CE 370

Sedimentation

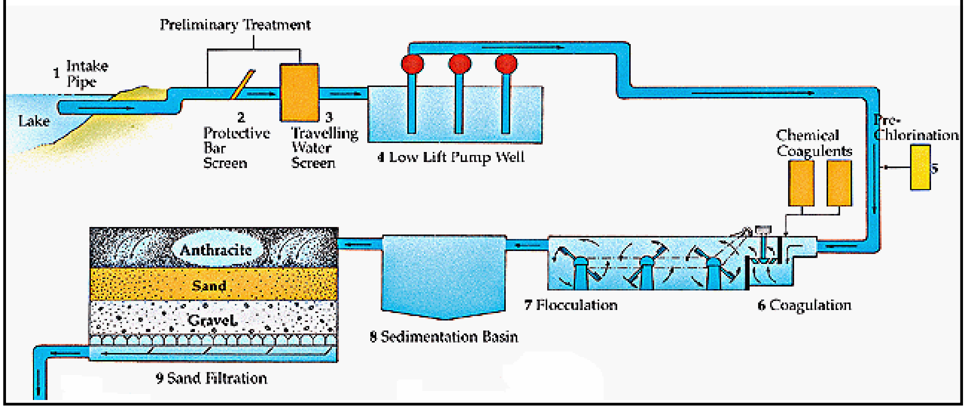
Sedimentation

- Objectives
- Uses
- Sedimentation Basins
- Types of Settling
- Sedimentation in Water Treatment
- Sedimentation in Wastewater Treatment

Overview of the Process

➢Location in the Treatment Plant

- After the source water has been coagulated and flocculated, it is ready for sedimentation.



Overview of the Process

➢Objectives of Sedimentation

To separate solids from liquid using the force of gravity. In sedimentation, only suspended solids (SS) are removed.

➢Use

Sedimentation is used in water and wastewater treatment plants

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Water Treatment

- Prior to filtration of surface water
- Prior to filtration of coagulated-flocculated water
- After adding lime and soda ash In softening of water
- In iron and manganese removal plants after treating the water

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Wastewater Treatment

- Removal of SS in primary sedimentation basins
- Removal of biological floc in activated sludge processes (final sedimentation basin)
- In tertiary treatment
- Removal of humus after trickling filters (final sedimentation basins)

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Sedimentation Basins

- Shapes
  - Circular, Rectangular, and square
- Sizes
  - Circular
    - 15 to 300 ft (diameter) and 6 to 16 ft (depth)
    - Typical sizes are 35 to 150 ft (diameter) and 10 to 14 ft (depth)
  - Square
    - 35 to 200 ft (width) and 6 to 19 ft (depth)
  - Rectangular (depends on sludge removal mechanism)
  - Freeboard
    - 1 to 1.25 ft for circular and square tanks

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Types of Settling

- Type I settling (free settling)
- Type II settling (settling of flocculated particles)
- Type III settling (zone or hindered settling)
- Type IV settling (compression settling)

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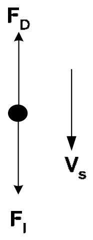
Type I settling (free settling)

- Settling of discrete (nonflocculent) particles
  - Settling of sand particles in grit chamber

- In type I settling, a particle will accelerate until the drag force, F_D, equals the impelling (due to weight) force, F_I; then settling occurs at a constant velocity, V_s.
  - $F_I = (\rho_s - \rho)gV$ where;
    ρ_s = particle density and V = particle volume
  - $F_D = C_D A_C \rho (V_s^2/2)$ where;
    C_D = coefficient of drag, A_C = particle cross-sectional area
  - Assuming spherical particles in a laminar flow regime:

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



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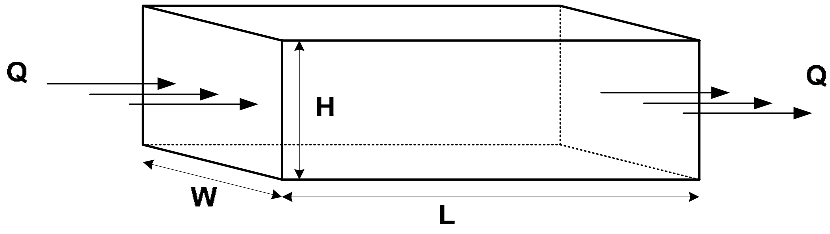
Type I settling (free settling)



