Measurements of iron concentrate stockpile weight, from laser mapping to investigation of effective parameters on surface density

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Abstract
Determination of stockpile weight and stockpile inventory are critical to any quarry or mining operation, whether it is required by accounting firms or used internally for the quarterly balance of production and sales. Generally, errors and problems originate from two factors. Volume of stockpile that is traditionally worked out from the mapping results has a low accuracy due to irregular shape of the stockpile. This factor could be corrected by laser mapping and preparation of 3D images. Using the average density for weight calculation is also another origin of the inaccuracy. To avoid this error the effect of pressure (height of the pile) on the density had to be considered. To do so, density of the surface layer of each stockpile was required. So this research mainly deals with the factors that can influence surface density. Thus, the stacker performance was modeled in the pilot plant of Mobarakeh Steel Company. The results indicated that type of the concentrate, feeding height, particle size, and moisture content are, sequenhally, the main factors that influence the density of surface layers.

Keywords: stockpile, weight, surface density, iron

1. Introduction

Reporting tonnages of stockpiled iron concentrate is critical for a mining operation. Whilst mine surveyors routinely utilize a variety of terrestrial and airborne surveying techniques to report stockpile volumes, the determination of a stockpile's density to derive a tonnage is a difficult exercise. In spite of load cells and weighing on conveyors, stockpile weight computation is inevitable in each inventory period; because of calibration and systematic errors and absence of weighing system on certain conveyors or stackers.

With attention to iron concentrate stockpile dimensions (13 m height, 300 m length and 33 m width); it is clear that the density of material in different heights of stockpile varies because of gravity pressure. On the other hand, experience in this field shows that tonnage of one meter of pile in length can vary from 420 to 460t.

However, stockpiles are not maintained in a standard shape (Fig. 1). Conventional stockpile measurement methods (for volume determination) do not take into account the surface irregularities; typical in pile slumping.

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In spite of different standard methods for determining the volume and density of bulk material [1, 2], a conventional method for each condition is required to consider all factors and parameters. Among these methods, laser mapping has become a popular tool for modeling stockpiles and for improving inventory control. Using laser mapping equipments, it is possible to do the precise mapping without climbing up the stockpile (which is not possible in the case of iron ore concentrate).

Total Station (a new Laser mapping equipment) offers the following laser surveying/scanning services: stockpile inventory measurement, topographic scanning of areas, conventional surveying, GPS surveying, equipment alignment, laser scanning with the ability to view scanned objects in 3D and preparation of "as-built" drawings. In laser mapping, data points are computer interpreted into digital images. The quality of the data image is directly proportional to the number of data points. Within the area of the scan, the accuracy can be as high as 1/1000 of an inch using a very high number of data points.

Precise laser volume determination of irregular-faced stockpiles eliminates the need for costly and time consuming stockpile grooming. A wide range of bulk inventory stockpiles, including coal, minerals, petroleum-coke, agricultural products and dry bulk chemicals can be measured by laser surveying [3, 4]. Fig. 2 shows a part of a stockpile which was mapped using laser technology.

Fig. 1. Measurements of stockpile volume. (Notice the irregularity in pile).

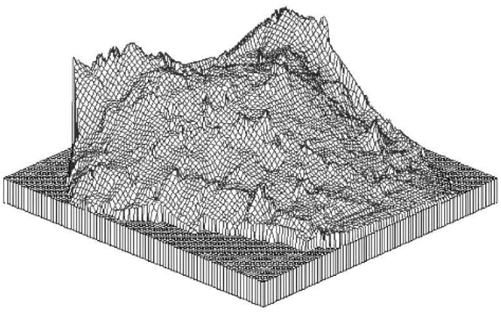


Fig. 2. typical 3-D map obtained by laser surveying.

