Storage of Bulk Solids

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Storage and Transport of Bulk Solids

Agriculture

Mineral processing

Fertilizer

Construction materials

Food processing

Pharmaceutical

and Many more industries..

Particulate Solids/ Bulk Solids

- Length scale: micron to cm
- Particles types (few listed below):
  - Abrasive
  - Tough
  - Rubbery
  - Soft
  - Dusty
  - Cohesive F
  - Free flowing

Storage Types

- Open storage
- Closed storage

Open storage

- Commonly used materials : Coarse solids like gravel, sand, etc.
- For large quantities : This is the most economical method.
- Problems: Environmental problems such as dusting or leaching of soluble material from the pile.

Sulphur storage

Coal storage

Coal could be a black bomb if improperly stored

If Coal needs to stored in closed container, continuous monitoring of gases (CO, CO_2) and temperature and proper ventilation system are necessary

Closed Storage

- Often, Three types of containers/vessels are used – Bin, Hoper and Silo.

Bins

- Larger diameter, Small height
- specified humidity and temperature condition
- Vented
- Mainly for dry materials

Hopers

Silos

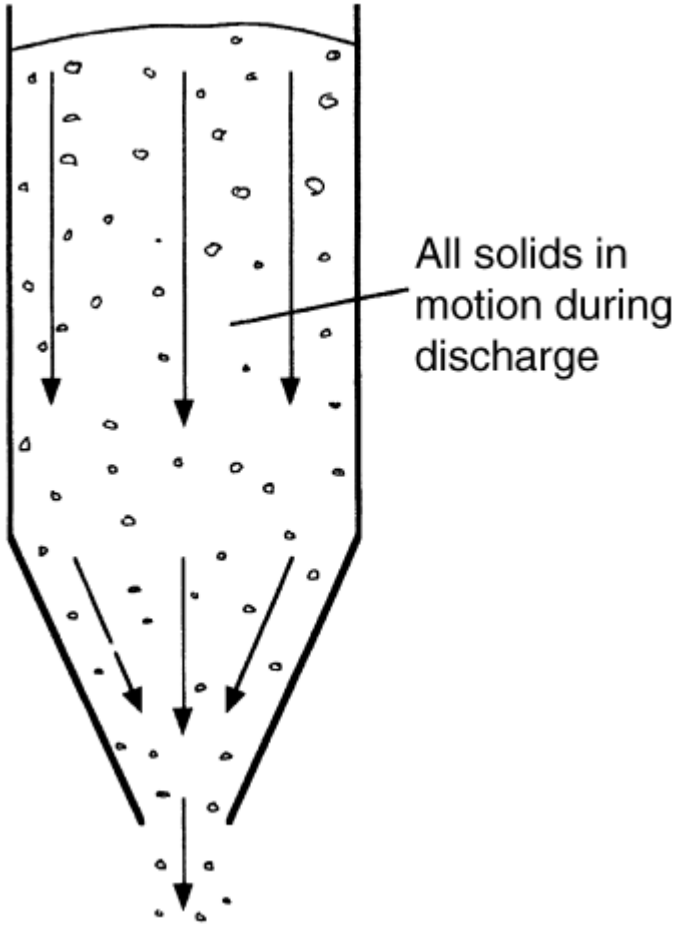
- Smaller diameter, Tall
- Made of concrete, wood, steel
- specified humidity and temperature condition
- Sealed (air-tight)

Design matters..

