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Waste of Pellet Feed in Water Drainage Using Scale-Down Bench Testing

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Abstract

The transport of iron ore in gondola-type wagons can be affected by the accumulation of rainwater because they are open at the top. To mitigate this issue, drains are incorporated along the entire length of the wagon to enable water drainage. Due to the vibration caused by this transportation method, the compaction of fine ore particles prevents water percolation, leading to drain clogging and hindering effective drainage. Increasing the slot opening of the drains to facilitate drainage could results in the loss of ore onto the railway tracks, generating several transportation problems. This study aimed to quantify the mass loss of pellet feed iron ore on a scale-down experimental bench testing, analysing the ore's particle size distribution and drains with slot opening of 0.6 mm and 1mm. The drain with a 1mm opening caused a 58% loss of the initial mass due to the formation of a preferential water flow from the top to the surface in contact with the drain, with particle transport through turbulent flow. The drain with a 0.6 mm opening did not exhibit a preferential water flow, and the mass loss was on average 12 times smaller than the 1 mm opening.

Keywords: iron ore, experimental bench, drainage, drain, granulometry, percolation.

1 Introduction

Pellet feed is an iron ore with high iron content and few contaminants, crucial for the global economy, being used in steel production, with significant demand in the automotive, machinery, and construction sectors [1]. Between the mine and the processing industries, or even at export ports, this input is usually transported in gondola-type wagons (open-topped rail vehicles used for transporting loose bulk materials), facilitating its handling during the loading and unloading stages [2]. As these wagons are open, they end up capturing rainwater, and the humidity imposes an increase in weight and, consequently, fuel consumption, or mass loss may occur during water drainage.

Granulated materials tend to have a specific particle size range for different particulate products, and in each of them, there is a portion of natural moisture, known as the hygroscopic coefficient, which intercalates with air molecules and fills the pores present in these agglomerated products. Once the assimilation of rainwater in the wagons occurs, the water begins to penetrate the ore through capillary forces, and within this perspective, the following scenarios can occur: one of natural saturation and another of superficial moisture retention, when the particulate absorption capacity is lower than the water precipitation rate [3,4]. In the second option, it is common for free water to form on the ore during railway transport, strongly affected by compaction during transportation. Studies directly analyzing the effect of water assimilation on iron ore wagons are scarce in the literature.

The authors of this study proposed the development of an experimental bench capable of analyzing these effects, among others related to the percolation and drainage of water by iron ores, whose patent has already been registered [5]. The use of side and bottom drains in transport wagons, when the transported ore adheres to the drain hole, causes severe losses if the slot opening is too large compared to the particle size. Therefore, this study aims to evaluate the percolation and drainage of water in pellet feed iron ore, as well as quantify mass losses, using an experimental bench, considering drains with two different slot openings: 0.6 mm and 1 mm.

2 Methods

The granulometric characterization of pellet feed was conducted using the electromagnetic sieve shaker, model SP-1100 - SPLABOR, as shown in Figure 1, covering a range of sieves with openings ranging from 0.045 mm to 0.710 mm, according to the ABNT NBR ISO 4701:2020.

Figure 1: Electromagnetic sieve shaker.

The structure of the designed experimental setup comprises three transparent acrylic towers arranged on a thin wooden plate. The internal dimensions of the towers are 80 mm x 80 mm x 500 mm. Incorporated in the bottom are interchangeable drains, providing versatility to be tested with various configurations. Vibration induction in the apparatus is achieved through vertical impacts, using an eccentric motor containing a striker pin controlled by a frequency inverter attached to the bottom of the table. Figure 2 provides a detailed schematic representation of the experimental setup, outlining the strategic arrangement of drains and test towers. For more comprehensive information, it is recommended to refer to Bogsan [6].

Two drains with slot openings of 0.6 mm and 1 mm were tested, produced using a 3D printer with ABS polymer material. The geometry of both drains contains 45 slot openings in an area of 6400 mm^2 and a thickness of 6 mm.

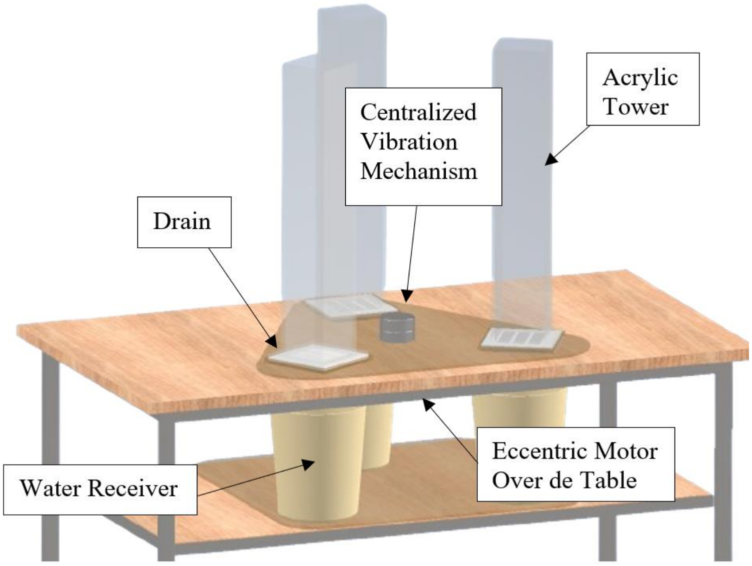

Figure 2: Experimental bench for percolation and water drainage in iron ore.

