Modeling granular flow dynamics and structure interaction: Insights from sedFoam solver

E. P. Montellà[1], J. Chauchat[1], C. Bonamy[1], D. Weij[2], G. H. Keetels[3], and T. J. Hsu[4]

[1]University of Grenoble Alpes, LEGI, G-INP, CNRS, 38000 Grenoble, France
[2]Plaxis B.V., Computerlaan 14, 2628 XK Delft, The Netherlands
[3]Delft University of Technology, Mekelweg 2, Delft, The Netherlands
[4]Civil and Environmental Engineering, Center for Applied Coastal Research, University of Delaware, Newark, DE 19711, USA

December 15, 2023

Abstract

Gaining insight into granular flow dynamics is crucial in several sediment transport applications. A critical aspect involves understanding how these dynamics drastically differ based on the initial volume fraction. Under shear deformations, loose granular beds trigger rapid, accelerated flows, while denser beds show delayed mobility and a creeping flow. The interplay of geometrical granular dilatancy and pore pressure feedback underlies these behaviors. To address these effects, a dilatancy model has been integrated into sedFoam [1], an OpenFoam-based software used in sediment transport applications. We've validated this model by reproducing numerically the experiments conducted by [2]. In this setup, a horizontal granular layer immersed in a viscous fluid was tilted beyond the critical angle to initiate an avalanche. Several initial volume fractions resulted in different observed behaviors. The successful alignment with experimental data suggests that sedFoam is able to capture the interplay between porosity changes and fluid pressure during the initial stages of the granular avalanche.

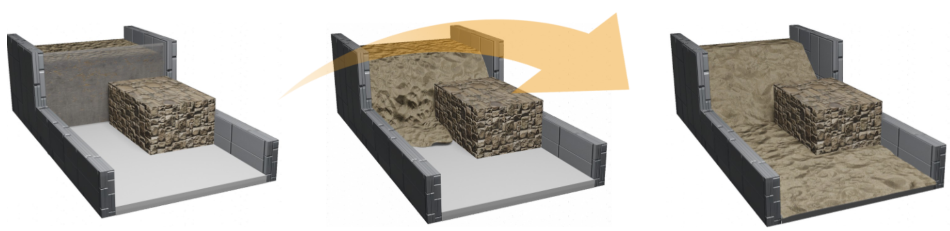

Figure 1: Evolution of the deposit during an immersed granular collapse.

We extended our findings to 2D configurations were dilatancy plays a key role. Specifically, attention was directed towards understanding the breaching mechanism and shear failures of granular columns. Initially, we replicated numerically the collapses of small-scale granular columns with varying initial fractions of [3]. Consistent with experimental results, we noticed that loosely packed columns initially contract, triggering rapid collapses via positive pore pressure. Conversely, densely packed columns dilate, generating negative pore pressure that stabilizes the column and leads to a slower collapse. Extending these discoveries to a larger scale, the model accurately predicts the dilative behavior and the turbidity currents observed in the breaching experiments of [4].

Previous tests have showcased sedFoam's capability to predict various natural coastal processes or human-induced activities such as dredging operations. However, there's a particular interest in understanding how fluid and granular flows interact with solid structures. To address this, a six-degree-of-freedom solver has recently been integrated into sedFoam. This enhancement sheds light on the interaction between particle and fluid forces on rigid objects within sediment transport applications. This implementation represents a significant leap towards comprehending intricate interactions among fluids, particles, and structures, offering deeper insights into sediment transport and structural responses.

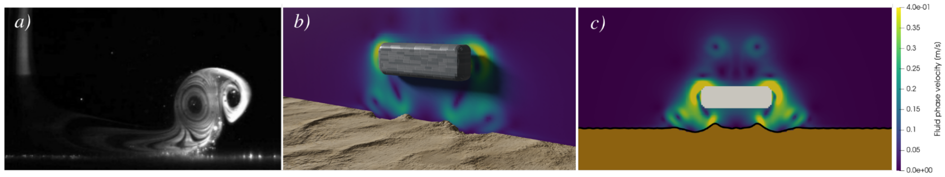

Figure 2: a) Structure of the double vortex rings interacting with a sediment bed [5]. b) Oscillating plate interacting with the erodible bed using sedFoam and c) slice of the numerical domain to illustrate the bedforms and the velocity field.

References

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