

Porous: هي المادة التي فيها جوفية

Composition الحبيبات

** Three most important characteristics of an individual particle.

① composition → size
porous

② Size → Affect properties
surface / unit volume

③ Shape

→ irregular (broken materials)
broken glass

- can't define it

- Refer to regular shape.

→ regular shape (spherical / cubical)

- precise definition by mathematical equation

الحبيبة منتظمة (مقورة)
أفضل شيء

① Handling Large quantities.

② Need to specify the system as a whole.

③ Defining a mean particle size.

Storage: - hoppers (silo)

Metering: - flow

تخزين المواد
في المخابض التي تبين
أو مصانع القمح

Mixing
Separation

BS British standard
↪

symmetry

ask

sphere

recieve

↪ أفضل شكل للتداول مع

~~Acicular~~

- Acicular (needle shaped)
- Angular (sharp edged)
- Flaky (plate like)
- Modular (Rounded, irregular shape)

• Sphere :-

* size of equivalent ~~star~~ spheres :-

① The sphere which will just pass through the same size of square aperture as the particle (screen).

② The sphere with the same settling velocity as the particle in a specified fluid.

③ The sphere of the same volume as the particle.

④ surface area.

⑤ Surface area / unit volume.

$$\psi_{\text{sphericity}} = \frac{\text{surface area of sphere}}{\text{surface area of particle}}$$

* $\psi_{\text{sphere}} = 1$

ای اشی غیر کروی sphere بدو یون fraction من 1

نفل tangent للکبیته علی ابد نقطین و 1 tangent یون Parallel

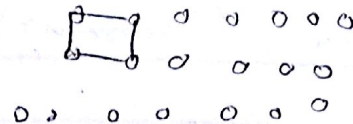
فریج
feret's diameter



Particle, حبات

① Crystalline / ~~Amp~~ Amorphous

ترتيب حبات



ترتيب حبات

crystalline, ترتيب حبات

Long range order :-

- ① Simple cubic (SC) 1 atom حبة →
- ② Body centered cubic (BCC) → 2 atoms حبة
- ③ Face centered cubic (FCC) → 4 atoms حبة

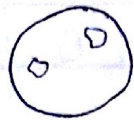
amorphous, ترتيب حبات

ترتيب حبات

ترتيب حبات

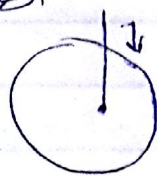
② Whether it is Porous

ترتيب حبات



③ Hardness, الصلابة

Brinell Hardness No.



10mm



Height, الارتفاع
(Brinell Hardness No.)

نوع
Vicker

area, المساحة

Hardness, الصلابة

- ④ Surface
- Rough
- Smooth

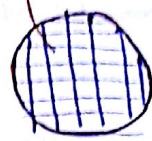


Particle size

Sieving (Screening)

(Top)

aperture



How to measure the size of the particle

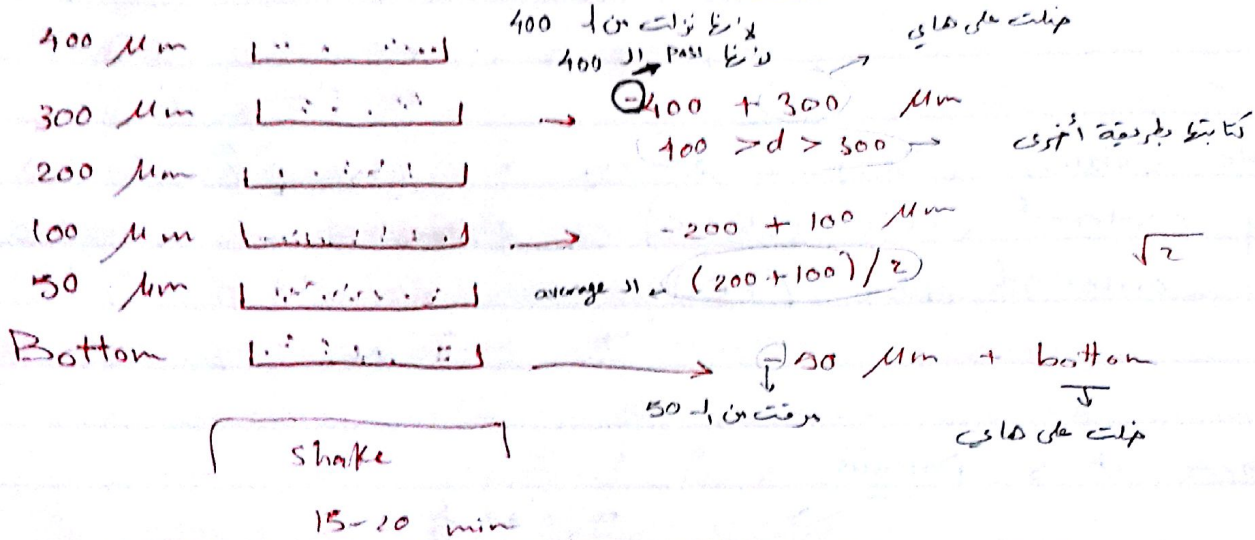


Table (1-1) بالكتاب

* Particle Passes through aperture depends on:-

- ① Size
- ② Orientation at the surface of the screen



* Lower limit of size:-

- ① The proportion of free space on the screen becomes very small as the size of aperture is reduced.
- ② The attractive forces between particles become larger at small particle sizes (stick together)

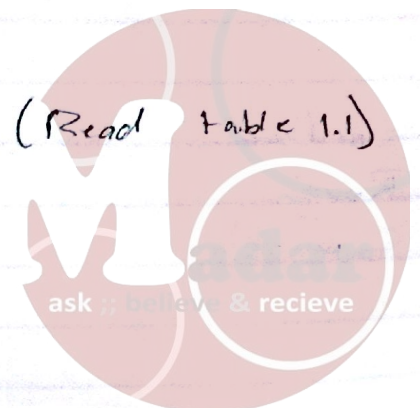
• Types:-

- 1) British standard (BS)
- 2) Tyler series (USA)

(Read Table 1.1)

screening

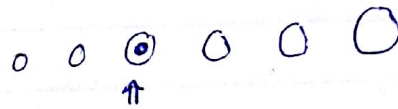
- ① Dry
- ② Wet



طريقة اخرى لقياس
size of particle

Microscopic analysis :-

(1 - 100 μm)



Coulter - counter

(1 - 100 μm)

أحد الأجهزة التي يقيس size عن طريق volt

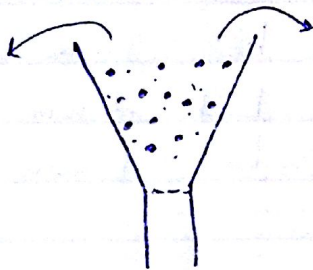
3. نيل التحليل إلى د طريقة استخدام هذا الجهاز ولتتخرج على ورقة .

* تأثير مختبرات

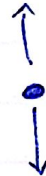
تليم لأرقام المقارم

H.W
1

Elutriation



air flow



settling velocity

له نوع جسيمات مختلفة الحجم
وينخل الهواء منهم

الجسيمات الصغيرة تخرج

* كل ما يزيد air flow الجسيمات الأكبر من حيله

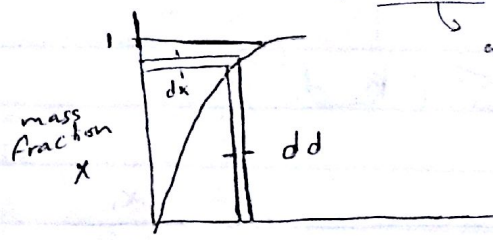
تأثير settling velocity إلى أقل من air flow ، يخرجها تأثير سرعة الهواء .

* Particle size distribution ..

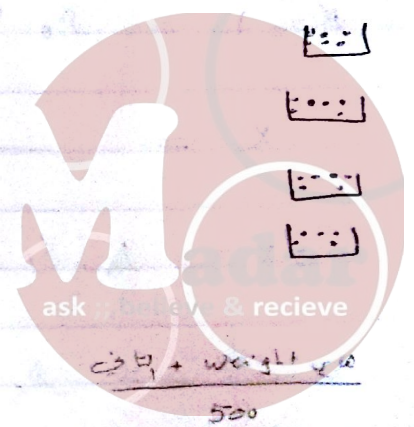
size distribution curve

(cumulative basis)

accumulation

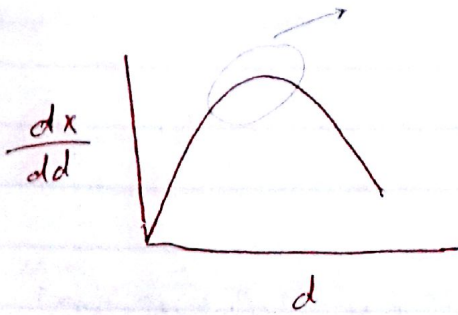


particle diameter d



6+5
500

اگر size distribution
طبیعی است



most frequently occurring size

→ Mean Particle size:

Product :-

80% 1 mm

15% 2 mm

5% 3 mm

15% 3 mm

15% 2 mm

80% 1 mm

Bond :-

$$d_{80} = 1 \text{ mm}$$

زی تقریب

را 80% من ایند

ما 80% ایند

→ Unit mass of particles consisting n particles, 1 mm

d_i :- diameter
 ρ :- density
Volume

$$X_i = n_i K_i d_i^3 \rho_s$$

K_i = constant depends on shape

ρ_s = density of solid

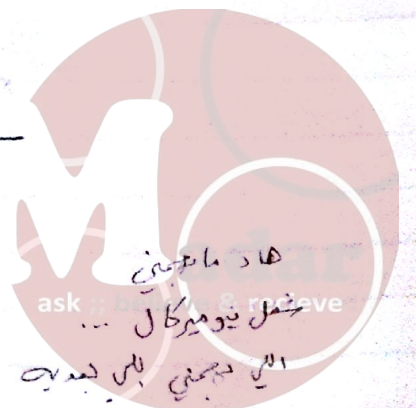
(n)
No. of
particles

$$X_i = 1 = \rho_s K_i \sum (n_i d_i^3)$$

$$X_i = \frac{1}{\rho_s K_i} \cdot \frac{X_i}{d_i^3}$$

$$dx = \rho_s K_i d_i^3 dn$$

$$\frac{dx}{dn} = \rho_s K_i d^3$$



* Volume mean diameter

* weight mean diameter $\rightarrow d_v$

$$d_v = \sum_i \frac{n_i d_i^3}{\sum_i n_i d_i^3}$$

$\rightarrow$ ساقی d_i^3

No. of particle d_i^3 گلوله

d_1, d_2, d_3
 $\sum n_i$
No. of particle

$$d_v = \sum_i x_i \cdot d_i$$

$\rightarrow$ ساقی d_i

mass fraction d_i گلوله

* Mean volume diameter :-

$$d_v = \sqrt[3]{\frac{1}{\sum_i \frac{x_i}{d_i^3}}}$$

$$d_v = \sqrt[3]{\frac{\sum_i n_i d_i^3}{\sum_i n_i}}$$

* Surface mean diameter :-

* Sauter mean diameter d_s :-

$$d_s = \frac{1}{\sum_i \frac{x_i}{d_i}}$$

$$d_s = \frac{\sum_i n_i d_i^3}{\sum_i n_i d_i^2}$$

* Mean Surface diameter :-

$$d_s = \sqrt{\frac{\sum_i x_i \cdot d_i}{\sum_i \frac{x_i}{d_i^3}}}$$



$$d'_{ls} = \sqrt{\frac{\sum n_i \cdot d_i^2}{\sum n_i}}$$

* Length mean (d'l) :-

$$d'l = \frac{\sum \frac{x_i}{d_i}}{\sum \frac{x_i}{d_i^2}}$$

$$d'l = \frac{\sum n_i \cdot d_i^2}{\sum n_i \cdot d_i}$$

* Mean Length diameter :-

$$d'l = \frac{\sum \frac{x_i}{d_i^2}}{\sum \frac{x_i}{d_i^3}}$$

$$d'l = \frac{\sum n_i \cdot d_i}{\sum n_i}$$

mem	d	n _i	x
10 - 8	9	-	
8 - 6	7	-	
6 - 4	5	-	
4 - 2	3	-	
2 - bottom	1	-	

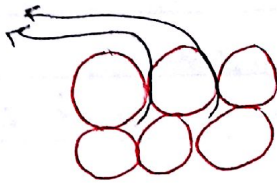
بفضل جلی اکتفا
کربل زی صلح



ask, believe & recieve

* Solids in bulk :-

Voids
الفراغات
من مسحة
الحبيبات



Voids
كلمة موصلة

→ Agglomeration :- (تكتل الحبيبات على بعضها بعض) → مرات مرفوعة ومرت بتغللتنا
سائل

- ① Mechanical inter locking
- ② Surface attraction $< 10 \mu m$.
result from forces

③ Plastic Welding
irregular Particles. من شكل منقسم

④ Electrostatic attraction
charges. ⇒

⑤ Effect of moisture (H_2O)

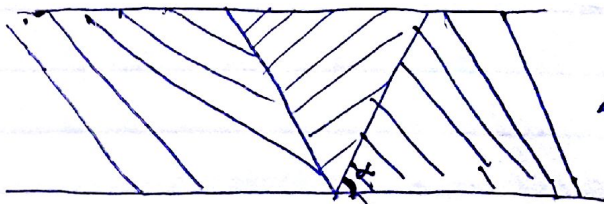
⑥ Temperature fluctuations. ⇒

دايا يتشكل سخانات (أثر باردا ساكنة) على الحبيبات

تغير في درجة الحرارة

flowing solids.

Mon. 12 / 10 / 2015

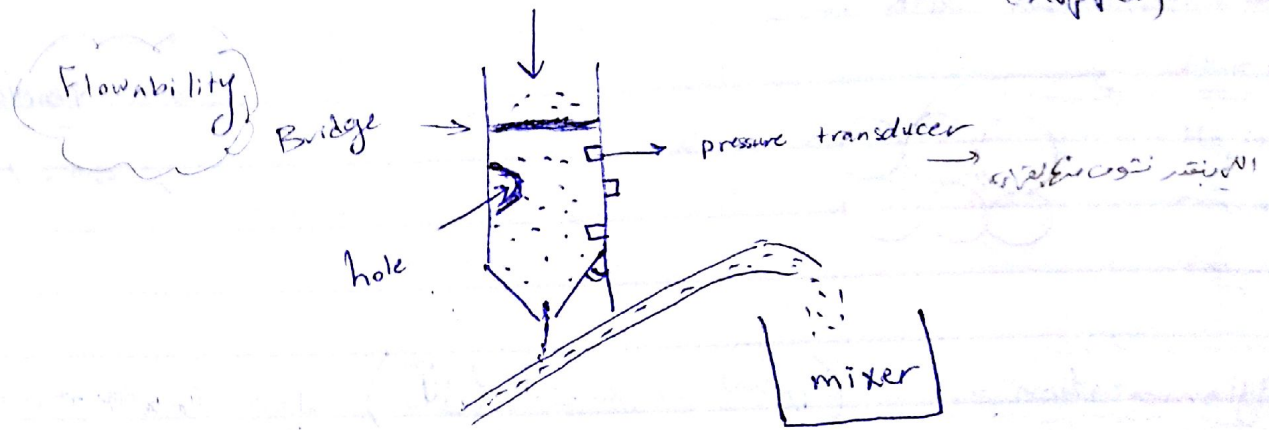


← Stationary solids

Angle
of friction



Silo (hopper)



عقبات جريان تتشكل من سد الجريان
Bridge

agglomeration تتشكل

hole سد الجريان

①

Conveying of Solids:-

- ① Gravity shutes → منسوب من أعلى للأسفل
- ② Air Slides → air →
- ③ belt conveyors → الحزام الناقل
- ④ Screw conveyors → زئ مائلة، الدائرية
- ⑤ Bucket elevator → زئ دوّاب (وعاء) كبير يرفع
- ⑥ Vibrating conveyors → يستخدم من الأوتار، الحزام
- ⑦ Pneumatic conveyors → زئ، رتم (2) سائل
بدي الفرق بينهم
الجريان يتكون موزعة في الهواء، لا سد الجريان
air →

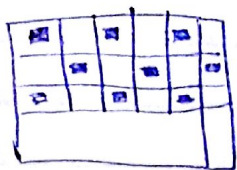
لـ طريق نقل
الـ

الموضوع الثاني

Blending (Mixing)

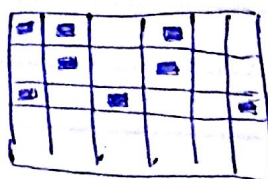
* Mechanisms:-

- ① Convective → جريان بصر على عترة
- ② Diffusion → جريان بصر عترة
- ③ Shear → تقطع طبقات layers



Uniform

Point uniformity



Overall degree of randomness



→ Degree of mixing :-

- ① Properties of the required mix.
- ② Should be easy to measure.
- ③ Suitable for a ~~var~~ variety of different mixtures.

For a completely random mix of uniform particles .

$$S_r^2 = \frac{P(1-P)}{n}$$

S_r^2 = variance

P = overall proportion of particles, 10% of the mixture.
 n = number of particles.

For a completely unmixed system :

$$S_o^2 = P(1-P)$$

No. of particles affect S_o^2 of particle size
 unmixed system

$$M = \frac{S_o^2 - S^2}{S_o^2 - S_r^2}$$

Where S^2 is unmixed material from a large number of samples.

