Formation of a sinkhole in the laboratory

Laboratory: Institut d'Alembert, Sorbonne Univ.
Supervision: Anaïs Abramian, Claire Lestringant, Fanny Papot
E-mail: anais.abramian@upmc.fr, claire.lestringant@sorbonne-universite.fr
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Until the 20th century, the network of underground quarries in Paris expanded considerably, making the ground of the city increasingly unstable. This led to the appearance of "sinkholes", where the roof of the quarry progressively disintegrates, forming a bell-shaped cavity that eventually reaches the surface and causes a sudden ground collapse (Fig. 1a, 1b). Sinkholes generally occur in a karstic geological context, where the soil exhibits some cohesion.

The shape and dynamics of a sinkhole can vary from one site to another depending on the size of the underground cavity, the type of soil, or the constructions at the surface. Since these parameters vary simultaneously, it is difficult to predict such events from field data alone. This difficulty can be overcome by studying the problem in the laboratory, under simplified and controlled conditions.

A 2D experiment consists in placing a cohesive granular medium between two glass plates (Fig. 1c). After removing the support holding the granular bed, the collapse forms a bell, then a finger or chimney, which progressively grows until it reaches the free surface. The objective of this experiment is to study the shape and dynamics of this cavity $h(x, t)$ as a function of the system parameters, such as grain size, cohesion, or orifice size.

For this purpose, we will use an innovative cohesive granular medium recently synthesized by Gans et al. 2020, in which the interparticle adhesion forces can be precisely controlled. This will allow us to identify different regimes, where the cavity either develops progressively or through fracturing. We expect to reveal self-similar solutions or scaling dynamics.

The experimental techniques will include Digital Image Correlation (DIC) to characterize the initiation and propagation of fractures, as well as statistical analysis of collapse sizes. For students interested in the theoretical aspect, the experiments may also be compared with damage mechanics models or with numerical simulations, either fluid-like or solid-like.

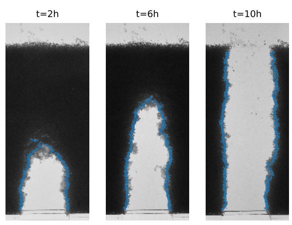
a.  b.  c. 

Figure 1: a. Ground subsidence, Place de l'Alma, November 8, 1915. b. Sinkhole, Mexico. c. Laboratory experiment.

Candidate profile: curious, resourceful, and interested in both designing new experiments, theory, and/or numerical simulations. Field measurements in Paris' quarries can also be included, depending on the candidate's interests.