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& JOHANSON
SCIENCE ENGINEERING DESIGN

Bulk Material Flowability Testing — What Is It And Why Does It Matter?

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OUTLINE

- Who is J&J?
- Common flow problems
- Flowability tests– what are they?
- So what?

WHO IS J&J?

A specialized engineering firm focused on providing clients solutions to material handling applications

- 55+ years experience, all industries
- 13,000+ materials tested, 7,500+ projects
- 650+ accumulated years of solids experience
- Offices in Australia, Brazil, Canada, Chile, Boston, Houston, California

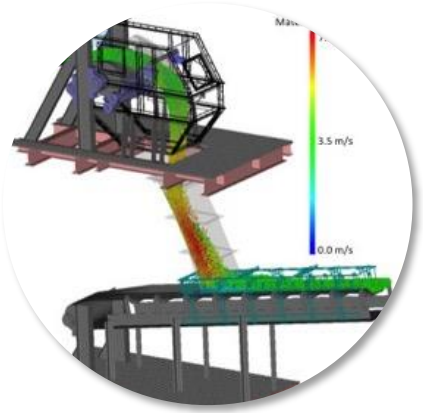
JENIKE & JOHANSON – Our Approach

Scientific approach – based on your materials

Not a trial and error approach

On-site Assessments & Inspections

Testing & Physical Modeling



Technology, Computer Simulations

Conceptual Engineering → Detailed Design

JENIKE & JOHANSON

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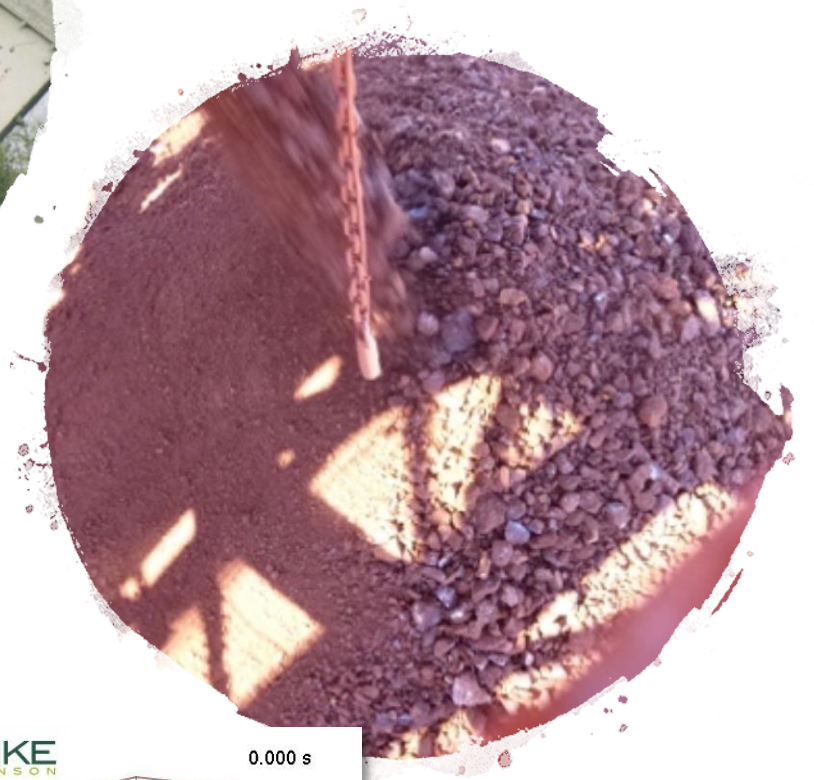
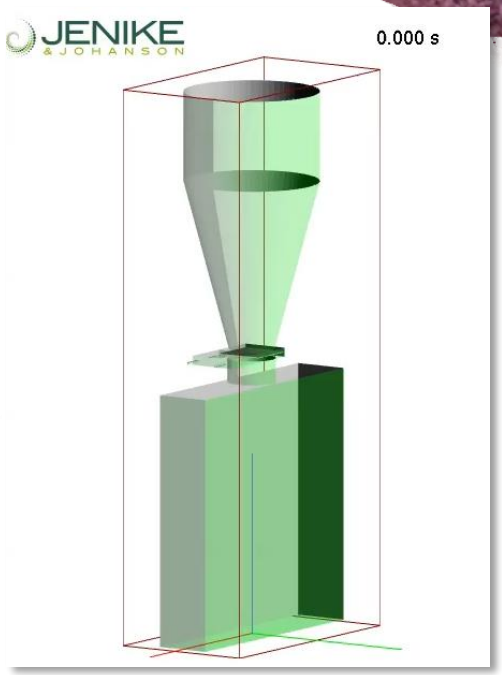




