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Compaction of Dry Sinter and Pellet Feed in Experimental Bench and Electromagnetic Shaker

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Abstract

The gondola cars employed in the transportation of iron ore feature an opening at their top, allowing the accumulation of free water during railway transit. To address this issue, drains are incorporated throughout the entire length of the car to facilitate water drainage. Due to the vibration induced by this mode of transport, the compaction of fine ore particles tends to decrease or prevent water percolation to the drains. The objective of this study was to compare the compaction characteristics of two ore types, sinter and pellet feed, using an experimental bench proposed by the authors and a standardized electromagnetic sieve shaker employed in particle size characterization. The electromagnetic shaker induced more substantial compaction in both ores compared to the experimental bench, representing an extreme case of vibration intensity. The compaction profile exhibited similarities in both mechanisms, with the initial minutes showing a more pronounced decline in the ore pile level, followed by a plateau until the conclusion of the experiment.

Keywords: iron ore, compaction, vibration, percolation, free water column, experimental bench.

1 Introduction

Railway transportation operations of iron ore face challenges related to draining accumulated water in open-top gondola cars, caused by weather conditions, due to, among other factors, the ore's compaction level [1]. This, in turn, is linked to a combination of factors, with one of the main and most relevant being the wagon's vibration along the railway network. Such vibration can be caused by various sources, such as the wagons passing over imperfections or welds in the tracks, or even being inherent to their own dynamic of movement along the route.

Sinter feed and pellet feed are two distinct types of iron ores: the former has a significant presence of organic particles and a wide granulometric variation, while the latter is characterized by finer particulate and a higher iron content due to beneficiation [2,3].

Naturally, when deposited and settled, iron ore, whether sinter feed or pellet feed, presents empty spaces between its composing particles. These spaces are larger in the case of sinter feed, due to the presence of coarser particles, than in pellet feed, which is characterized by a finer particle size distribution. Such spaces are utilized by water to perform the percolation process and flow, successfully carrying out drainage. However, when subjected to continuous vibration, the ore particles, especially the smaller ones, tend to rearrange and settle, filling and eliminating the empty spaces between them, becoming increasingly compacted [4]. In this way, free passages are eliminated, creating an obstacle to the flow and drainage of accumulated water, as there are fewer and fewer empty spaces and free passages for water to percolate; thus, hindering and impeding the flow and drainage.

The aim of this study is to compare the compaction level of a scale-down bench testing proposed previously by authors, designed to simulate a real scenario of accumulated water drainage due to rain in open-top gondola cars, with a vibration apparatus consisting of an electromagnetic sieve shaker, representing an extreme case of intensity.

2 Methods

This study utilized an electromagnetic sieve shaker, specifically the SP-1100 - SPLABOR model, for screening purposes [5] as shown in Figure 1. Three cylindrical vessels with internal diameters of 47 mm and heights of 256 mm as shown in Figure 2, along with a scale-down bench testing designed for simulating drainage and percolation using a vibration simulation device (see Bogsan, [6]) showcased in Figure 3, were employed. And iron ore samples of the sinter feed and pellet feed types, displayed in Figure 4.

