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Development of an experimental bench to evaluate percolation and water drainage in iron ore

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Abstract

The formation of free water in gondola-type open wagons for transporting ore is a problem to be mitigated in rail transport, because even with the use of drains at the head and floor, the accumulation of water always occurs, both due to the compaction of the ore fines that form a very dense pulp as well as by clogging the drains. This project aimed to develop an experimental bench to evaluate the efficiency of drains used in wagons to transport iron ore, evaluating the effects of moisture and ore compaction on percolation and drainage, as well as the effects of vibration on compaction of particulates. Important aspects were observed in the tests with sinter feed ore, such as the initial mass concentration of water. The higher the humidity at the beginning of the test, the longer it took to eliminate the same amount of water added to the ore surface. As for vibration, the percolation time of a water column and subsequent drainage compared to the static test shows a value 10 times greater.
Keywords: Ore, Experimental Bench, Water Percolation, Drainage.

1 Introduction

The rail transport of iron ore in open wagons of the gondola type is subject to the weather during the trajectory between the mine and the port of disposal. A large accumulation of water on the load increases the total weight transported. Granulated materials tend to have a specific granulometric range for different particulate products and, in each of them, there is a portion of natural moisture, known as the hygroscopic coefficient, which is intercalated with air molecules and fills the pores present in these agglomerated products [1, 2].

Once the assimilation of rainwater occurs in the wagons, the water starts to penetrate the product from capillary forces. The degree of filling of the pores with liquid will be the greater the finer it is, and the lesser will be the presence of air between its grains. Natural saturation scenarios or superficial moisture retention can occur when the particulate absorption capacity is lower than the water precipitation rate [3, 4]. In the event of any of these scenarios, if there is not an efficient capture and drainage system for this excess moisture, the formation of an accumulation of water above the load, known as free water, appears. This phenomenon is not desirable, bringing a series of operational barriers for the unloading at its destination.

One of the alternatives currently applied in these wagons is the use of drains installed in specific positions in order to drain the accumulated water and retain the ore [5, 6]. However, over time, these drains end up clogging, requiring constant cleaning or replacement maintenance.

The present work aimed to develop an experimental bench that allows the evaluation of water percolation by different inputs transported on railroads as well as the efficiency of drains installed in different positions and with variable shapes. An study was carried out with sinter feed iron ore and polymeric drains, allowing the survey of the water percolation time by the ore and subsequent drainage from different mass concentrations of water at the beginning of the test. In addition, vibration was inserted to simulate the displacement of the wagon and consider the effects of packing the load. The results showed that for the ore with the highest water mass concentration at the beginning of the experiment, the time for percolation and flow was longer than for the condition with the lowest concentration. Vibration condition also impose larger time to percolation than static condition.

2 Methods

A device containing a reservoir with a square section of 80 mm on the side and 500 mm in height was made of acrylic to visualize the inserted inputs. In the lower part of this reservoir, flanges allow the attachment of interchangeable drains for water drainage and ore retention. The drain produced in polymeric material through a 3D printer has 45 slits with an area of 1mm by 20mm in length. Figure 1 presents a schematic drawing of the device developed for the experimental drainage tests, containing the reservoir for the insertion of ore and water, in addition to flanges for changing drains and an eccentric motor for vibrating the apparatus.

The process of inserting ore into the reservoir takes place with a constant drop height from the upper end of the device. The insertion of water was done by a dripper designed to imitate rain precipitation and avoid the formation of preferential channels of flow through the walls of the ore column. A standard mass of 1400 g of sinter feed ore was standardized, allowing the initial formation of a 100 mm ore column from the bottom surface where the drain is fixed. The water column, which is inserted after the ore is introduced, was standardized at 200mm above the ore column.