COMMON FLOW PROBLEMS

COMMON FLOW PROBLEMS

Stockpile ratholes

Limited live capacity

“FLOWABILITY”

Flowability is a function of the material AND the equipment

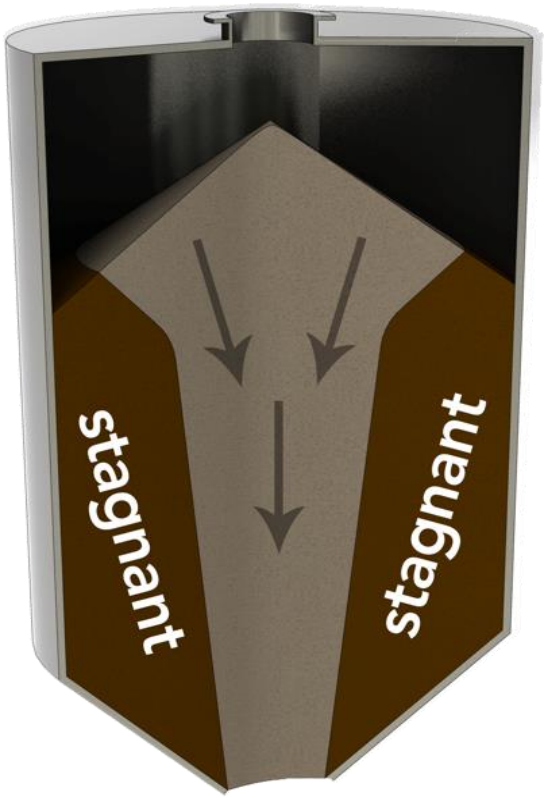
“Poor flowing” material can be handled easily in properly designed equipment

“Easy flowing” material can present flow problems in poorly designed equipment

FUNNEL FLOW

Issues

- Some material is stagnant
  - Caking, product degradation, spoilage
- Arching, ratholing, and erratic flow can occur
- Limited live capacity
- Varying bulk density



Features

- Low headroom
- First-in, last-out
- Ratholes may develop
- Fine powders will flood
- Sifting segregation issues exacerbated

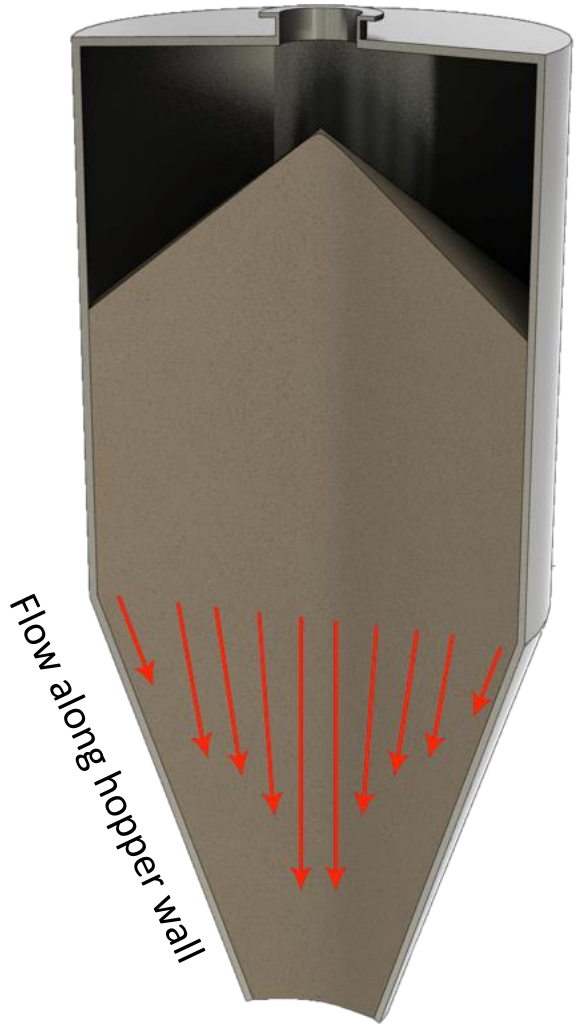
MASS FLOW

Features

- Smooth, steep hopper
- First-in, first-out
- Ratholes cannot form
- Fine powders deaerate
- Sifting segregation minimized
- Uniform feed

Suitable for

- Cohesive materials
- Fine powders
- Degradable material
- Materials that segregate by sifting