Eg: Assess the following mixer

مثال 1.3 التمثيل

S^2	0.25	0.006	0.015	0.018	0.019
Mixing time (s)	30	60	90	120	150

20% of mixture

Each sample = 100 particles.



* un mixed system

$$\begin{aligned} S_o^2 &= p(1-p) \\ &= 0.2(1-0.2) \\ &= \end{aligned}$$

* Random mixture

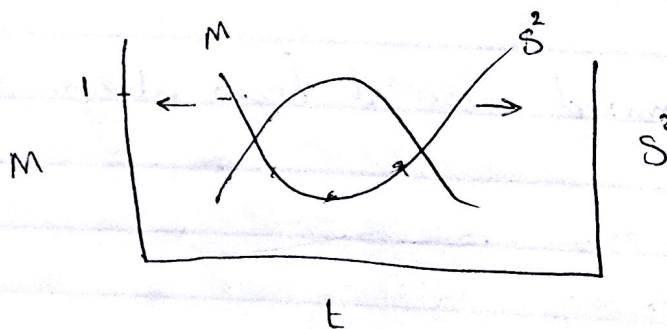
$$\begin{aligned} S_r^2 &= p(1-p)/n \\ &= 0.2(1-0.2)/100 \\ &= 0.0016 \end{aligned}$$

$$M = \frac{S_o^2 - S^2}{S_o^2 - S_r^2} = \frac{0.16 - S^2}{0.16 - 0.0016}$$

$$M = 1.01 - 6.3 S^2$$

Example(2)

T (s)	30	60	90	120	150
S^2	0.025	0.006	0.015	0.018	0.019
M	0.852	0.972	0.915	0.896	0.891



Mean concentration
Standard deviation

for 30 samples

Mixer → horizontal

Filled → 30% capacity with 20% black sand.

Rotates at 21 rpm

Nine rotations.

Sample No.	No. of black particles	Total particles	P_i	P_i^2
1	36	114	$(36/114) \times 100$	997.3
⋮	⋮	⋮	= 31.58	⋮
30	20	112	17.9	318.9
<u>Total</u>			<u>629.5</u>	<u>14372.2</u>

Table * دليلاً على الأمانة التي هي من أجل تفصيل أفضل

Mean Concentration
of black sand

$$\bar{X}_i = \frac{\sum_{i=1}^n X_i}{n}$$

$$\bar{P}_i = \frac{\sum_{i=1}^{30} P_i}{n} = \frac{629.5}{30} = 20.98$$

Standard deviation

$$S = \sqrt{\frac{(\sum_{i=1}^n x_i^2 - \bar{x} \sum_{i=1}^n x_i)}{n-1}}$$

$$S = \sqrt{\frac{\sum_{i=1}^{30} P_i^2 - \bar{P} \sum_{i=1}^{30} P_i}{n-1}}$$

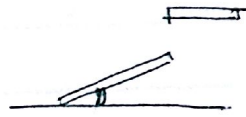
$$S = \sqrt{\frac{14372.2 - (20.98/629.5)}{30-1}} = 6.33$$



Mixer inclined on angle

① First case

② Second case



$$S_2 = 7.21$$

standard deviation

الانحراف المعياري

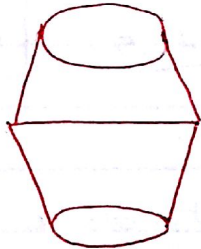
$$S_1 = 6.33$$



التي أصغارا قبل شوي

Low standard deviation $\Rightarrow$ high uniformity
high standard deviation $\Rightarrow$ poor mixture

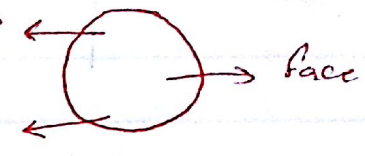
Double Cone mixer



rpm time

Sampling

top



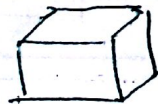
bottom

* ch. ②
3

* Size Reduction of Solids

① Combustion

Surface area



② Drying

من السطح الى الجو

Surface area

H₂O



من الجو الى السطح

Surface area

من السطح الى الجو

الحيات كغاية آتت في بئر من السطح الى الجو

③ Mixing



- sudden impact



coarse

relatively few large particles

relatively few particles of intermediate size

No. of fine particles

حبيبات ناعمة
في مقادير كبيرة

- Energy of blow increased

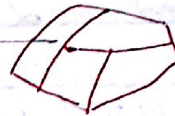


smaller size, numerous

fine, increased

fissures (cracks) تشققات في الحبيبات

اول ما يتكسر، يتكسر من عند cracks
بعين يتكسر من عند مناطق الضعف
cracks.



Tension



Elongation

استطالة - تقارب

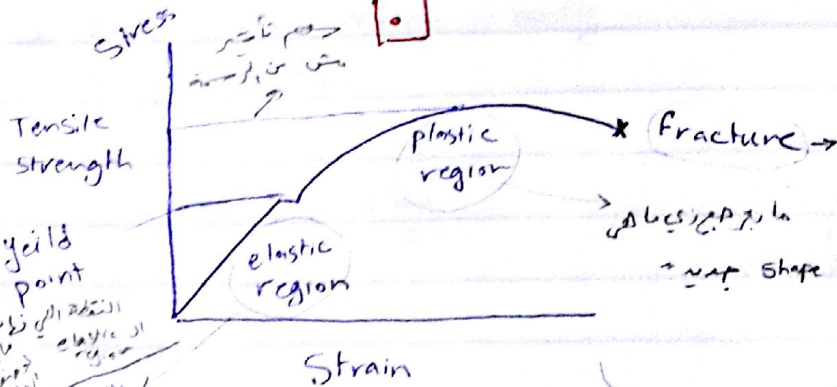


Necking

دائما، الاستطالة بتغير دينامي

Weak connections

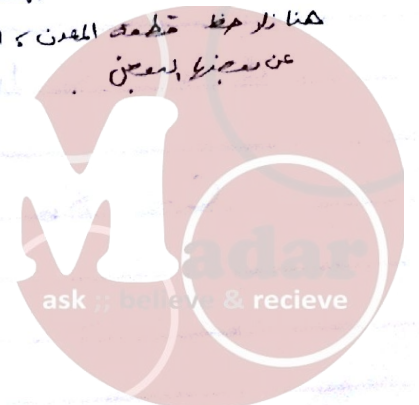
بين الجزيئات



هنا لا حفظ نقطة المرن، انضغاط
عن نقطة المرن

Shape change

reversible
irreversible



$$\frac{dE}{dL} = -CL$$

constant
P → power
unit

dE = Energy required
 dL = change of unit mass.

- Rittinger's Law :-

$$P = -2$$

$$E = C \left(\frac{1}{L_2} - \frac{1}{L_1} \right)$$

$$C = K_R \cdot f_c$$

K_R = Rittinger's constant.

f_c = crushing strength

- آية الله انكرت اولاً في f_c الى آخر
من الله انكرت من الاول.

$$E = K_R f_c \left(\frac{1}{L_2} - \frac{1}{L_1} \right)$$

Energy required $\propto$ increase in surface

المادة تتغير في حالطوبى
الطبع حبات ناعمة

Used for fine grinding

fine 500 microns

- Kick's Law :-

$$P = -1$$

$$E = C \ln \left(\frac{L_1}{L_2} \right)$$

$$C = K_K \cdot f_c$$

K_K = Kick's constant.



$$E = K_k \cdot f_c \cdot \ln \left(\frac{L_1}{L_2} \right)$$

← الحيات الكبيرة Used for coarse crushing

2 millimeters and above.

- Bond Law

$$P = -3/2$$

$$E = 2C \left(\frac{1}{\sqrt{L_2}} - \frac{1}{\sqrt{L_1}} \right)$$

بين الحجمين الى فوق

Used for intermediate size

- Energy Utilization

- ① Elastic , Plastic
- ② Friction between particles and with machine.
- ③ Noise ... and many others.

- Methods of operating crushers:-

A) Free crushing.

- ① Feeding the material at low rate.

→ the product escape readily

- ② Residence time.

→ Short.

- ③ Undersize material

→ Avoid.



B) choke feeding ..

1- Machine is kept full of material → discharge of products is impeded.

2- Residence time → long .

3- Higher degree of crushing → Energy consumption is high .

→ See the table

انواع طاحنت

- Hammer mill ذري طاحنة
- Jaw طاحنة

ما يده في عناء كثير
ولكن نقراتها في الطاب

colloidal انفرج

- Ball mill → طاحنة كروية *
Capacity ~ ~~at~~ almost 50% volume.

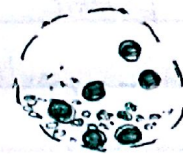
Balls

Steel, Ceramics → crushing strength

Mixing of balls.

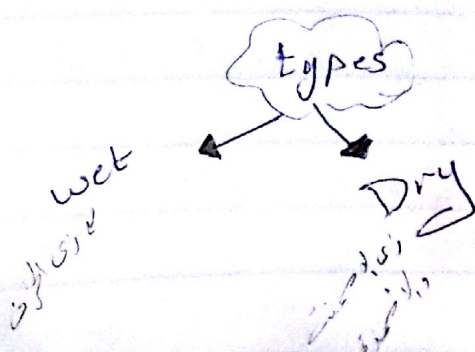
Large → feed

Small → fine



* Factors affecting milling

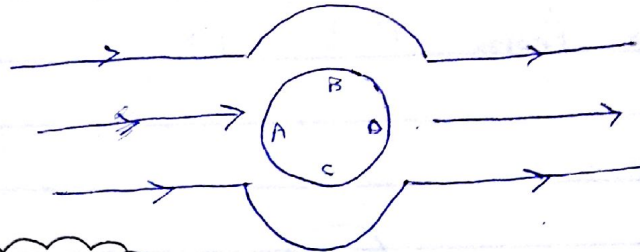
- ① Rate of feed.
- ② Speed of rotation .
- ③ Weight of balls.
- ④ Discharge material
- ⑤ Slope of the mill ... and others .



* Chapter (3) :

* Particles / fluid system.

Fluid past cylinder in a direction $\perp$ to its axis



شروط

* Non viscous fluid: -

A & D $\rightarrow$ fluid at rest.

B & C $\rightarrow$ velocity is at max.

Kinetic energy : max. at B & C $\Rightarrow$ $\frac{1}{2} m u^2$
 and zero at A & D $\Rightarrow$

* Pressures falls from A to B
 and from A to C

الضغط ينخفض من A إلى B و C

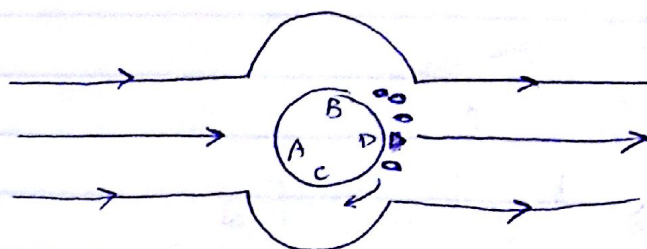
يرتفع ثانية

arises again from B to D
 C to D

$\rightarrow$ At A and D are the same.

* No net force exerted by the fluid on the cylinder
 $\therefore$ No drag

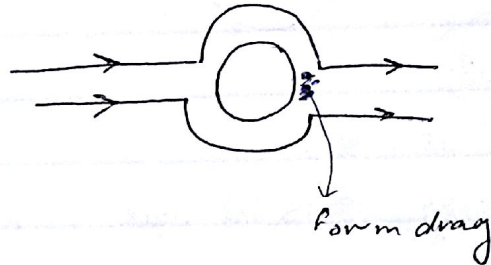
* Viscous fluid



decreases from A to B
and A to C

and ~~increases~~ rises again from B to D
and from C to D.

→ Boundary Layer :-



* total force F

① Skin friction

② Form drag

* Stokes Law :- → at Low Re No. (Reynolds)

$$F = 3 \pi \mu \cdot d \cdot u$$

F = drag force

μ = viscosity

d = diameter of the sphere

u = velocity of fluid relative to the particle.

$$Re = \frac{\text{density} \cdot \text{velocity} \cdot \text{diameter}}{\mu \rightarrow \text{viscosity}}$$

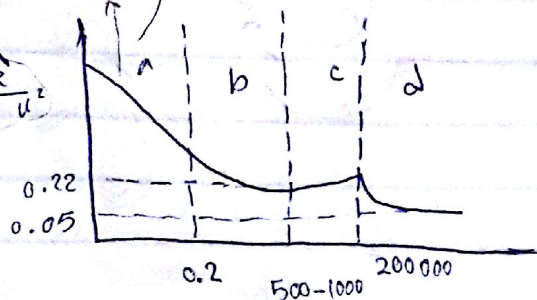
R' = force exerted on unit projected ^{area} of particle in a plate at right angles to its direction of motion

Stokes Region

curve of Stokes

curve of Stokes

$$\log \frac{R'}{\rho u^2}$$



region a
Stokes Region
ask & receive

log Re

Q. 2

n_i	d_i	$n_i d_i^3$	$n_i d_i^4$
0.20	0.250	—	—
0.60	0.125	—	—
0.2	0.085	—	—
		0.00412	0.000937

دائراً
percentage
n
x

$$d_r = 0.21$$

$$E = 9$$

$$f_c = 70$$

$$L_1 = 6$$

$$L_2 = 1$$

$$q = k \times 70 \left(\frac{1}{0.1} - \frac{1}{0.21} \right)$$

$$E = 0.013 \times 100 \left(\frac{1}{0.21} - \frac{1}{0.1} \right)$$

$$6 \text{ kW}$$

Quiz

انظر

$$E = k f_c \ln \left(\frac{L_1}{L_2} \right)$$



* Region a

$$10^{-4} < Re' < 0.2$$

Equation of curve :-

$$\frac{R'}{\rho u^2} = 12 Re'^{-1} \quad \text{--- (1)}$$

Straight line of slope = -1

form friction = $1/3$

skin friction = $2/3$

* Region b

$$0.2 < Re' < 500-1000$$

Eq. I

$$\frac{R'}{\rho u^2} = \frac{12}{Re'} \left[1 + \frac{3}{16} Re' \right] \quad \text{--- (2)}$$

Eq. II

$$\frac{R'}{\rho u^2} = 12 Re'^{-1} \left[1 + 0.15 Re'^{0.687} \right] \quad \text{--- (3)}$$

form drag $\Rightarrow$ increasing

لزيادة الجهد المتحرك

* Region c :-

$$500-1000 < Re' < 2 \times 10^5$$

Equ. of curve

$$\frac{R'}{\rho u^2} = 0.22 \quad \text{--- (4)}$$

skin friction $\Rightarrow$ negligible



* Region D :-

$$Re' > 2 \times 10^5$$

Equ. of curve

$$\frac{R'}{\mu u^2} = 0.05 \quad \text{--- (5)}$$

→ Total force on the particle :-

• In Region a :-

from Eq. I :-

$$\frac{R'}{\mu u^2} = 12 Re'^{-1}$$

$$R' = 12 \mu u^2 \frac{1}{u d \rho}$$

resistance

$$R' = \frac{12 \mu u}{d}$$

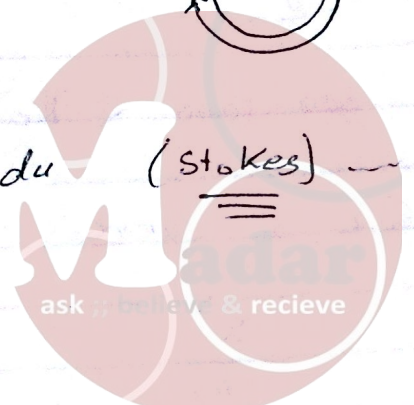
→ Projected area of particle = $\frac{1}{4} \pi d^2$

→ Total force

$$R' (\text{force}) = \frac{\text{drag}}{\text{area}}$$



$$F = \frac{12 \mu u}{d} \cdot \frac{1}{4} \pi d^2 = 3 \pi \mu d u \quad (\text{Stokes}) \quad \text{--- (6)}$$



• In Region b :-

Eq 3 :-

$$\frac{R'}{\rho u^2} = 12 Re^{-1} [1 + 0.15 Re^{0.687}]$$

$$R' = 12 \rho u^2 \frac{\mu}{u d} [1 + 0.15 Re^{0.687}]$$

$$= \frac{12 \mu u}{d} (1 + 0.15 Re^{0.687})$$

$$F = \frac{12 \mu u}{d} (1 + 0.15 Re^{0.687}) \cdot \frac{1}{4} \pi d^2$$

$$= 3\pi \mu u d (1 + 0.15 Re^{0.687}) \quad \text{--- (7) } \checkmark$$

• In Region c :-

Eq 4 :-

$$\frac{R'}{\rho u^2} = 0.22$$

$$F = 0.22 \rho u^2 \cdot \frac{1}{4} \pi d^2$$

$$= 0.055 \pi d^2 \rho u^2 \quad \text{--- (8)}$$

"Newton's Law"

• In Region D :-

Eq. 5:-

$$R' = 0.05 \rho u^2$$

$$F = 0.05 \rho u^2 \cdot \frac{1}{4} \pi d^2$$

$$= 0.0125 \pi d^2 \rho u^2$$

$$= 0.0125 \pi d^2 \rho u^2 \quad \text{--- (9)}$$

Drag and buoyant :-

Frictional Fluid (drag)



driving force due to gravity

Settling force due to gravity :-

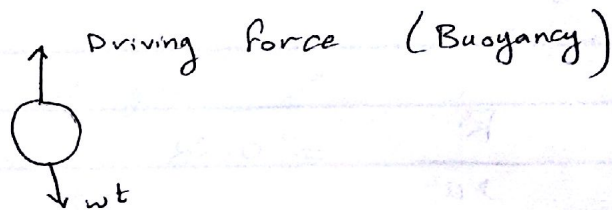
Driving



buoyant

wt

* Gravity Driving Force :-



Driving force (Buoyancy)

wt

$$F_G = (\rho_s - \rho) g V_p$$

F_G :- gravity Driving force.

