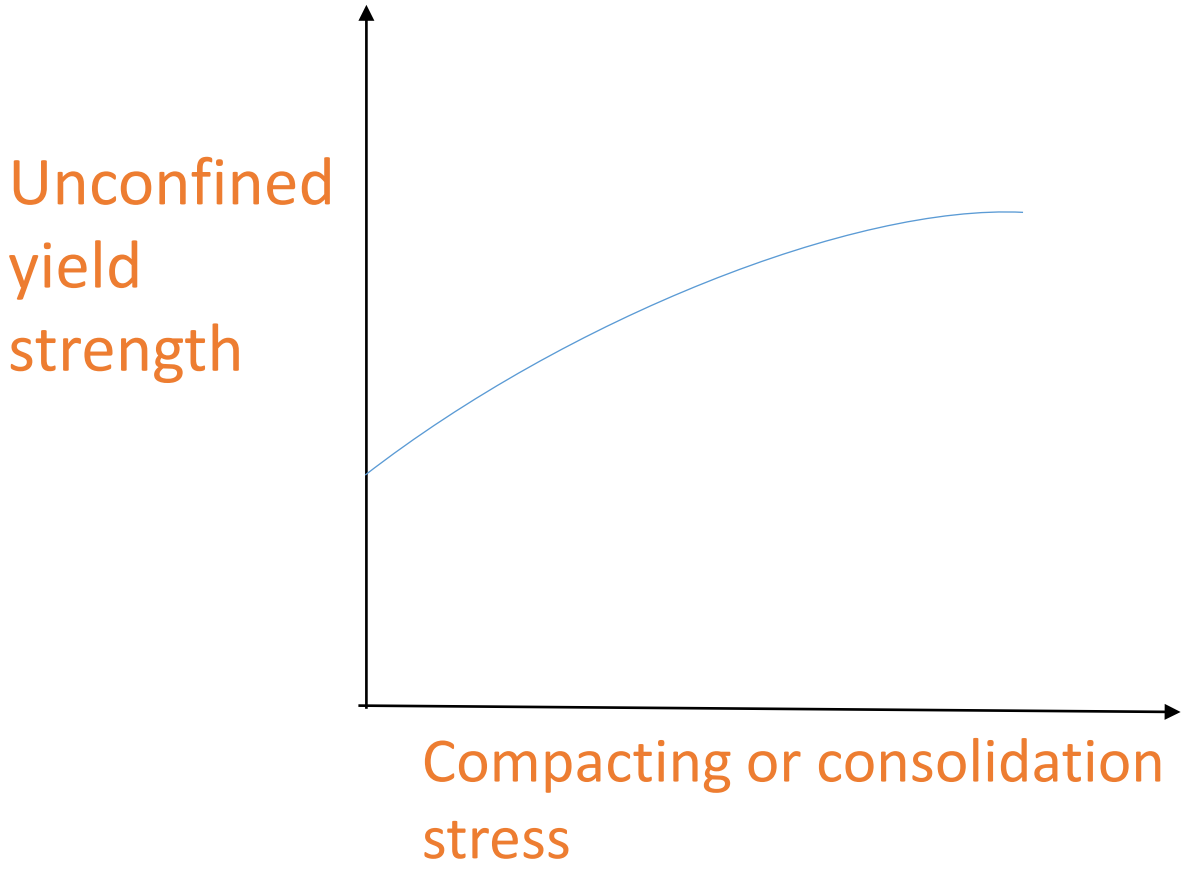
Storage of Solids

Lecture-3

Dr. Swambabu Varanasi

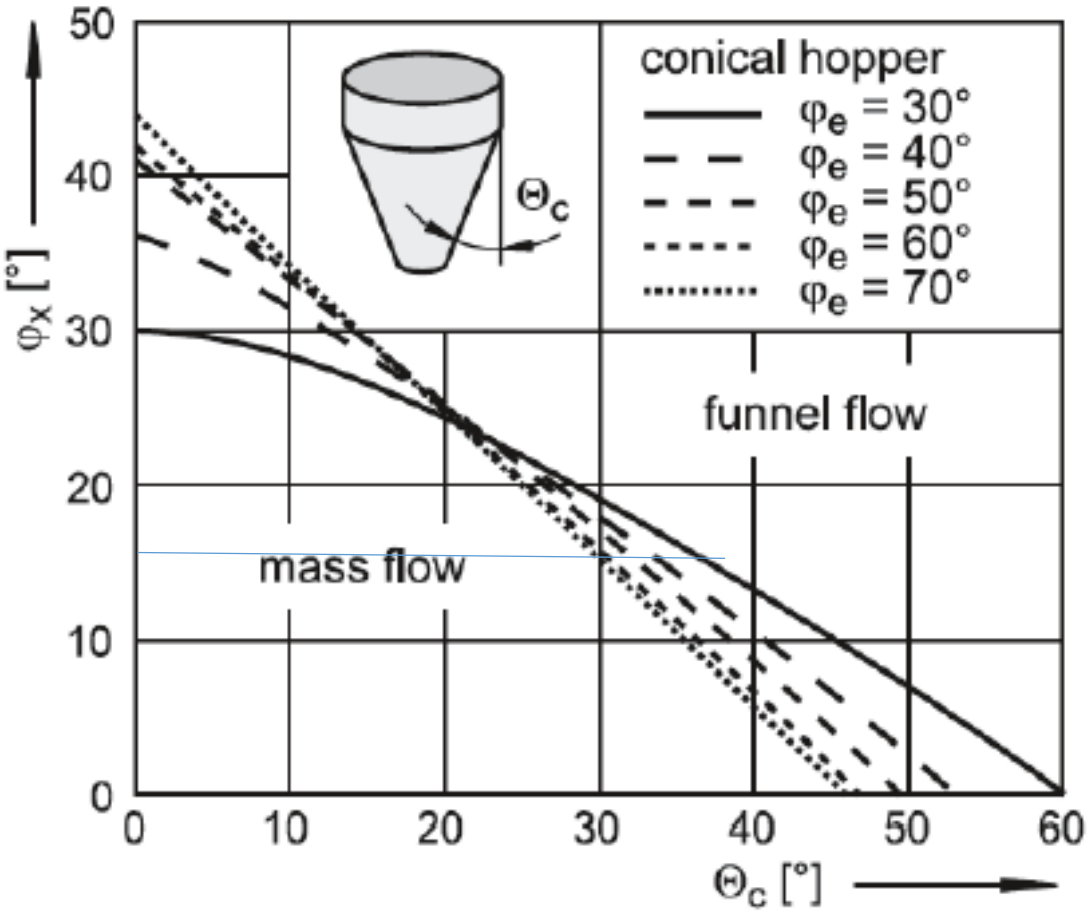