Required for material that is:

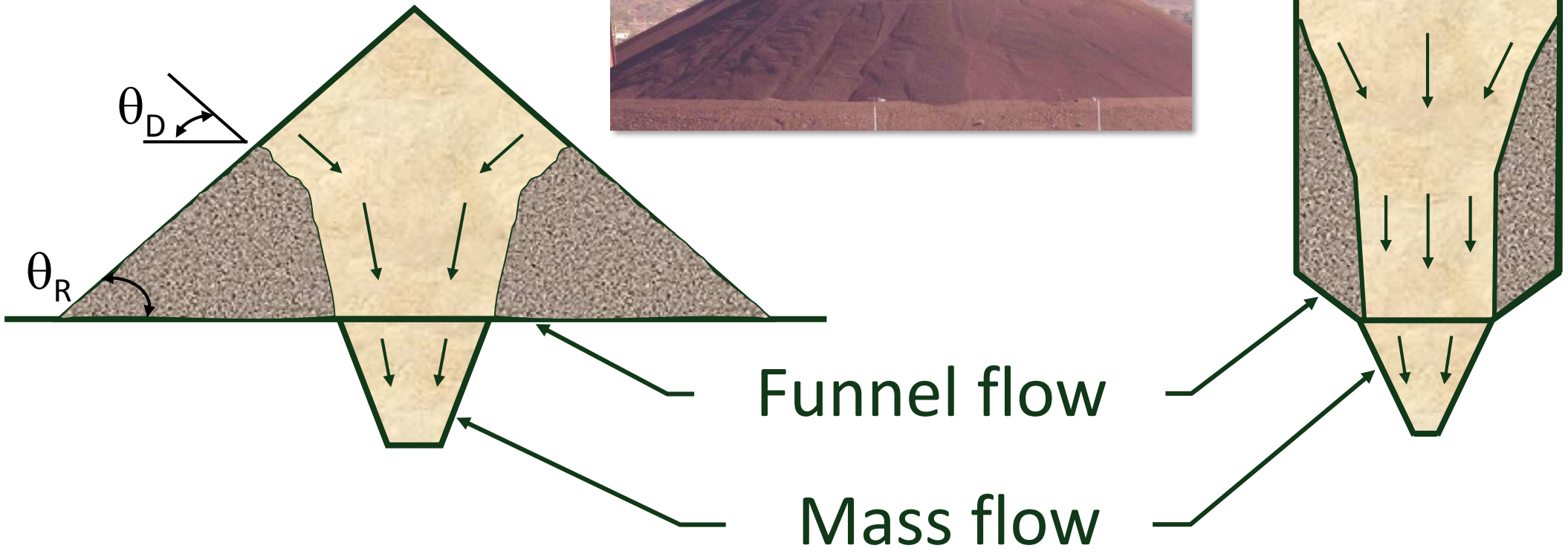
- Cohesive
- Fine
- Degrades over time
- Sifting segregation is a concern

Achieving mass flow requires:

- Flow along hopper walls,
- Outlet large enough to prevent arching
- Correct feeder design