ρ_s :- solid density.

ρ :- fluid density.

V_p :- volume of particle

* Drag force :-

$$F_D = \frac{C_D \cdot A_p \cdot \rho \cdot u_s^2}{2}$$

F_D :- Drag force

C_D :- drag coefficient

A_p :- projectal area of particle.

u_s :- settling velocity of particle.

* Drag Coefficient :-

$$C_D = \frac{24}{Re} \Rightarrow F_D = \frac{\left(\frac{24}{Re}\right) \left(\frac{\pi}{4} d^2\right) \cdot \rho \cdot u_c^2}{2}$$

$$Re = \frac{\rho \cdot u \cdot D}{\mu}$$

$$F_D = 3\pi \mu \cdot d u \rightarrow \text{same as region ; [Stokes Law]}$$

* At equilibrium -

• In region a

$$\rightarrow V_p(\rho_s - \rho) g = 3\pi \mu \cdot d u_0, \quad V_p = \frac{\pi}{6} d^3 \quad \text{diameter}$$

$$\text{imp } u_0 = \frac{d^2 g}{18 \mu} (\rho_s - \rho)$$

Terminal settling velocity $\rightarrow$ for one particle

• In region c

$$\left(\frac{\pi}{6}\right) d^3, \quad V_p (\rho_s - \rho) g = 0.055 \pi d^2 \rho u_0^2$$

$$u_0^2 = 3 d g (\rho_s - \rho) / \rho$$

$\rightarrow$ Region A

$$\text{Particle A} \rightarrow u_{0A} = \frac{d_A^2 \cdot g (\rho_A - \rho)}{18 \mu}$$

$$\text{Particle B} \rightarrow u_{0B} = \frac{d_B^2 g (\rho_B - \rho)}{18 \mu}$$

$$\text{if } u_{0A} = u_{0B} \rightarrow \frac{d_B}{d_A} = \sqrt{\frac{\rho_A - \rho}{\rho_B - \rho}}$$

→ Region c

Particle A → $u_{0A}^2 = \frac{3 d_A g (\rho_A - \rho)}{\rho}$

Particle B → $u_{0B}^2 = \frac{3 d_B g (\rho_B - \rho)}{\rho}$

if $u_{0A} = u_{0B}$ → $\frac{d_B}{d_A} = \frac{\rho_A - \rho}{\rho_B - \rho}$

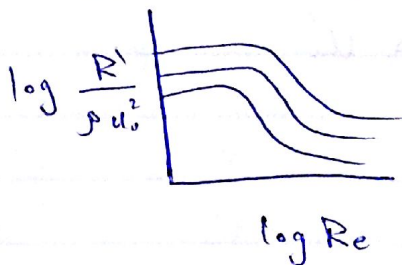
→ Result: $\frac{d_B}{d_A} = \left[\frac{\rho_A - \rho}{\rho_B - \rho} \right]^S$

$S = 1/2$ → Stokes region (a)

$S = 1$ → Newton's region (c)

$1/2 < S < 1$ → region (b), Intermediate region.

* Non-spherical particles :-



Separate curve for each shape.
→ must be obtained.

→ Region a

Flow → Stream Line

→ low Re

Drag $\frac{R'}{\rho u^2} = K \cdot Re^{-1}$

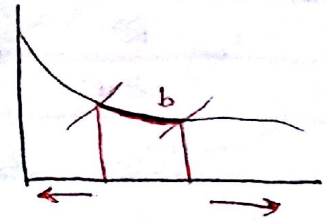
→ shape factor (K always 12)



* Region b

Transition conditions.

→ All values will be shifted.



* Region c

- Cylinders with axes // to direction of motion.

$$\frac{\text{Length}}{D} = 1 \quad \Rightarrow \quad \frac{R'}{\rho \cdot u^2} = 0.3$$

$$\frac{\text{Length}}{D} = 5 \quad \Rightarrow \quad \frac{R'}{\rho \cdot u^2} = 0.35$$

$$\frac{\text{Length}}{D} = 20 \quad \Rightarrow \quad \frac{R'}{\rho \cdot u^2} = 0.45$$

$$\frac{\text{Length}}{D} = \infty \quad \Rightarrow \quad \frac{R'}{\rho \cdot u^2} = 0.6$$

→ Values are higher than the value of 0.22 for spheres.

⇒ Terminal falling velocity

$$u_0 = \frac{g d^2 \cdot (\rho_s - \rho)}{18 \mu}$$

* Heywood Approach:-

- Mean Projected diameter is defined as the diameter of a circle having the same area as the particle when viewed from above and lying in its most stable position.

$$\text{Vol.} = K \cdot d_p^3$$

K - constant depends on shape

$$K \text{ (for sphere)} = \frac{\pi}{6}$$



- Table 3.4 , corrections.

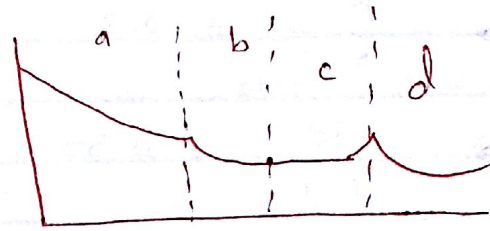
$$\log \frac{R'}{\rho u^2} \quad Re^{1/2} = \text{corrections.}$$

- Table 3.5

$$\log \frac{R'}{\rho u^2} \quad Re^{1/4} = \text{corrections.}$$

Wed, 4 / 11 / 2015

* Unknown Re .



Eq (10)

$$F_G = (\rho_s - \rho) g V_p$$

$$F_G = (\rho_s - \rho) g \frac{1}{6} \pi d^3$$

$$R_o \cdot \frac{1}{4} \pi d^2 = \frac{1}{6} \pi d^3 (\rho_s - \rho) g$$

$$R_o = \frac{2}{3} d (\rho_s - \rho) g$$

Divide by ρu_o^2 .

$$\frac{R_o}{\rho u_o^2} = \frac{2}{3} \frac{d g (\rho_s - \rho)}{\rho u_o^2}$$

$$\log \frac{R'}{\rho u^2}$$

$$\frac{R_o}{\rho u_o^2} Re^{1/2} = \frac{2 d g}{3 \rho u_o^2} (\rho_s - \rho) Re^{1/2}$$

ينبع $\Rightarrow$



$$\frac{R_o'}{\rho u_o^2} \frac{u_o^2 d^2 \rho^2}{\mu^2} = \frac{2 d g}{3 \rho u_o^2} (\rho_s - \rho) \frac{u_o^2 d^2 \rho^2}{\mu^2}$$

$$= \frac{2 d^3 \rho g (\rho_s - \rho)}{3 \mu^2}$$

Galileo No.

$$\frac{R_o'}{\rho u_o^2} Re_o'^2 = \frac{2}{3} Ga$$

$$Ga = \frac{d^3 \rho g (\rho_s - \rho)}{\mu^2}$$

Galileo No.

$$Ga = 18 Re_o'$$

$$Ga < 3.6$$

$$Ga = 18 Re_o' + 2.7 Re_o'^{1.687}$$

$$3.6 < Ga < 10^3$$

$$Ga = \frac{1}{3} Re_o'^2$$

$$Ga > 10^3$$

Re حاليه

Table 3.2 في الكتاب 3.3 المرفقة بالبريد

Diameter Unknown

$$\log Re = \dots$$

$$Re = \dots$$

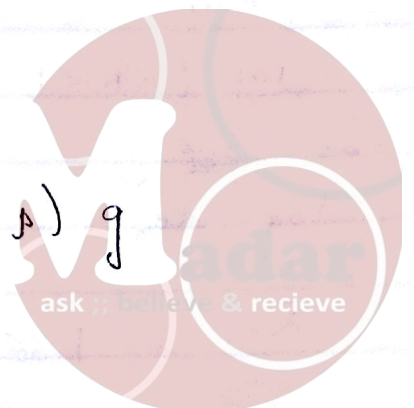
$$Re_o = \frac{\rho u_o d}{\mu}$$

Diameter (Unknown)

$$R_o' = \frac{2}{3} d (\rho_s - \rho) g$$

$$R_o' \frac{1}{4} \pi d^2 = \frac{1}{6} \pi d^3 (\rho_s - \rho) g$$

$$\frac{R_o'}{\rho u_o^2} = \dots$$



دiameter) 100' & Re
جو ال جتو.

$$\frac{R_o'}{\rho u_o^2} Re_o'^{-1} = \frac{2}{3} \frac{d (\rho_s - \rho) g}{\rho u_o^2} Re_o'^{-1}$$

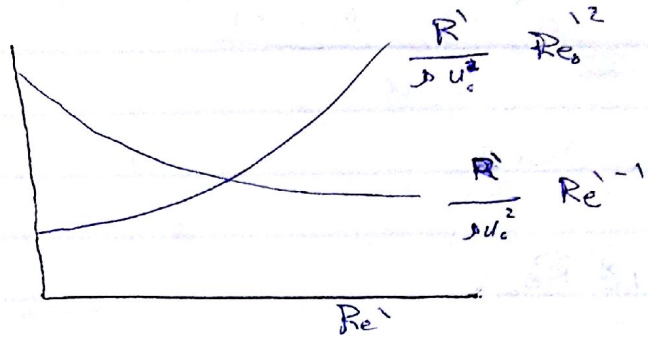
$$\frac{R_o'}{\rho u_o^2} Re_o'^{-1} = \frac{2}{3} \frac{d (\rho_s - \rho) g}{\rho u_o^2} \frac{1}{u_o d \rho}$$

$$= \left(\frac{2}{3} \frac{\mu g (\rho_s - \rho)}{\rho^2 u_o^3} \right) \checkmark$$

Table 3.3

Tables 3.3 & 3.4

$$\frac{R_o'}{\rho u_o^2} Re_o'^2 \quad \text{or} \quad \frac{R_o'}{\rho u_o^2} Re_o'^{-1}$$



$$Re = \frac{\rho u_o d}{\mu}$$

Example

u_o ?

Spherical steel Partick

Dia. 0.4 mm

Settling velocity in oil ?

Oil sp. gr. 0.82

$\mu = 10 \text{ mNs/m}^2$

Sp. gr. Steel = 7.87

$$\frac{R_o'}{\rho u_o^2} Re_o'^2 = \frac{2 d^3 \rho g (\rho_s - \rho)}{3 \mu^2} = 24.2$$

$$\log (24.2) = 1.384$$

Table 3.2

$$\log Re_o' = 0.222$$

$$Re_o' = 1.667$$

$$Re = \frac{u_o d \rho}{\mu}$$

$$u_o = 51 \text{ mm/s}$$

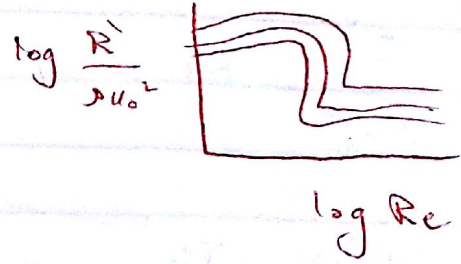


- Non-Spherical Particles:-



separate curve for each shape.

⇒ must be obtained



• flow ⇒ streamline (Low Re)

Prag

$$\frac{R'}{\mu^2} = K Re^{-1.2}$$

K always 12

نشر ال
شرح المحاضرة
الملاحقة



Region (b)

Transition Conditions

All values will be shifted



و باقی زکلی که تم کتابت صفحه (22) بالبرق

* Terminal falling velocity

$$u_0 = \frac{gd^2(\rho_s - \rho)}{18\mu}$$

سای گانت ل spherical Particle

* Heywood Approach *

Mean Projected diameter is defined as the diameter of a circle having the same area as the particle when viewed from above and lying in its most stable position.



$$\frac{R_o'}{\rho u_o^2} = \frac{4 K d_f g}{\pi \rho u_o^2} (\Delta_s - \Delta)$$

$$I) \frac{R_o'}{\rho u_o^2} Re_o^2 = \frac{4 K \rho d_f^3 g (\Delta_s - \Delta)}{\mu^2 \pi} \quad \text{No } u_o \quad \text{دفعه ها به هم وابسته است}$$

$$II) \frac{R_o'}{\rho u_o^2} Re_o^{-1} = \frac{4 K' \mu g}{\pi \rho^2 u_o^3} (\Delta_s - \Delta) \quad \text{No } d \quad \text{دفعه ها به هم وابسته است و diameter}$$

Use:

Table 3.4



$$\log \frac{R_o'}{\rho u_o^2} Re_o^{1/2} = \text{correction (s)}$$

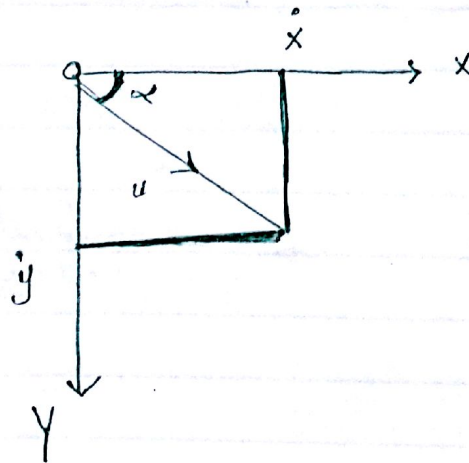
Table 3.5



$$\log \frac{R_o'}{\rho u_o^2} Re_o^{-1} = \text{correction (s)}$$

مقاله
corrections
قبل

Acceleration Motion:-



- The velocity u can be resolved into two component $\dot{x}$ and $\dot{y}$
- $\dot{x}$ and $\ddot{x} \Rightarrow$ Denote the 1st & 2nd derivatives of the displacement x in the x -direction with respect to time.
- $\dot{y}$ and $\ddot{y} \Rightarrow$ for y -direction

ask, believe & receive

$$\cos \alpha = \frac{\dot{x}}{u}$$

$$\sin \alpha = \frac{\dot{y}}{u}$$

$$u = \sqrt{\dot{x}^2 + \dot{y}^2}$$

Mon. 8/11/2015

→ ~~Force act~~
→ Acceleration Motion :-

$$\dot{x} = \frac{dy}{dx}$$

$$\cos \alpha = \frac{\dot{x}}{u}$$

$$\sin \alpha = \frac{\dot{y}}{u}$$

$$u = \sqrt{\dot{x}^2 + \dot{y}^2}$$

volume
↓
 $V_g (\rho_s - \rho)$

Force acting on the particle

$$\frac{m}{\rho_s} g (\rho_s - \rho)$$

$$mg \left(1 - \frac{\rho}{\rho_s}\right)$$

2- The drag force
 $F = R \cdot A$

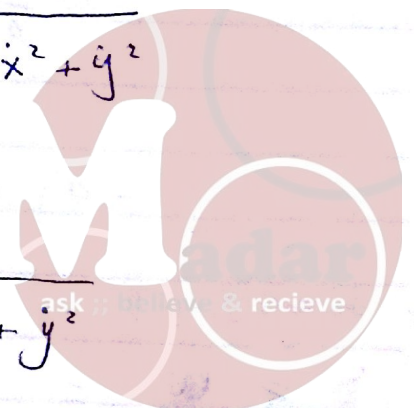
$$F = \frac{R}{\rho u^2} \rho u^2 A$$

the component in the x-direction.

$$\frac{R}{\rho u^2} \rho u^2 A \cos \alpha = \frac{R}{\rho u^2} A \rho \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}$$

in y-direction.

$$\frac{R}{\rho u^2} \rho u^2 A \sin \alpha = \frac{R}{\rho u^2} A \rho \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2}$$



$$m \ddot{x} = \frac{-R}{\rho u^2} \rho A \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2} \quad \text{--- (1)}$$

$$m \ddot{y} = \left(\frac{-R}{\rho u^2} \right) \rho A \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2} \quad \text{--- (2)} + mg \left(1 - \frac{\rho}{\rho_s} \right)$$

* Assumptions ^{y-axis}

1) Motion of a particle when form drag is negligible.