The data obtained from the mapping procedure can be downloaded to a PC to calculate the volume. A simple model has been developed in which the stockpile is divided in 'n' layers (as shown schematically in Fig. 3) with equal thickness (height); and the total weigh could be calculated from the following equation (this is the subject of a paper under review)

$$W_t = \sum W_i = \sum_{1}^{n} \rho_i V_i$$

Where:
W_t = total weight of the stockpile
W_i = weight of layer i
V_i = volume of the layer i (measured from the mapping data)
ρ_i = average density of the concentrate in layer ith (can be measured by compacting the concentrate at different pressures)

For the above calculation, the density of concentrate at different heights of the pile (e.g. ρ_1, ρ_2, ρ_3, …, corresponding to layers 1, 2, 3, ….) is required. If "ρ_1" (surface density) is known, then the density of the following layers can be determined by compacting a sample of concentrate at different pressures (P_1, P_2, P_3, …). However, in order to determine the variation of density of iron ore concentrate with compaction pressure, the density of concentrate on the surface of stockpile is required. So, as the main objective of this research, an extensive investigation was preformed on the surface density of different stockpiles in Mobarakeh Steel Company.

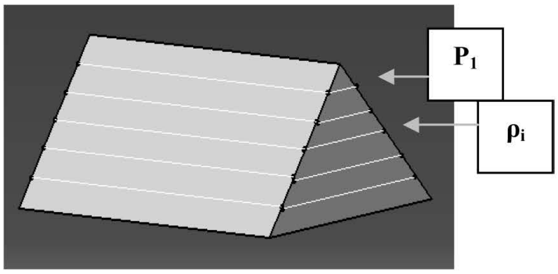


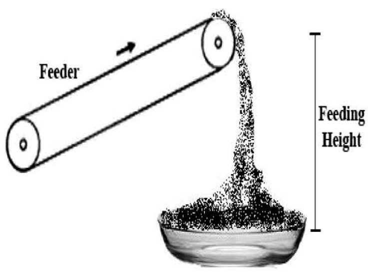
Fig.3. Schematic presentation of layers in the stockpile.

2. Procedure and Experiments

In order to determine the surface density, three different types of iron concentrates (Chadormalo, Gole Gohar and Choghart) were used. Size distributions of these concentrates are listed in table 1.

The application of stacker was simulated in the pilot plant of MSC using the mixer and feeder of the pelletizing equipment (Fig. 4). Concentrates were fed (poured) into a container of fixed volume from different heights. The density was then calculated by determining the weight of the concentrate in the container.

(A)



(B)

Fig. 4. (A) equipment used to model the stacker. (B) Schematic presentation of pile formation model.

Table 1. Size distribution of iron concentrates.

Iron concentrate	< 0.045 mm	0.15-0.045 mm	0.15-0.2 mm	0.2-0.6 mm	0.6-1 mm
Chadormalo	82.43	16.19	-	-	-
Choghart	42.76	42.94	6.83	6.57	0.48
Gole Gohar (Coarse)	11.82	20.97	10.16	39.83	6.69
Gole Gohar (fine)	76.8	8.13	-	-	-

3. Results and discussion

The surface density value is an essential parameter that is used in calculating density at different pressures. The surface density depends on many parameters that were examined and are reported in the following sections.

3.1. Effect of iron concentrate

Fig. 5 shows the change of surface layer density with the type of concentrate at different feeding heights. As can be seen, density of Gole Gohar concentrate is higher than that in other concentrates at any stacker height.

3.2. Effect of feeding height

The distance between the stacker tip and the pile (feeding height) of iron concentrate is one of the parameters that influences surface density. The higher this distance, the more compaction of concentrates on dropping, and the bigger the surface density (Fig. 5). As seen in Fig. 5, when this distance changes from 10 to 150cm, the increase in density is about 0.1gr/cm^3. This effect is more pronounced for the concentrates with higher particle size (e.g. Choghart). A similar trend was seen for all of the concentrates.

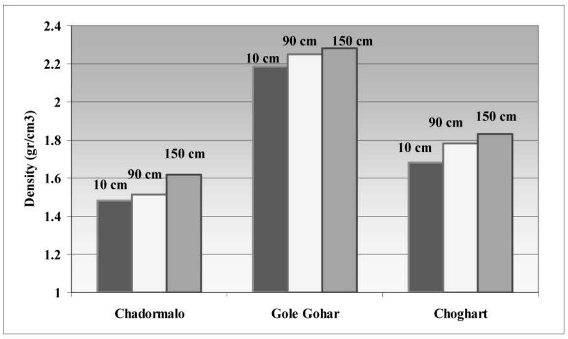


Fig. 5. Density changes with different concentrates and feeding heights.