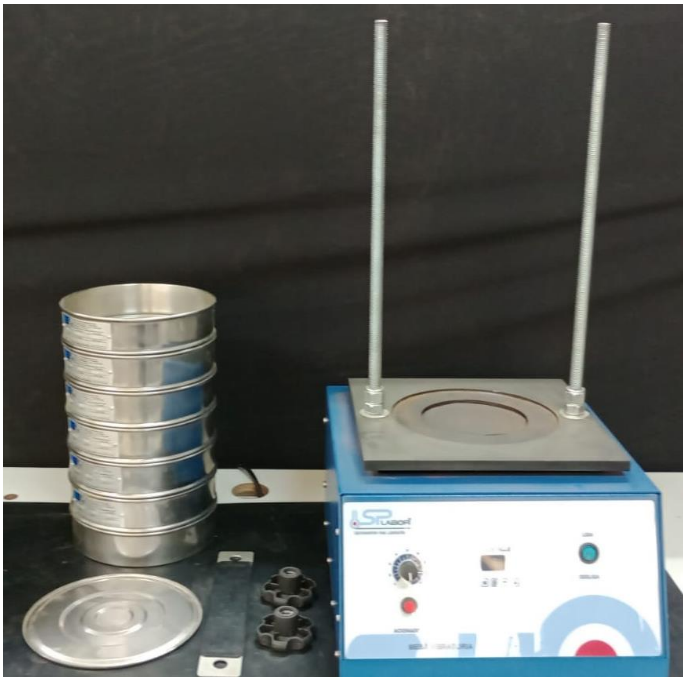


Figure 1: Electromagnetic sieve shaker SP-1100 - SPLABOR.

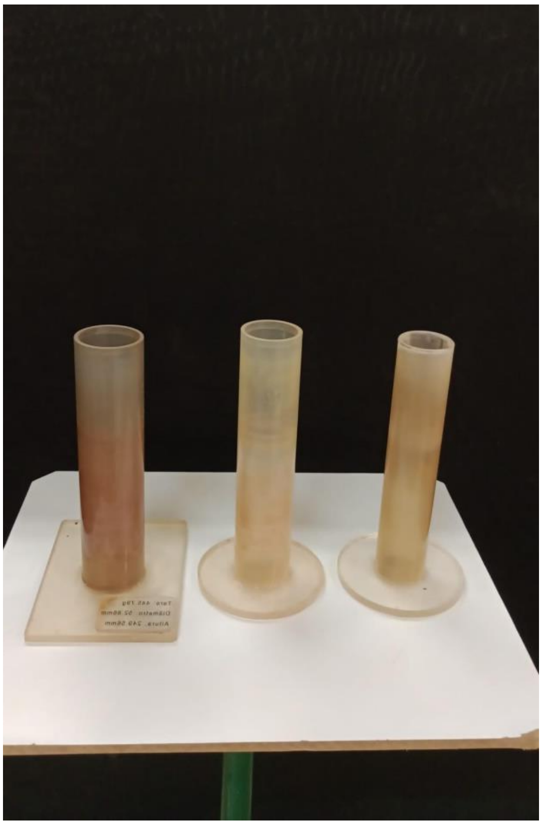
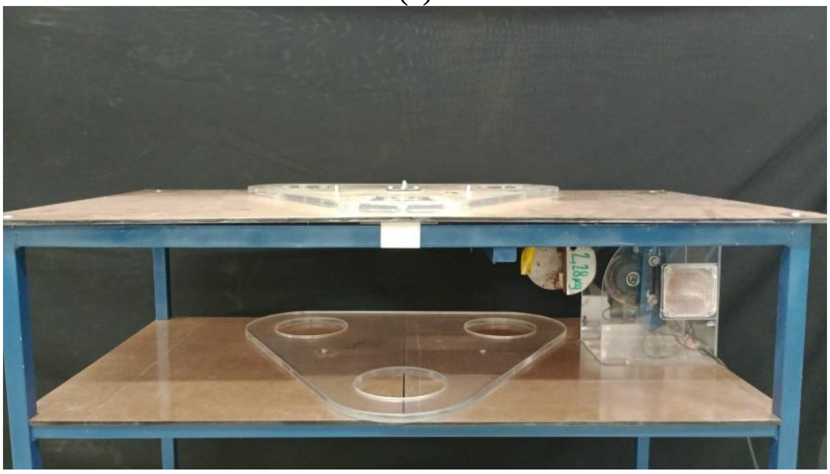


Figure 2: Acrylic measuring cylinders.