Non-sphere Region a

* Region (a)

$$\frac{R}{\rho u^2} = K \cdot Re^{-1}$$

$$\ddot{x} = \frac{-A \dot{x} \rho}{m} \frac{K u}{u \cdot d} \sqrt{\dot{x}^2 + \dot{y}^2}$$

$$\ddot{x} = \frac{-K \mu}{m d} A \dot{x} \quad (\text{No } \dot{y}) \quad \text{--- (3)}$$

$$\ddot{y} = \frac{-K \mu}{m d} A \dot{y} + g \left(\frac{\rho_s - \rho}{\rho_s} \right) \quad \text{--- (4) No } \dot{x}$$

$$\begin{aligned} K &= 12 & V &= \frac{\pi}{6} d^3 & u &= \sqrt{\dot{x}^2 + \dot{y}^2} \\ m &= \rho_s V & A &= \frac{\pi}{4} d^2 \end{aligned}$$

* Spherical particle :-

$$\ddot{x} = \frac{\frac{\pi}{4} d^2 \cdot 12 \mu}{\frac{\pi}{6} d^3 \rho_s d} \dot{x} = -18 \frac{\mu}{d^2 \rho_s} \dot{x} = \textcircled{-a \dot{x}}$$

$$\ddot{y} = \frac{\frac{\pi}{4} d^2 \cdot 12 \mu}{\frac{\pi}{6} d^3 \rho_s d} \dot{y} + \left(1 - \frac{\rho}{\rho_s} \right) g = \textcircled{\frac{-18 \mu}{d^2 \rho_s} \dot{y}} + \left(1 - \frac{\rho}{\rho_s} \right) g$$

$$= -a \dot{y} + b$$

* Constants [imp.]

$$\frac{b}{a} = u_0 = \frac{d^2 g}{18 \mu} \left(\rho_s - \rho \right) \quad \text{settling velocity}$$

y-direction

$$\ddot{y} = -ay + b$$

$$\dot{y} = -ay + bt + \text{constant}$$

$$y = \frac{b}{a}t + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a}\right)e^{-at} \quad \text{--- (6)}$$

where v = initial component of the velocity of the particle in the y-direction

$$\ddot{x} = -ax$$

$$\dot{x} = -ax + \text{constant}$$

$$x = \frac{w}{a} \left(1 - e^{-at}\right), \quad w: \text{component of the velocity of the particle in the x-direction at } t=0$$

x-direction

$$e^{-at} = 1 - \frac{ax}{w} \Rightarrow t = -\frac{1}{a} \ln \left(1 - \frac{ax}{w}\right) \rightarrow \text{into (6)}$$

$$y = \frac{b}{a} \left(-\frac{1}{a} \ln \left(1 - \frac{ax}{w}\right)\right) + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a}\right) \left(1 - \frac{ax}{w}\right)$$

$y = f(x)$ $\rightarrow$ used in design of settling tank.

* No force drag $\rightarrow$ Region a [low Re]



II - assumption.

* Absence of gravity

$$m\dot{x} = \frac{-R'}{\rho u^2} \rho A' \dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}, \quad \dot{y} = 0$$

$$m\ddot{x} = \frac{-R'}{\rho u^2} \rho A' \dot{x}^2, \quad A = \frac{1}{4}\pi d^2$$

$$m = \rho \frac{\pi}{6} d^3, \quad u = \sqrt{\dot{x}^2 + \dot{y}^2}$$

$$\Rightarrow \ddot{x} = -\frac{R'}{\rho u^2} \frac{1.5}{d} \dot{x}^2 \quad \rightarrow \text{for regions A, B \& C}$$

In Region a $10^{-4} < Re < 0.2$

$$\frac{R'}{\rho u^2} = 12 Re^{-1}, \quad \ddot{x} = \frac{-18 \mu}{d^2 \rho} \dot{x}$$

$$x = \frac{w}{a} (1 - e^{-at})$$

In Region C $500-100 < Re < 10^4$

$$\frac{R'}{\rho u^2} = 0.22 \quad \rightarrow \quad \ddot{x} = -\frac{0.33}{d} \frac{\rho}{\rho_s} \dot{x}^2$$

$$\rightarrow \text{New constant } c = \frac{0.33}{d} \frac{\rho}{\rho_s}$$

$$x = \frac{1}{c} \ln(wct + 1)$$

Region b $\rightarrow$ graphical solution



III- Assumption

under the action of gravity $\dot{x}=0$

$$m\ddot{y} = -\frac{R'}{\mu u^2} \cdot A' \dot{y} \sqrt{\dot{x}^2 + \dot{y}^2} + mg\left(1 - \frac{\rho}{\rho_s}\right)$$

$$m\ddot{y} = -\frac{R'}{\mu u^2} \cdot A' \dot{y}^2 + mg\left(1 - \frac{\rho}{\rho_s}\right)$$

$$\ddot{y} = -\frac{R'}{\mu u^2} \cdot \frac{1.5}{d} \cdot \frac{\rho}{\rho_s} \dot{y}^2 + g\left(1 - \frac{\rho}{\rho_s}\right)$$

* In region a

$$\frac{R'}{\mu u^2} = 12 \text{ Re}^{-1} \Rightarrow \ddot{y} = -\frac{18}{d^2 \rho_s} \mu \dot{y} + g\left(1 - \frac{\rho}{\rho_s}\right)$$

$$\Rightarrow y = \frac{b}{a} t + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a}\right) e^{-at}$$

* In region c

$$\frac{R'}{\mu u^2} = 0.22 \Rightarrow \ddot{y} = -c \dot{y}^2 + b$$

* Region b $\Rightarrow$ graphical solution

تذكر

$$K = \frac{\text{Volume}}{d^3}$$



Ex. Distance of a spherical particle of head?
 Dia = 0.1 mm, $\rho = 11400 \text{ kg/m}^3$ settling in water before it reaches 99% of its u_0
 water $\rightarrow \rho = 1000 \text{ kg/m}^3$, $\mu = 10 \text{ mNs/m}^2$
 • Assume Stokes region (region a)

$$u_0 = \frac{g d^2}{18 \mu} (\rho_s - \rho)$$

$$= \frac{d^2 \rho_s}{18 \mu} g \left(1 - \frac{\rho}{\rho_s}\right)$$

$\left(\frac{1}{a}\right) \swarrow$ $\swarrow (b)$

$$b = 9.18 \left(1 - \frac{1000}{11400}\right) = 8.9 \text{ m/s}^2$$

$$a = 18 \times 10 \times 10^{-3} / (0.1 \times 10^{-3})^2 \times 11400 = 1579 \text{ s}^{-1}$$

$$\rightarrow u_0 = \frac{b}{a}$$

$$\rightarrow y = \frac{b}{a} t + \frac{v}{a} - \frac{b}{a^2} + \left(\frac{b}{a^2} - \frac{v}{a}\right) e^{-at}$$

$$\rightarrow y = \frac{b}{a} (1 - e^{-at})$$

$$5.61 \times 10^{-3} = 5.7 \times 10^{-3} (1 - e^{-1574t}) \rightarrow t = 0.003 \text{ (s)}$$

substitute into the
y-equation

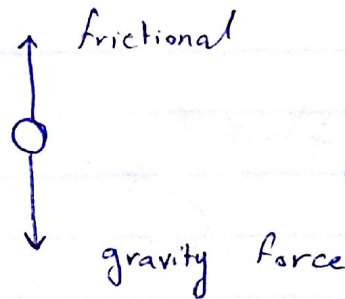
$$\rightarrow y = 1.3 \times 10^{-5} \text{ m} = 0.013 \text{ mm}$$



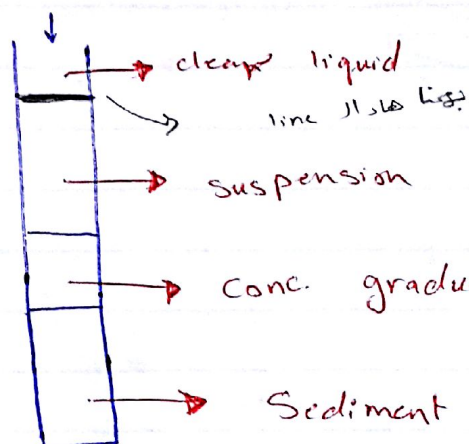
ch. (5)

* Applications :

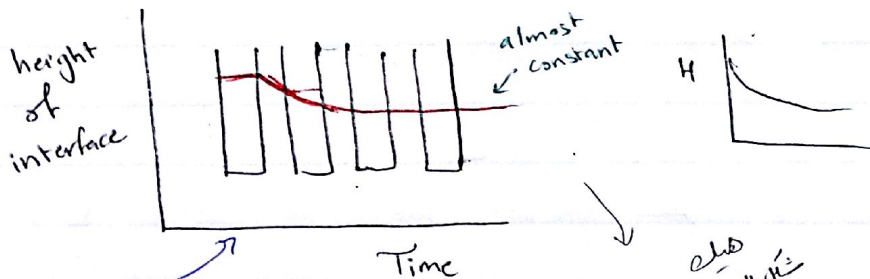
Sedimentation :



Slurry $\Rightarrow$ hindered settling

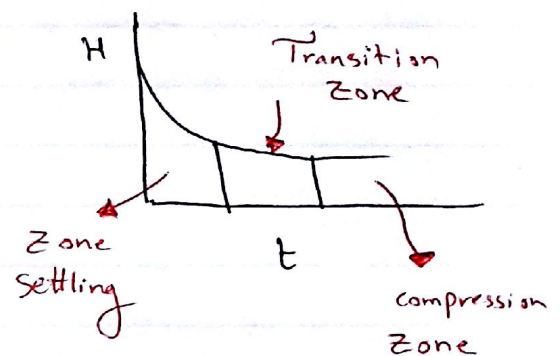


graduated cylinder



The basis of design

منطقة الترسب



[sediment zone]

* Robinson's Approach

$$U_o = \frac{d^2 g (\rho_s - \rho)}{18 \mu} \Rightarrow U_c = \frac{K'' d^2 (\rho_s - \rho_c) g}{\mu_c}$$

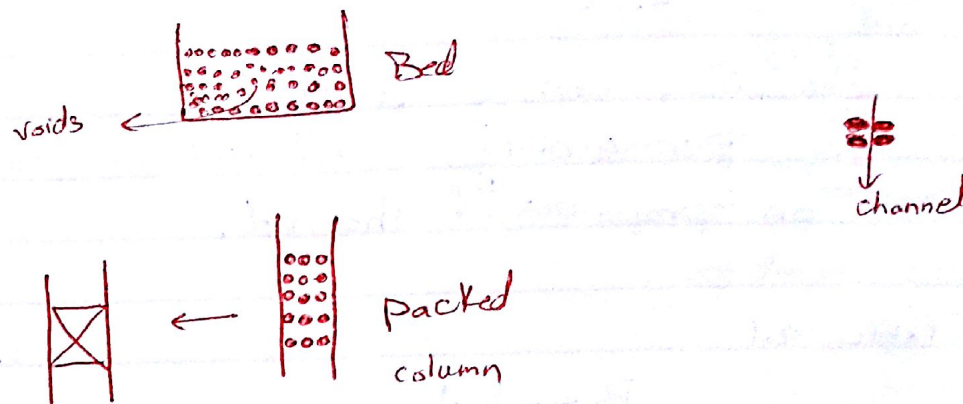
$$K'' = \frac{1}{18} \Rightarrow \rho_s - \rho_c = \rho_s - \left[\rho_s (1-e) + e \rho \right] = e(\rho_s - \rho)$$

for suspension

* ch.4

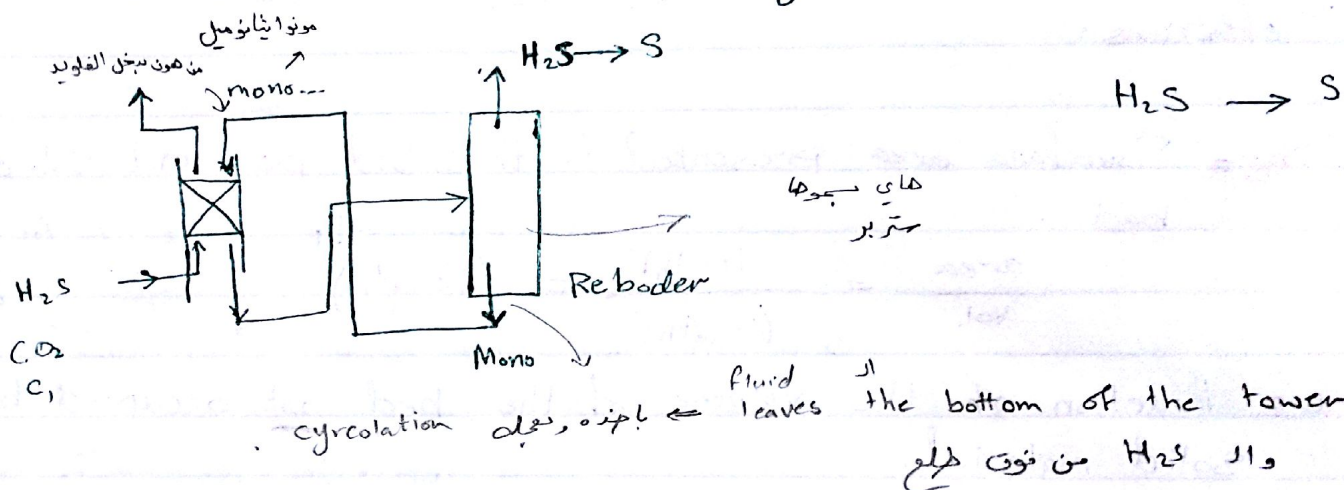
* Packed Bed:-

flow of fluids through Granular Beds and Packed Columns.



منه يخرج الغازات
التي لا تفاعل فيها

Gas Cleaning Plant



* flow of fluid through granular bed.

• Darcy's Law

$$\frac{1}{A} \frac{dV}{dt} = u = K \frac{(-\Delta P)}{l} \quad \text{--- (1)}$$

$-\Delta P$ = Pressure drop across the bed.

u = Avg. velocity of flow of fluid $\left(\frac{1}{A} \frac{dV}{dt} \right)$

l = Thickness of the bed (height of the bed)

A = Cross Sectional area of bed

V = Vol. flow (flowing in time t)

K = Const. depends on physical properties of the bed and fluid

$$\Rightarrow \frac{\pi}{D^2}$$

ask & receive

$$u = \frac{K (-\Delta P)}{\mu \cdot L} \quad [2]$$

$$\text{viscosity} \leftarrow \mu = \frac{B (-\Delta P)}{\mu \cdot L} \quad [3]$$

μ = it is viscosity of fluid.
 B = Permeability coefficient for the bed depends only on properties of the bed.

Table 4.1

$B \Rightarrow$ high

$\Rightarrow$ ease of passing

كيف لا تكون voids عالية
 الفلويده بمرور غير آيسه اعلاه او اسفله

Definitions:

S_B = Surface area presented to the fluid per unit vol. of bed.

$$\frac{\text{area}}{\text{Vol.}} = \frac{(\text{length})^2}{(\text{length})^3} = (\text{length})^{-1} \rightarrow 1/m \quad \text{for sphere } \frac{6}{d}$$

e = Fraction of the volume of the bed not occupied by solid material.

$\rightarrow$ Fractional voidage.

$\rightarrow$ Voidage

$\rightarrow$ Porosity

$\rightarrow$ dimensionless

شوائب نسيجه

فجوات فراغات

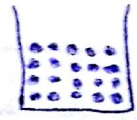
$1 - e$ = Fractional vol. of the bed occupied by solid material
 $\leftarrow$ هاء الجسيمات



S = specific surface of the particles.

$$= \frac{\text{surface area of particle}}{\text{vol. of particles}}$$

$$\frac{(\text{length})^2}{(\text{length})^3} = (\text{length})^{-1}$$



wall effect

اذا كان diameter صغير
في تأثير لا wall
لو كبير لا تأثير

for asphere :-

$$S = \frac{\pi d^2}{\frac{\pi}{6} d^3} = \frac{6}{d} \rightarrow \text{diameter}$$

$$S_B \neq S$$

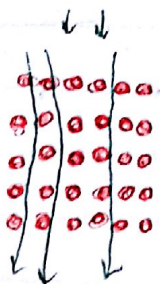
$$S_B = (1-e)S$$

Table 4.1 : Shows values for B, S, e

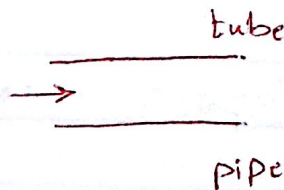
* Carman - Kozeny Equ :-

⇒ Stream line flow (development of equation)

$\Delta P, u, e, S_B, S$



Channels



نقطة الـ pass الى الجوفية للغول

- Flow through tube:

$$u_t = \frac{d_t^2 (-\Delta P)}{32 \mu l_t} \quad (4)$$

u_t = velocity of fluid

d_t = diameter of the tube

l_t = length of the tube

سرعت حرکت
ال توبه
مشی

- Free space in bed consists of a series of channels.

$$u_i = \frac{d_m^2}{K' \mu} \cdot \frac{-\Delta P}{l'} \quad (5)$$

d_m = equivalent dia of the pore channel.