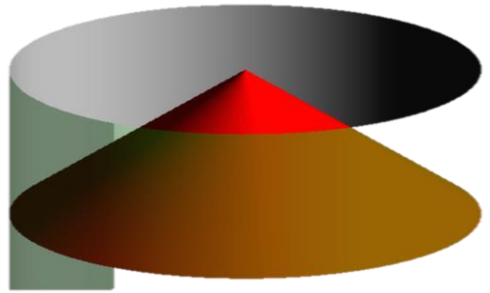
STOCKPILES: Expanded Flow Analogy

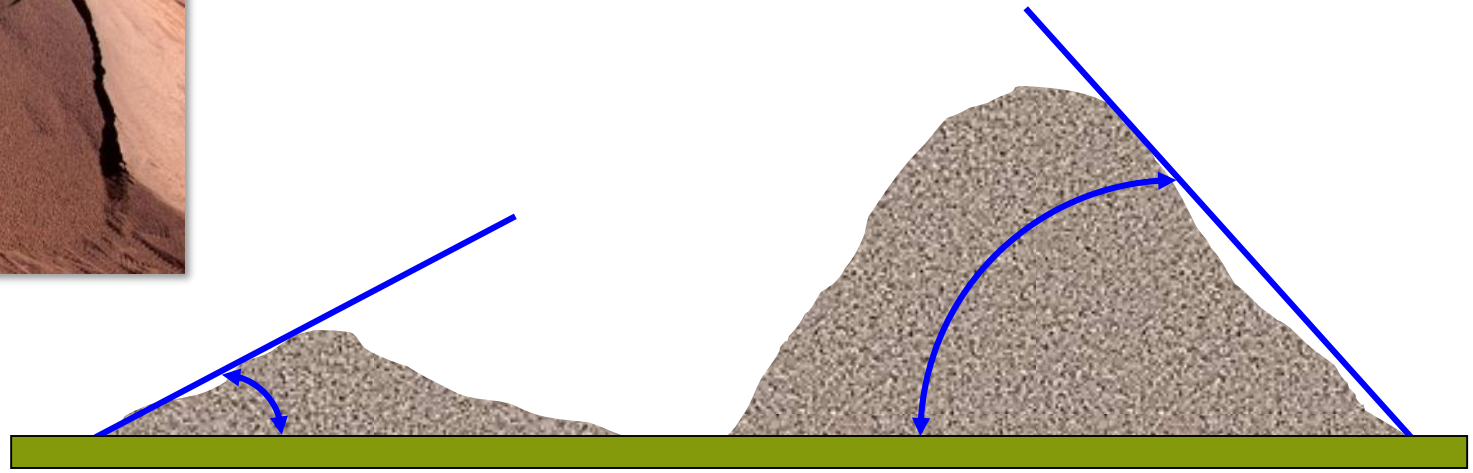
θ_D = Drawdown angle
θ_R = Angle of repose



WHAT ABOUT ANGLE OF REPOSE?

- How to measure?
- How to utilize data?

