WHAT TO KNOW IF YOU WANT FLOW

When handling materials there is no one perfect solution that works for all bulk solids. Whether you are working with pharmaceutical or metal powders, carbon fibre, ash, cereals, minerals, waste or anything else, knowing the material is the only way to ensure that the equipment will perform well with that bulk solid.

What are the Benefits of Knowing the Material?

Knowing your material brings assured performance, a longer useable life, and a far lower total cost of ownership than if the material is not properly considered. For example, if you need a hopper and cost is the primary factor, a conical hopper would be the obvious choice as they are fairly easy to make. However, a cone is often not the best shape for material flow, whilst defining its slope and outlet size is haphazard if material properties have not been used in design.

A conical hopper forces a bulk solid to converge simultaneously in two planes which can mean no flow issues or residual material that is reluctant to discharge. This reduces both usable volume and plant performance, and requires manual interventions to encourage flow, exposing operators to hazards and leads to hammer rash which can make matters worse.

To establish the hopper shapes, wall angles and outlet sizes needed you must spend time material testing. Investing in that research will pay for itself many times from the get-go and over the service life of the equipment.

Wall Friction

During solids handling there are many situations where materials are required to slip against a contact surface, eg the wall of a hopper, the flights of a screw conveyor or mixer blades.

A material's resistance to sliding can be established using a wall friction tester.

Ajax's tester measures the force needed to push the bulk solid across a wall surface for a variety of contact loads. The data can be presented in a graph of normal stress (σ_n) against wall shear stress (τ), usually in N/m2. The slope of the line is the characteristic wall friction angle, (ϕ_w) see equation below.

$$\phi_w = \tan^{-1}(\tau/\sigma_n)$$

Bulk Density

Bulk density is used to size hoppers and screw conveyors but it's also useful for assessing flowability. Whilst it is simple to measure by establishing the volume occupied by a known mass of bulk solid, it is rarely a single invariant value. Variability in the bulk density tends to indicate a sensitivity to handling and storage.

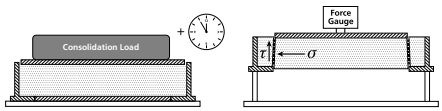
When flowing the material tends to be in its loosest condition. When stored volume falls as the material settles, compacts under its own weight and de-aerates. Low bulk density tends to indicate poor flow. A material's flowability can be characterised by changes in bulk density using the Hausner Ratio (HR), calculated by comparing a material's tapped bulk density against its loose bulk density and ranked as the table below:

Hausner Ratio	Material 'Flowability'
1.0 - 1.1	Free Flowing
1.1 - 1.25	Medium Flowing
1.25 - 1.4	Poor Flowing
Over 1.4	Very Poor Flowing

Shear Strength

Shear strength indicates how cohesive a solid is and how much resistance it offers to deformation and flow. This is the key parameter for establishing a reliable outlet size for gravity flow.

VERTICAL SHEAR CELL TEST



This figure indicates the stages of testing; once the shear strength (τ_s) and bulk density (ρ_b) are known a simple force balance helps determine the minimum outlet diameter (D_{crit}) required to destabilise a rat hole or an arch, see equation:

$$D_{crit} = \frac{4 * \tau_s}{\rho_b * g}$$

For slot outlets this minimum outlet size can be halved if an outlet 3 x longer than the width is used.

From Data to Design

Once you know your material's characteristics it is possible to confidently produce an appropriate design. Understanding the results is just as important as having them. For example, data can help design a hopper but it won't tell you that using a screw feeder below it could reduce the headroom needed, increase storage capacity and improve material flow. Innovation is often key to using the data to produce a practical working solution.

Note testing should always be representative of actual process material and conditions, often it is wise to consider the worst case.