K' = dimensionless, depends on the structure of the bed.

l' = length of channel

u_i = avg. velocity through pore channel.

$$l \propto l'$$

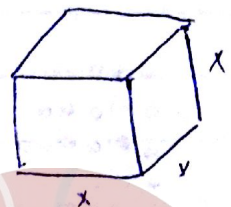
u (eq. 1 & 2) & u_i (eq. 5)

Dupuit approach

In a cube of side x

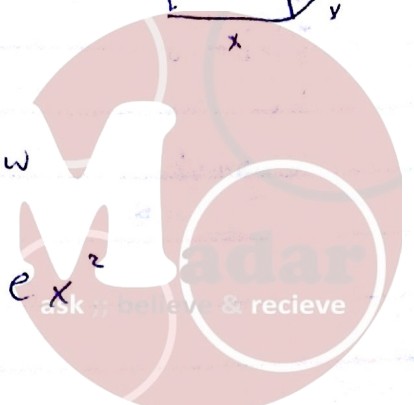
$$\text{Vol. of cube} = x^3$$

$$\text{Vol. of free space} = ex^3$$



Mean x-sectional area for flow

$$= \frac{\text{free vol.}}{\text{height}} = \frac{ex^3}{x} = ex^2$$



Vol. flow rate through the cube = $u x^2 \left(\frac{m}{s} \cdot m^2 \right)$

$\therefore$ linear velocity through pores

$$u_i = \frac{u x^2}{e x^2} = \frac{u}{e} \quad \text{----- (6)}$$

* Kozeny approach:-

$$d_m' = \frac{e}{S_B} = \frac{e}{S(1-e)}$$

In summary

$$u_i = \frac{u}{e}$$

$$l' \propto l$$

$$d_m' = \frac{e}{S(1-e)}$$

Eq. (5) becomes

$$u_i = \frac{d_m'^2}{K' \mu} \cdot \frac{(-\Delta P)}{l'}$$

$$u = \frac{1}{K''} \cdot \frac{e^3}{S_B^2} \cdot \frac{1}{\mu} \cdot \frac{-\Delta P}{l} \quad \text{--- [7]}$$

$$u = \frac{1}{K''} \cdot \frac{e^3}{S^2(1-e)^2} \cdot \frac{1}{\mu} \left[\frac{-\Delta P}{l} \right] \quad \text{--- [8]}$$

K'' = Kozeny's Const. = 5
= dependent on porosity, particles shape

Equ (8)

compare with eq. (2)

eq. (2) لا ارشح

eq. (8) كذا الجزئية لا بد من

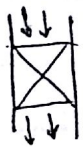
permeability coefficient

B

$$B = \frac{1}{K''} \cdot \frac{e^3}{s^2 (1-e)^2} \quad \text{--- [9]}$$

* Kozeny's Applications:-

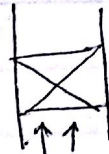
Wed. 18/11/2015



packed bed
Eq. 8



slurry
Filtration
Eq. 5



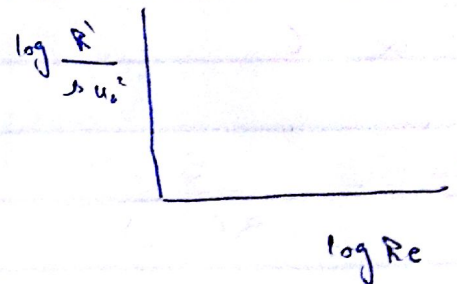
Eq. (8)
Fluidization

* Streamline & Turbulent Flow:-

$$u_1 = \frac{u}{e}$$

$$d_n' = \frac{e}{s_B} = \frac{e}{s(1-e)}$$

$$Re_1 = \frac{u_1 \cdot d_n}{\mu}$$



Substitute

$$Re_1 = \frac{u}{e} \cdot \frac{e}{s(1-e)} \cdot \frac{1}{\mu}$$

$$Re_1 = \frac{u \cdot 1}{s(1-e) \mu} \quad \text{--- (10)}$$

Re is Backed Bed

Reynold for packed bed

~~consider~~ the



sequently high volumetric rates of flow of liquid can be achieved without producing a high linear velocity at the overflow. Its action will be seen to be similar to that of a thickener which is effecting incomplete clarification.

The Hydraulic Jig

The hydraulic jig operates by allowing material to settle for brief periods so that the particles do not attain their terminal falling velocities, and is therefore suitable for separating materials of wide size range into their constituents. The material to be separated is fed dry, or more usually in suspension, over a screen and is subjected to a pulsating action by liquid which is set in oscillation by means of a reciprocating plunger. The particles on the screen constitute a suspension of high concentration and therefore the advantages of hindered settling are obtained. The jig usually consists of a rectangular-section tank with a tapered bottom, divided into two portions by a vertical baffle. In one section, the plunger operates in a vertical direction; the other incorporates the screen over which the separation is carried out. In addition, a stream of liquid is fed to the jig during the upward stroke.

The particles on the screen are brought into suspension during the downward stroke of the plunger (Fig. 17.8a) and are then allowed to settle during the upward stroke when the input of water is adjusted so that there is virtually no flow through the bed (Fig. 17.8b). The period of the plunger is small so

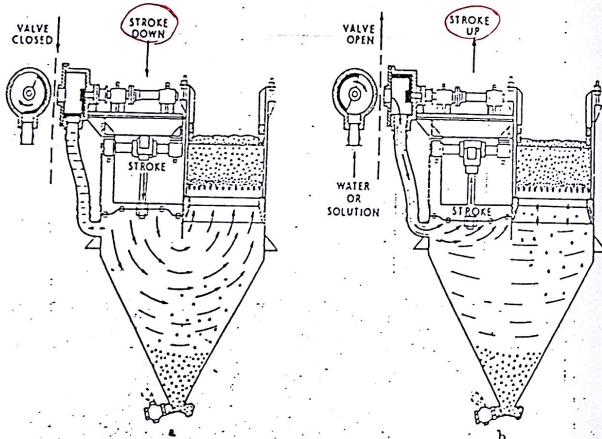


FIG. 17.8. Hydraulic jig: (a) Downward stroke (b) Upward stroke

that the denser material tends to collect near the screen and the lighter material above it. After a short time the material becomes divided into three strata, the bottom layer consisting of the large particles of the heavy material, the next of large particles of the lighter material together with small particles of the heavy material, and the top stratum of small particles of the

CLASSIFICATION OF SOLID PARTICLES

light material. Large particles wedge at an earlier stage than small ones and therefore the small particles of the denser material are able to fall through the spaces between the larger particles of the light material. Many of these small particles then fall through the supporting gauze.

Four separate fractions are obtained from the jig and the successful operation of the plant depends on their rapid removal. The small particles of the heavy material which have fallen through the gauze are taken off at the bottom of the tank. The larger particles of each of the materials are retained on the gauze in two layers; the denser material at the bottom and the less dense material on top. These two fractions are removed through gates at the side of the jig. The remaining material, consisting of small particles of the light material, is carried away in the liquid overflow.

Rifled Tables

The rifled table, of which the Wilfley table (Fig. 17.9) is a typical example, consists of a flat table which is inclined at an angle of about 3° to the horizontal. Running approximately parallel to the top edge is a series of slats, or riffles as they are termed, about $\frac{1}{4}$ in. in height. The material to be

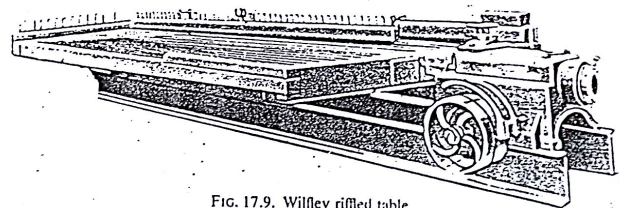


FIG. 17.9. Wilfley rifled table

separated is fed on to one of the top corners and a reciprocating motion, consisting of a slow movement in the forward direction and a very rapid return stroke causes it to move across the table. The particles also tend to move downwards under the combined action of gravity and of a stream of water which is introduced along the top edge, but are opposed by the riffles behind which the smaller particles or the denser material tend to be held. Thus, the large particles and the less dense material are carried downwards, and the remainder is carried parallel to the riffles. In many cases, each riffle is tapered with the result that a number of fractions can be collected. Rifled tables can be used for separating materials down to about 300-mesh in size, provided that the difference in the densities is large.

Centrifugal Separators

The use of cyclone separators for the removal of suspended dust particles from gases has already been referred to in Chapter 8, and a method has been given for calculating the size of the smallest particle which will be retained in the separator. By suitable choice of operating conditions, it is possible to



* Consider the forces acting on the bed fluid in a bed of unit x-sectional area and thickness l

$$\text{specific surface} = S = \frac{\text{surface area}}{\text{volume}}$$

Vol. at particles in the bed = $l(1-e)$ total?
 specific surface at particle = $S l(1-e)$.

thus the resistance force = $R_1 S l(1-e)$.

$$(-\Delta P) \cdot e = R_1 \cdot S \cdot l(1-e)$$

$$R_1 = \frac{e}{S(1-e)} \cdot \frac{(-\Delta P)}{l} \quad \text{--- (11) divide } (\rho u^2)$$

$$u_1 = \frac{u}{e}$$

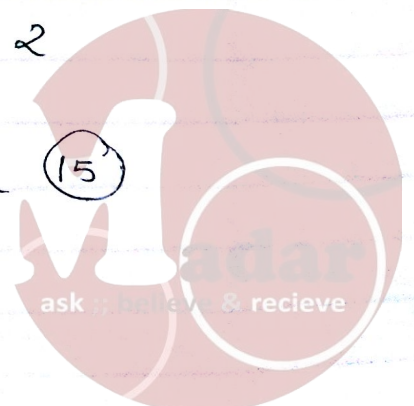
$$\frac{R_1}{\rho u_1^2} = \frac{e^3}{S(1-e)} \cdot \frac{(-\Delta P)}{l} \cdot \frac{1}{\rho u^2} \quad \text{--- (12)}$$

(*) for flow through packed beds of solid particles.

$$\frac{R_1}{\rho u_1^2} = 5 Re_1^{-1} + 0.4 Re_1^{-0.1} \quad \text{--- (13)}$$

if $Re_1 < \text{about } 2$

$$\frac{R_1}{\rho u_1^2} = 5 Re_1^{-1} \quad \text{--- (15)}$$



* For flow of fluids through beds at hollow packing

$$\frac{R_1}{\mu u_1} = 5 Re_1^{-1} + Re_1^{-0.1} \quad \text{--- (16)}$$

* For flow through Ring Packings "Ergun Equation"

$$\frac{-\Delta P}{L} = \frac{150 (1-e)^2}{e^3} \frac{\mu u}{d^2} + 1.75 \frac{(1-e)}{e^3} \frac{\rho u^2}{d} \quad \text{--- (17)}$$

$$S = 6/d \Rightarrow d = 6/S$$

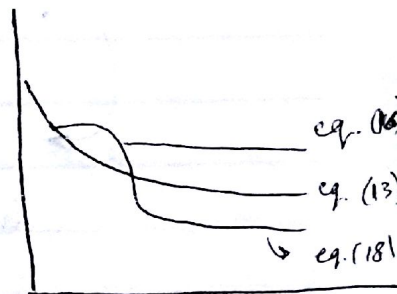
$$\left[\frac{\Delta P}{L \rho u^2} \cdot \frac{e^3}{(1-e)} \right] = 4.17 \left[\frac{\mu S (1-e)}{\rho u} \right]^{Re_1^{-1}} + 0.29$$

↪

eq. (12)

$$\frac{R_1}{\rho u^2} = 4.17 Re_1^{-1} + 0.29 \quad \text{--- (18)}$$

$$\frac{R_1}{\rho u^2} = \frac{\Delta P \cdot e^3}{S (\rho u^3) \cdot (1-e)}$$



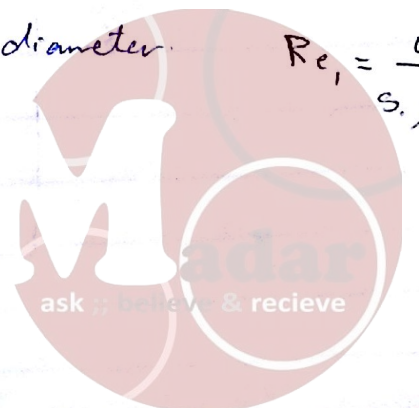
[Small diameter container → high wall effect ~~the~~ the other way for larger diameter.

K''

• Carman

$$K'' = \left(\frac{L'}{L} \right) \cdot K \quad \text{--- (19)}$$

$$Re_1 = \frac{u \cdot \rho}{S \cdot \mu \cdot (1-e)}$$



$$\left(\frac{\ell'}{\ell} \right)$$

$$\frac{\ell'}{\ell} = \text{tortuosity} \quad \text{منقول}$$

→ measure at the fluid path length through the bed compared with the actual depth at the bed.

K_0 = Factor depends on the shape at the x-sectional area at a channel

* Circular pipe $K = 2$

* Rectangular $K = 2.65$

* Wall Effect.

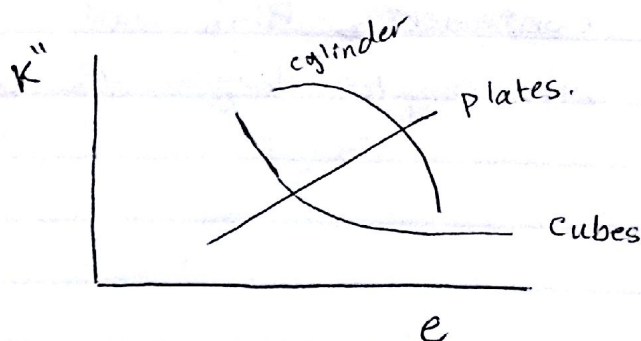
→ correction factor

$$f_w = \left(1 + \frac{1}{2} \frac{S_c}{S} \right)^2$$

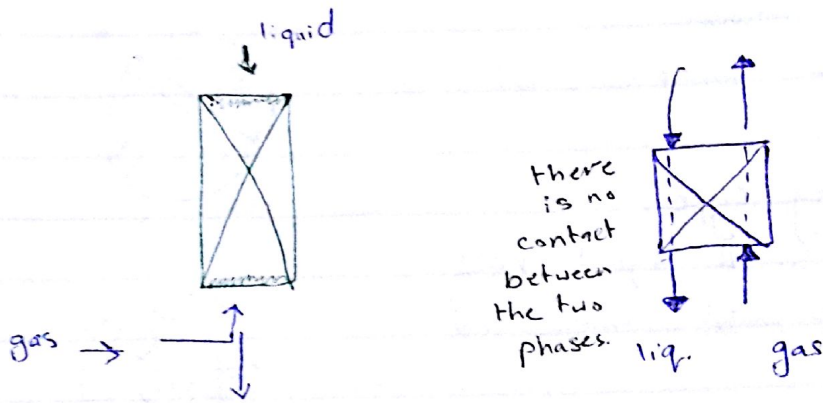
S_c : surface at container per unit volume at bed
Eq:- (8) becomes.

$$u = \frac{1}{K''} \cdot \frac{e^3}{S^2 (1-e)^2} \cdot \frac{1}{\mu} \cdot \frac{-(\Delta P)}{\ell} f_w \quad (21)$$

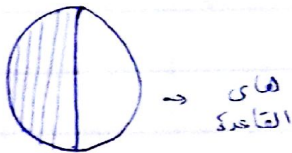
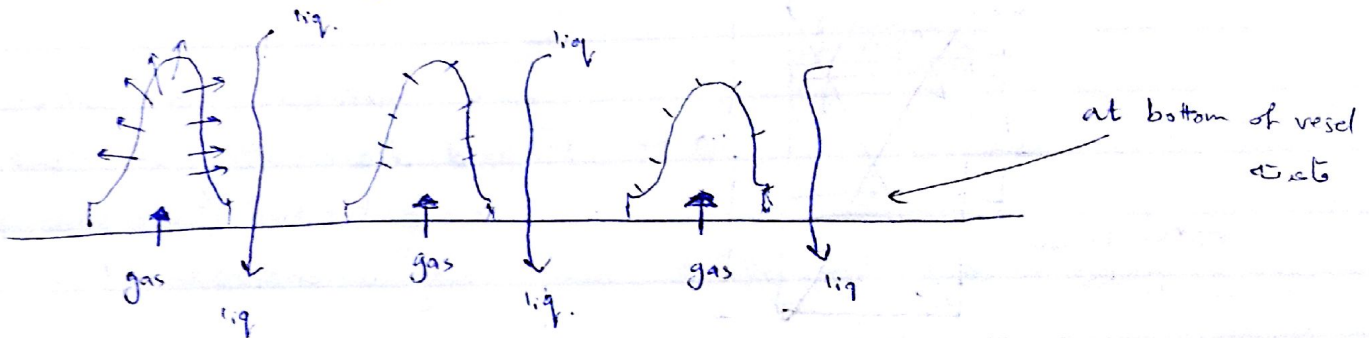
→ Always don't use correction unless is asked from you.



* Application (absorption)



* Vessel design : bottom



* Vessel design : top

* Types of fluid distribution :-

- I) Simple orifice Type
 - Fine distribution
 - Risk of plugging



II) Notched chimney Type

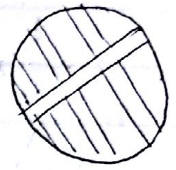
- No Plugging
- Use for medium & upper flowrate



ask & recieve

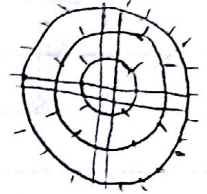
III) Notched Trough Distributor

- Large size of tower
- Higher gas rates

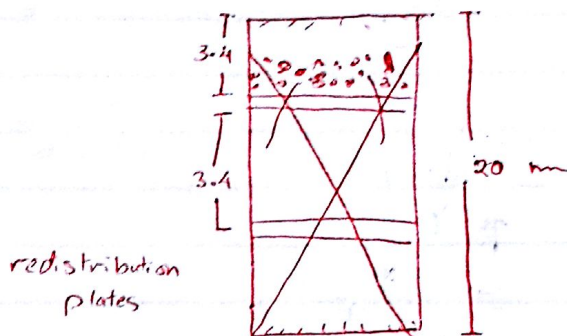


IV) Perforated Ring type

- High gas rates & small liquid rate
- Suitable where P must be minimized.