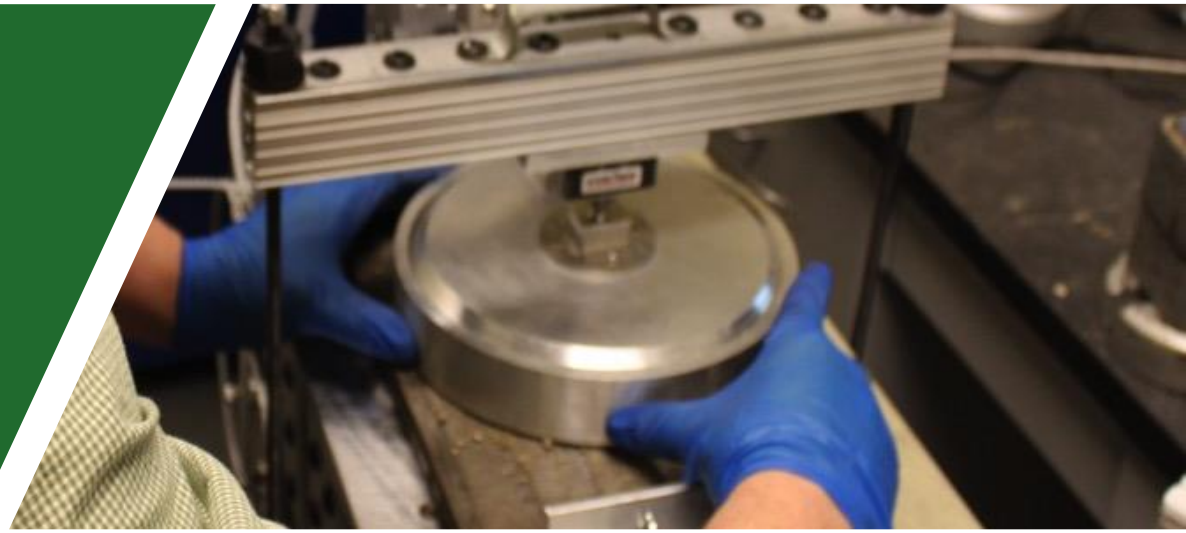


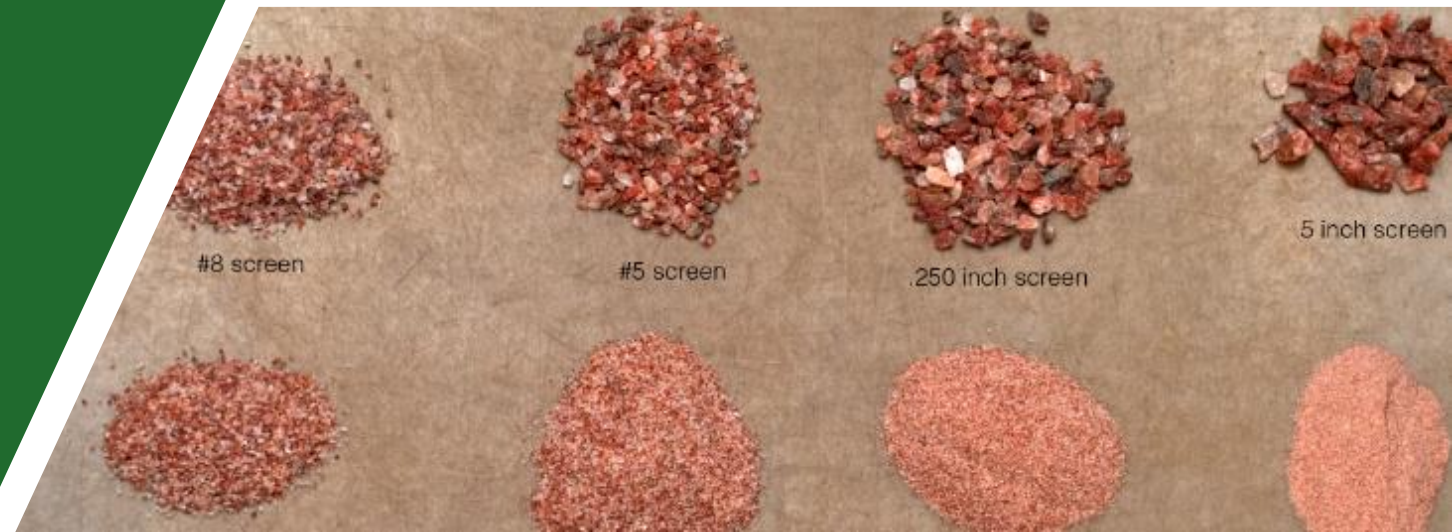


BULK MATERIAL TESTING

Standard tests:

- Cohesive strength
- Wall friction
- Bulk density/compressibility
- Particle density
- Permeability
- Segregation potential
- Particle size distribution