(a)



(b)

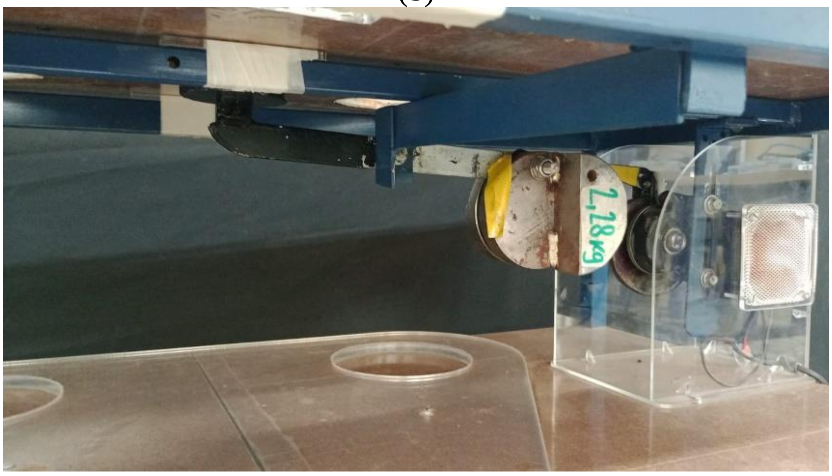


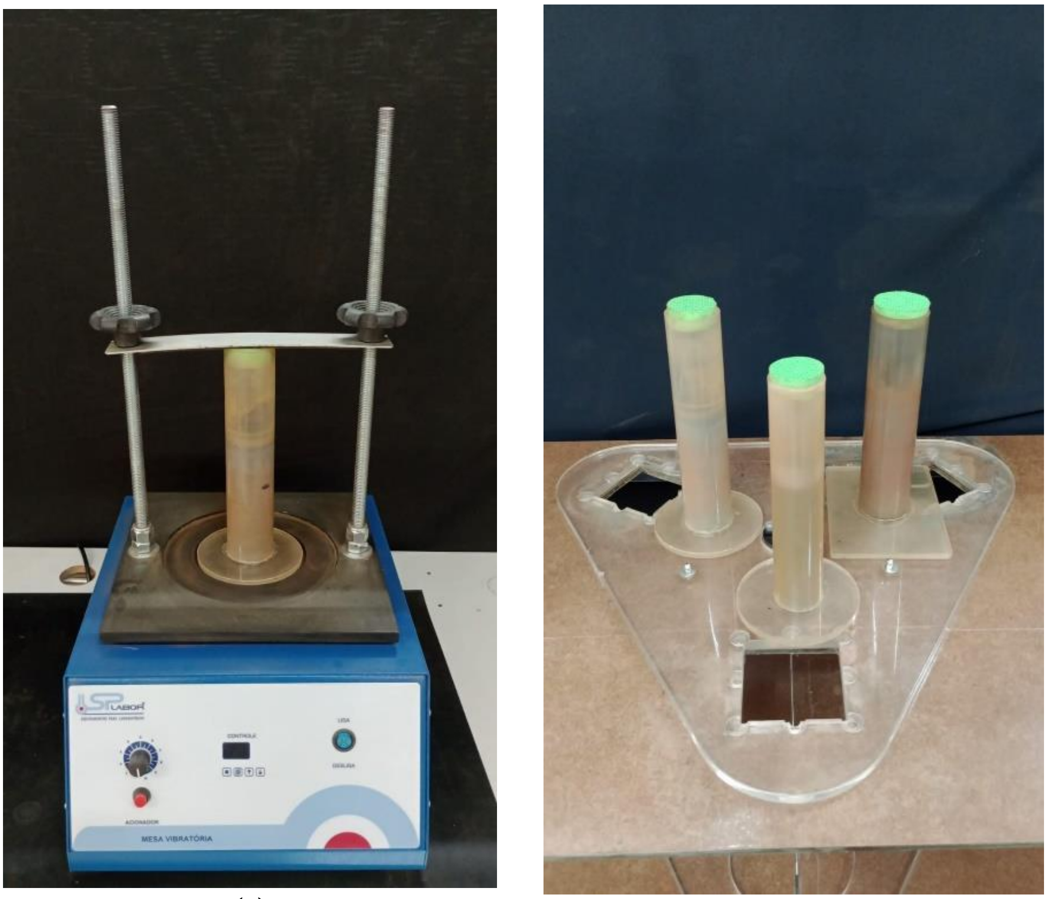
Figure 3: Overview of the scale-down bench testing setup (a), Bench vibration replication device (b).