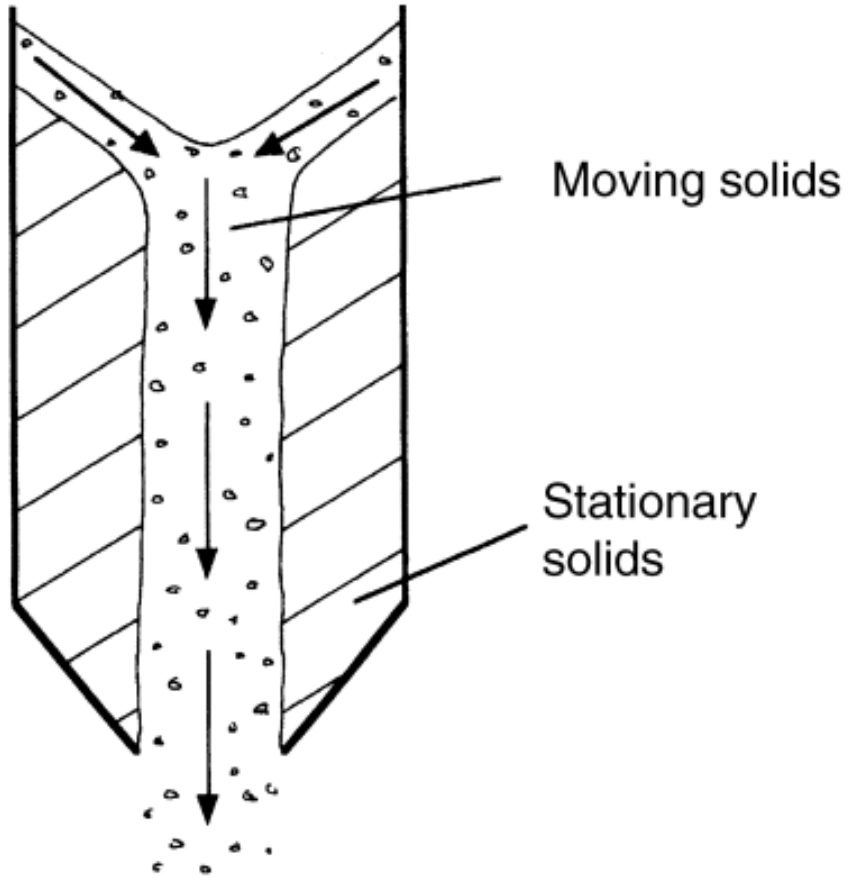
Mass flow

Funnel flow

Types of flow in Silo's

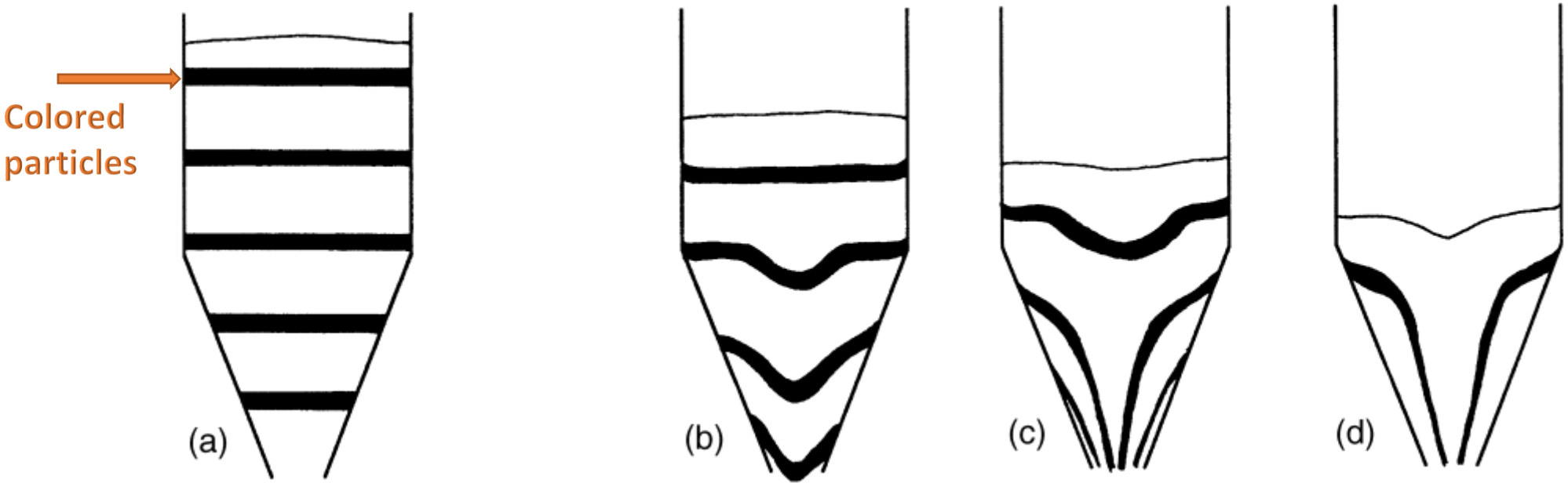


Mass Flow



Core Flow

Mass flow pattern in Silo's



When the outlet valve is closed

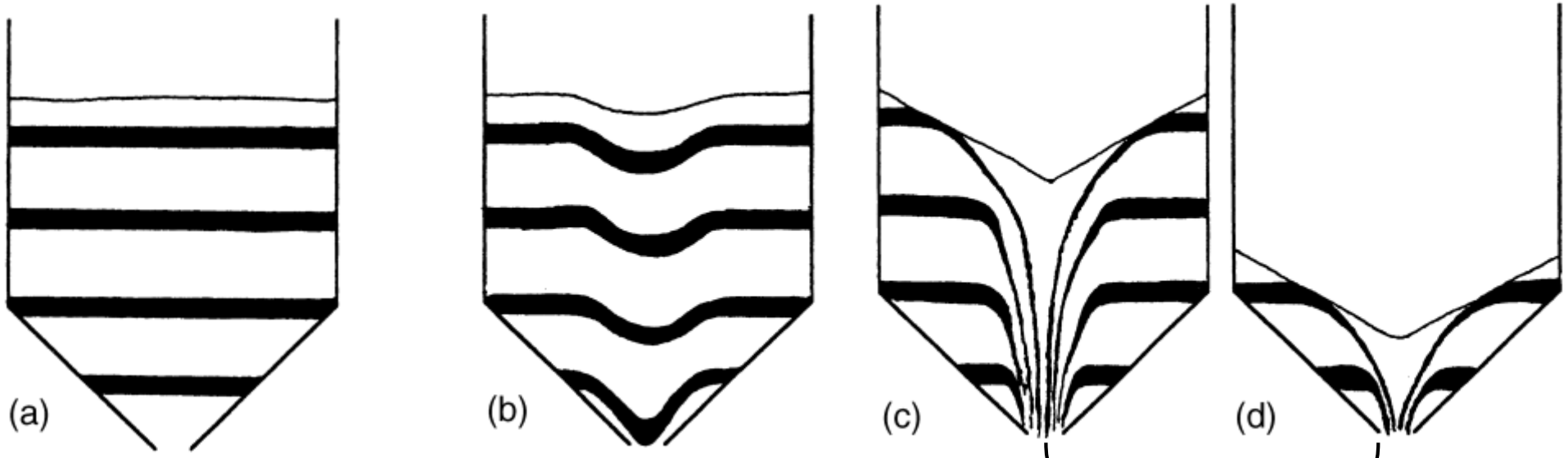
When the outlet valve is open → Time

https://youtu.be/-ziFKcQ2UjU

Advantages: Motion of the powder is uniform and almost steady,
Bulk density of discharges is constant
Flow stresses are low