Design Procedure for mass flow hopper

1. Flow function from uniaxial compression test

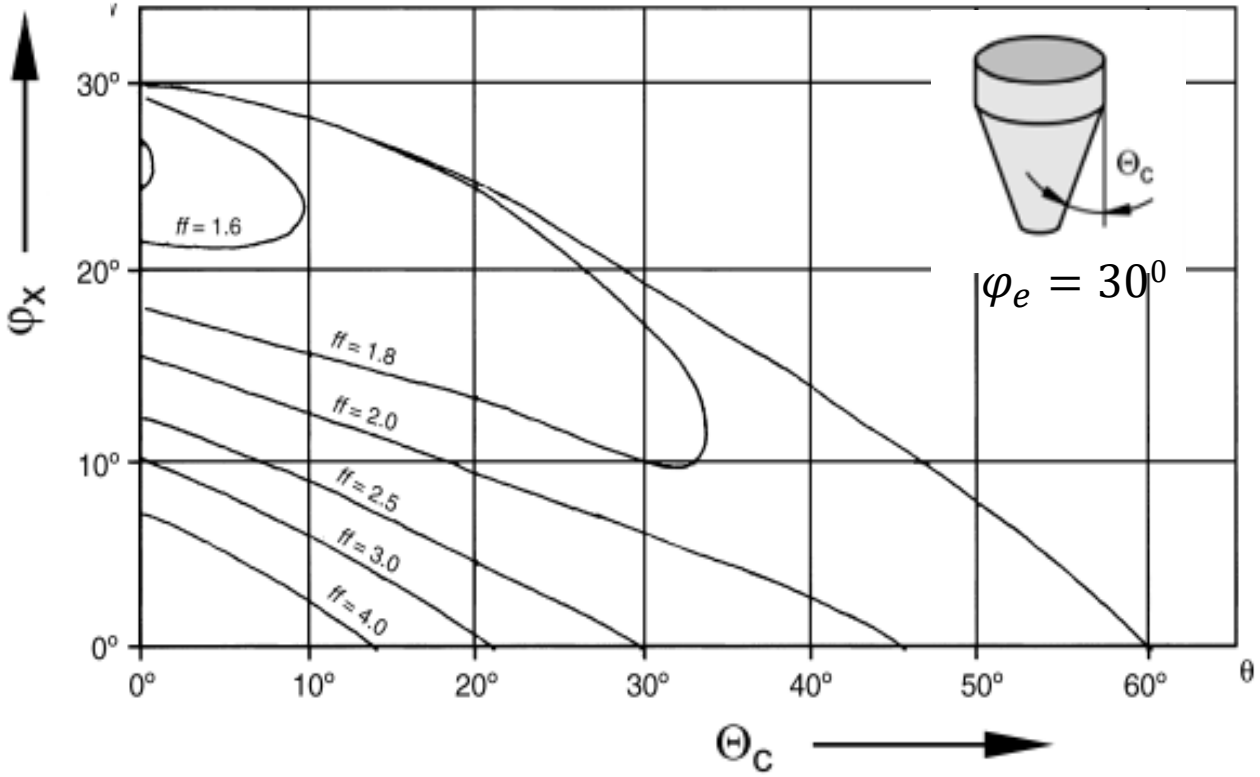