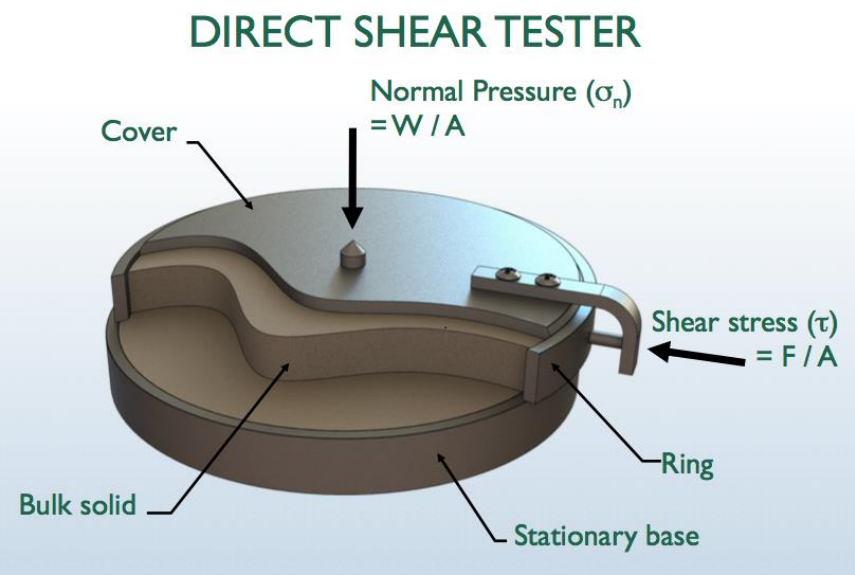
BULK MATERIAL TESTING

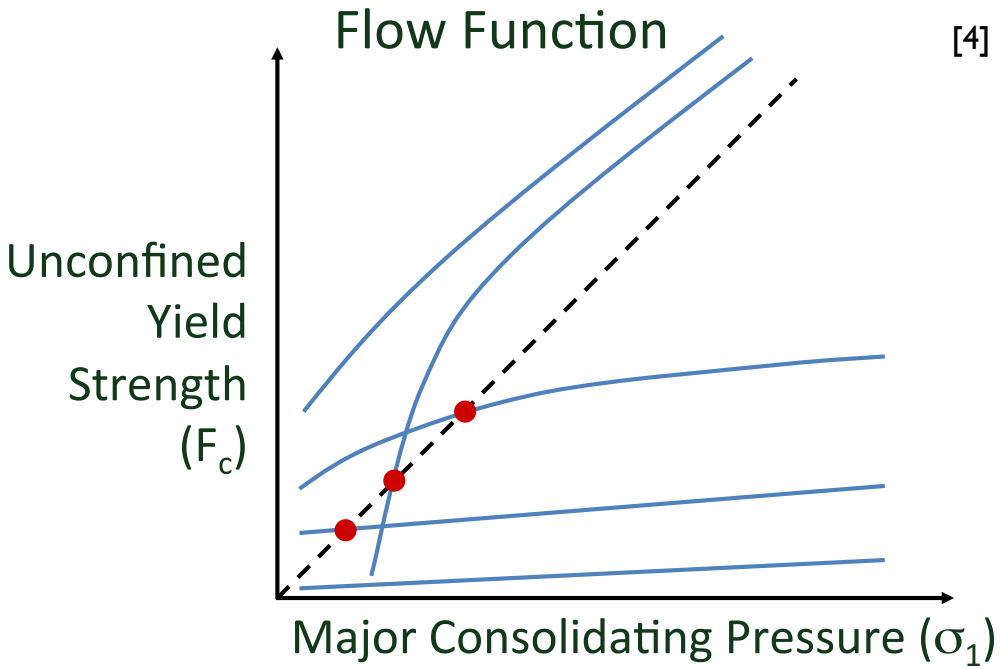
Other common tests:

- Angle of repose (AOR) / Drawdown angle
- Belt surcharge angle
- Particle density
- Fluidization
- Pneumatic conveying
- Maximum belt inclination angle
- Transport Moisture Limit (TML)
- Dust Extinction Moisture (DEM)
- Wear testing

Iron Ore AOR and Belt Surcharge Angle

FLOWABILITIY TESTING:
Cohesive Strength



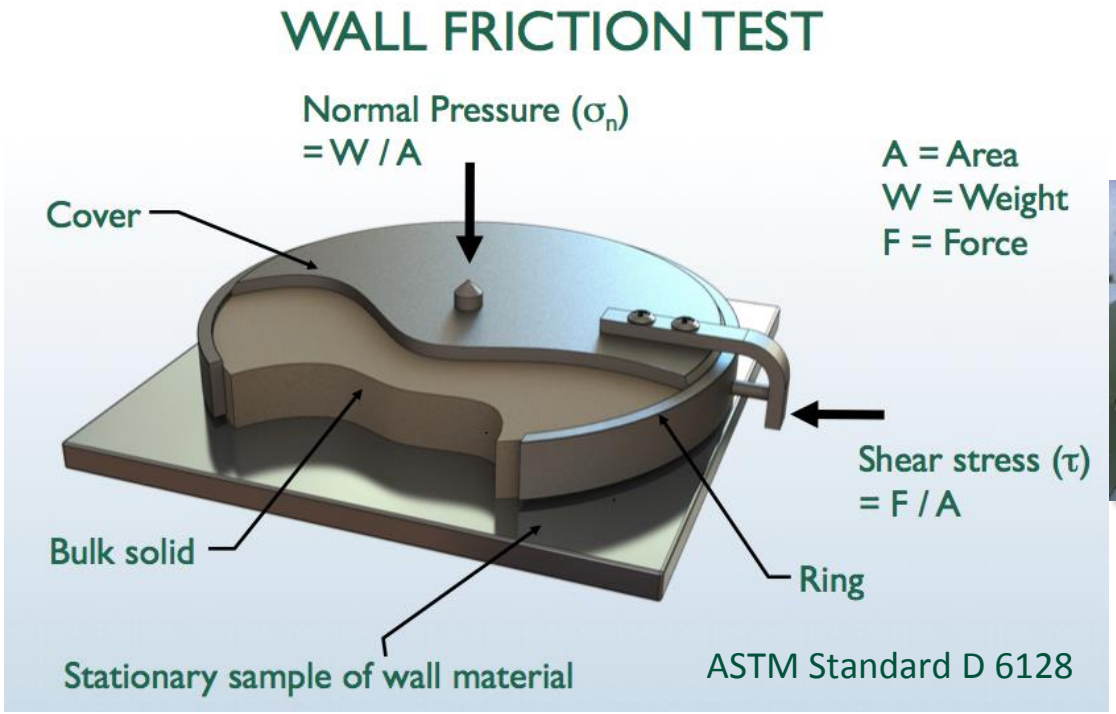


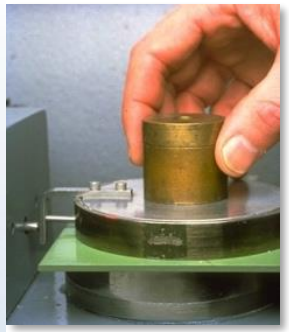
[4]

