BASIC KNOWLEDGE

STORAGE AND FLOW OF BULK SOLIDS

The term "bulk solids" generally refers to materials in the form of collections of single or individual particles. These particles may be very fine (powder) or coarse. Examples are ores, cement, foodstuffs or chemical products. Bulk solids are stored in tanks, containers or silos, depending on quantity. The storage facilities must be designed such that they neither impair product quality nor cause disturbances to the removal of the bulk solids.

Bulk solids do not behave like Newtonian fluids either when flowing or when at rest in storage. In contrast to Newtonian fluids, bulk solids can also transmit transverse strain when at rest, and accordingly form surfaces which tend to be stable. Nor are analogies with the behaviour of solids usually possible. For example, in contrast to solids, a bulk solid cannot transmit any significant tensile stresses.

Consequently, in order to describe the behaviour of bulk solids there is a dedicated discipline known as bulk mechanics or powder mechanics, which is founded on that of soil mechanics.

For more information on the subject: Schulze, D.: Powders and Bulk Solids, Springer, Berlin Heidelberg New York (2007)

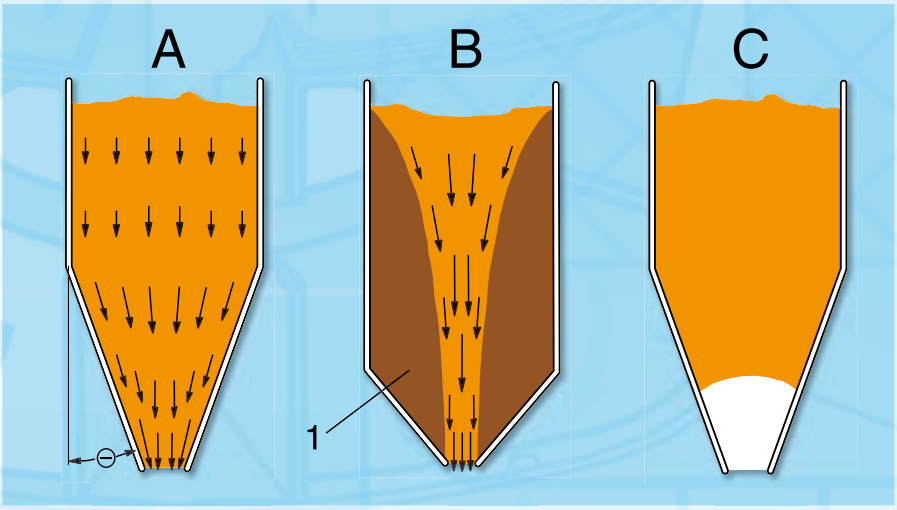
Typical phenomena when bulk solid is flowing out of a hopper or silo are:

- **Mass flow**
  The entire vessel contents are in motion during discharge of the bulk solid. If the area above the hopper is high enough, a uniform sinkage across the cross-section occurs (piston flow).

- **Funnel flow**
  Only a limited zone above the discharge opening, which can widen out upwards in a funnel shape, is in motion during discharge of the bulk solid. At the sides of the flowing bulk so-called dead zones are formed, in which the material is at rest. The material rests in those zones for a long time, and is only discharged towards the end of the emptying process. Moreover, a bulk solid which is not very free-flowing may become compacted in the dead zones to such an extent that it will not flow out by gravity alone.

- **Arching**
  In the case of poor flowing, cohesive bulk solids, a stable arch may form in the discharge hopper causing the material flow to come to a stop.

- **Segregation**
  When filling storage containers, segregation may occur if the particles are of differing size, shape or density. Segregation by its nature reduces product quality.



A mass flow, B funnel flow, C arching
Θ angle of hopper wall, 1 dead zones

Whether mass or funnel flow is occurring depends on the flow properties of the bulk solid and on the wall material and angle of inclination of the hopper walls. The required angle of the hopper walls can be calculated if the flow properties are known. The flow properties are measured using shear testers. With these measured values, the minimum size of the discharge opening to avoid arching can also be calculated.