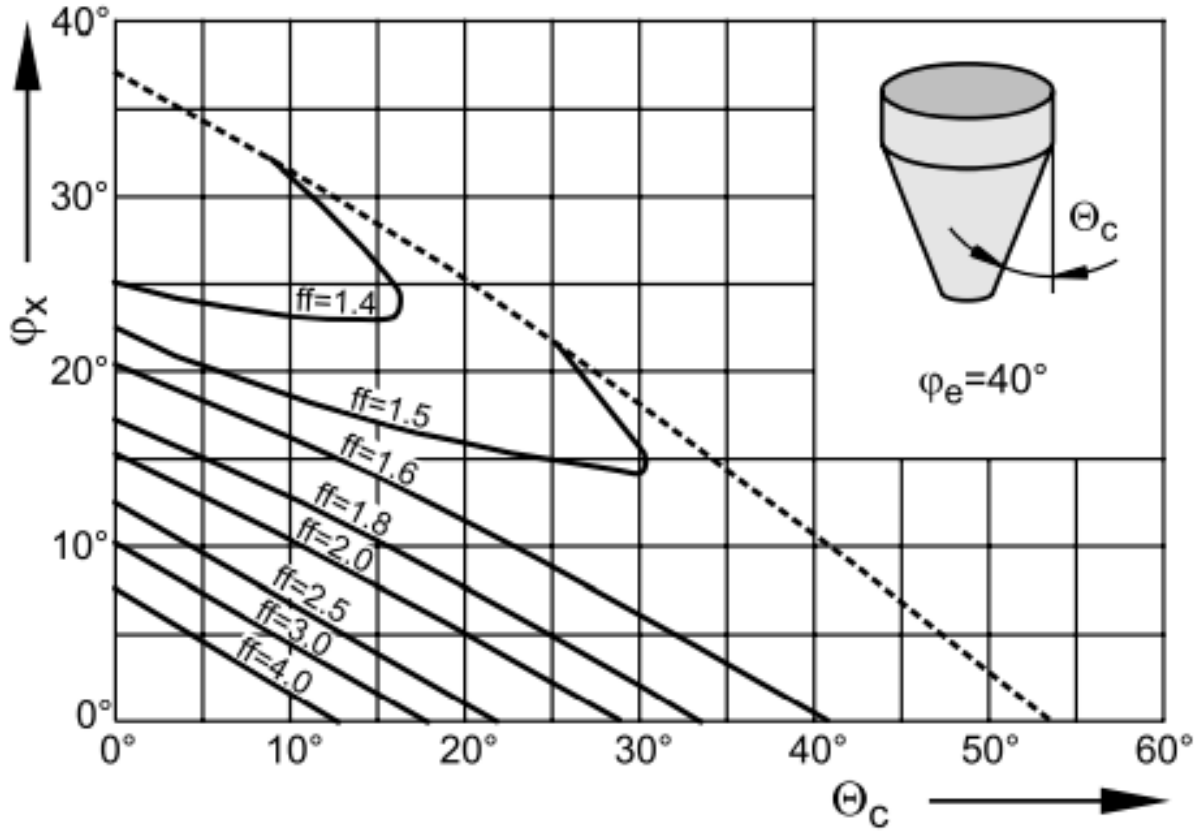
2. Determine Angle of internal friction (φ_c) and wall friction (φ_x) – Jenike Shear tester

