it is observed that they change enormously from cases with and without equilibrium. The analysis here proposed stepped out from the possibility to lead on experimental assessments of the kinetic theories in any position inside the flow domain. The results allowed to build a picture of the rheological distribution that is rather simple: throughout the flow depth there are layers that are collisionally dominated, whereas the complementary domains are essentially frictional. Moreover, on the base of a mechanical energy balance for the bulk mixture, a matching was established between Bagnold's (1954) theory and the more recent kinetic theories.