

## 9. SEGREGATION

Separation articles by size, density, or other material properties occurs when concentrations of one type of particle in a hopper or pile is much greater than the average for the entire mass. The process of separating the particles into different relative concentrations is referred to as segregation is the opposite. Segregation processes are the opposite of mixing processes, which in the latter the particles are blended into relatively uniform consistency.

Segregation is important in handling of powders because in many operations you want to avoid concentrations of one particle type or another.

### 9.1 Mechanisms

We need to understand the mechanisms that cause segregation before we can design systems to minimize the effect. Differences in size, density, shape and resilience all contribute to segregation. By far, particle size difference is the most important parameter.

Four primary mechanisms cause segregation:

- **TRAJECTORY SEGREGATION.** When a powder cloud is in flight, groups of fine particles can travel farther than single large particles. For coarse particles, the larger particles tend to travel the farthest.
- **PERCOLATION OF FINES (also called sifting).** If a mass of particles is disturbed (by stirring, shaking, vibrating) such that the individual particles move relative to each other, a rearrangement in the packing occurs.

If a powder has a size distribution, it is easier for smaller particles to move into the void spaces between larger particles during the disturbance. Hence, in a storage hopper there is a tendency for small particles to migrate downward in the direction of gravity. A very small size difference is sometimes sufficient to cause a measurable segregation.

Segregation upon pouring a powder into a pile occurs frequently due to the percolation (as well as trajectory) mechanisms (Figure 9-1).

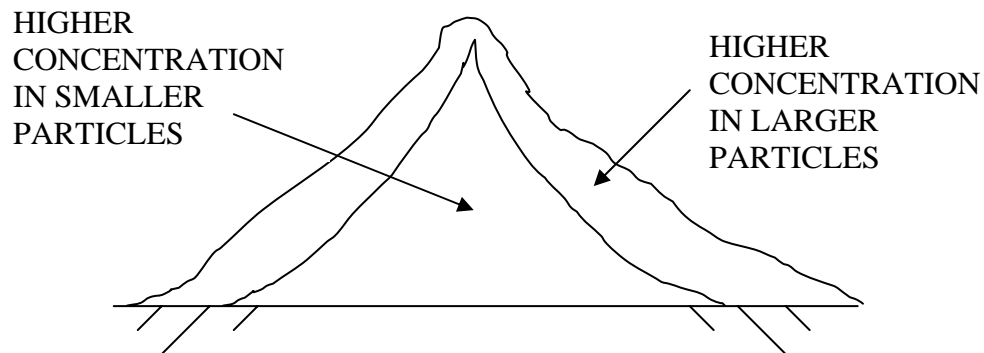


Figure 9-1. Segregation of particles when poured into a pile due to percolation.

- **RISE OF COARSE PARTICLES UPON VIBRATION.** This effect can be demonstrated by submerging a large steel ball bearing in sand in a beaker. Upon vibrating the beaker the ball bearing rises to the top of the sand. This occurs even when the larger particle is much denser than the fine particles.
- **ELUTRIATION SEGREGATION** (also called fluidization). When a powder is discharged from a hopper, or is poured into the top of a hopper, a large volume of air is displaced. The air velocity may exceed the terminal velocity of the smaller particles. This can cause the fines to suspend while the coarse particles settle out. The fines eventually settle on top of the suspension and form a layer on top of the powder that is concentrated in the fines.

### ***9.2 Reduction in Segregation***

Methods to reduce segregation are aimed at reducing the effects that cause segregation.

- Make sizes of components as close as possible to the same size.
- Reduce the absolute size of the particles. Usually segregation is not a problem for particles smaller than about 30 microns for particle densities in the 2000 to 3000 kg/m<sup>3</sup> range. For more dense particles the size must be smaller than 30 microns. For very small particles the surface forces act to minimize the segregation effect on individual particles. However, if the surface forces cause the particles to agglomerate into larger particles, then segregation may become a problem again.
- A small amount of liquid may be added to a powder to increase its attractive forces between particles and minimize fines migration.
- Avoid situations that promote segregation
  - Avoid pouring where the powder forms a sloping surface,
  - Avoid pouring into the core of a hopper,
  - Avoid vibrations, shaking, stirring (unless done to promote mixing),
  - Use mass flow hoppers.
- Use continuous mixing.
- Use materials with large aspect ratios. Fibers and flakes do not segregate as easily as spherical shapes. Rough surfaces also reduce the segregation effect.

### **9.3 Example**

A transport truck is loaded with a well mixed powder with a wide size distribution. The truck delivers the product to a facility 20 miles from the its loading point.

Is the material likely to segregate?

Yes, due to vibrations from the transport.

What material will exit first? Last?

Fines are more likely to exit first and coarse to exit last.

What options do you have to minimize the segregation at the delivery site?

Additives to reduce segregation (liquid? Fibers?)

Do the mixing at the delivery site.

Change the particle size mixture at the supply site to a more uniform size.