Disadvantage : Erosion of wall happens in certain cases which will lead to contamination

Core flow pattern in Silo's



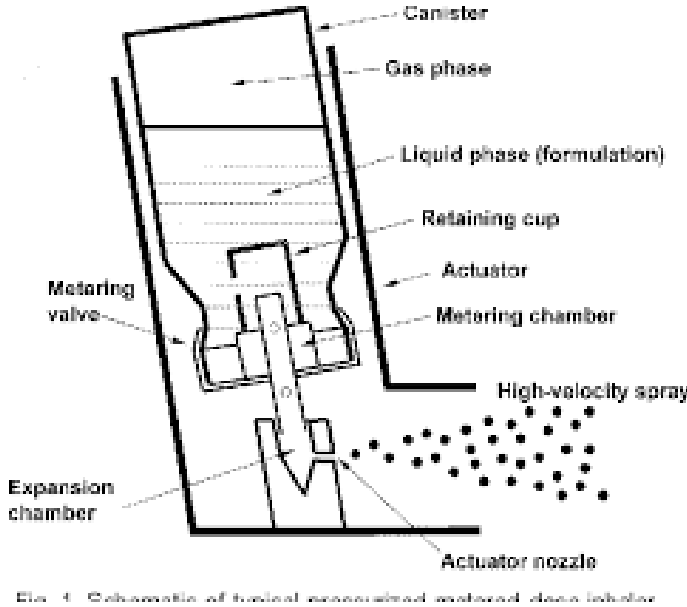
Time difference is high and sudden fall

When the outlet valve is closed

Time

When the outlet valve is open

Inhaler



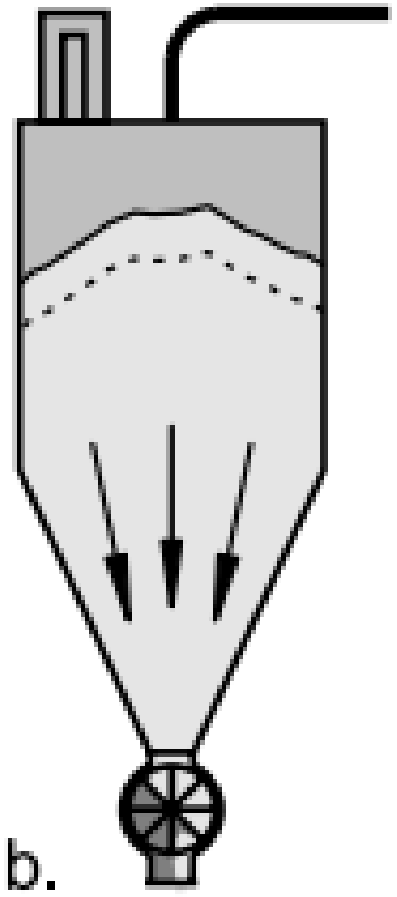
Ref: Principles of metered-dose inhaler design by S. Newman

Dairy Powder packing

Design matters..

