Bulbous head formation in bidispersed shallow granular flows over inclined planes

Irana F. C. Denissen†*, Thomas Weinhart†, Stefan Luding† and Anthony R. Thornton†

† Multiscale Mechanics, Engineering Technology, University of Twente
P.O. Box 217, 7500 AE Enschede, The Netherlands
*e-mail: i.f.c.denissen@utwente.nl

ABSTRACT

Predicting the behaviour of hazardous natural granular flows (e.g. snow slab avalanches, debris-flows and pyroclastic flows) is vital for an accurate assessment of the risks posed by such events. In these situations, the process of kinetic sieving leads to an inversely graded vertical particle-size distribution, with larger particles on top of smaller particles. As the surface velocity of such flows is larger than the mean velocity, the larger material is then transported to the flow front. This creates a horizontal size segregation structure, resulting in a flow front composed of purely large particles. Moreover, the frictional properties of the granular material in geophysical flows is usually size-dependent, where the larger particles are often more frictional. Thus, the large material in the front reduces the mobility of the flow front, resulting in a so-called bulbous head [1], see Figure 1.

One of the main challenges of simulating these hazardous natural granular flows is the enormous number of particles they contain, which makes discrete particle simulations too computationally expensive to be practically useful. Continuum methods are able to simulate the bulk flow- and segregation behaviour of such flows, but have to make averaging approximations to reduce the degrees of freedom from a huge number of particles to a handful of continuum fields. We use a depth-averaged model to predict the flow profile for such flows, based on flow height, depth-averaged velocity and particle-size distribution [2]. Small-scale periodic discrete particle simulations are used to determine the material parameters of the continuum model [3].

In this talk, we show that the bulbous head structure emerges naturally from this depth-averaged continuum framework, and that the long-time behaviour of this solution of the depth-averaged continuum model converges to a novel travelling wave solution [4]. Furthermore, we validate a simple 1D continuum level simulation against a computationally expensive 3D particle simulation, where we see surprisingly good agreement between both approaches, considering the approximations made in the continuum model. We conclude by discussing how combining both the continuum and discrete approaches can be used to reveal deeper insight.

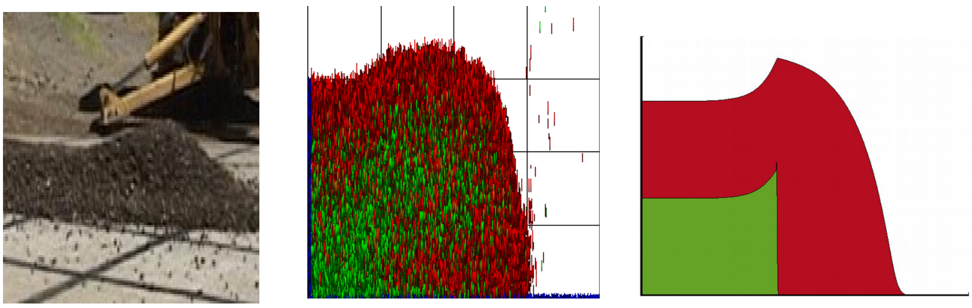

Figure 1: Examples of the bulbous head in shallow granular chute flows. Experiments at the USGS debris-flow flume (left, picture courtesy of USGS), discrete particle simulations (middle) and depth-averaged continuum level simulations (right). The x-axis is scaled by 1/100 in the middle and right figures.

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