The first stage is the drying process of 1500 g of pellet feed, which was carried out for 24 hours in a kiln oven at a temperature of 110ºC, aiming to completely remove the moisture absorbed from the environment. Subsequently, water was added to achieve a sample with 40% saturation. In the acrylic tower, the saturated ore was carefully deposited, ensuring a uniform distribution along the cross-sectional area of the tower. Finally, through the dripping device, 1000g of deionized water was poured over the already saturated ore, accommodated in the tower, resulting in the formation of a free water column over the ore, providing a faithful representation of pellet feed characteristics regarding its saturation and drainage response.

After the complete exhaustion of water from the dripper, the vibration system of the experimental setup was activated, and the timer was started, thus marking the beginning of the experiment, as depicted in Figure 3. A strategically positioned container below the tower collected all drained water, along with a portion of ore that flowed through the drain. This moisture was subjected to a 24-hour period in the kiln oven at 110ºC, promoting the complete evaporation of water, resulting in the preservation of only the pellet feed, the quantity of which was subsequently quantified.

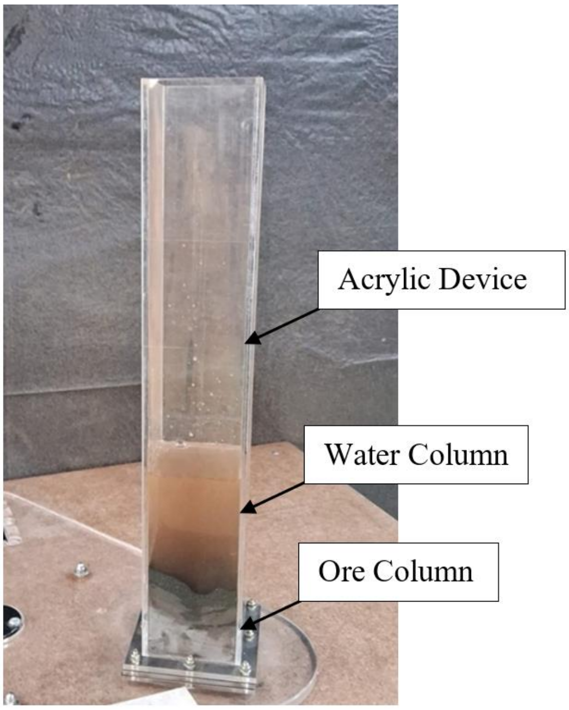

Figure 3: Acrylic device with iron ore and water column.

3 Results

As observed in Figure 4, the particle size distribution of pellet feed iron ore has a higher mass percentage in particles smaller than 0.10 mm, as the majority of fines were retained in the sieves with smaller openings. The iron ore was not retained in sieves larger than 1 mm: ϕa represents the mass fraction passing through the sieves and D is the particle size.

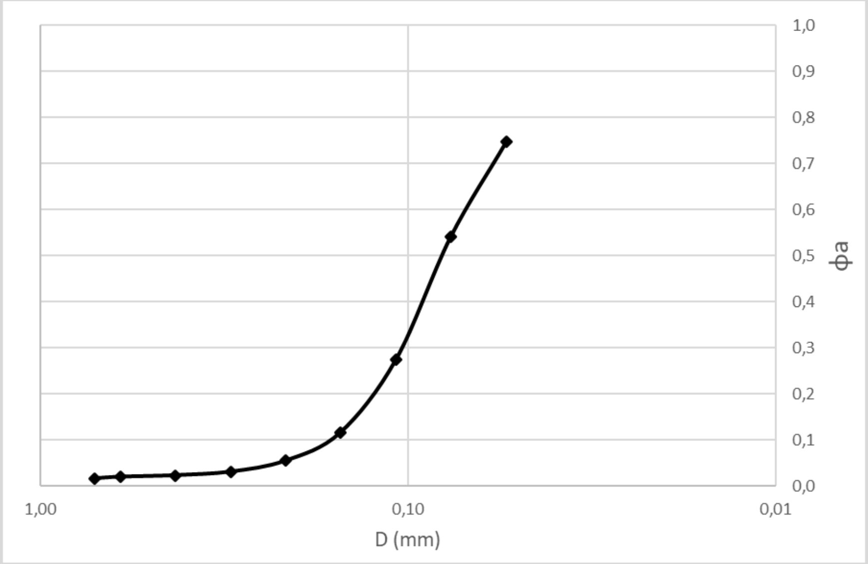

Figure 4: Particle size distribution of the pellet feed.

The experiments conducted with drains featuring 1 mm slot openings revealed the occurrence of a preferential water flow, leading to erosion in the ore stack extending from the upper surface to the base of the tower, where the drain is located. This resulted in an average waste of 865 g of ore. The representation in Figure 5 illustrates the typical behaviour of erosion following the formation of the preferential water flow during the process of water percolation and drainage with 1 mm drains opening. Consequently, experiments conducted with this configuration had an average duration of 7 minutes, while the 0.6 mm drain took an average of 142 minutes to achieve complete percolation and drainage without evidence of preferential water flow formation.