3.3. Effect of moisture

To recognize the moisture effect, iron concentrates were dried in an oven at 105°C for 15 min and then water was added manually in a mixer. Experiments were carried out for 100 and 150 cm feeding heights. The variation of surface density as a function of moisture percent, for Choghart and Chadormalo concentrates, are shown in Figs. 6 and 7, respectively. The results show that density slightly decreased with an increase in moisture up to 6wt%. Then, surface density increased rapidly. Decrease in surface density below 6wt% moisture might be due to particle bridging and prevention of compaction. Low moisture plays a role as a binder. With increasing the moisture above 6wt%, free mobility and sliding of particles are activated, and the free space is filled with finer particle or water; therefore, surface density increases.

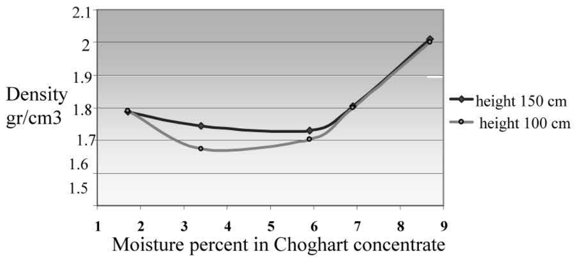


Fig. 6. Density changes as a function of moisture percent in Choghart concentrate.

Density change with moisture was also reviewed by other researchers [5, 6)]. They reported that mechanisms governing the relationship between bulk density and moisture content are the inter-particle friction, tightened size distribution and agglomerate formation. The results suggest that when moisture content is small (e.g. < 6.5wt%) the mechanisms of inter-particle friction and tightened size distribution results in a decrease in bulk density. When moisture content is larger, the mechanism of agglomerate formation becomes effective too, which, together with the mechanism of inter-particle friction, result in an increase in bulk density

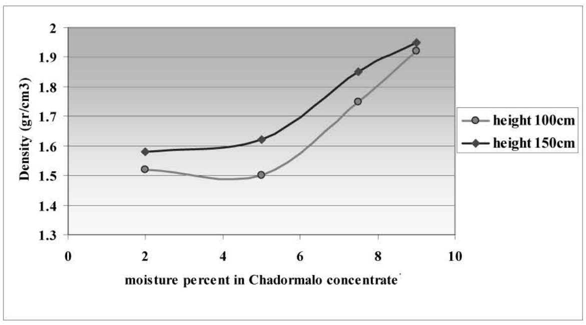


Fig. 7. Density changes as a function of moisture percent in Chadormalo concentrate.

3.4. Effect of particle size

Average particle size and size distribution of concentrates obviously influence the compaction on dropping and, thus, the surface density. To investigate this effect, mixtures of fine and coarse Gole Gohar, at different ratios were used for density measurements. As shown in Fig. 8 a mixture of 30 percent fine concentrate has the highest density.

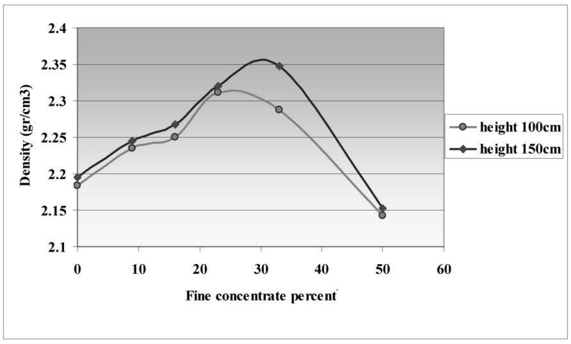


Fig. 8. Effect of fine concentrates percent on surface density.

4. Conclusion

- Information of the density of the surface layer of the stockpile is required to determine the density of the alternate layers under pressure of the higher layers.
- The surface density of the stockpile depends on: the type of concentrate, particle size and distribution, moisture content and the distance between stacker tip and stockpile surface (feeding height).
- At fixed moisture content, particle size and distribution have the highest effect on the surface density, so the surface density of Gole Gohar (with coarser particles) is higher than that of Chadormalo and Choghart concentrate.

Acknowledgement

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