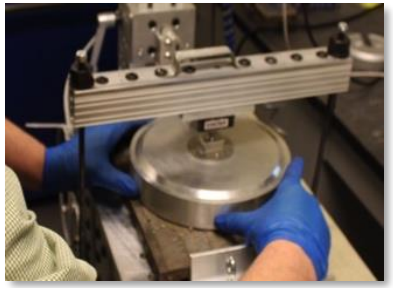
Recommended Hopper Outlet

[4]Jenike, A.W., Storage and Flow of Solids, Bulletin 123, University of Utah Engineering Station, 1964 (revised, 1976).

FLOWABILITIY TESTING:
Wall Friction

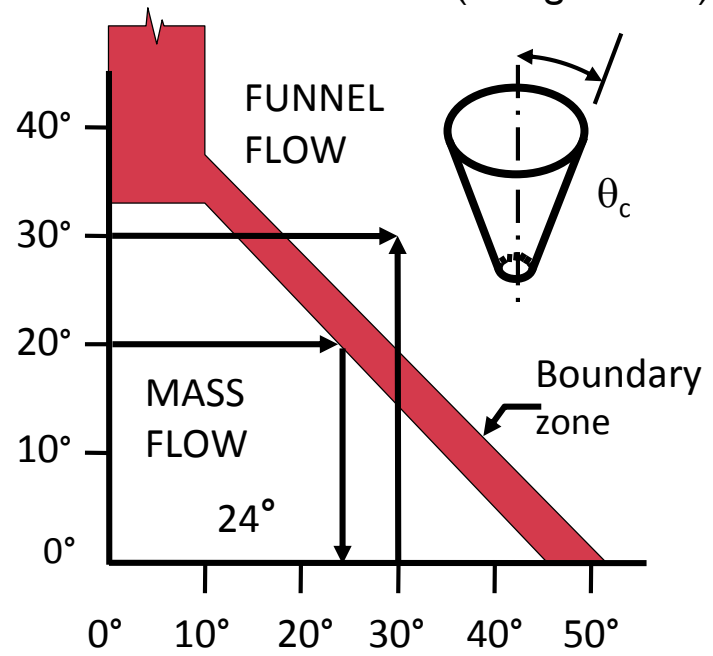






ϕ': Wall friction angle

Wall Friction Test Results (Design Chart)[4]



θ_c : Conical hopper angle, from vertical

Note: There is no magic angle!

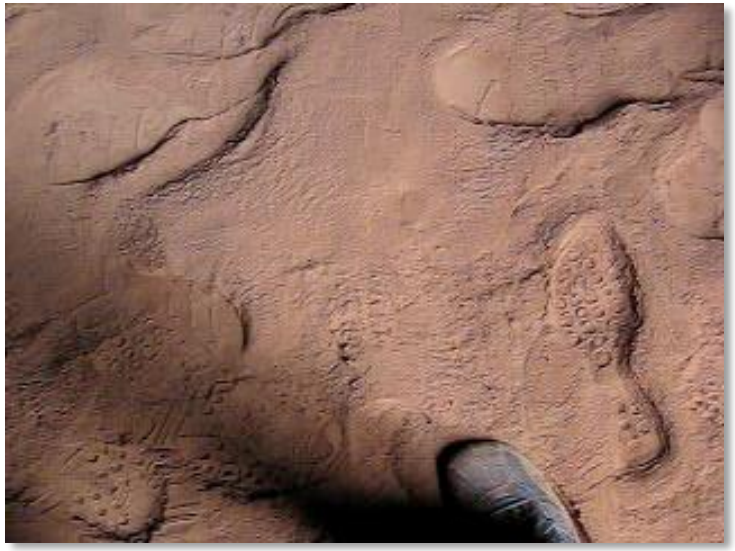
Recommended Mass Flow Hopper Wall Angle

[4]Jenike, A.W., Storage and Flow of Solids, Bulletin 123, University of Utah Engineering Station, 1964 (revised, 1976).

WHAT AFFECTS FLOWABILITY?