Flow problems: Bridging/Arching and Ratholing

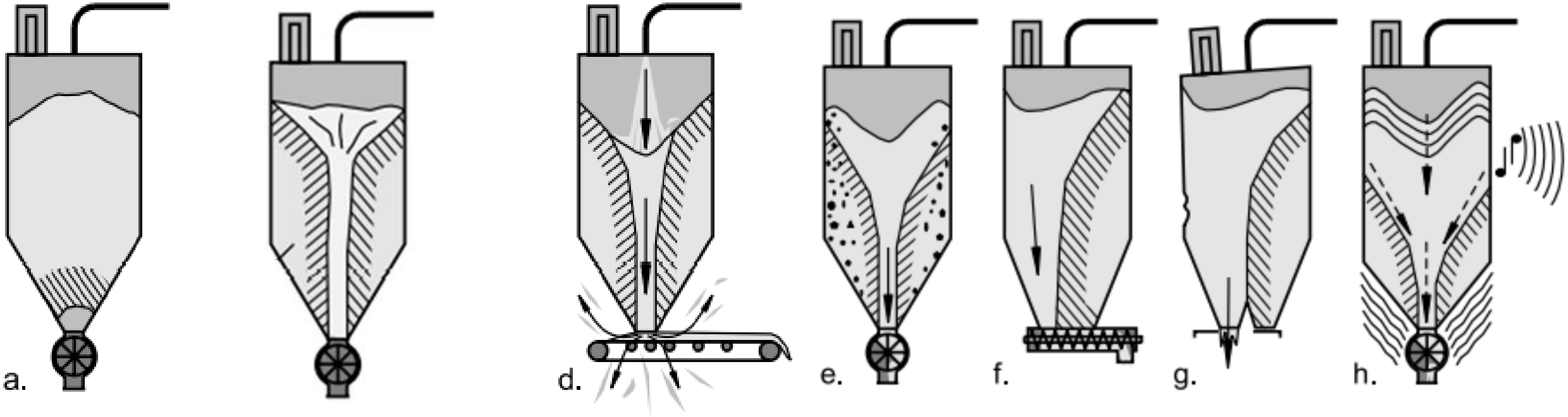
https://www.siperm.com/en/



Mass flow

Traces of hammering at a hopper wall

Flow problems in Silo's



Arching

Rat Hole

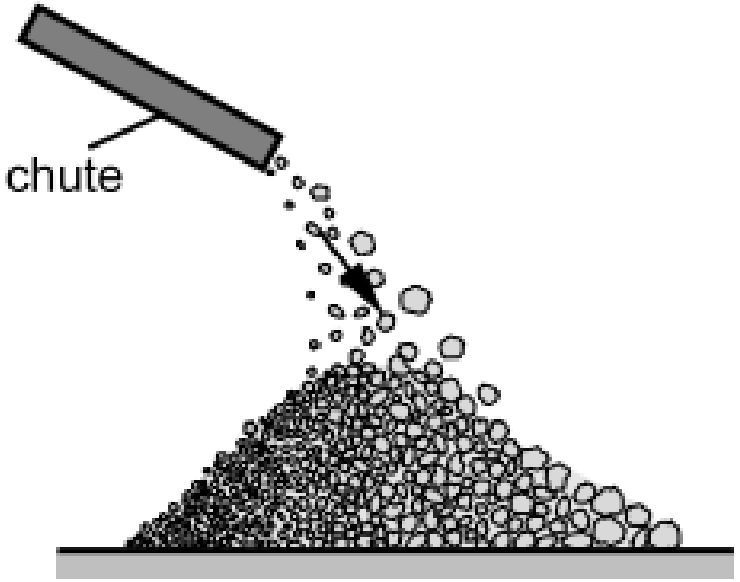
Flooding

Segregation

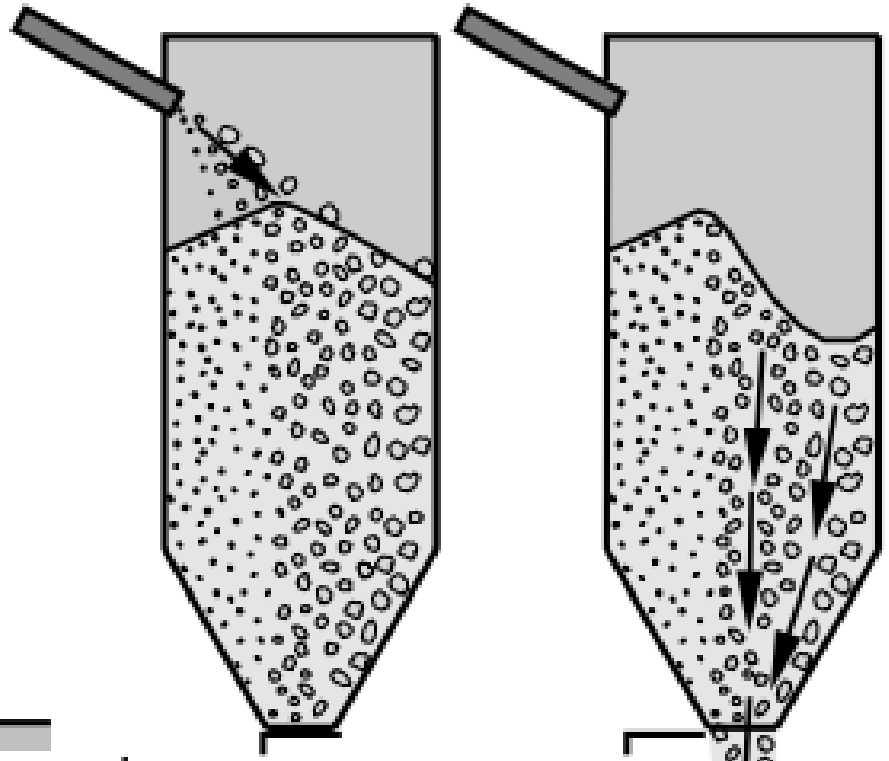
Non-uniform discharge and buckling

Vibration

Segregation



a.



