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POREPRESSURE RELAXATION DURING GRANULAR COMPACTION

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Summary The compaction of a granular assembly immerged in a fluid implies complex interactions between viscous forces and grain contact forces. We present the study of the compaction under tapping of a granular packing fully immerged in water. In order to follow the interaction between the grains and the fluid, we measured the pore pressure at the base. A simple model is proposed to understand the time relaxation of the pore pressure.

INTRODUCTION

Powder compaction is an old subject that has recently attracted the attention of physicists as the propotype of non thermal disordered systems. The complex evolution of an initially loose granular packing submitted to external perturbations like vibration has been precisely studied [1, 2, 3]. In all the previous studies the role of the interstitial fluid is negligible. However, the fluid can play an important role in the compaction dynamics as shown for example by the liquefaction phenomena. Grains in a fluid can interact both by direct frictional contact and by viscous forces though the fluid. Dense granular packing in a fluid can then behave like a granular material or a suspension, and the transition between both behaviors is not clearly understood. An initialy loose sand saturated with water can liquefied when submitted to vibration (an earthquake for exemple). As the material compacts, the fluid has to escape developing pressure gradients enough to carry the weight of the grains.
In this work, we investigate a simple configuration where both viscous and contact interaction are present. A granular packing fully immerged in water is compacted under vertical tapping. In order to determine the role of the liquid we measure the time evolution of the pore pressure under the packing during compaction.

EXPERIMENTAL SETUP

The experimental set up is presented in Figure 1. A rectangular box separated in two is fixed on top of an electromagnetic vibrating device. Both sides of the box are full of water, but grains are placed on one side only. The particles are 112 ± 20 μm diameter spherical glass particles. A differential pressure sensor measures the water pressure difference between the two sides of the box and an accelerometer is attached at the bottom of the tank. Before the experiment starts, the granular material is stirred in order to create a suspension. We then wait until all the material is settled at the bottom of the container. The pressure difference between the two side is then zero, as the weight of the grains is carried by the box. We then impose a vertical controled acceleration and measure the time evolution of the pressure. These signals are digitized at 10 kHz using an acquisition board.

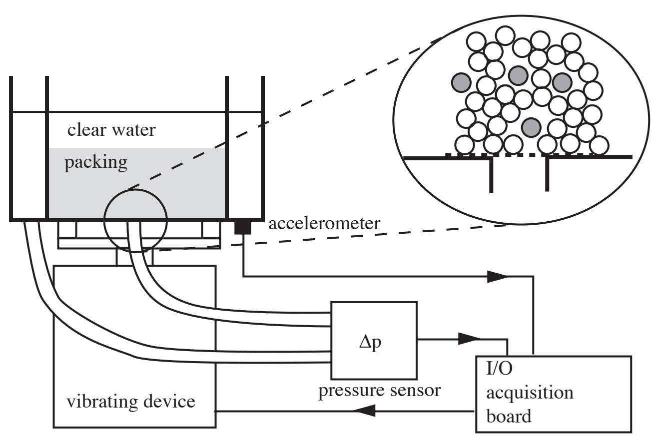

Figure 1. Experimental setup.

PORE PRESSURE MEASUREMENTS

A typical pore pressure relaxation is shown on Fig. 2 for a maximum acceleration of 19 m/s^2 and a « tapping time » of 250 ms. This relaxation is very close to an exponential relaxation and can be explained by a simple model. If we note h_0

the height of the packing in the most compact configuration, and h the height in a loose configuration, the pore pressure may be written as an hydrostatic pressure due do suspended particles in the packing (see insert of Fig. 1 for a schematic view) :

$$\Delta P = \phi \Delta \rho g (h - h_c) \tag{1}$$

where ϕ is the particle volume fraction and $\Delta\rho$ the density difference between the particles and the liquid.
This pressure induces a flow inside the deformable porous packing of permeability k. Using Darcy's law, the governing equation for the height is then

$$\frac{dh}{dt} = -\frac{k}{\eta}\phi_c h_c \Delta\rho g \frac{h - h_c}{h^2} \tag{2}$$

where η is the liquid dynamic viscosity and ϕ_c is the random close packing volume fraction. This model is in qualitative agreement with the experimental results and helps understand why pressure relaxation is a slow process compared to the typical time scale of the tapping.

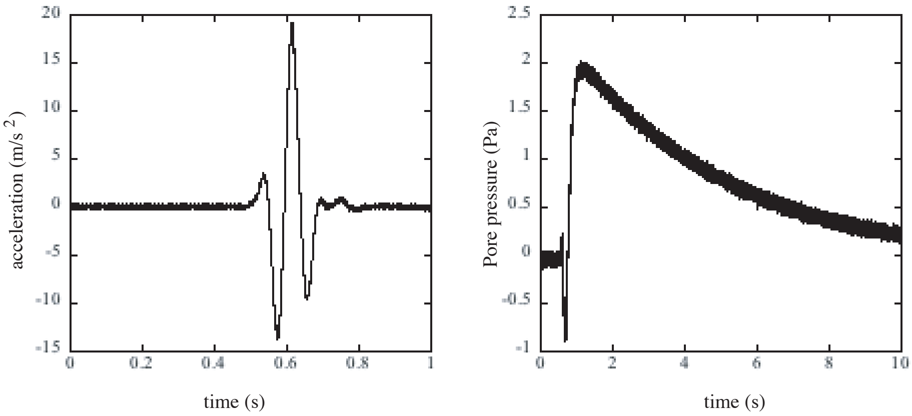

Figure 2. Acceleration (left) and pore pressure relaxation (right) versus time for a 2 cm high packing of 112 μm glass spheres.

CONCLUSIONS AND PERSPECTIVES

We show that the pore pressure inside a packing relaxes exponentially when the material is submitted to a rapid solicitation such as a vertical tapping. If the time between two successive solicitations is shorter than the typical relaxation time, then the pressure may build up until it balances the weight of particles, leading to liquefaction of the liquid/particles mixture.

References

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