Redistribution Plate



* To make sure there will be a good distribution at liquid leaving the bed (not passing only in one channel)

* Packings:-

- 1- Broken Solids
- 2- Shaped Packings
 - a- Should be uniform size
 - b- Uniform characteristics of bed.
- 3- Desired voidage
- 4- No channelings
- 5- Resistance to flow $\Rightarrow$ less
- 6- More effective surface/unit vol.

* Rasching rings.

F.g 4.13, 4.14, 4.15

* Intalox

* Saddle

Table 4.3

wires



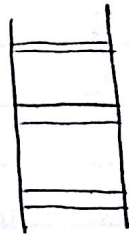
• Size of packings :-

• Influences :-

- 1) H & D of the column.
- 2) ΔP
- 3) ~~const.~~ cost

⇒ **Grids** :- → عازلة في توزيع السائل في برج التبريد
→ cooling tower distribution

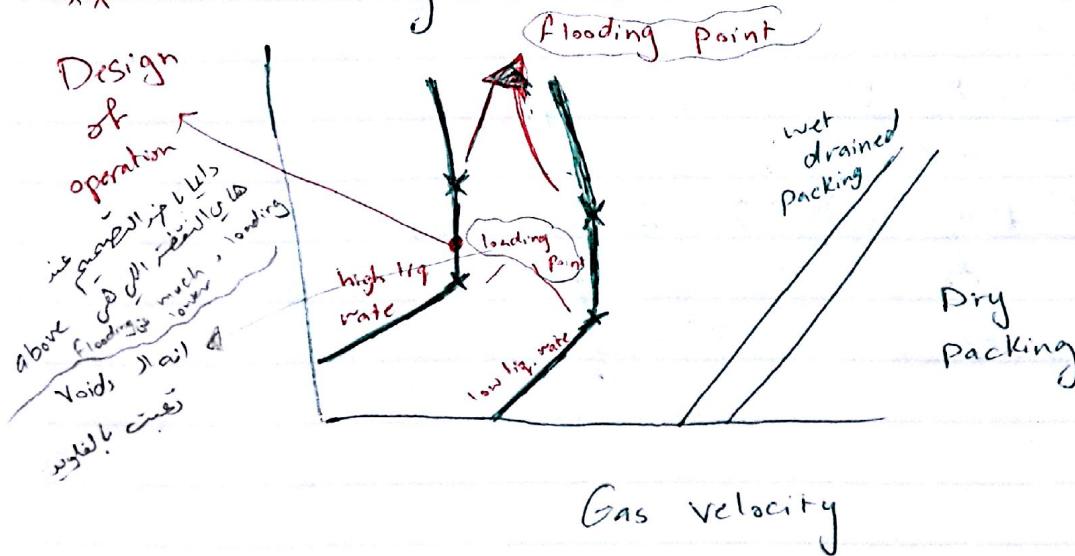
- 1) Large Space between individual grids.



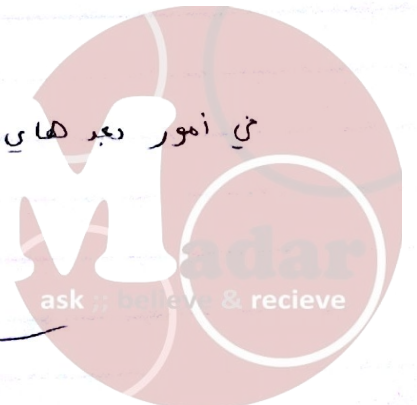
- 2) Give low ΔP .

- 3) Accept fluids with suspended particles.

**** Gas Velocity vs. ΔP :-**



في أمور بعد هاي بالكتاب (ما عندنا) ندرجها بانتقال المارة "Mass"

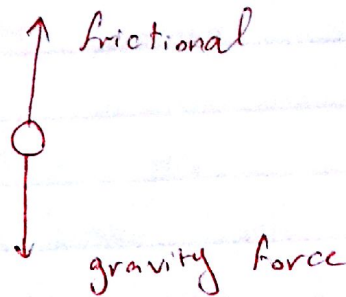


* (ch. 5)

عليك الترتيب

* Sedimentation

هي عملية settling كذا



انظري ص 4 بالقرن نفط بالزيت

* Robinson's

* For low concentrated suspension

$$\mu_c = \mu (1 + K'' C)$$

$$K'' = 2.5$$

$$C \approx 0.02 \quad (\text{Vol. conc. of particles})$$

* For high concentration suspension

$$\mu_c = \mu_0^{K''} (1 - a' C)$$

$$a' = 0.609 \quad (\text{for spheres})$$

$$u_0 = \frac{d^2 g (\rho_s - \rho_c)}{18 \mu}$$

$$u_c = \frac{K'' d^2 (\rho_s - \rho_c) g}{\mu_c} \quad \text{for suspension}$$

$$K'' = \frac{1}{18}$$



* Flocculation (Agglomeration)

Flocculation
Agglomeration

↓ Prevention

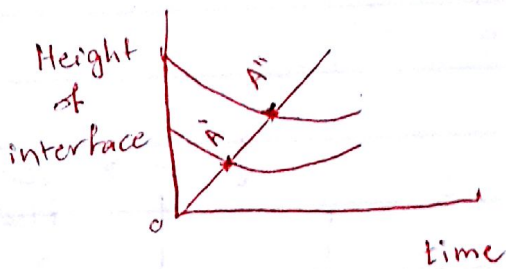
① Agitation

② Chemicals

③

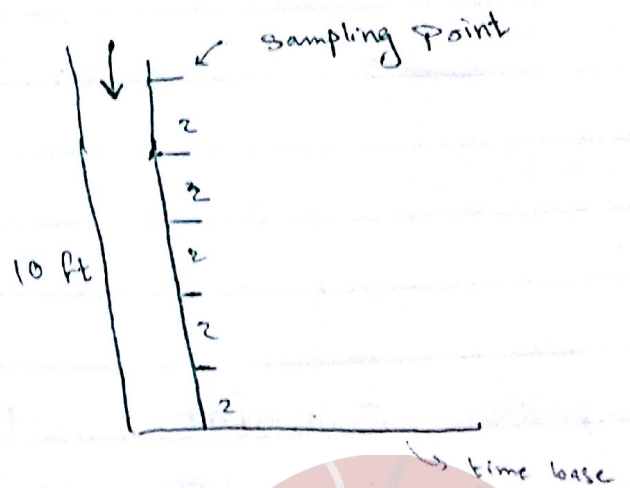
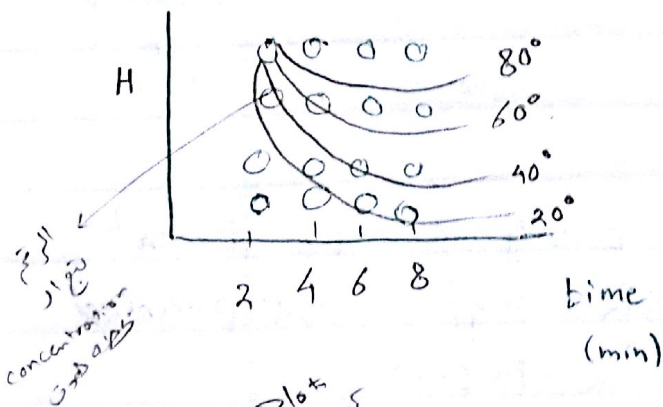


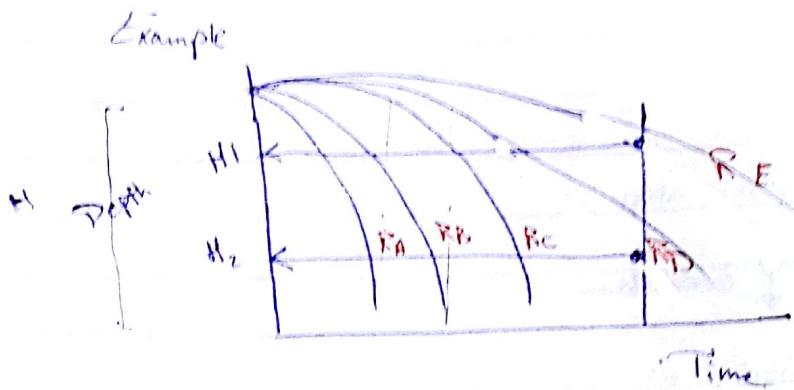
$$\frac{D_{vessel}}{D_{particle}} > 100$$



$$\frac{dA'}{dA''} = \text{const.}$$

* Sedimentation





Conversion of solids
half of the point

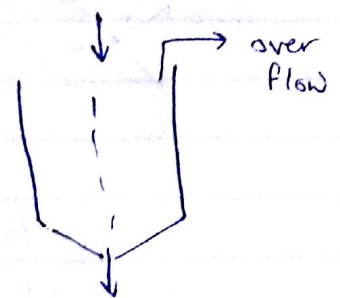
* Fraction Removed is

$$R_T = R_C + \frac{H_2}{H} (R_D - R_C) + \frac{H_1}{H} (R_E - R_D)$$

Over flow rate

$$V_o = \frac{H}{t} \times \text{conversion factor}$$

$$V_o = \frac{10 \text{ ft}}{18 \text{ min}} \times \frac{1440 \text{ min}}{\text{day}} \times \frac{7.48 \text{ gal}}{\text{ft}^3} \approx 6730 \text{ gal/day.ft}^2$$



Clarifier
Thickener

* Example: Clarifier is to be designed to treat waste water having 320 mg/l suspended solids and a flow of 2 MGD

Batch → handout

→ 2 million gallon/Day

① Determine the design detention time & design over flowrate if 65% of solids are to be removed.

② Determine Dia. & Depth of vessel.

ask, learn & receive

	Mid Point
20-30%	6.7
30-40%	2.9
40-50%	2
50-60%	1.3
60-70%	0.8

H = 10

$$R_T = 20 + \frac{6.7}{10} (30 - 20) + \frac{2.9}{10} (40 - 30) + \frac{2}{10} (50 - 40) + \frac{1.3}{10} (60 - 50) + \frac{0.8}{10} (70 - 60)$$

$$R_T = 33.7\%$$

over flow rate

$$V_o = \frac{10 \text{ ft}}{16 \text{ min}} \times \frac{1440 \text{ min}}{\text{day}} \times 7.48 \frac{\text{gal}}{\text{ft}^3} \approx 6730 \frac{\text{gal}}{\text{day}}$$

Conversion 1.44
RT%
ظرف مایه
Flux برات
ft³

Example

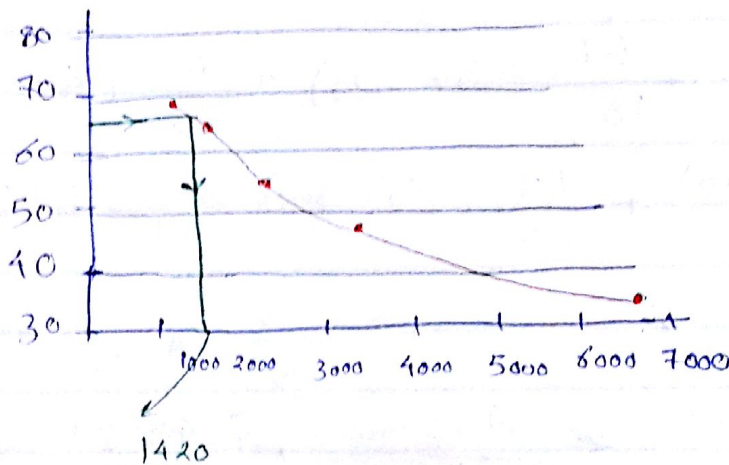
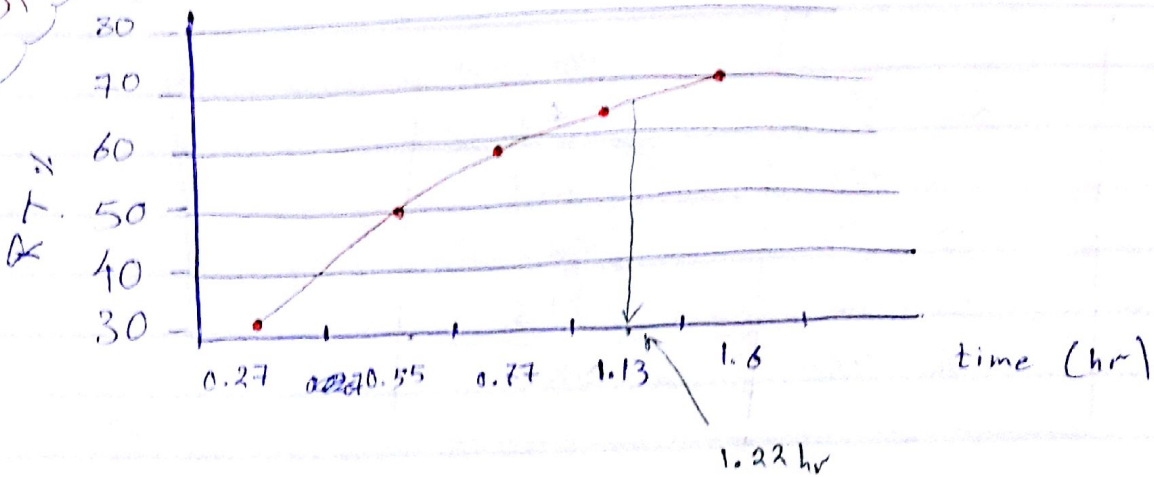
Time		V _o	RT%
min	hr		
16	0.27	6730	33.7
33	0.55	3260	48.7
46.2	0.77	2340	56.7
67.8	1.13	1590	63.8
96	1.6	1120	68.6

تابع المثال
لف

هنا الجدول
يوضح كل الحركه
التي نلاحظها
او graph

* كمره بايدي زمن غير و...
h و... RT كل زمن





* Scaling up & down :-

$$\text{Design Detention time} = (1.22) (1.75) = 2.14 \text{ hr}$$

$$\text{Design overflow rate} = (1420) (0.65) = 923 \text{ gal/day ft}^2$$

$$A = \frac{2 \times 10^6 \text{ gal}}{\text{day}} \times \frac{\text{day} \cdot \text{ft}^2}{923 \text{ gal}} = 2167 \text{ ft}^2$$

$$A = \frac{\pi}{4} D^2$$

$$D = 52.5 \text{ ft} = 55 \text{ ft}$$

$$D = \frac{V}{Q}, \quad V = \text{vol}, \quad Q = \text{flow rate}$$

$$= \frac{\frac{\pi}{4} D^2 H}{Q} \Rightarrow H = \frac{Q \times \text{time}}{\frac{\pi}{4} D^2} = 10 \text{ ft}, \quad 3 \text{ inch}$$

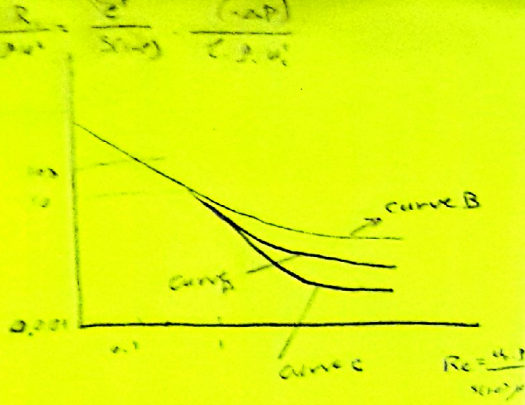
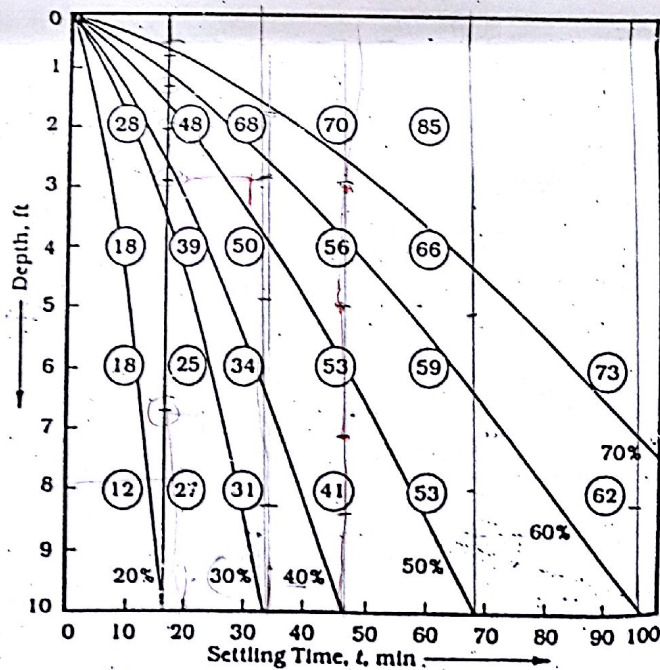


Table 3.1. Percent Suspended Solids Removal at Given Depths

Time (min)	2 ft	4 ft	6 ft	8 ft	10 ft
0	0	0	0	0	0
10	28	18	18	12	•
20	48	39	25	27	•
30	68	50	34	31	•
45	70	56	53	41	•
60	85	66	59	53	•
90	88	82	73	62	•

a. Data showed an increase in solids concentration

Figure 3.11. Graph Showing Suspended Solids Removal (as a percent) at Various Depths and Settling Times.

