جلسه ۱۶:

ته نشینی (۱)

درس: مهندسی تصفیه آب و فاضلاب

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Sedimentation

- Also called clarification
- Naturally occurs in lakes and where the water slows down
- It is perhaps the most widely used unit operation
- Chemical precipitation is a form of sedimentation where chemicals are added to bring dissolved impurities out of solution
- The tank can be rectangular or circular

تانک دوار

Video clip inserted

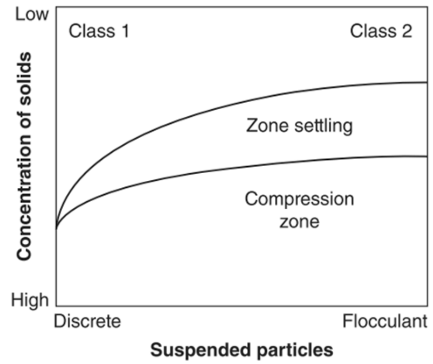
Classification

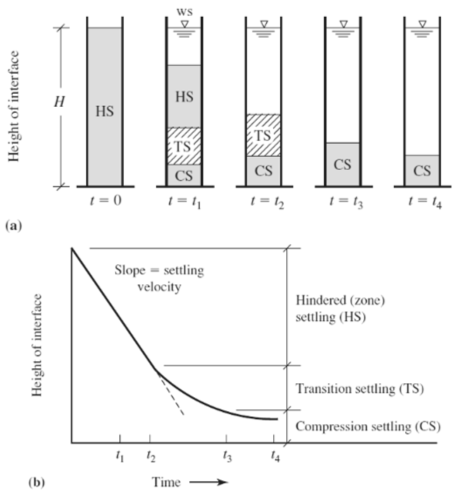
- Class 1 clarification is where particles have little tendency to coalesce and the suspension is rather dilute. Such non-flocculating, discrete particles do not alter their size, shape, or weight during settling. Sedimentation of such particles in dilute suspensions is unhindered by the presence of other settling particles = sand
- If the particles flocculate, the sedimentation regime in a rather dilute suspension is called Class 2.

Classification

- Zone settling: when floc concentrations increase, the particles are closer together and the interparticle forces hold the particles in a fixed position relative to each other. This results in subsidence of the mass of particles as a whole.
- Compaction/Compression: At still higher concentrations, the particles come in actual contact with one another and the weight of the particles is partly supported by the flocculated mass.

Classification





نوع س

Idealized schematic of Type III and IV settling in a column (*a*) and a graph of the corresponding settling curve (*b*).

Class 1

- Particles accelerate until the frictional resistance (drag) of the fluid equals the weight of the particle in the suspending fluid. Then a uniform speed (terminal velocity) is reached.
- $F_I = F_D$

$$F_I = (\rho_s - \rho)gV$$

where F_I is the impelling force, g the gravity constant, V the volume of the particle, and ρ_s and ρ are, respectively, the mass density of the particle and the fluid.

Drag

$$F_D = C_D A_c \rho v_s^2/2$$

- A_c is the projected area in the settling direction. ρ is the fluid density and v_s the settling velocity.
- C_D is the drag coefficient and is NOT constant (it changes with the Re number).

$$\boldsymbol{R} = v_s d\rho/\mu = v_s d/\upsilon$$

ویسکوزیته

- گرانروی:
- گرانروی پویا (دینامیکی) یا گرانروی حرکتی (سینماتیکی)

- Dynamic viscosity (also known as absolute viscosity) is the measurement of the fluid's internal resistance to flow while kinematic viscosity refers to the ratio of dynamic viscosity to density.

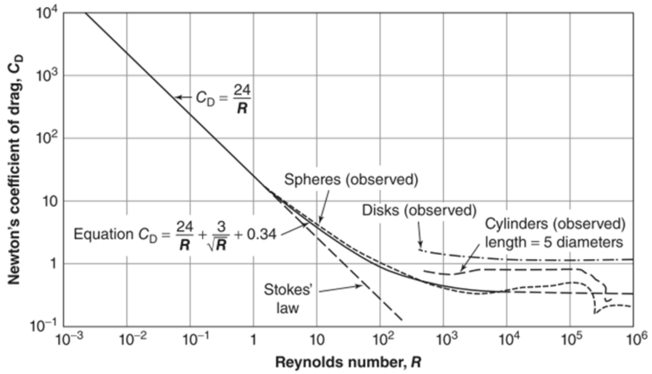
ویسکوزیته

- Two fluids with the same dynamic viscosities can have very different kinematic viscosities depending on density and vice versa.
- Simply put, dynamic viscosity gives you information on the force needed to make the fluid flow at a certain rate, while kinematic viscosity tells how fast the fluid is moving when a certain force is applied.

Newton's Drag Coefficient

- For Re<0.5 → $C_D = 24/\text{Re}$
- For $0.5<\text{Re}<10^4$ → $C_D = \frac{24}{\boldsymbol{R}} + \frac{3}{\boldsymbol{R}^{1/2}} + 0.34$
- $\text{Re}>10^4$ → (Spheres) $C_D = 0.4$

Newton's Drag Coefficient



Class 1

$$v_s = \{(2g/C_D)[(\rho_s - \rho)/\rho](V/A_c)\}^{1/2}$$

or, for spherical particles, $V = (\pi/6)d^3$ and $A_c = (\pi/4)d^2$

$$v_s = \{(4/3)(g/C_D)[(\rho_s - \rho)/\rho]d\}^{1/2}$$

or, approximately,

$$v_s = [(4/3)(g/C_D)(s_s - 1)d]^{1/2}$$

Here s_s is the specific gravity of the particle and $d = 3/2\, V/A_c = 6\, V/A$,
where A is the surface area of the particle.