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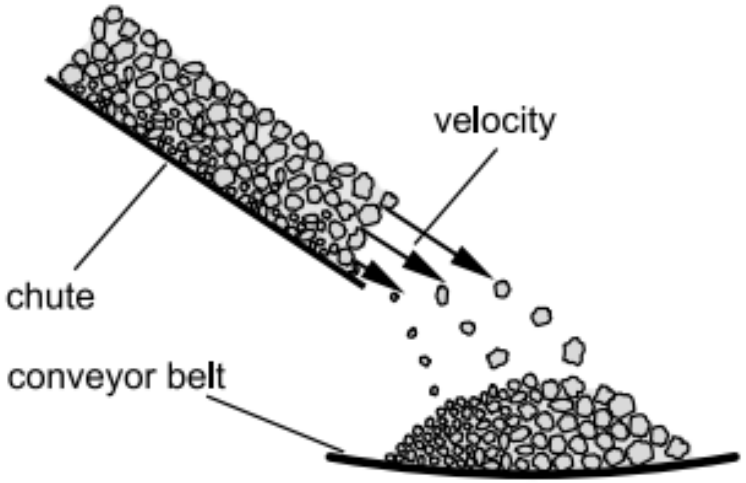
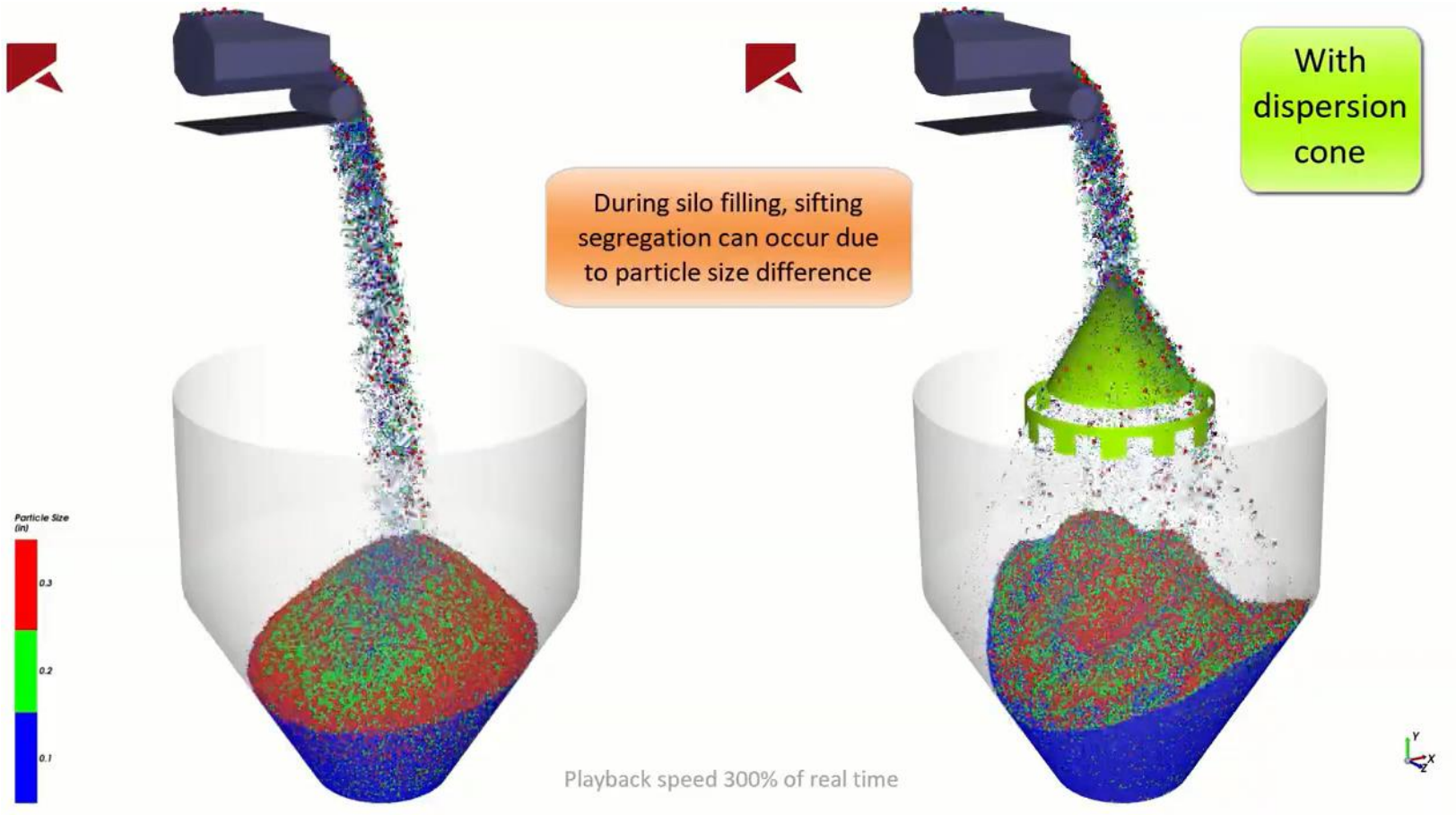
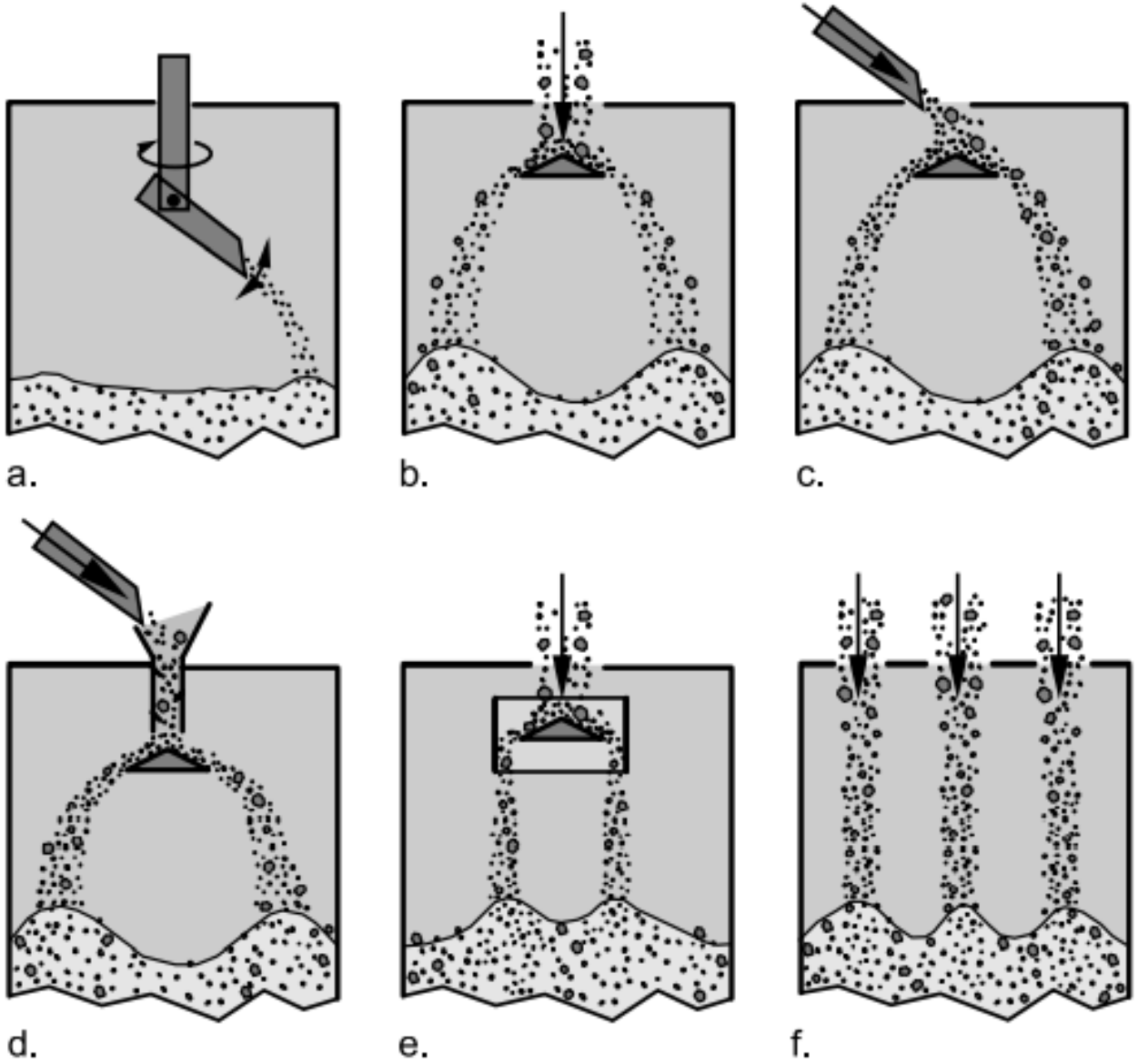