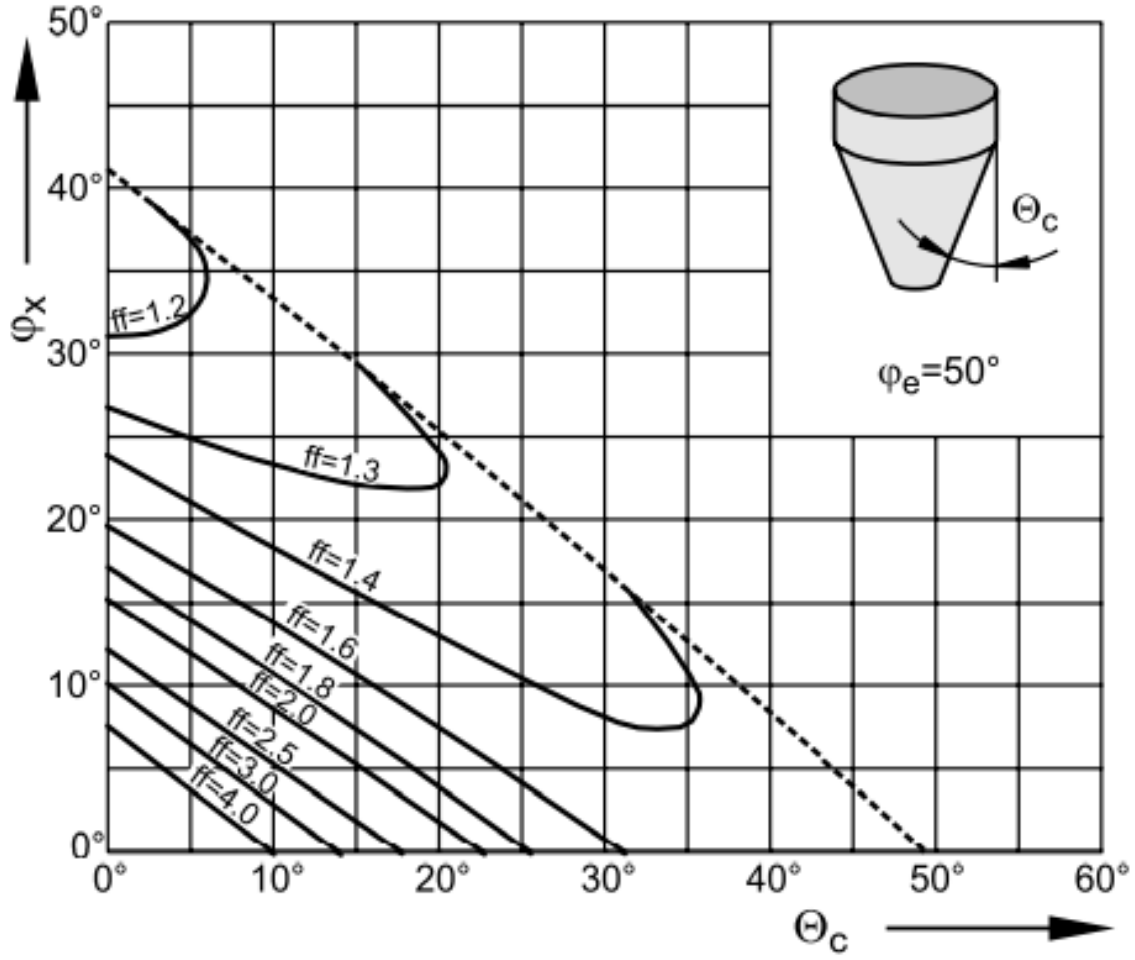
3. Determine hopper angle

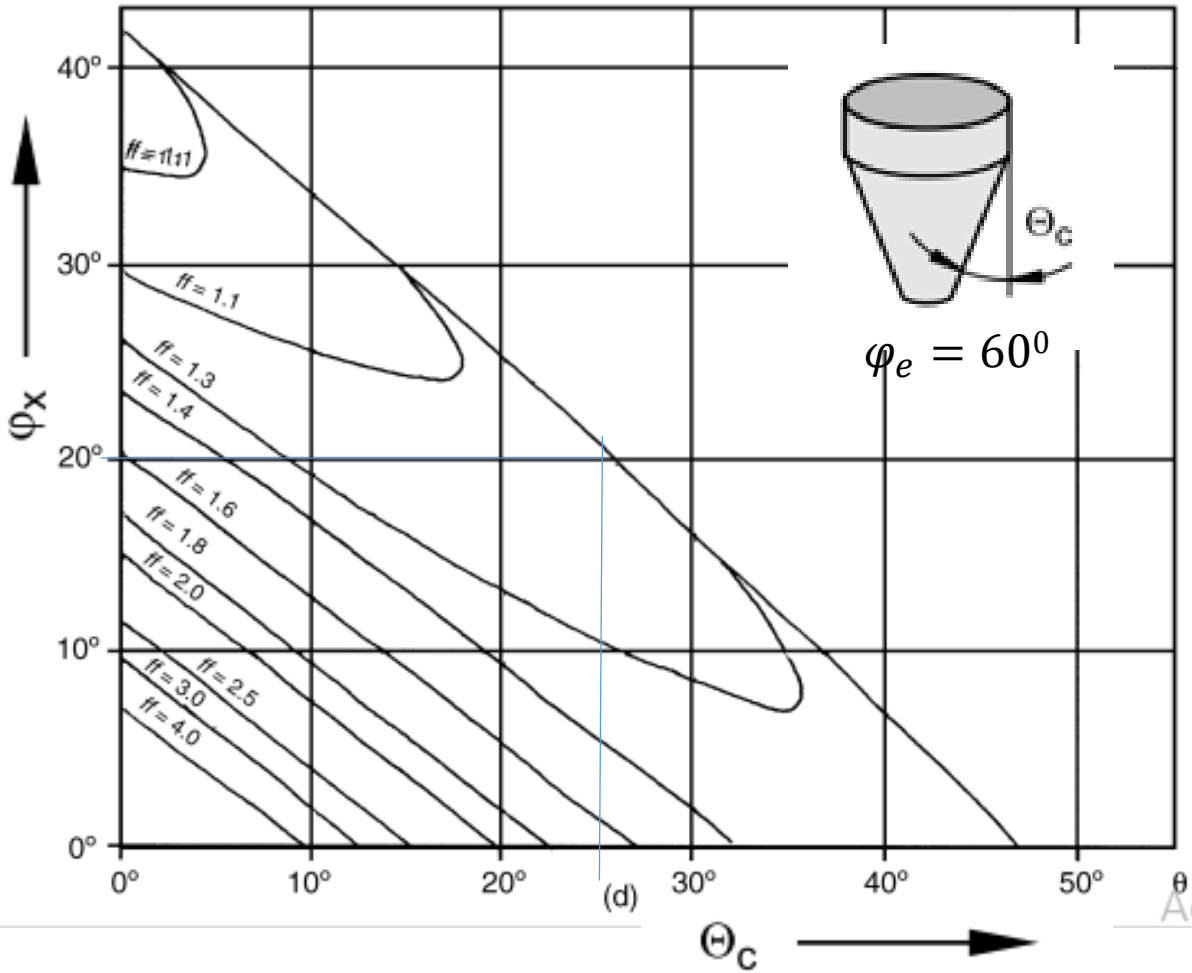


4.Determine ff_c value


φx
30°
20°
10°
0°
ff = 1.6
ff = 1.8
ff = 2.0
ff = 2.5
ff = 3.0
ff = 4.0
0°
10°
20°
30°
40°
50°
60°
θ
Θc
Θc
$\varphi_e = 30^0$


φx
40°
30°
20°
10°
0°
ff=1.4
ff=1.5
ff=1.6
ff=1.8
ff=2.0
ff=2.5
ff=3.0
ff=4.0
0°
10°
20°
30°
40°