Figure 4: Iron ore: sinter feed (left) and pellet feed (right).

Initially, granulometric characterization tests were conducted for both types of ore, employing an electromagnetic shaker tray on a vibrating machine with sieves ranging from 0.045 mm to 0.710 mm for pellet feed ore and from 0.045 mm to 31.5 mm for sinter feed ore, following the ABNT NBR ISO 4701:2020 standard [7]. This aimed to gain a comprehensive understanding of both particle compositions.

A measuring cylinder filled with sinter feed ore was attached to the vibrating table, reaching a predetermined height of 160 mm, as shown in Figure 5-a. The machine was then activated at maximum power, with vibration interruptions every 6 minutes for manual measurements of the new respective heights. This process continued for one hour (60 minutes, 10 measurements). The procedure was repeated with the other two cylinders (triplicate) and with pellet feed ore, also in triplicate.

On the experimental bench, the three cylinders were simultaneously fixed, positioned equidistantly from the impact center of the table, as illustrated in Figure 5-b. Once again, all cylinders were filled with sinter feed iron ore up to a predetermined height of 160 mm. The vibration simulator of the bench was then activated, and, similarly to the vibrating table, vibration was interrupted every 6 minutes to verify each new respective height. The entire procedure was repeated with pellet feed iron ore.



(a) (b)

Figure 5: Measuring cylinder filled with ore and attached to the vibrating table (a) and the reduced experimental bench (b).

3 Results

Figure 7 displays the particle size profile for both types of ore, where ϕa represents the mass fraction passing through the sieves and D is the particle size. It is observed that the sinter feed presents a particle size distribution with larger variation range than the pellet feed, as the former contains raw extraction features with organic particles and rocks, while the latter undergoes prior beneficiation.