The mass concentrations of water and ore were varied in five saturation percentages: 20, 40, 60, 80 and 100%, where the value of 100% represents the supersaturated solution where the formation of free water on the surface of the sample begins. These

saturations are equivalent to water mass concentrations of 2.8%, 5.4%, 7.9%, 10.3% and 12.5% respectively.
The start of counting the time that the water takes to percolate and be drained in the device is done right after the insertion of the water column over the ore. At the end, when the drip starts showing that almost all the water has been drained, the process is ended.
In addition to the static flow, a vibrating device containing an eccentric motor was coupled to the structure of the device, in order to observe the effects on the accommodation of ore particles in the drainage time.

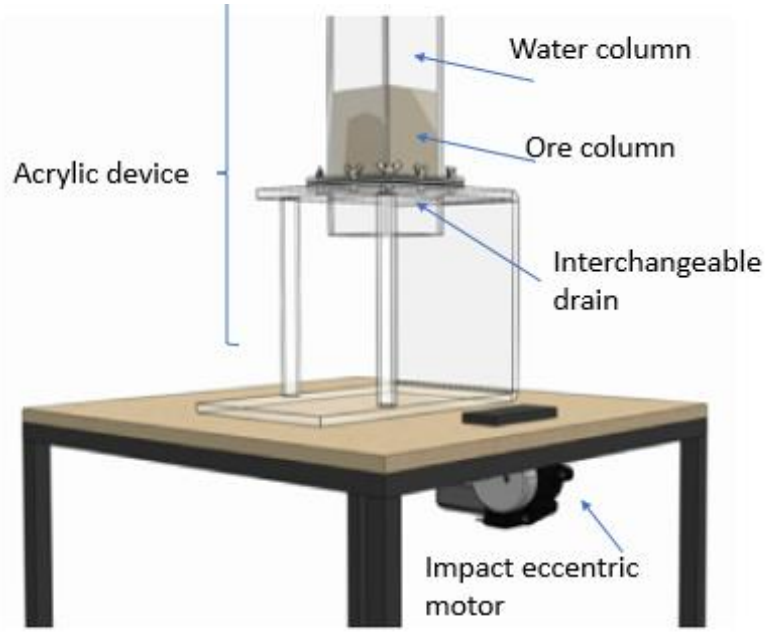

Figure 1 - Experimental apparatus for simulating percolation and water drainage in iron ore.

3 Results

The physical aspects of the aggregated particles after preparation of the initial moisture percentage are seen in Figure 2, equivalent to the mass concentrations of water of 2.8%, 5.4%, 7.9%, 10.3% and 12.5% respectively. It is possible to verify the tendency of greater compaction and agglomeration of the particles as the concentration of water in the mixture increases.
These characteristics of greater adhesion between particles directly influence the free flow of water through the ore and the drain, as can be seen in the graph of Figure 3. The longer time for the decrease of the water column is associated with the higher initial concentrations of water in the ore, that is, the more humid the mixture, the longer the time for percolation and drainage of free water.
The effect of vibration can be seen in the graph in Figure 5. The vibration causes more pronounced compaction of the ore column, which starts to behave as a filtering element, considerably increasing the time for water percolation and drainage.

Figure 2 - Mass water concentrations: (a) 2,78%; (b) 5,41%; (c) 7,89%; (d) 10,26%; (e) 12,50%