50°
60°
Θc
Θc
φe=40°

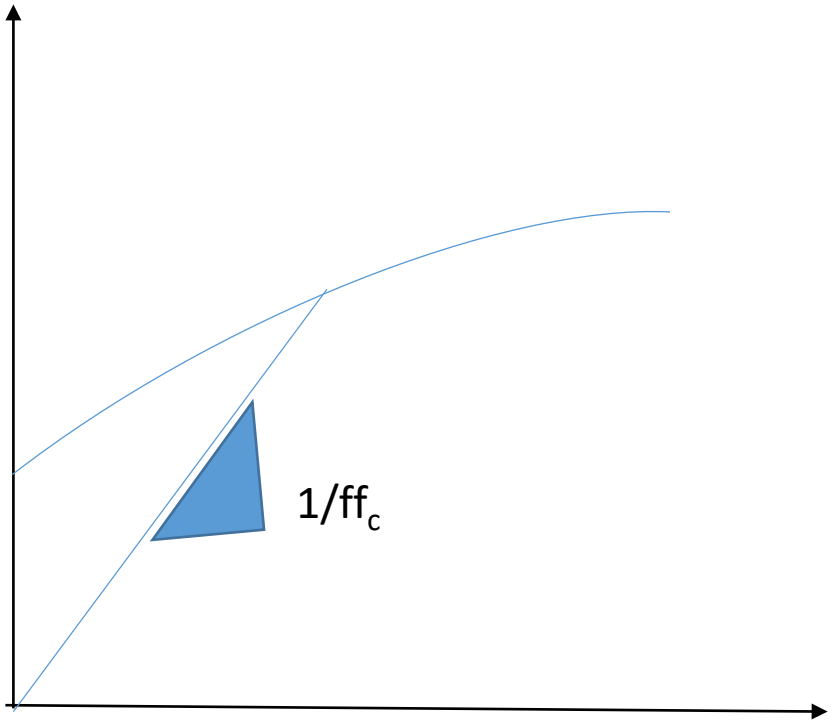

50°
40°
30°
20°
10°
0°
φx
ff=1.2
ff=1.3
ff=1.4
ff=1.6
ff=1.8
ff=2.0
ff=2.5
ff=3.0
ff=4.0
0°
10°
20°
30°
40°
50°
60°
Θc
Θc
φe=50°


40°
30°
20°
10°
0°
φx
ff = 1.11
ff = 1.1
ff = 1.3
ff = 1.4
ff = 1.6
ff = 1.8
ff = 2.0
ff = 2.5
ff = 3.0
ff = 4.0
0°
10°
20°
30°
40°
50°
θ
Θc
Θc
$\varphi_e = 60^0$