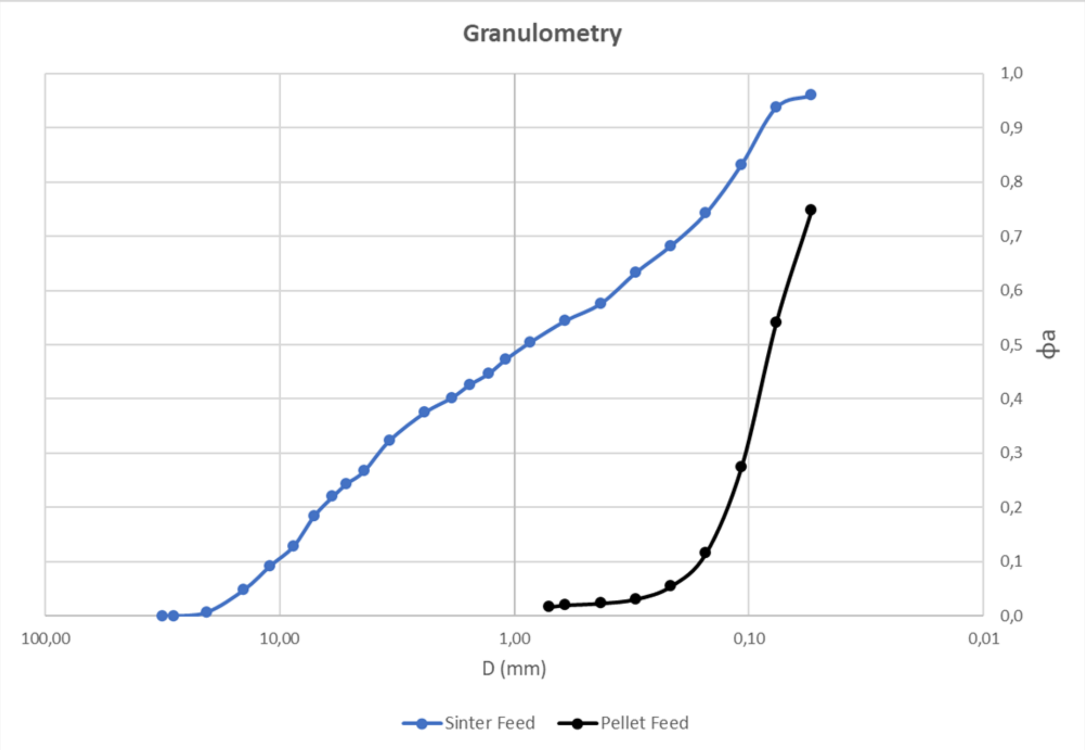


Figure 6: Particle size distribution for both types of ore.

In Figures 7 (Sinter Feed) and 8 (Pellet Feed), a comparison of the average height drop profiles for each ore type is presented, considering the electromagnetic shaker and the scale-down bench testing. These profiles depict the level of compaction for each ore type and under two conditions. It is evident that the compaction intensity is higher in the electromagnetic shaker in both cases. The graphs in Figures 7 and 8 show that the compaction intensity is more pronounced in the electromagnetic shaker. There is a greater, faster, and more abrupt drop in the electromagnetic shaker compared to the experimental bench. This difference is explained by the fact that the electromagnetic shaker represents an extreme scenario, while the bench only simulates the vibration occurring in the railway wagons along the track, being less intense but still sufficient to provide a considerable level of vibration and compaction.

Compaction in the electromagnetic shaker almost reaches its maximum level (as observed by the height drop) in the early time intervals and then stabilizes rapidly. In the reduced experimental bench, during the first-time interval, a more pronounced height drop and compaction are also observed, although not as much as in the electromagnetic shaker. However, over the test period, a gradual and smooth height drop and compaction are observed in the experimental bench.

The electromagnetic shaker machine directly acts on the propped-up test tube on the bench. For the proposed experimental bench, impacts occur at the bottom of the fixing plane, and the cylinders are detached on the surface, allowing for elevation with each impact.

