



## Bulk Density of Powders Made Easy

Bulk density of powders and bulk materials has always been one of the major factors to consider when characterizing flowability, stacking and storage. Many methods for measuring the bulk density can be subjective at best. These types of methods can be cumbersome, time consuming and inaccurate. One method is a standard “tap” test. This involves filling a container or a beaker with a powder, then tapping it for a specified number of times (100, 180 times are fairly standard). The tapping part is done either with a specific mechanical device or, even more subjectively, a person. Calculations for bulk density are usually made using a Hausner Ratio or Carr Index, which compute a ratio of powder in a loose fill condition to tapped bulk density. Both the Hausner Ratio and Carr Index, while establishing flowability empirically, have been criticized in industry as not having a strong theoretical basis.

Such methods have been practiced for some time. This is due to the fact the equipment required is very low cost and the technique easy to learn. In some cases, this is merely because there was not an alternative method at the time. The reasoning of “It is what we have always done” also applies in this type of case.

But what exactly is “bulk density” and why is it so important in characterizing bulk solids? Why are so many companies concerned with the bulk density of their material?

Bulk density is, basically, how a material will compact under various loads and can also be an indicator of flow. Think of a bag of potato chips. During the initial fill, the bag is filled to the top with chips. Then, under gravity and the load of the chips, the chips settle down to the bottom of the bag. The voids in between the chips are filled by the chips themselves settling. Thus, when you open the bag of chips, you see the bag as half filled (or half-empty if you are a pessimist).

The above is a simple analogy. In bulk solids practice, there are some other parameters to consider. The bulk density of fine-grained materials (or small particles) is very dependent on the consolidation strength. Coarse powders, such as dry sand, are not as compressible, thus, they have a lower bulk density. Granulated sugar is an easy flowing, coarse material while confectionary sugar is a fine, cohesive material. If you filled a beaker with granulated sugar and tapped it 100 times, you would not see much compression of the material; the voids between the particles would not be filled due to the coarse nature of the material. Do the same test with the fine ground confectionary sugar and observe that a noticeable compression of the material would occur due to the fine particles filling the voids.

Why is this important? Bulk density is used to assess things like the mass content of a bin or hopper. This mass content can be plotted against fill level in the bin. Stacking considerations are another important aspect. From the bulk density information, you can determine how compressible the material is and how many bags you can stack on a pallet. This stacking calculation is also used for storage of the material in warehouse.

Bulk density can be used for a realistic assessment of what a material will be like when received by a customer. For example, you fill a 55 gallon drum with material and ship this to your customer. The customer opens the drum and sees it is 2/3 full. Given the bulk density of the material, the customer will know they did receive the proper amount and the material has merely settled. And, certainly, bulk density can be an indicator of how well or not a material flows. The greater the change in a material’s bulk density from initial fill to final consolidated bulk density, the less likely that the material will flow.

But, back to the easy method of realizing bulk density. Recently, Brookfield Engineering developed a Powder Flow Tester (see figure 1). This instrument is used



Figure 1: Brookfield's Powder Flow Tester



Figure 2a: Brookfield's Vane Lid Figure 2b: Brookfield's Wall Friction

to characterize properties of bulk solids for bulk density, flow function, wall friction, internal powder friction angle, arching dimension, rat hole diameter, hopper half angle and time consolidation.

The vane lid (see figure 2a) if use for flow function and time con-

solidation tests while the friction lid (see figure 2b) is used for wall friction and bulk density testing. The bulk density measurement can be done one of two ways: as part of the flow function test or as a dedicated bulk density test. The dedicated bulk density tests takes about 2.5 minutes to run.

An example of a dedicated bulk density test using the Brookfield Powder Flow Tester is given by the graph:

The bulk density graph illustrates the density of the samples over different consolidating stresses (see figure 3). In general, a free flowing powder will show very small change in bulk density from initial fill density to final consolidation stress; the bulk density from initial fill to final consolidation will basically be a flat line. A cohesive or poor flowing powder will generally show a large increase in bulk density (about 30-50%) from initial fill density as consolidating stress increases.

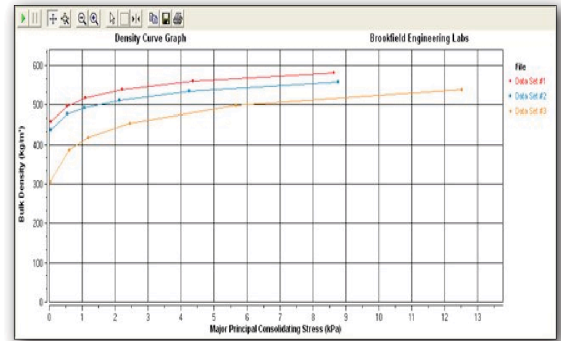


Figure 3: Bulk Density Graph

The Data Set #2 sample shows an initial fill density of about 440kg/m<sup>3</sup> and then rise to about 550 kg/m<sup>3</sup> at the higher 8.5 kPa consolidation stress, a change of about 20%. This indicates the material is free flowing. That is, compaction at higher consolidation stresses is not going to be an issue. The Data Set #3 sample shows an initial fill density of 300 kg/m<sup>3</sup> to a final value then rises to about 540 kg/m<sup>3</sup> at the higher 12.5 kPa consolidation stress, a change of about 45%. This indicates the material is more cohesive and will have a problem flowing. Compaction of this product at higher consolidations will be much greater.

This simplified dedicated bulk density test requires virtually no training. Results are realized in a few minutes for analysis of the sample. The Brookfield Powder Flow Pro software also allows the user to export this data to Excel, create reports, and share data files with other users for data analysis. The easy to use Comparison feature of the software allows for up to eight samples to be compared. Thus, if a control sample has been defined, subsequent samples can be pulled up and compared to the control.

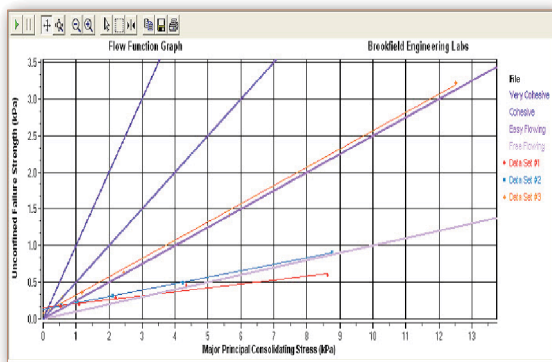


Figure 4: Flow Function Graph

The corresponding flow function graphs for the bulk density graphs in Figure 3 appear as shown in Figure 4 of the comparison section of the Powder Flow Pro software. The Flow Function graph (see figure 4) for Data Set #1 shows this material to be free flowing as indicated by the bulk density graph in Figure 4. For Data Set #3, this clearly shows the material to be cohesive as expected from the bulk density data. Of course, this is dependent on particle size and formation. There are occasions when a material will show a more easy flowing behavior in the flow function, but its bulk density has a higher disparity from initial fill to final consolidation due to the shape of the particles and how they align.

Through the use of the Brookfield Powder Flow Tester, quick, definitive tests for bulk density are easily accomplished; operator error is removed from the equation. Accurate, comparative results are quickly and easily defined, not only for bulk density, but for additional flow properties such as flow function, wall friction, arching dimension and rat hole diameter. The Brookfield Powder Flow Tester is a complete instrument for defining powder flow properties.