Clogging of granular material in vertical pipes discharged at constant velocity

D. López-Rodríguez[1], D. Maza,[1] and I. Zuriguel.[1]
[1]Univesidad de Navarra (UNAV) (Spain)

Ore passes are underground excavated tubes that allow communicating different levels of a mine. The main use of these structures is the transportation of rocks and ore, fundamentally, using gravity as driving force [1]. A frequent and serious problem 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 experimental study of clogging in verticals pipes with flat faces materials has been thoroughly studied. The first experimental approach was introduced by Janda [2]. Nevertheless, the behavior of spheres has not been analyzed experimentally, althrought, some numerical simulations have been performed [3] [4].

In this work we introduce an experimental setup that is showed in Fig. 1. It consists on a long narrow pipe full of balls which are extracted at a constant rate by means of a conveyor belt placed at bottom. The granular material are spherical glass beads of 0.6 cm diameter. The pipe, made of transparent methacrylate has a length of 200.0 cm and its placed vertically. The inner diameter is 2.2 cm which imply an aspect ratio between pipe and particle diameters of 3.67. The time registered between two consecutive clogs, typically named avalanche's time, is registered and analyzed to get the distribution of avalanche duration. Also, we register the locations of arches that clog with a camera. These locations allows us to calculate the probability that a clog occurs at different positions.

We are not aware of any work that characterizes the position at which clogs occur along the pipe and the present work is an improvement from previous investigation of Janda et. al [2]. Also, we will analyze the dependence between clogging events with the aspect ratio, time distribution between clogs and spatial clog's distribution along the pipe. We also obtein an interesting phenomenon, which is the spontaneous formation of helical patterns. Recent findings have shown that these helical patterns lead to clogging reduction [3].

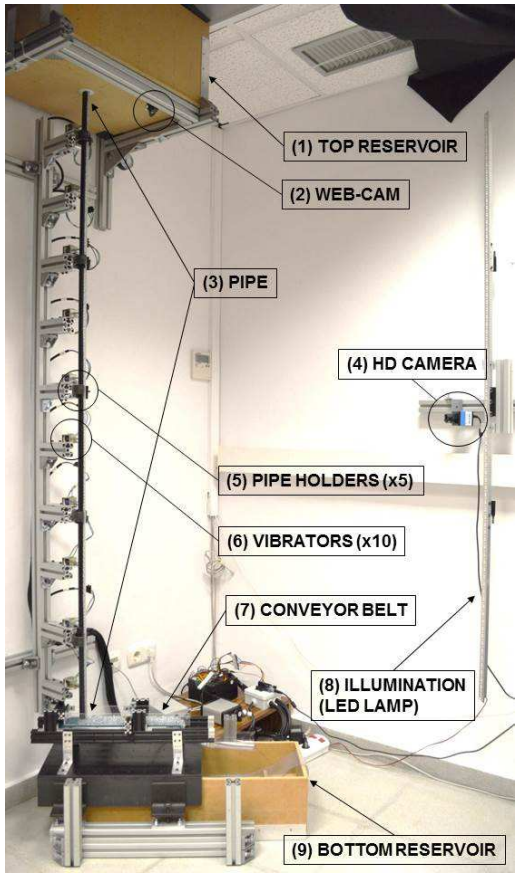

Figure 1: Experimental setup. In the image: (1) top reservoir from which the pipe is filled; (2) web-cam used to determine the time at which a clog occurs; (3) two meters long transparent pipe; (4) camera that takes pictures of the entire pipe; (5) pipe holders; (6) 10 vibrators controlled independently used to break the clogs; (7) conveyor belt that extracts the granular material; (8) lamp led; (9) bottom reservoir.

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