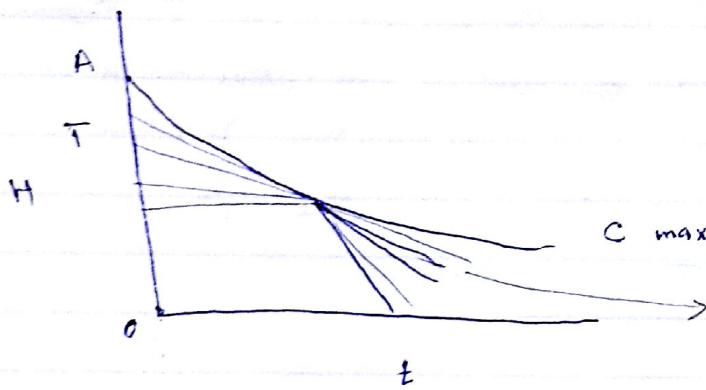
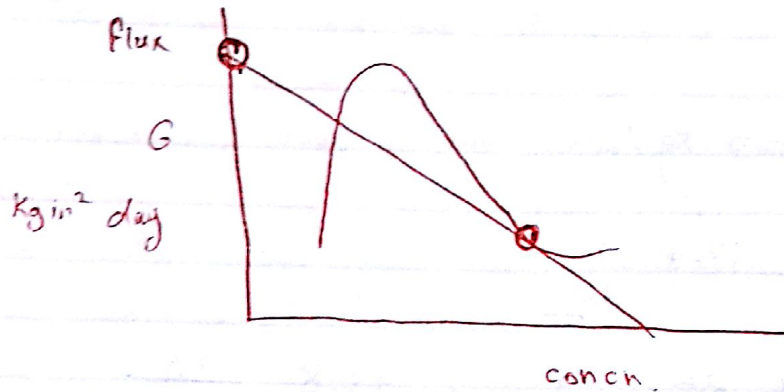


نیل graph بڑا آفتی
نیل table = عورع

بد الخط من ركبة المنحنى التي تارل

من كى اتين

mid ask & receive

* Kynch Theory

من النقطة نصل tangents

$$\text{concn. } C = C_0 \cdot \frac{OA}{OT}$$

$$\begin{aligned} \psi &= C \cdot u_c \\ &= C_0 \cdot \frac{OA}{OT} \cdot u_c \end{aligned}$$

* A thickener treats $0.044 \text{ m}^3/\text{s}$ (1MGD) of a suspension containing 2000 mg/l of solids. → million gallon per day

Solid concn.	Settling velocity
1000	2.74
1500	2.01
2000	1.37
2500	0.73 →
3000	0.42
4000	0.22
5000	0.13
6000	0.07



Clarifier $\Rightarrow$ clear liquid.

Solid concentration of 151

* Calculate the area of thickener required to give underflow concn. of 6000 mg/l $\rightarrow$ milligram/liter

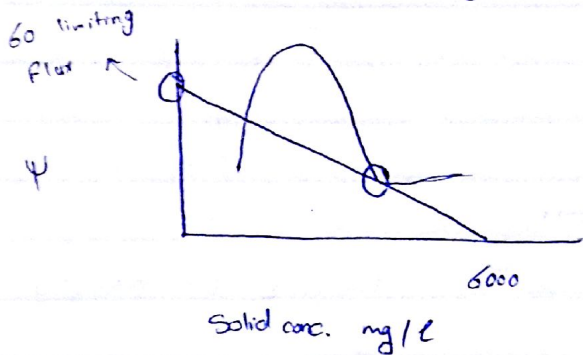
$$G = X_i \cdot V_i$$

$$2500 \frac{\text{mg}}{\text{l}} = 2.5 \frac{\text{kg}}{\text{m}^3}$$

1 m³ = 1000 L

$$V_i = 0.73 \frac{\text{m}}{\text{h}} = 17.4 \frac{\text{m}}{\text{day}}$$

$$G = 17.4 \frac{\text{m}}{\text{day}} \times 2.5 \frac{\text{kg}}{\text{m}^3} = 43.8 \frac{\text{kg}}{\text{m}^2 \cdot \text{day}}$$



Feed Solids

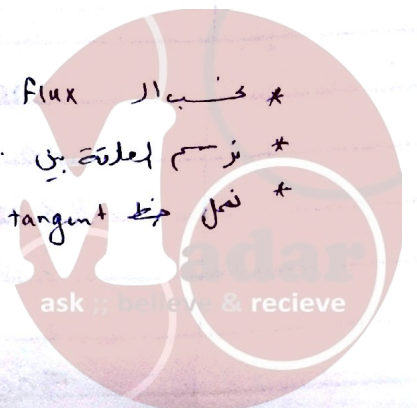
$$0.044 \frac{\text{m}^3}{\text{s}} \times \frac{2 \text{ kg}}{\text{m}^3} \times \frac{8.64 \times 10^4 \text{ s}}{\text{day}} = 7600 \frac{\text{kg}}{\text{day}}$$

$$\text{Area} = \frac{7600 \frac{\text{kg}}{\text{day}}}{60 \frac{\text{kg}}{\text{m}^2 \cdot \text{day}}} = 127 \text{ m}^2$$

لو اريد اخرج area
منه
الايضا باخرج ال area
الايضا



* حساب ال Flux
* من رسم العلاقة بين Flux & conc.
* نصل خط tangent من نقطة 6000 على المحور x مع النقطة 60



Ch. 6

**

Fluidization

$\Delta P \propto$ low rate of flow

Frictional drag on particle = Particle apparent wts

* The particles become rearranged $\Rightarrow$ offer less resistance to flow of fluid.

* Velocity of fluid is increased $\Rightarrow$ individual particles separate from one another $\Rightarrow$ freely supported by fluid $\Rightarrow$ fluidized bed.

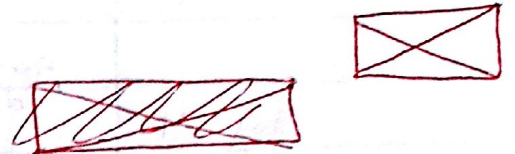
resistance to flow



• At higher velocities of flow $\Rightarrow$ Distinction between gas & liquid.

• With liquid:

Maintains uniform character
 $\rightarrow$ particulate fluidization.



• With gas:

$\rightarrow$ Aggregative (gas)



• Froude Group

$$= \frac{u_{mf}^2}{gD}$$

u_{mf} = min velocity of flow

D = Dia. of Particle.

* Froude value < unity

↳ Particulate (liq.)

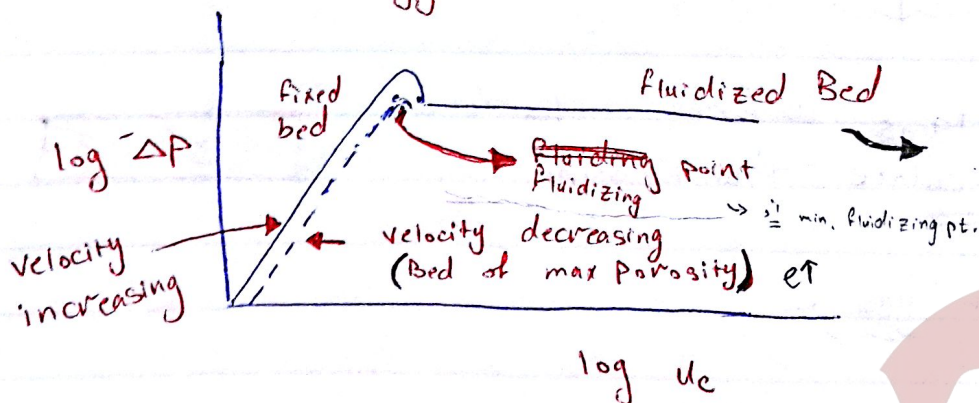
* ~~particulate~~ ^{Froude} value > unity.

↳ Aggregative (gas)

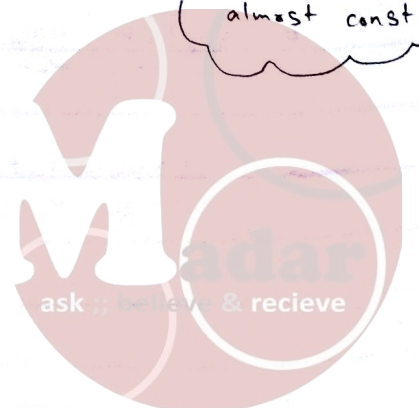


• Requirement :

- 1- Particles Shape
- 2- Free irregularity & channelling
- 3- Hard $\Rightarrow$ Agglomeration.



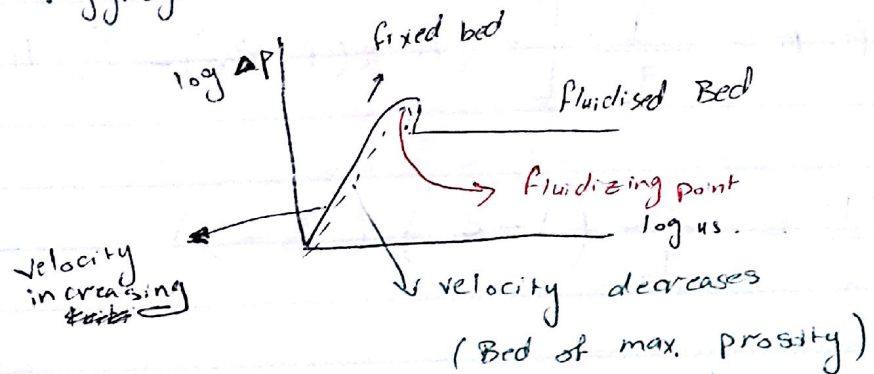
کُل با زدت
 ال Flow
 بصر ال ΔP
 almost const.



Bed

With gas :-

- ① At high velocities two phases formed continuous phase dense, emulsion phase (liquid)
 - ② Discontinuous phase lean, bubble phase (vapor)
- Boiling bed
→ Aggregative



* Bed height :-

let l_0 a height of bed where

$e = 0$ (single lump)

L = height of bed of fluidized

then
$$e = \frac{L - l_0}{L}$$

$$= 1 - \frac{l_0}{L} \quad \text{--- ①}$$

$$L_2 = L_1 \frac{1 - e_1}{1 - e_2} \quad \text{--- ②}$$

bed height for any new value

Known bed height at e_1

Known

calculate e_1 or any other value.



force ΔP it exists = force of gravity - buoyant force of displaced fluid
on this solids

let l_m = bed height at the start of fluidization
 A = cross sectional area
 e_m = min. porosity for fluidization

$$\Delta P \cdot A = \frac{g}{g_c} \left[l_m A \rho_s (1 - e_m) - l_m A \rho (1 - e_m) \right] \quad \text{--- (3)}$$

$$\frac{\Delta P}{l_m} = \frac{g}{g_c} (1 - e_m) (\rho_s - \rho) \quad \text{--- (4)}$$

Now If l = height of expanded bed.
 e = porosity of bed.

Combinations eq. (2) & (4) :-

$$\frac{-\Delta P}{l} = \frac{g}{g_c} (1 - e) (\rho_s - \rho) \quad \text{--- (5)}$$

$$\frac{-\Delta P}{l(1 - e)} = \frac{g}{g_c} (\rho_s - \rho)$$

$$= \text{const} \quad \text{--- (6)}$$

* Stream line conditions :-

Eq. (8)
 بتساير (4)

$$u = \frac{1}{K^2} * \frac{e^3}{s^2(1 - e)^2}$$

$$* \frac{1}{u} * \left(\frac{-\Delta P}{l} \right)$$

ask, believe & receive
 Eq. 5

Eq. (6) unit as above for spherical particles

$$s = \frac{6}{d}$$

$$(7) \quad U_c = 0.0055 \frac{e^3}{1-e} \cdot \frac{d^2 (\rho_s - \rho)}{\mu} \cdot g$$

* Min. Fluidizing velocity (u_{mf}) =

Eq. (7) become:-

$$U_{mf} = 0.0055 \frac{e_{mf}^3}{1-e_{mf}} \cdot \frac{d^2 (\rho_s - \rho)}{\mu} \cdot g$$

If $e_{mf} = 0.4$
into (8)

$$U_{mf} \text{ at } e_{mf} = 0.4 \\ = 0.0059 \frac{d^2 (\rho_s - \rho)}{\mu} \cdot g \quad \text{--- (9)}$$

equ (8) $\Delta u \rightarrow L$ لا
equ (9) $\Delta u \rightarrow L$ لا
 e_{mf} 0.4 (1.1) لا

No longer streamline
for larger particles.

* Eign Eq.

(equ. (17) Notes) $\Delta u \rightarrow L$ (4)

$$-\frac{\Delta P}{l} = 150 \frac{(1-e)^2}{e^3} \cdot \frac{\mu u}{d^2} + 1.75 \frac{1-e}{e^3} \cdot \frac{\rho u^2}{d}$$

ask, believe & receive

— $\Delta u \rightarrow L$ —→

• at fluidizing:

$$-\frac{\Delta P}{\tau} = 150 \frac{(1-e_{mf})^2}{e_{mf}^3} \frac{\mu \cdot u_{mf}}{d^2} + 1.75 \frac{(1-e_{mf})}{e_{mf}^3} \cdot \frac{\rho u_{mf}^2}{d}$$

--- equ (10)

$\frac{\Delta P}{\tau}$ from equ (5)

multiply both sides by

$$\frac{\rho d^3}{\mu^2} (1-e_{mf})$$

$$\frac{\rho (\rho_s - \rho) g d^3}{\mu^2} = 150 \frac{1-e_{mf}}{e_{mf}^3} \left(\frac{u_{mf} \cdot d \cdot \rho}{\mu} \right) + \frac{1.75}{e_{mf}^3} \left(\frac{u_{mf} \cdot d \cdot \rho}{\mu} \right)^2$$

--- equ (11)

(Re)²

This equ. can be solved for u_{mf}

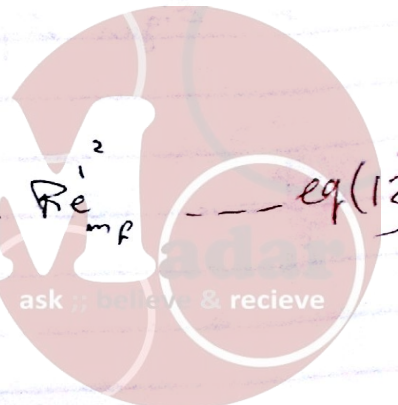
$$Ga = \frac{\rho (\rho_s - \rho) g d^3}{\mu^2}$$

$$\frac{u_{mf} \cdot d}{\mu} = Re_{mf}$$

Equ (11) becomes.

$$Ga = 150 \times \frac{1-e_{mf}}{e_{mf}^3} \times Re_{mf} + \frac{1.75}{e_{mf}^3} Re_{mf}^2$$

--- eq (12)



for $e_{mf} = 0.4$

$$Re_{mf}^2 + 51.4 Re_{mf} - 0.0366 Ga = 0$$

--- eq (13)

thus

$$(Re_{mf}') \text{ at } e_{mf} = 0.4 = 25.7 \left(\sqrt{1 + 5.53 \times 10^{-3} Ga} - 1 \right) \quad \text{eq (14)}$$

علاقة بين سرعة الجريان المتوسطة U_{mf} وعدد رينولدز Re_{mf}' (باعتبار كثر)

$$Re_{mf}' = \frac{U_{mf} \cdot d \cdot \rho}{\mu}$$

$$U_{mf} = \frac{\mu \cdot Re_{mf}'}{d \cdot \rho} \quad \text{--- eq. (15)}$$

عند $K'' = 5$ ، $K'' = 3.36$

في هذه الحالة

equ. (8) becomes :-

$$(U_{mf}) \text{ at } e_{mf} = 0.4 = \frac{0.0083 d^2 (1 - \phi) g}{\mu} \quad \text{--- Eq (16)}$$

لكن ما جدنا نتوصلنا ك بدنا ضلنا على $K'' = 5$ ما انتجنا الامتصاص



Wed. 23/12/2015

$$Re_o' = \frac{u_o d \rho}{\mu}$$



$$Ga = 1.8 Re_o'$$

$$Ga < 3.6$$

settling velocity < Fluid flow

Chap. 11

$$Ga = 1.8 Re_o' + 2.7 Re_o'^{1.587} \quad 3.6 < Ga < 10^3$$

$$Ga = \frac{1}{3} Re_o'^{12}$$

$$Ga > 10^3$$

$$Re_{m.f} = \frac{u_{m.f} \cdot d \cdot \rho}{\mu}$$

Re_o' you know u_o

Ga Re Eq. 1, 2, 3

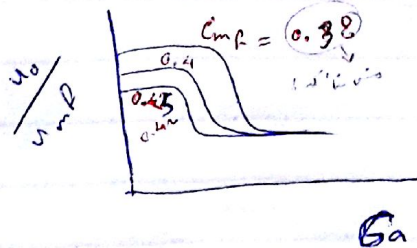
for any value of e_{mf}
Calculate Re_{mf}' from Eq. (12)

$$\frac{Re_o'}{Re_{mf}'} = \frac{u_o d \rho}{u_{mf} d \rho} = \frac{u_o}{u_{mf}}$$

$$\frac{Re_o'}{Re_{mf}'} = \frac{u_o}{u_{mf}}$$

or u_o settling

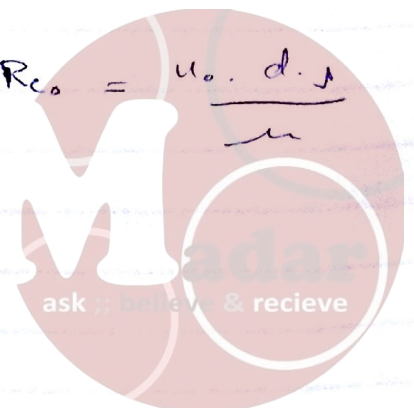
minimum fluid (fluidization)