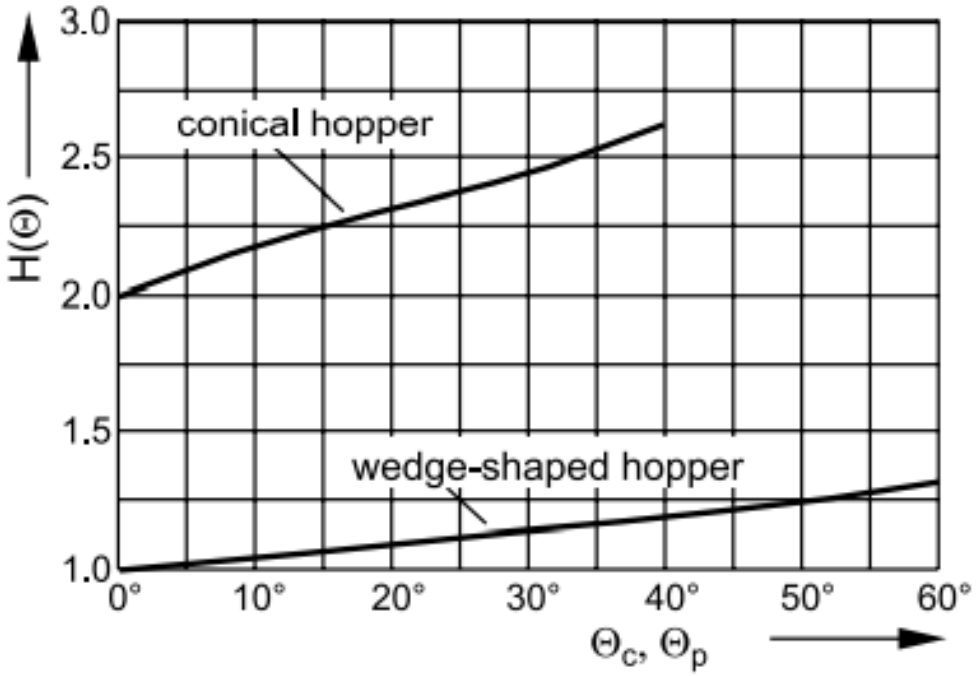
(d)

6. Determine critical σ_c

Unconfined yield strength



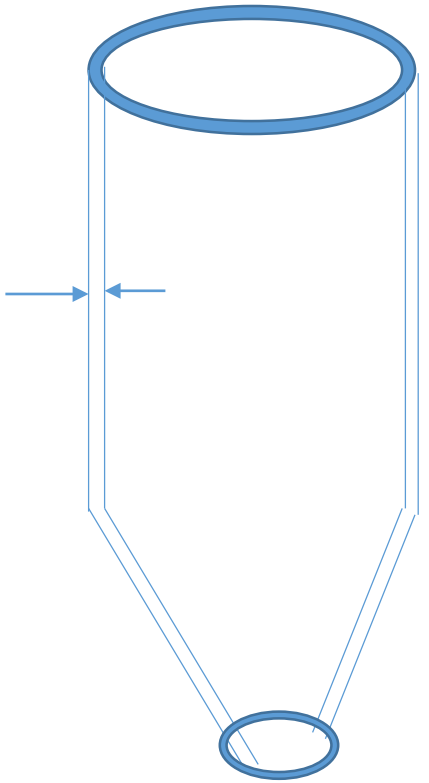
7. Estimate H(Θ) value



8. Estimate Outlet diameter of hopper $B = \frac{H(\theta)\sigma_{crit}}{\rho_B g}$

9. Estimate the diameter and height of hopper based on mass or volume of powder to be stored.

10. Mass flow rate of powder



$$M_P = \frac{\pi}{4}\sqrt{2}\rho_B g^{0.5} h^{0.5} B^2$$

Design Problem

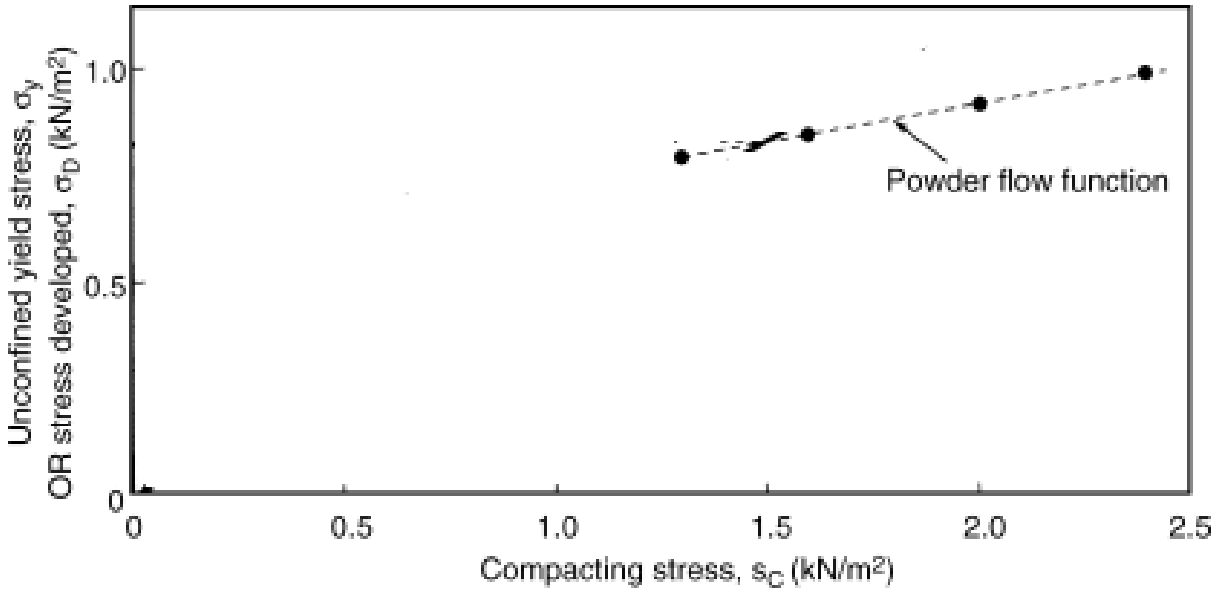
- Powder having the angle of internal friction of 30^0 and angle of friction on SS is 19^0 needed to be stored in a silo. Bulk density of powder is 1300 kg/m^3. Design the conical hopper SS silo.

