Stresses in banks and piles:

A contribution of Jean Jacques Moreau

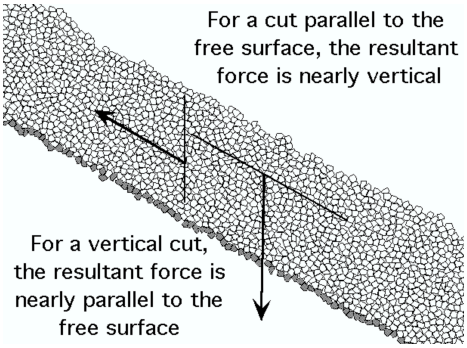
Farhang Radjaï [*] [‡]

[*] Université Montpellier, CNRS, LMGC, Place Eugène Bataillon, 34095 Montpellier, France
[†] CEA, DEN, DEC, SPUA, LCU, F-13108 Saint Paul lez Durance, France
[‡] MultiScale Material Science for Energy and Environment, UMI 3466 CNRS-MIT, CEE, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge 02139, USA

e-mail: franck.radjai@univ-montp2.fr

ABSTRACT

Nearly 20 years ago, the stress fields inside and at the bottom of granular heaps were considered by several authors as an example of some odd behaviours of granular materialsIn particular, a local pressure dip was observed beneath granular heaps and modelled by introducing a closure relation between stress components [1]. Such closures were criticized on general grounds [2] and some authors showed that the pressure dip is a possible solution of continuous elasto-plastic models applied to heaps [3]. We reproduce here the analysis of stresses in 2D and 3D heaps composed of irregular polygons and spheres, respectively, performed by Jean Jacques Moreau in 1998 using his Contact Dynamics Method [4]. This work was presented in 14th French Conference of Mechanics in 1999. I briefly present the original simulations of Moreau and his numerical analysis of the simulation data. Moreau found that the resultant force on a plane parallel to the free surface is nearly vertical, indicating that the pile is at incipient failure everywhere along the free surface. Furthermore, the resultant force on a vertical plane is nearly parallel to the free surface. This is less evident but it can be shown that it is a consequence of the first property due to the theorem of "reciprocal cuts". The is a macroscopic *arching effect* in the sense that the grains located inside the region between a vertical cut and the center of the heap are maximally supported by the grains located in the region outside the cut.



[1] Cates, M. E., Wittmer, J. P., Bouchaud, J.-P. and Claudin, P., Development of stresses in cohesionless poured sand, Phil. Trans. Royal Soc. of London A, 356, 2535-2560, 1998.

[2] Savage, S. B. 1997 Problems in the statics and dynamics of granular materials. In Proc. "Powders and Grains '97" (Behringer, R.P. and Jenkins, J.T., eds.), pp. 185-194. Balkema, Rotterdam, 1997.

[3] Didwania, A.K., Cantelaube, F., and Goddard, J.D., Static multiplicity of stress states in granular heaps. Proc. Roy. Soc. Lond. A 456, 2569-2588, 2000.

[4] Moreau, J.J.. Some numerical methods in multibody dynamics: Application to granular materials. Eur. J. Mech. A/Solids 13 (Supp. 4), 93-114, 1994.