- Particle size and distribution
- Particle shape
- Aspect ratio
- Moisture
- Time at rest
- Temperature
- Relative humidity
- Chemical composition

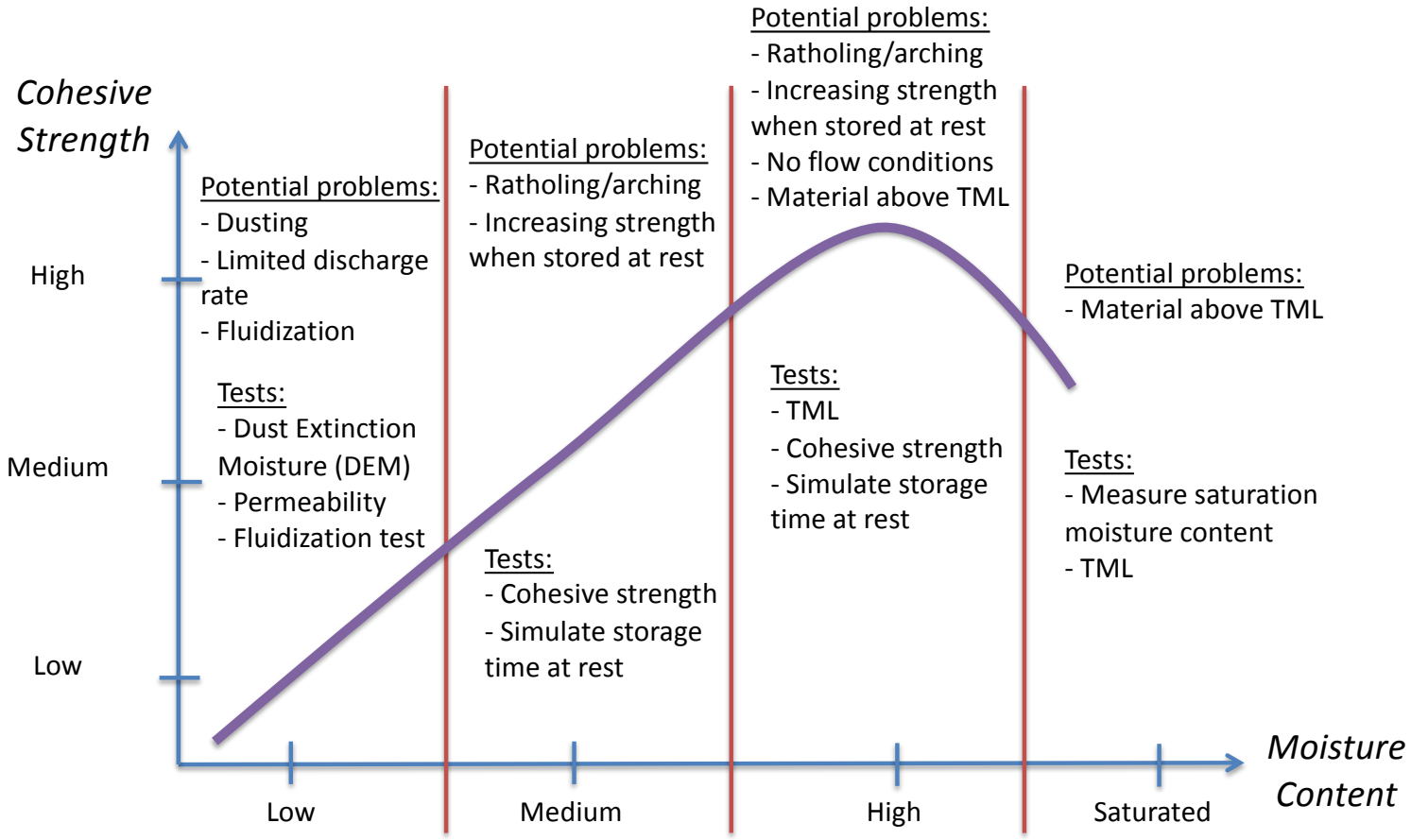
Bauxite @ 22% mc



Bauxite @ 18% mc

It's critical to match your process conditions!

How Material Changes with Moisture Content



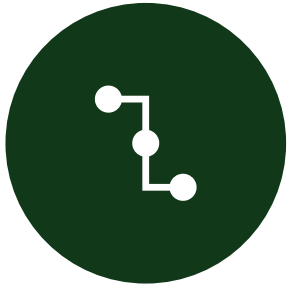
Note: Wall friction should be measured at all operating conditions as the friction of the material is independent of cohesive strength i.e. dry ore could have higher friction than wet ore.

SO WHAT?

ARE YOU IN THE BUSINESS OF MINING?

OR THE BUSINESS OF FLOW?

CONCLUSION



Flowability testing is key in providing inputs to the design basis

Testing must be performed on representative samples and at anticipated process conditions

Without flowability test data, it is a guessing game → increases project risk

The science has been around for over 60 years – tried and true

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