Granular suspended bridges as the cause of clogging in vertical narrow pipes

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The packing of mono-disperse spheres in a narrow cylinder produces a set of structures as the ratio between the cylinder diameter to the sphere diameter is varied [1]. These structures determine the force distribution between particle to particle and particle to wall. Thus, the packing and the material properties affect the movement of material through a cylindrical channel.

A frequent situation with this type of transportation is clogging. The system clogs due to the development of hanging arches that are able to support the weight of the material above them. The study of this kind of phenomenon can be interesting to other situations, e.g., the blood flow through veins and arteries, the transport of rocks by pipes in mining and the pedestrian flow in narrow corridors.

The experimental study of clogging in verticals pipes has been scarcely studied. The first experimental approach was introduced by Janda [3] where the grannular material was composed by platy particles. Nevertheless, the behavior of spheres has not been yet analyzed experimentally, although some numerical simulations have been performed [4, 5].

In this work we introduce an experimental setup consisting on a long narrow cylinder full of spherical beads which are extracted at a constant rate by means of a conveyor belt placed at bottom (Fig. 1). The granular material is formed by plastic beads of 5 to 8 mm. The cylinder, made of transparent methacrylate has a length of 2000 mm and its placed vertically. The inner diameter is varied between 10-26 mm which implies an aspect ratio between pipe and particle diameters of 2-4. The time between two consecutive clogs, typically named avalanche duration, is registered. The avalanche duration can be converted to avalanche mass by considering the flow rate and later, analyzed to get the avalanche distribution. Also, we register the locations of arches that clog the pipe with a camera. These locations allow us to calculate the probability that a clog occurs at different positions.

We analyze the dependence of clogging on the aspect ratio, the avalanche distribution between clogs and the spatial clog's distribution along the pipe. We also observe an interesting phenomenon, which is the spontaneous formation of helical patterns. Recent findings have shown that these helical patterns lead to clogging reduction [4].

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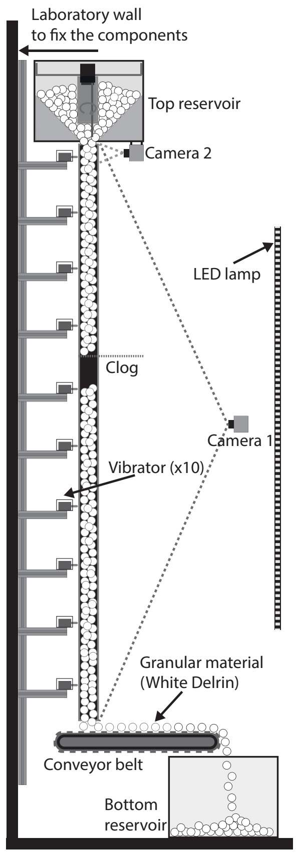

Fig. 1. Experimental setup. In the image from top to bottom: a reservoir from which the cylinder is filled, a camera (Camera 2) used to determine when a clog occurs, a long and narrow cylinder, 10 vibrators controlled independently used to break the clogs, a camera (Camera 1) that takes photos of the entire pipe, a conveyor belt that extracts the granular material; a LED lamp and a bottom reservoir.