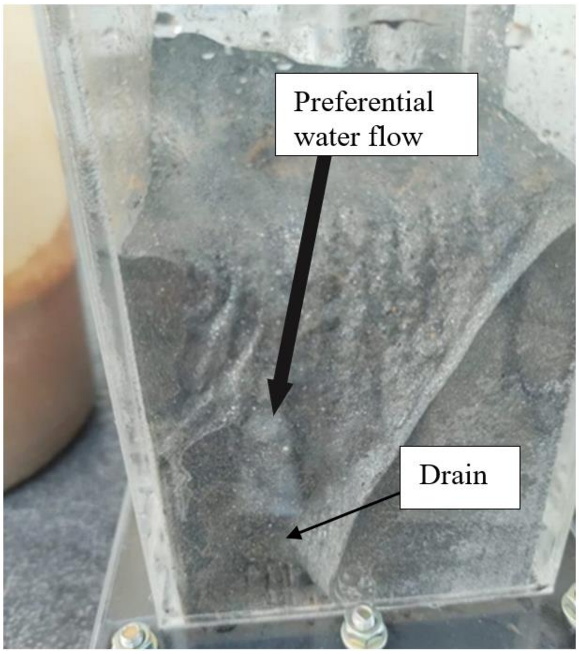

Figure 5: Preferential water flow with pellet feed.

The analysis in Figure 6 highlighted the wastage of iron ore in experiments with 1 mm and 0.6 mm drains. The average mass loss in 0.6 mm drains was less than 5% of the initial mass after conducting 8 identical tests, clearly indicating superior performance for this configuration. On the contrary, the ore loss with 1 mm drains reached 58% of the initial mass, indicating a 12 times higher loss compared to the 0.6 mm drain.

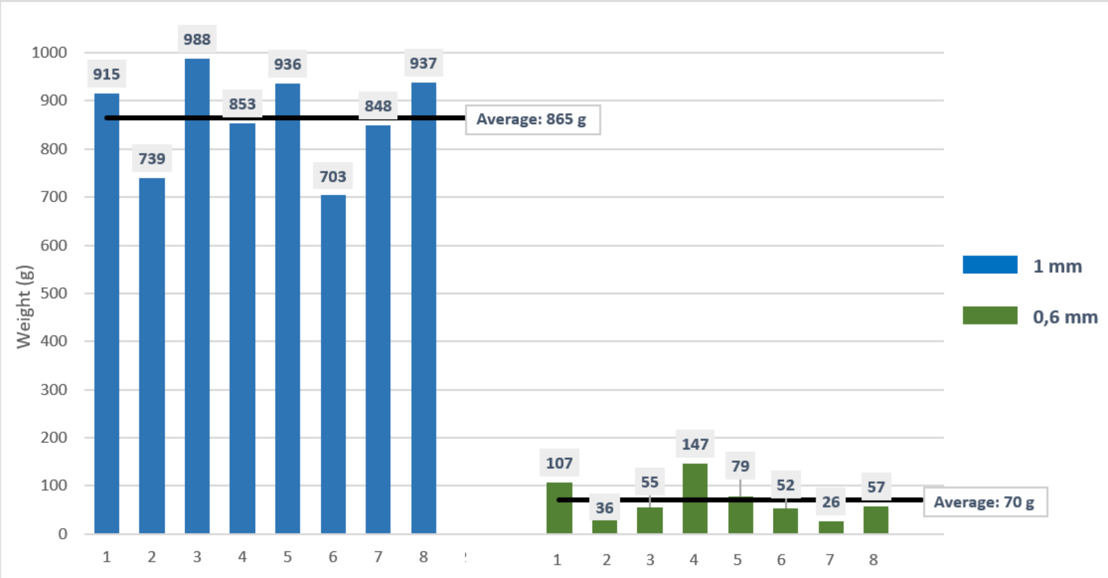

Figure 6: Wasted iron ore for different drain slot openings.

4 Conclusions and Contributions

The drainage of pellet feed iron ore using drains with a 1 mm opening results in considerable losses, amounting to 58% of the initially deposited mass in the assay.

The occurrence of preferential water flows in all the tests conducted with straight 1 mm opening drains indicates that their practical application is negligible in the field. This phenomenon is attributed to the significant presence of fine particles, mostly smaller than 0.10 mm, coupled with vibration, which aids in passing through the drain.

The ore wastage with the 0.6 mm opening drain proved to be, on average, 12 times less, although it took 20 times longer when compared to the 1 mm drain. This suggests that the 0.6 mm drain configuration may offer a more efficient and less wasteful alternative in practical applications.

The experimental bench proves to be useful for studies of this type, avoiding empirical tests in the field, which take time and are not always capable of comparison.

Considering that the same gondola cars can transport different types of ore, the larger slot of the drains does not always represent a good solution, due to the possibility of mass loss of the load through different mechanisms, as shown by the bench results.

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