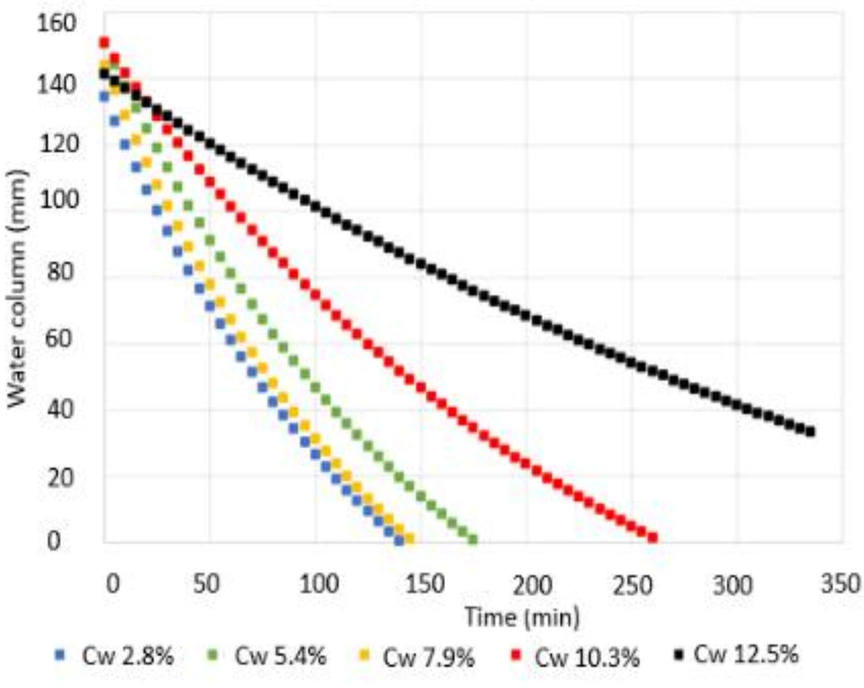

Figure 3 - Water column level over time for different initial percentages of water mass concentration in iron ore sinter feed

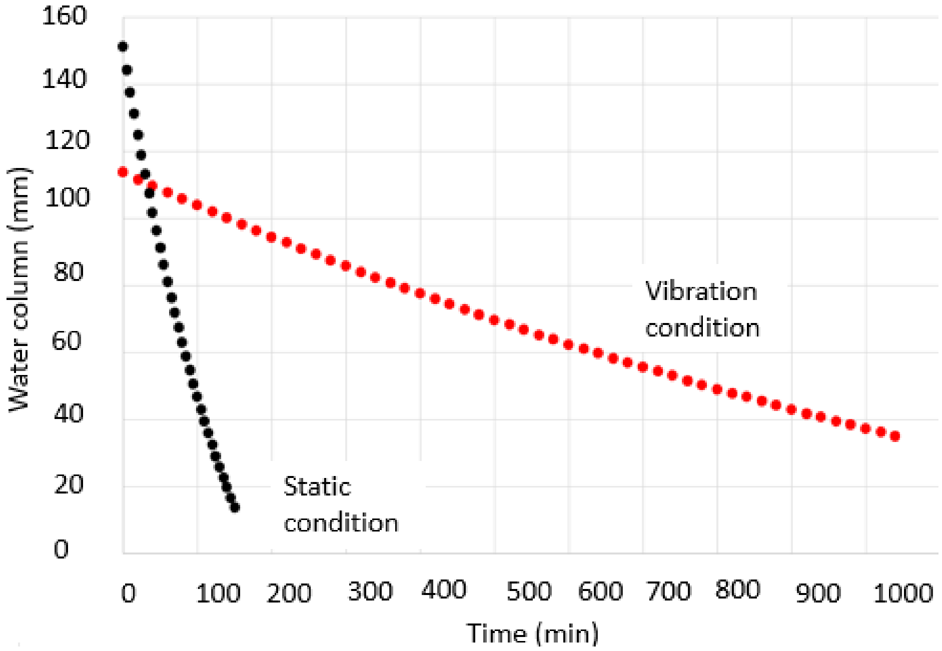

Figure 4- Water column level over time for static test condition and considering the effect of vibration.

4 Conclusions and Contributions

In conclusion, it is noted that the device developed to evaluate the percolation and drainage of water from ores transported on railroads by gondola-type wagons proved to be effective, as it allowed the characterization of the water flow as desired.
The two initial evaluations made in the device showed the importance of evaluating the initial conditions of humidity of the transported ore, since the water accumulated on the surface will take longer to drain if it is in conditions of higher humidity. At the same time, the vibration imposed in the experiment showed that the time scale for the flow in the same initial condition is much longer than for a static condition. The evaluated sinter feed ore presented a behaviour known as compressive cake, presenting characteristics of a filter element, which makes the water accumulated on the surface take a long time to be drained through the lower part of the ore column. This leads to the idea that the elimination of water from the top of the wagon may be more effective than from the bottom.

Acknowledgements

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