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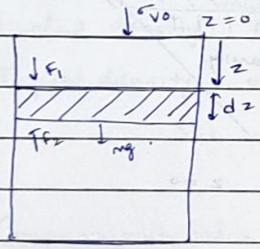
MECHANICAL OPERATIONS (MK)

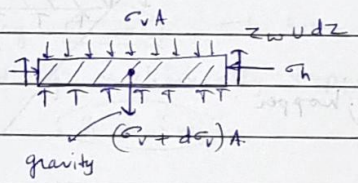
→ study of processing, handling, characterization and application of wide variety of particulate solids / Bulk solids.

→ Size redn (comminution)
Handling (storage)
Mixing / Agitation
Separation → Screening, filtration, cyclone separator, gravity based settling
fluidization

→ Storage of solids
① bins, silos, hoppers

silo





τ_w = friction between solid particles and wall

σ_h = horizontal normal stress

σ_v = vertical normal stress ↑ increases as we go ↓ down.

$$A\sigma_v + \rho_b g A\, dz = \tau_w U dz + (\sigma_v + d\sigma_v) A$$

$$\frac{d\sigma_v}{dz} = \rho_b g - \frac{\tau_w U}{h}$$

↓ because more and more particles are pushing down

σ_{v0} = surcharge stress

→ $\sigma_{v0} = 0$ nothing is there
$\neq 0$ if piston or lid is there

$\tan\phi_x = \frac{\tau_w}{\tau_h}$ ⇒ angle of wall friction

$k = \frac{\sigma_h}{\sigma_v}$ → lateral stress
↓ usually varies but taking const
↓ takes care of internal friction (particle-particle)

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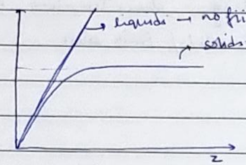
$$\frac{d\sigma_v}{dz} = \rho_b g - \frac{\sigma_v K U \tan\phi_x}{A}$$ → Janssen's equation



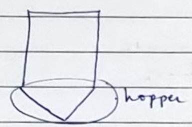
$\sigma_v \uparrow$, $\sigma_h \uparrow$ as we go down

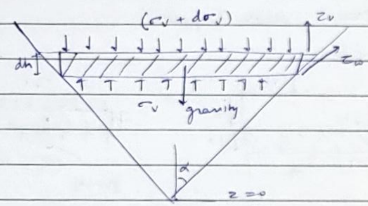
→ Bulk density – depends on how a person fills the solid in a container (someone can compress it more)

→ Max normal stress → property of metal wall → after this breakdown occurs.

→ $\tan\phi_x$ → bulk solid and ~~particle~~ metal.

Hopper





$$\frac{d\sigma_v}{dh} = \frac{\tau_v U}{A} - g\rho_b$$

Normal stress is negligible

→ stress decreases as we go down.

ϕ_e = angle of internal friction

→ Critical diameter to avoid arching → as we go down stress decreases and cohesive forces dominate

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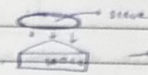
Carr flowability index

Flowability :- how easily a bulk solid can move from stationary to moving state

Floodability : tendency to flood or move in an unstable or liq like flow. (uncontrolled flow)

→ Carr flowability index is quantification of flowability
It is used to determine flow behaviour of material

1. Compressibility Index
2. Angle of repose
3. Angle of spatula
4. Uniformity / Cohesion Index



Aerated density :- (ρ_{bo}) no tapping → sieve with mesh size [illegible]

Tapped density : obtained by mechanically tapping
(ρ_t) $\quad \rho_t \geq \rho_{bo}$

Compressibility index : (K_I)

ability of powder to be compressed in a container

$$K_I = \frac{\rho_t - \rho_{bo}}{\rho_t} \times 100$$

$K_I \uparrow$, low flowability

Hausner ratio :- $H = \frac{\rho_t}{\rho_{bo}}$

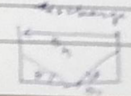
$H \downarrow$, more flowability

Angle of repose :- steepest angle relative to horizontal plane at which a material can be piled

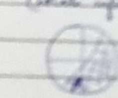
low & high flowability

Poured

Drained
slope angle of material retaining in a container after centre outlet discharge



Dynamic (rotating cylinder)



[illegible]

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Angle of spatula

angle between horizontal and slope of heap

low angles, high flowability.

Cohesion index

Measurement of cohesive forces.

more cohesive force, less flowability

Uniformity = $\frac{D_{60}}{D_{10}}$ (Identifies size similarity using sieve analysis)

- D_{60} → Sieve size which will allow 60% of materials to pan.
- D_{10} → Sieve size which allows 10% of materials to pan.

uniformity $\propto$ flowability.

D_{60} = effective particle size

D_{60} = particle size at which 60% of particles are finer and 40% are coarser

shear :- force tending to deform a body by slippage along a plane

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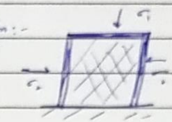
Unconfined yield strength

The force or stress required to deform or break a material when it is not confined by a container (free unstressed surface). Important to study flowability

Incipient flow:

Particles has just started sliding against each other whole material failure does not occur but local failure occurs

→ consolidation:-



HYDRAULIC TRASPORT OF SLURRY

Durand equation is used to calculate pressure drop

$$\left|\left(\frac{-\Delta P_m}{-\Delta P_l}\right)\right| = 1 + 150(1-\varepsilon)\left(\frac{Dg(\rho_s-\rho_l)}{U_{avg}^2(\rho_l)\sqrt{C_D}}\right)^{1.5}$$

Pneumatic transport of Bulk solid

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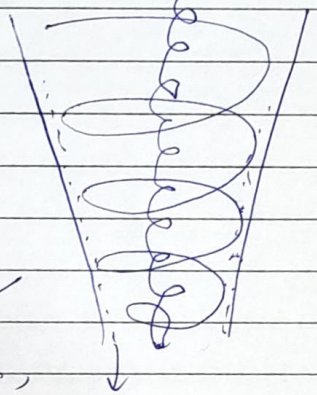
Cyclone separator (helical ~~path~~ path)

Use centrifugal force generated by spinning gas stream to separate the particulate matter

→ dual vortex is formed. VT as air moves down as area ↓

→ Outer vortex spirals downward carrying most of the coarser particles.

→ Inner vortex created near the bottom of the cyclone spirals upward.



→ fan can be used to take the air out (clean gas)

Inlet area is such that air flows tangentially

(low pressure region is developed in the centre)

used for filteration, classification of particles (separation of particles)

(air) gas - ~~solid~~ separation

driving force

Centrifugal force, gravity diff

→ hydrocyclones → solid - liq

→ When the air reaches bottom, it begins to flow radially inward and out the top as clean gas