Class 1

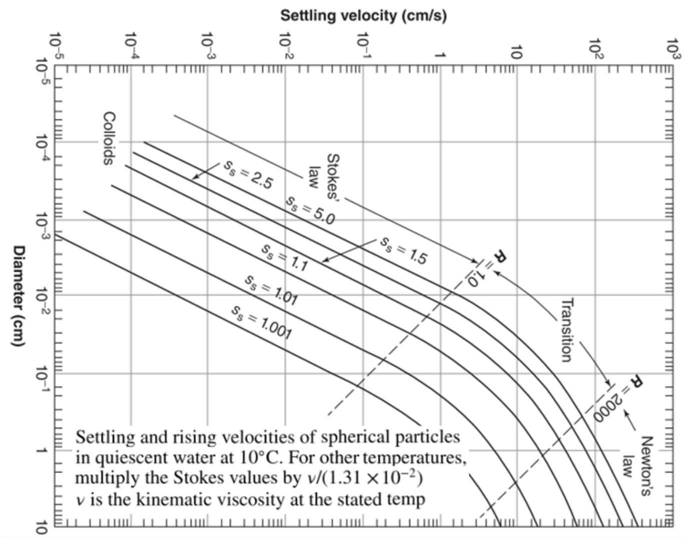
- Turbulent flow $C_D = 0.4$ $\quad v_s \approx [(3.2g(s_s - 1)d]^{1/2}$
- Viscous resistance $C_D = 24/Re$, gives "Stoke's law"

$$v_s = (g/18)[(\rho_s - \rho)/\mu]d^2$$

- or:

$$v_s = (g/18)[(s_s - 1)/\upsilon]d^2$$

where v_s = settling velocity of particles, ft/s (m/s); g = acceleration of gravity = 32.2 ft/s^2 = 9.81 m/s^2; d = diameter of particle, ft (m); ρ_s = density of particle, lb-s^2/ft^4 (kg/m^3); ρ = density of water, lb-s^2/ft^4 (kg/m^3); μ = absolute viscosity of water, lb-s/ft^2 (N-s/m^2); υ = kinematic viscosity of water, ft^2/s (m^2/s); s_s = specific gravity of particles; and 1 = specific gravity of water.



Example

- Compare the settling velocity of a spherical silica particle (specific gravity = 2.65, diameter = 5x10^{-3} cm at 20C) and a small organic colloid in winter (density of 1100 kg/m^3, 10 μm diameter at 4C)

$v = 1.010 \times 10^{-6} m^2/s$ at 20°C.

At 4°C, $\upsilon = 1.666 \times 10^{-6}$ m^2/s.

Answer

- Assuming Stoke's law applies for the silica particle:

$$v_s = (g/18)[(s_s - 1)/\upsilon]d^2$$
$$v_s = (9.81/18)[(2.65 - 1)/(1.010 \times 10^{-6})](5 \times 10^{-5})^2$$
$$= \mathbf{2.22 \times 10^{-3}\ m/s = 0.222\ cm/s}.$$

- Must check if assumption is true:

$$\boldsymbol{R} = v_s d/\upsilon$$
$$= (2.22 \times 10^{-3})(5 \times 10^{-5})/(1.010 \times 10^{-6})$$
$$= \mathbf{1.1 \times 10^{-1}}, \text{ and } \textbf{Stokes' law applies}.$$

Answer

- Now the colloid

$$v_s = (g/18)[(s_s - 1)/\upsilon]d^2$$
$$= (9.81/18)[(1.1 - 1)/1.666 \times 10^{-6}](10 \times 10^{-6})^2$$
$$= 0.0328 \times 10^{-4}$$
$$= \mathbf{3.28 \times 10^{-6}\ m/s}.$$

- Check Stoke's

$$\boldsymbol{R} = v_s d/\upsilon$$
$$= (3.28 \times 10^{-6})(10 \times 10^{-6})/(1.666 \times 10^{-6})$$
$$= 19.7 \times 10^{-6}$$
$$= \mathbf{1.97 \times 10^{-5}}, \text{ and } \textbf{Stokes' law applies}.$$

Spherical assumption

- The suspended matter in water and wastewater is seldom spherical. The irregular particles generally composing suspensions possess greater surface area per unit volume than do spheres and, because of this, settle more slowly than do spheres of equivalent volume
- Moreover, the frictional drag changes with the orientation of particles relative to the direction of motion.

Spherical assumption

- Irregularities in shape exert their greatest influence on drag at high values of Re
- At low values (R < 10), the settling velocities of rod-like and disk-like spheroidal particles are, respectively, 78% and 73% of the velocity of an equal-volume sphere.
- For particles of irregular shape, $A/V = 6/\psi d = S/d$ where ψ is called the sphericity and $S=6/\psi$ is called the shape factor of the particle

Class 2

- Also called hindered settling
- When a discrete particle settles through a liquid in free fall, the liquid displaced by the particle moves upward through an area large enough not to interpose friction. In hindered settling, by contrast, particles are spaced so closely that the friction rises as the velocity fields around the individual particles interfere.
- It is necessary to perform settling column analysis/test, since no mathematical formula or design procedure is available due to high complexity