Pressure Distribution and stresses under granular heaps with the Distinct Element Method

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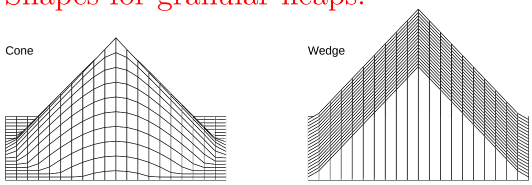
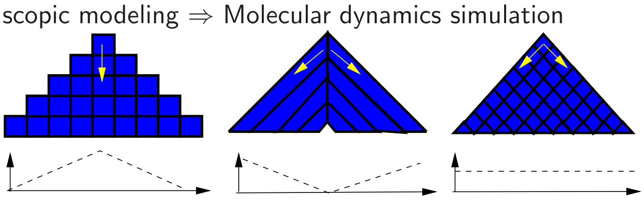
Shapes for granular heaps:



Outline of the problem:

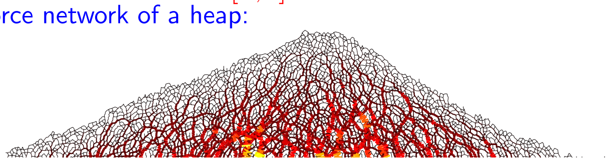
– Many "generic" Models for the pressure distribution under granular heaps are possible.
– A-Priori Calculation on the particle level without any macroscopic modeling ⇒ Molecular dynamics simulation



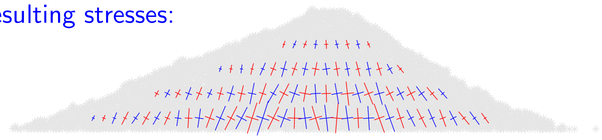
– In experiment, granular cones show a pressure dip, but not granular wedges.
– Is there a dip at all, and why?

Simulation results [1,3]:

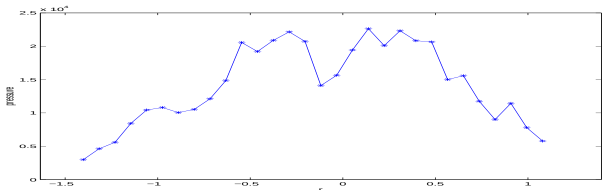
Force network of a heap:



Resulting stresses:

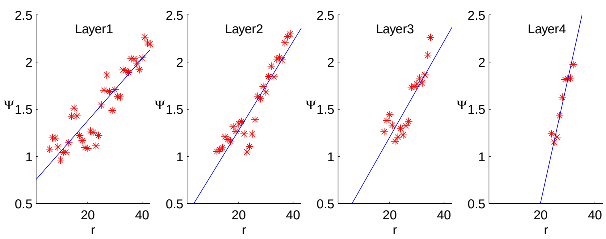


Corresponding Pressure Distribution:

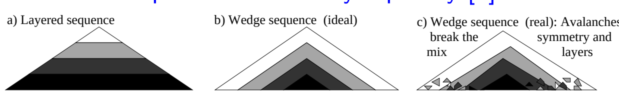


Angle of the stresses:

No evidence for "fixed pricipal axes" proposed in [2]



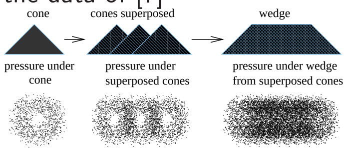
Effect of Heap Histories & Polydispersity [3]:

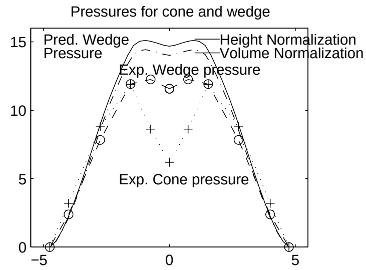


– Heap by building the heap layer by layer ⇒ no pressure dip
– Monodisperse heaps ⇒ no pressure dip
– Polydisperse heaps ⇒ pressure dip **if** constructed in wedge sequence, no pressure dip **if** constructed in layered sequence
– Consistent with experimental results on 3d-cones [6]

Difference between cones and wedges:

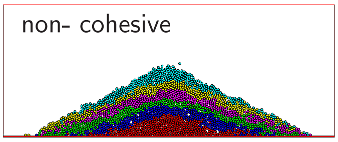
Gedankenexperiment [4] :
Superpose cones to wedge
Experimental verification with the data of [7]

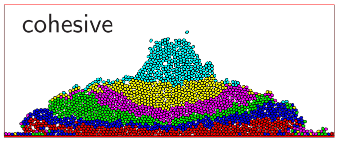




Effects of Cohesion [5]:

– Pouring the heap from a point-like source leads to wedge-sequence type of heaps as expected
– For strongly cohesive materials layering occurs even for point-like-source





Simulation Method [3]:

Integrator: Predictor-Corrector 5th order → large timestep, high stability, $\mathrm{d}t = 0.1\sqrt{m/Y} \cdot \pi$

Force Laws:

– Contact force: $F_{c,\perp} = Y \cdot A/l$. with inverse characteristic length $\frac{1}{l} = \frac{l_1+l_2}{l_1 \cdot l_2}$
– Normal Damping force:

$$F_{d,\perp} = \begin{cases} Y \cdot \frac{\mathrm{d}A}{\mathrm{d}t}/l, & \text{for approach} \\ \max\left(Y \cdot \frac{\mathrm{d}A}{\mathrm{d}t}/l, -F_{c,\perp}\right) & \text{for separation} \end{cases}$$

– Tangential force/ friction:

$$F_{d,\parallel}(t) = F_{d,\parallel}(t-\Delta t) + Y_t \cdot v_t \cdot \Delta t + \sqrt{m_{eff,\parallel} \cdot Y_t} v_t$$

References:

[1] H.-G. Matuttis, A. Schinner, K. Kassner, in preparation

[2] J. P. Wittmer, P. Claudin, M. E. Cates, and J. -P. Bouchaud, Nature 382, 336 (1996). An explanation for the central stress minimum in sand piles .

[3] H.-G. Matuttis, Simulations of the pressure distribution under a two dimensional sand-pile of polygonal particles, to appear in Gran. Matt. 2/98

[4] H.-G. Matuttis, A. Schinner, Influence of the heap shape on the density of granular materials and the pressure distribution, accepted by Gran. Mat.

[5] H.-G. Matuttis, The effect of cohesion on the pressure distribution under granular heaps, in preparation

[6] T. Jotaki and R. Moriyama, J. of the Soc. of Powder Technol. , Japan 16, 184 (1979), On the Bottom Pressure Distribution of the Bulk Materials Piled with the Angle of Repose .

[7] F. H. Hummel and E. J. Finnan, Proc. Instn. Civil Engn. 212, 369 (1821), the former: Minutes of Proc. of the Instn. of civil Engineers with other selected papers.