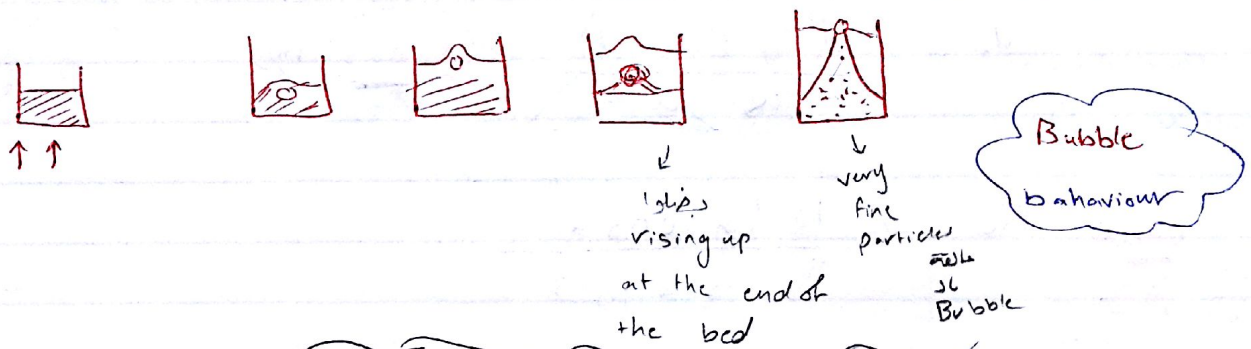
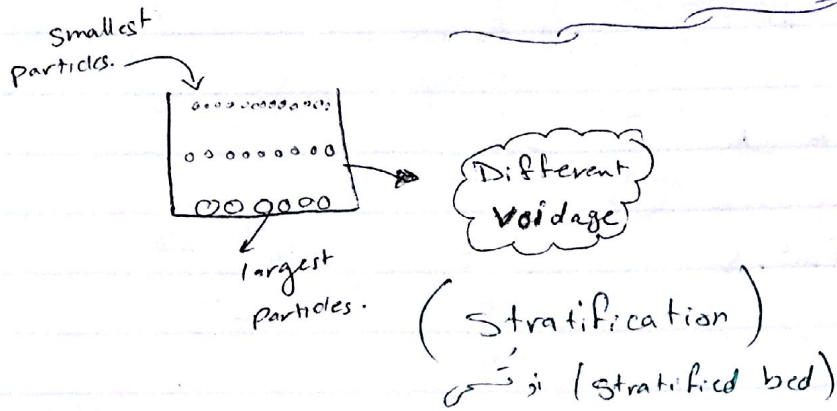
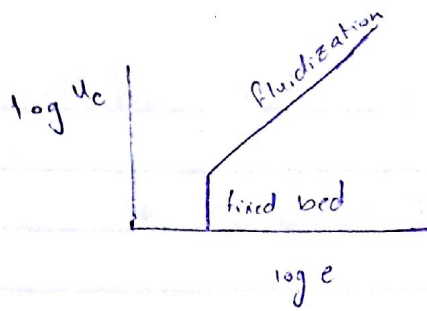


$$Re_o = \frac{u_o \cdot d \cdot \rho}{\mu}$$

or u_o
at higher value

or lower $-j$





* oil passes upward through a bed of particles.

$$D_{ia} = 10^{-4} \text{ m}$$

$$\rho = 2600 \text{ kg/m}^3$$

$$\epsilon = 0.48$$

$$\rho_{oil} = 900 \text{ kg/m}^3$$

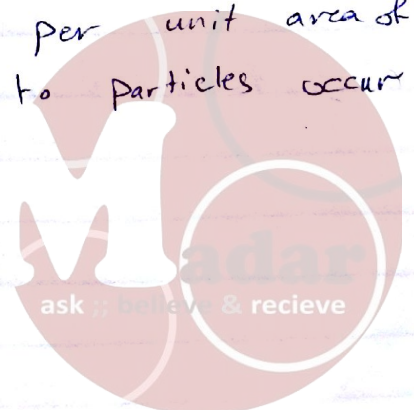
$$\mu = 3 \times 10^{-3} \text{ Ns/m}^2$$

$$g = 9.81$$

→ Calculate the mass flowrate of oil per unit area of bed at which fluidization and transport to particles occur



→



$$u_{mf} = 0.0055 \frac{e^3}{1-e} d^2 \frac{(\rho_s - \rho)g}{\mu}$$

$$G = \rho u$$

$$\frac{\text{kg}}{\text{m}^3} \cdot \frac{\text{m}}{\text{s}} = \text{kg/m}^2 \cdot \text{s} \rightarrow \text{Flux}$$

$$* \rho * = * \rho *$$

$$G_a = 0.06 \text{ kg/m}^2 \cdot \text{s}$$

value of G_a is fluidization

fluid velocity = u_0

$$u_0 = \frac{d^2 g (\rho_s - \rho)}{18 \mu} = 0.003 \text{ m/s}$$

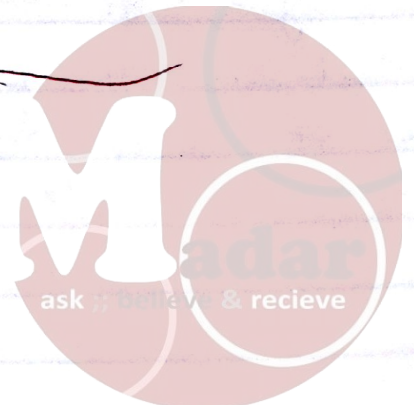
check $Re = \frac{10^{-4} \times 0.003 \times \rho}{3 \times 10^{-3}}$

$$= 0.093 \checkmark$$

$$G_* = u_0 \rho = (0.003)(900)$$

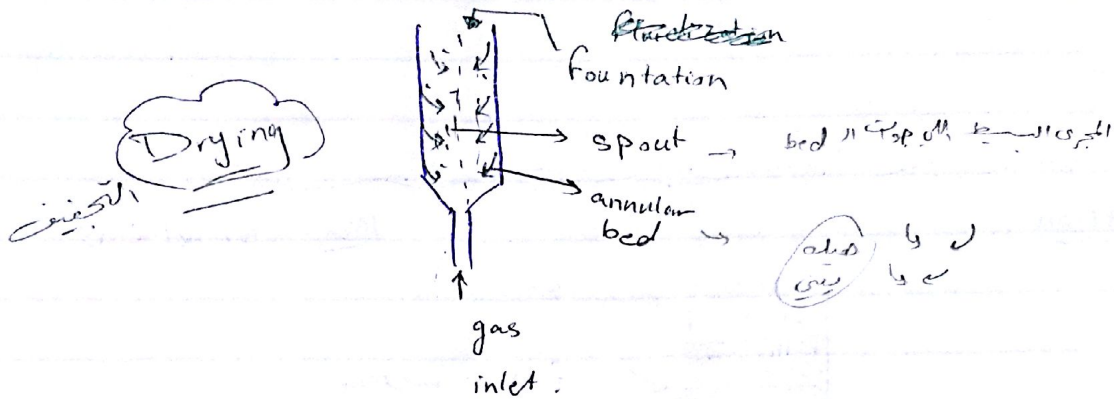
transport

$$= 2.8 \text{ kg/m}^2 \cdot \text{s}$$

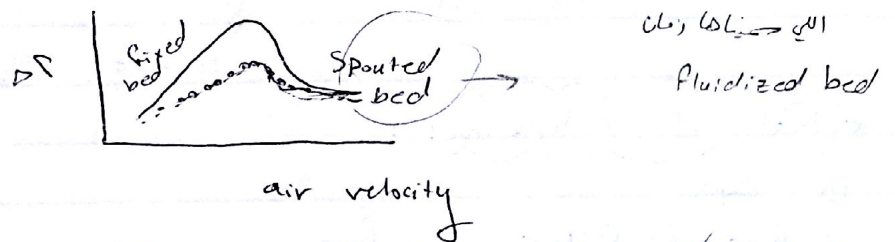


App. Fluidization

* Spouted Bed :-



ratio *
التي تتحرك في الفراغ
(spout) *



ch. 7

* Filtration

• selecting equipment

① * Properties of fluid

μ, μ_m, ρ , corrosivity $\rightarrow$ $\sqrt{F_{Eu}}$

② * Concentration of solids in suspension

$\Rightarrow$ Consider pretreatment $\rightarrow$ Process



③ * Heating

ask, believe & recieve

④ * Effect of contamination

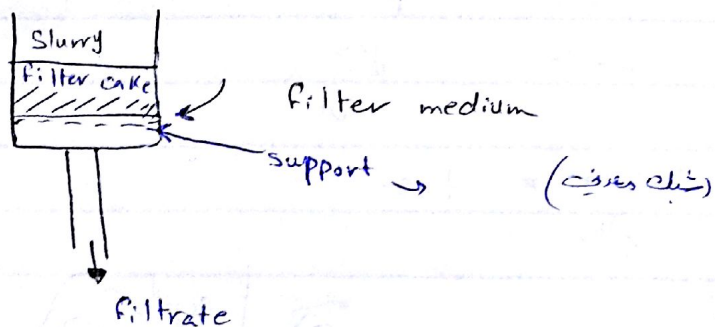
⑤ * Valuable material

Solid, liq., both

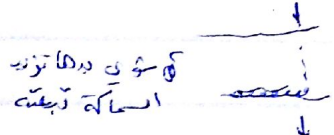
فصل ١٢ - فصل ١٣ - فصل ١٤ - فصل ١٥ - فصل ١٦ - فصل ١٧ - فصل ١٨ - فصل ١٩ - فصل ٢٠ - فصل ٢١ - فصل ٢٢ - فصل ٢٣ - فصل ٢٤ - فصل ٢٥ - فصل ٢٦ - فصل ٢٧ - فصل ٢٨ - فصل ٢٩ - فصل ٣٠ - فصل ٣١ - فصل ٣٢ - فصل ٣٣ - فصل ٣٤ - فصل ٣٥ - فصل ٣٦ - فصل ٣٧ - فصل ٣٨ - فصل ٣٩ - فصل ٤٠ - فصل ٤١ - فصل ٤٢ - فصل ٤٣ - فصل ٤٤ - فصل ٤٥ - فصل ٤٦ - فصل ٤٧ - فصل ٤٨ - فصل ٤٩ - فصل ٥٠ - فصل ٥١ - فصل ٥٢ - فصل ٥٣ - فصل ٥٤ - فصل ٥٥ - فصل ٥٦ - فصل ٥٧ - فصل ٥٨ - فصل ٥٩ - فصل ٦٠ - فصل ٦١ - فصل ٦٢ - فصل ٦٣ - فصل ٦٤ - فصل ٦٥ - فصل ٦٦ - فصل ٦٧ - فصل ٦٨ - فصل ٦٩ - فصل ٧٠ - فصل ٧١ - فصل ٧٢ - فصل ٧٣ - فصل ٧٤ - فصل ٧٥ - فصل ٧٦ - فصل ٧٧ - فصل ٧٨ - فصل ٧٩ - فصل ٨٠ - فصل ٨١ - فصل ٨٢ - فصل ٨٣ - فصل ٨٤ - فصل ٨٥ - فصل ٨٦ - فصل ٨٧ - فصل ٨٨ - فصل ٨٩ - فصل ٩٠ - فصل ٩١ - فصل ٩٢ - فصل ٩٣ - فصل ٩٤ - فصل ٩٥ - فصل ٩٦ - فصل ٩٧ - فصل ٩٨ - فصل ٩٩ - فصل ١٠٠

⑤ * Filtration :-

Mon. 28/12/2015



* Rate of Filtration :-

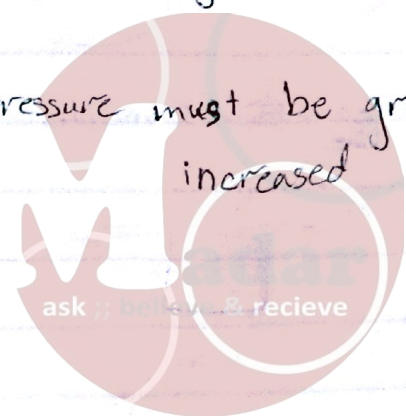
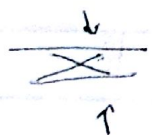


- ① ΔP
- ② Area of filtering surface.
- ③ Viscosity of filtrate
- ④ Resistance of filter medium and initial layers of cake
- ⑤ Resistance of filter cake.

* Theory

Filtration Pressure constant. $\Rightarrow$ Rate of flow will progressively diminish

Flowrate maintained const. $\Rightarrow$ The pressure must be gradually increased



Eq. (8) can be applied (Blocked Bed)

$$u = \frac{1}{K''} \cdot \frac{e^3}{S^3(1-e)^2} \cdot \frac{1}{\mu} \cdot \frac{(-\Delta P)}{l}$$

$$\rightarrow \rightarrow \frac{\delta}{d}$$

$$u = \frac{1}{A} \cdot \frac{dv}{dt} = \frac{e^3 \cdot -\Delta P}{S^3(1-e)^2 \cdot S^2 \mu \cdot l}$$

1. Cake $\rightarrow$ uniform
 $\Rightarrow e = \text{const.}$

V = vol. of filtrate which has passed in time t .

A = total x-sectional area of filter cake.

u = velocity of filtrate.

l = cake thickness.

S = Specific surface of particle.

e = voidage

ΔP = Pressure drop.

μ = viscosity

* (Formation of cake) :-

① The rate of flow is greatest at the beginning.

$\Rightarrow$ Resistance is minimum.

② High initial rates of filtration may result in plugging of the pores of the filter cloth

$\Rightarrow$ very high resistance.

③ Orientation of particles.

seelecseeale

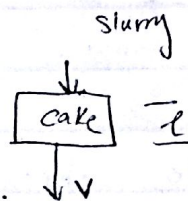


$$\Rightarrow \frac{1}{A} \cdot \frac{dV}{dt} = \frac{-\Delta P}{r \mu l}$$

$$r = \frac{(1-e)^2 \cdot S^2}{e^3} = \text{const. for given Solid filtrate material}$$

specific resistance

* Thickness of cake + vol. of filtrate :-



① * Mass of Solids in filter cake = $(1-e) A \cdot \overset{\text{Volume}}{l} \cdot \rho_s$

② * Mass of liq. retained filter cake = $e \cdot A \cdot l \cdot \rho$

$\therefore$ mass fraction of Solids in original suspension.

- Mass Balance between the Solids & the slurry and in cake

$$(1-s)(1-e) A \cdot l \cdot \rho_s = I v \rho + A e J \cdot l \cdot \rho$$

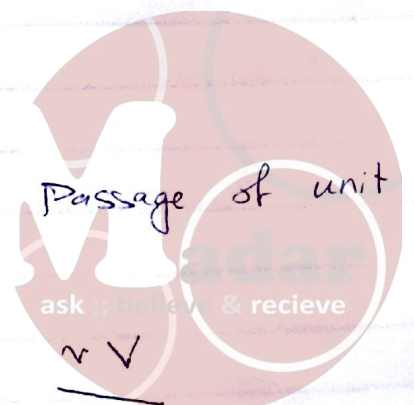
$$\therefore \text{if } \rho_s = \rho \begin{cases} l = \dots \\ v = \dots \end{cases}$$

If v = vol. of cake deposited by Passage of unit vol. of filtrate

$$v = \frac{l A}{V}$$

or

$$l = \frac{v V}{A}$$



Substitute in Eq. ①

$$\frac{1}{A} \cdot \frac{dV}{dt} = \frac{(-\Delta P)}{r \mu} \cdot \frac{A}{v V}$$

$$\frac{dV}{dt} = \frac{A^2 (-\Delta P)}{r \mu \cdot v \cdot V}$$

*

في eqn (1)
 filtration $\propto \frac{1}{V}$

- For Filtration at const. rate :-

$$\frac{t}{V} = \frac{r \mu \cdot v}{A^2 (-\Delta P)} \cdot V$$

$$-\Delta P \propto V^2$$

- For Filtration at const. P :-

$$\frac{t}{V} = \frac{r \mu \cdot v}{2 A^2 (-\Delta P)} \cdot V$$

في eqn (2)
 filtration $\propto \frac{1}{V}$

* Done By:-
Tareem Barakat

ملاحظات للمتحان

وحدات الحساب

Particle size و system التي يتصل عليه

approach و يفضل على نفس الـ

Theory في نظريتنا $L_1 + L_2$

Filter medium
 Filter cake

الفلاتر بتمت (الوقت) الفلاتر بتمت (نيت بيسل)

Filter medium

في الفلاتر

Frame باللات (الوقت)

ask & receive

Back flow ← في الفلاتر ← في الفلاتر

* Best wishes *

Back wish