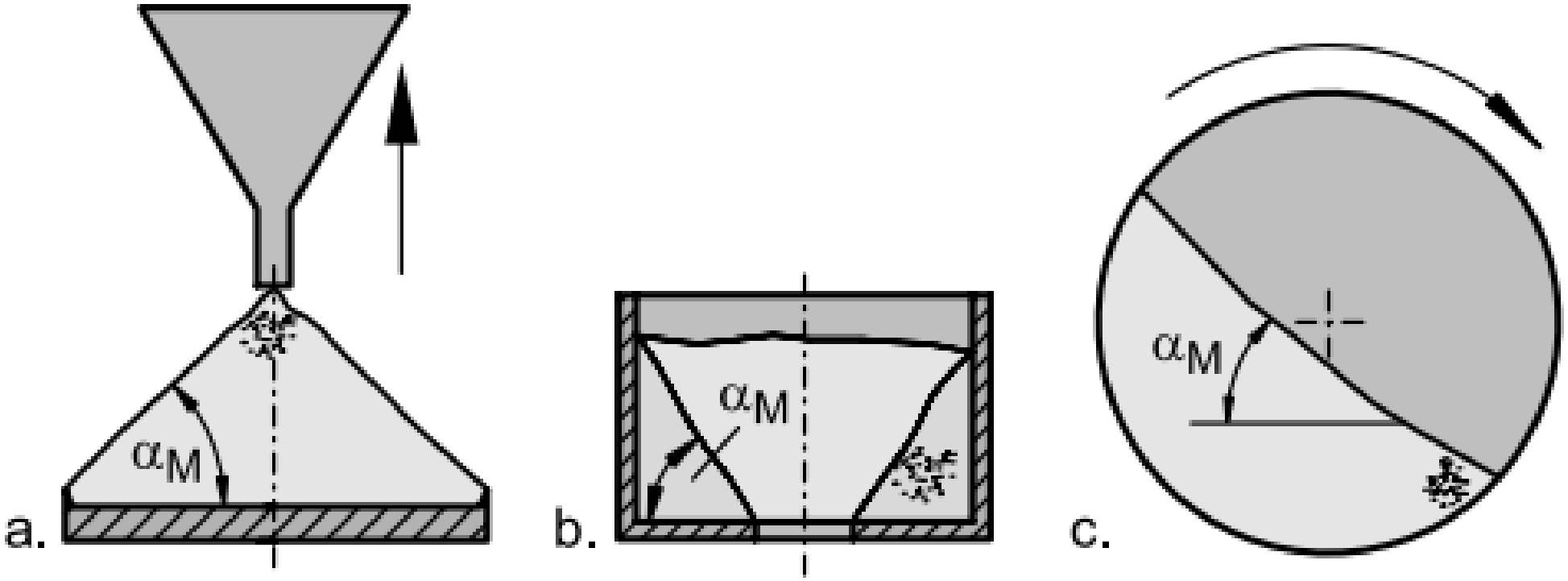


Source: https://www.youtube.com/watch?v=o8eo-9CVpQ8

Elimination of Segregation



Flowability of powder sample



https://www.youtube.com/watch?v=MNl_bGDV8Hw&t=148s

https://www.youtube.com/watch?v=7UM5R-oMBHc

Angle of Repose (degrees)	Expected Flow
25-30	Excellent
31-35	Good
36-40	Fair
41-45	Passable
46-55	Poor - Needs agitation
56-65	Very Poor
>66	Very, Very Poor

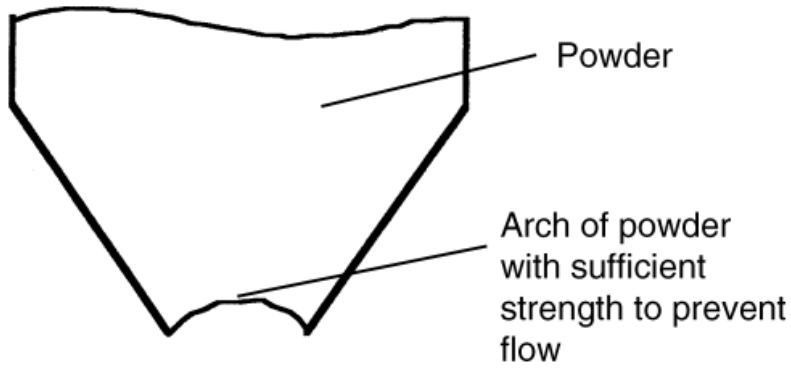
Although AOR tells the flow ability of materials, doesn't correlate with the hoper angle

Factors influences the flow of particles

- Stresses in Bulk Solids
  - Powder internal friction
  - Cohesion
- Wall Friction
- Compressibility/ permeability
- Process conditions
  - Temperature
  - Humidity
- Time consolidation

Arching

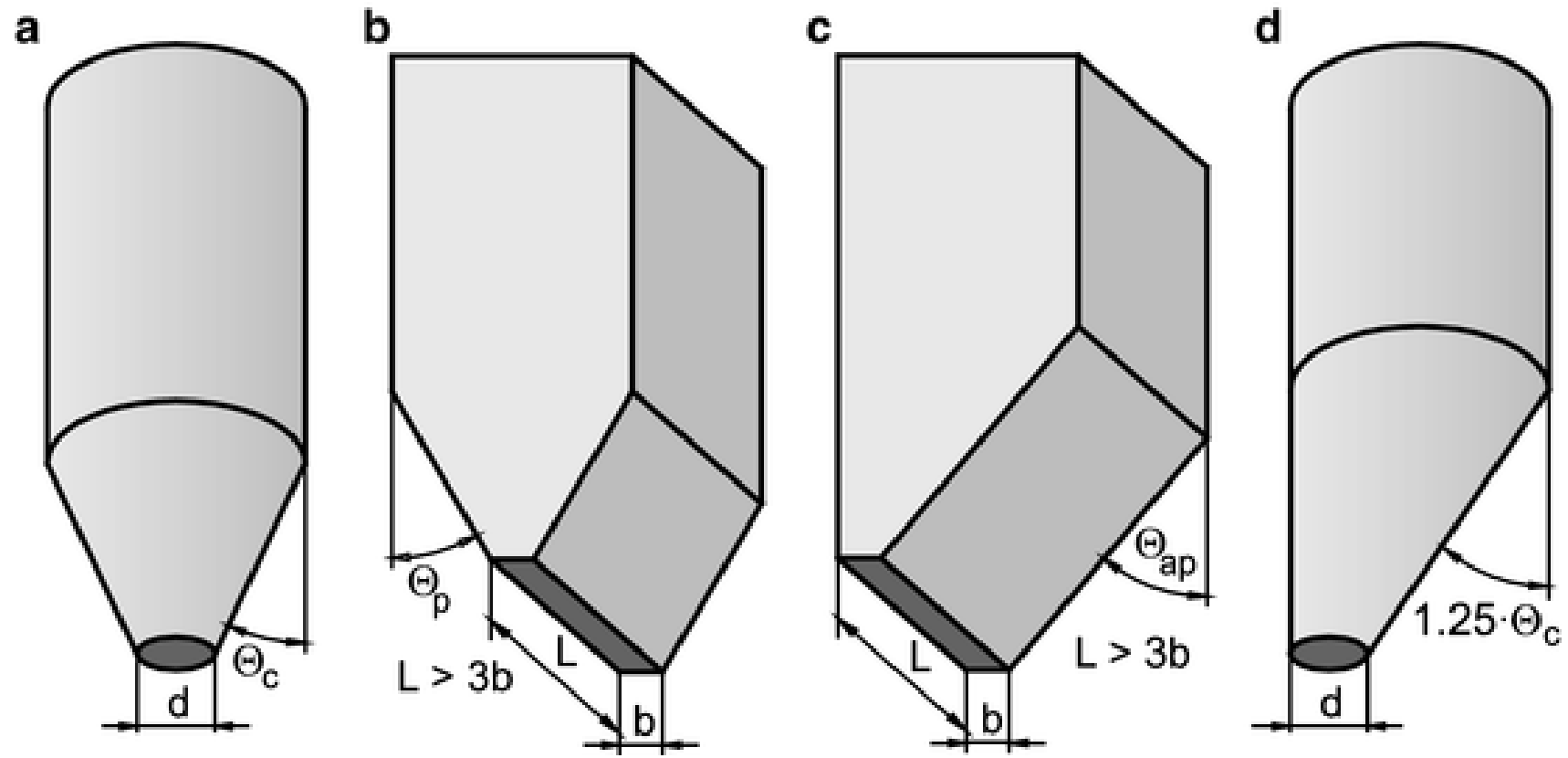
- Arching – a stable arch forms above the silo outlet which stops the discharge of powder.