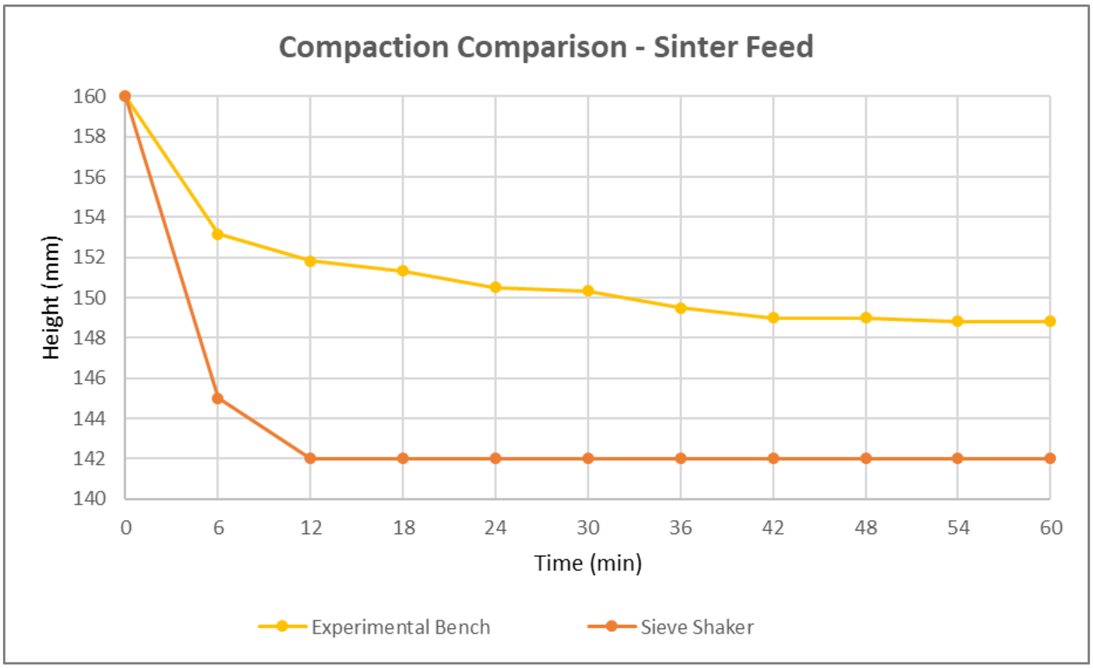


Figure 7: Comparison of compaction for Sinter Feed.

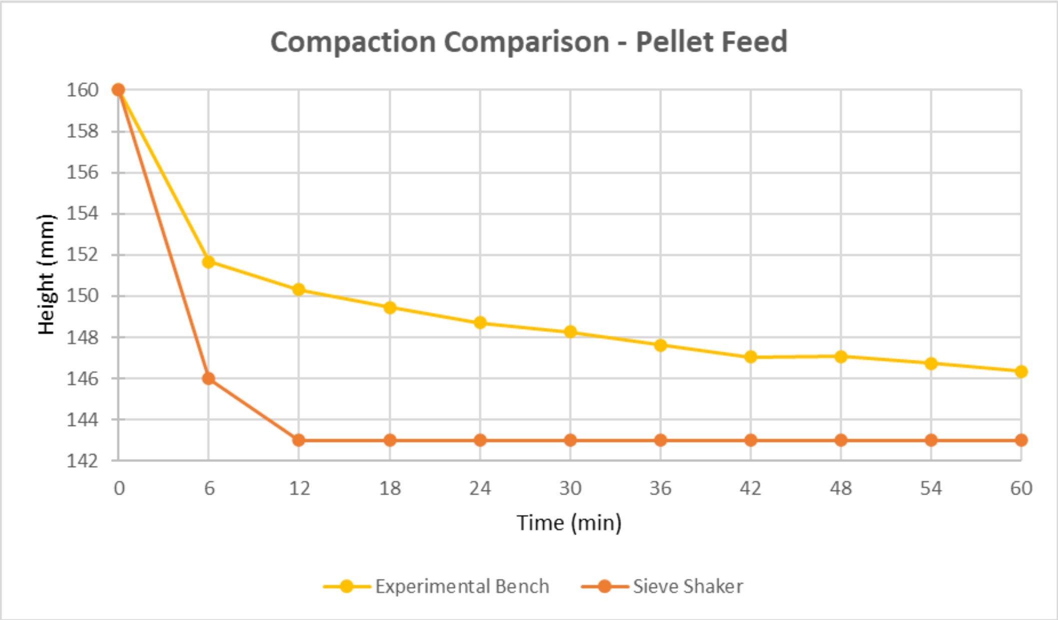


Figure 8: Comparison of compaction for Pellet Feed.

4 Conclusions and Contributions

The experiment demonstrates that for both iron ore types, the electromagnetic shaker consistently exhibited more intense compaction and in a shorter time. This is attributed to the coupling of the measuring cylinder adjusted on the electromagnetic shaker and only deposited on the bench in the case of the experimental bench.

The height drop profiles for both ores are similar, suggesting that the granulometry of each has little to no effect on compaction.

The experimental bench, which is still in the testing phase, can be modified in terms of variation levels and still needs to be compared with an instrumented wagon that obtains real vibration information in the field when transporting ore gondola cars.

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