  Uniaxial compression test results

Unconfined yield strength	2.4	2.0	1.6	1.3
Consolidation stress	0.97	0.91	0.85	0.78

Solution

1. Flow function

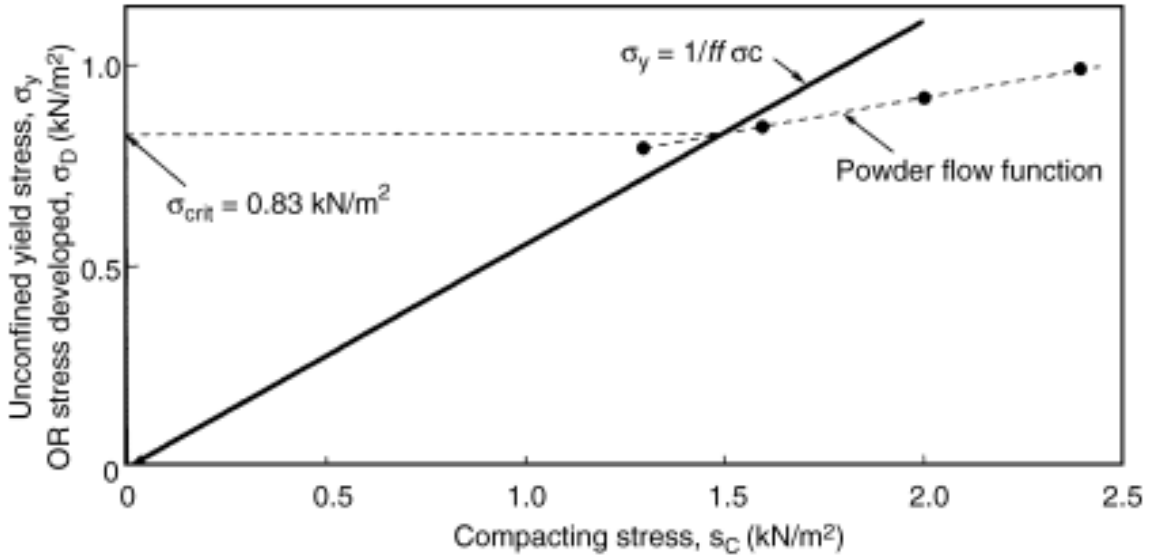


2. Angle of internal friction $(\varphi_c) = 30^0$
   Angle of wall friction (θ_c) = 19^0

3. Hopper angle = 27.5^0

4. ff_c = 1.8

5. Critical stress = 0.83



- H (Θ) = 2.46
- Outlet diameter $$B = \frac{2.46 \times 0.83 \times 10^3}{1300 \times 9.81} = 0.160\,\mathrm{m}$$