- Two Causes for arching:
- Coarse grained bulk solids can build up arches due to interlocking and wedging of particles.
- To mitigate this:
  - The circular outlet of a conical hopper is at least 6 to 10 times the maximum particle size, Xmax
  - The width of the rectangular outlet of a wedge-shaped hopper should be at least 3 to 7 times Xmax

https://www.youtube.com/watch?v=CP3fMa9iq8w

Hoppers



Arching

Another reason for arching:

- An arch occurs when the strength developed by the solids is greater than the stresses acting within the surface of the arch.

- When fine-grained and cohesive bulk solids used, powder develop strength (compressive strength, unconfined yield strength) under the action of compact stress due to adhesive forces between individual particles.

- This type of arching can be avoided by a sufficiently large outlet opening.

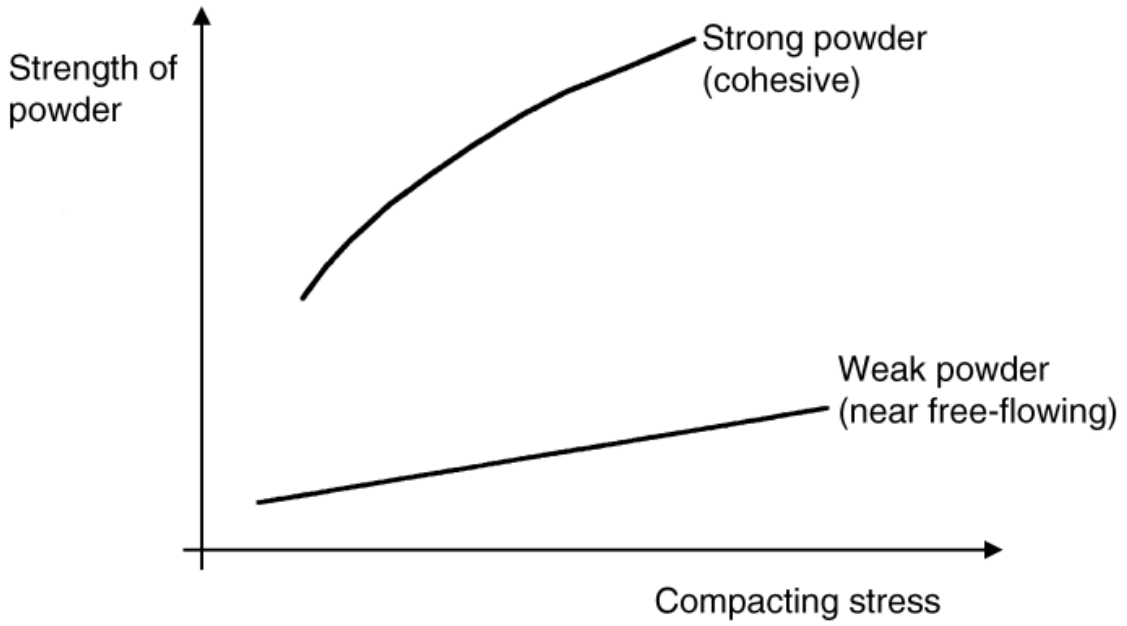
Flow – No Flow criterion

- Gravity flow of a solids occurs :

  stress developed by the solids (σ_D) > compacting stresses in arch (σ_C)

$$ff = \frac{\sigma_C}{\sigma_D} = \frac{\text{compacting stress in the hopper}}{\text{stress developed in the powder}}$$

- Higher the ff, lower the flowability
- ff depends on:
  - The nature of the solid
  - The nature of the wall material
  - The slope of the hopper wall.



Thank you