EXERCISE 10.1

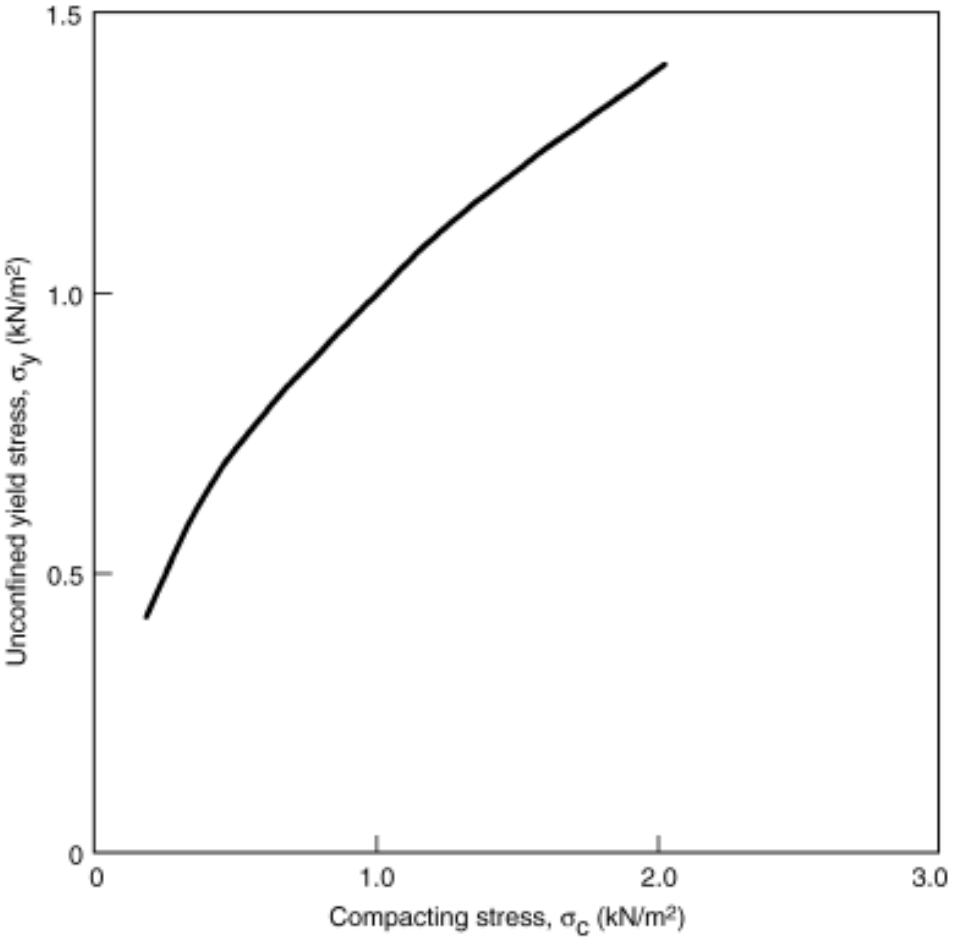
Shear cell tests on a powder show that its effective angle of internal friction is 40^0 and its powder flow function can be represented by the equation: $\sigma_y = \sigma_c^{0.45}$ where σ_y is the unconfined yield stress and σ_C is the compacting stress, both in kN/m^2.

The bulk density of the powder is 1000 kg/m^3 and angle of friction on a mild steel plate is 16^0. It is proposed to store the powder in a mild steel conical hopper of semi-included angle 30^0 and having a circular discharge opening of 0.30 m diameter.

Will mass flow occurs? If not, What is the critical outlet diameter to give mass flow?

Exercise 10.2: A powder has an effective angle of internal friction of 60^0 and has a powder flow function represented in the graph.

If the bulk density of the powder is 1500 kg/m^3 and its angle of friction on mild steel plate is 24.5^0, determine, for a mild steel hopper, the maximum semi-included angle of cone required to safely ensure mass flow, and the minimum size of circular outlet to ensure flow when the outlet is opened.



Exercise 10.3: The hopper that feeds a conveyor belt and periodically blocks at the outlet and needs to be 'encouraged' to restart. The graduate makes an investigation on the hopper, commissions shear cell tests on the powder and recommends a minor modification to the hopper. After the modification the hopper gives no further trouble and the graduate's reputation is established. Given the information below, what was the graduate's recommendation?

Existing Design: Material of wall – mild steel

Semi-included angle of conical hopper – 33^0

Outlet – circular, fitter with 25cm diameter slide valve

Shear Cell test data: Effective angle of internal friction = 60^0

Angle of wall friction = 8^0

Bulk Density = 1250 kg/m^3

Powder flow function $\sigma_y = \sigma_c^{0.55}\ \sigma\ in\ kN/m^2$

Assignment - 1

1. Explain with the aid of sketches what is meant by the terms mass flow and core flow with respect to solids flow in storage hoppers?
2. The starting point for the silo design philosophy is the flow-no flow criterion. What is the flow-no flow criterion?
3. What is the powder flow function? Is the powder flow function dependent on (a) the powder properties, (b) the hopper geometry, (c) both the powder properties and the hopper geometry?
4. What is meant by critical failure (yield) of a powder? What is its significance?
5. Derive Janssen equation. State it's applications.
6. A powder is poured gradually into a measuring cylinder of diameter 3 cm. At the base of the cylinder is a load cell which measures the normal force exerted by the powder on the base. Produce a sketch plot showing how the normal force on the cylinder base would be expected to vary with powder depth, up to a depth of 18 cm.
7. How would you expect the mass flow rate of particulate solids from a hole in the base of a flat-bottomed container to vary with (a) the hole diameter and (b) the depth of solids?

Submission link – http://kgpmoodlenew.iitkgp.ac.in/moodle/ (login and go to Mechanical operations course page, Storage of solids -> Assignment on Storage of solids (upload pdf file)

Submission date : 27-08-2023, 11.59PM, Late submissions will not be accepted , any malpractices will lead to zero internal marks

Thank you

https://www.youtube.com/watch?v=ndl-RjXV0O4