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Type I Settling

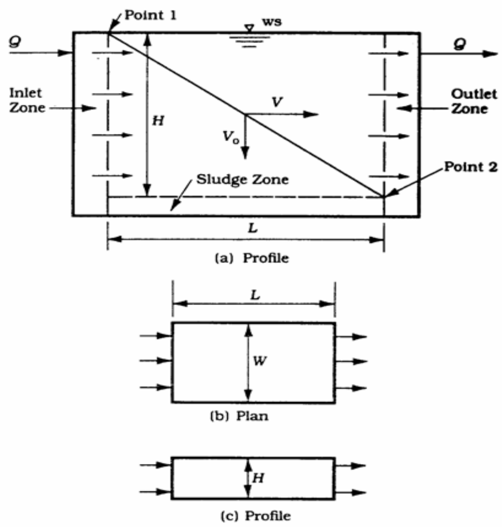


FIGURE 9.6 *Ideal Rectangular Settling Basin*

Design Equations

The detention time of the particle that enters at point 1 and get removed at point 2 is given by:

$$t = \frac{H}{V_0} \text{.....(1)}$$

The detention time is also equal to the length divided by the horizontal velocity:

$$t = \frac{L}{V} \text{.....(2)}$$

The horizontal velocity is equal to flowrate divided by cross-sectional area:

$$V = \frac{Q}{HW} \text{.....(3)}$$

Combining equations 2 and 3 to eliminate *V* gives:

$$t = \frac{LWH}{Q} \text{.....(4)}$$

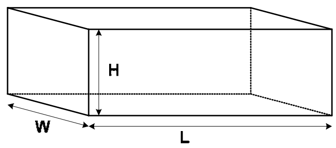
Design Equations

Since *LWH* is the basin volume, *Vol*, the detention time, t, is equal to the basin volume divided by the flow rate:

$$t = \frac{Vol}{Q} \;.....(5)$$

From equation 1 and 4:

$$\frac{LWH}{Q} = \frac{H}{V_0} \;.....(6)$$



Rearranging yields:

$$V_0 = \frac{Q}{LW} \;.....(7)$$

Or: $V_0 = \frac{Q}{A_p}$ = overflow rate or surface loading (m^3/d-m^2)

Where $\boldsymbol{A_p}$ is the plan area of the basin

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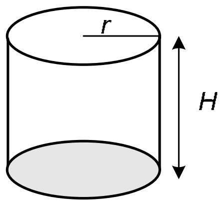
Design Equations

For an ideal circular settling basin, the horizontal velocity is given by:

$$V = \frac{Q}{2\pi r H}$$



and

$$V_0 = \frac{Q}{A_p}$$ = overflow rate or surface loading (m^3/d-m^2)

The depth of an ideal rectangular or circular basins is given by:

$$H = V_o t$$

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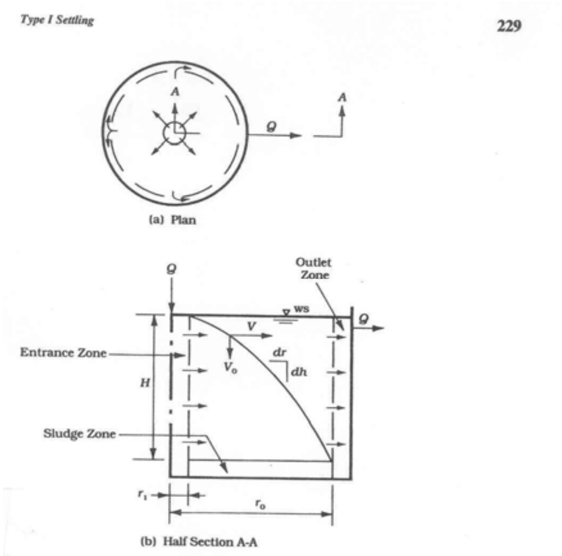
Design Equations



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Type II settling (settling of flocculated particles)

- Particles flocculate during settling; thus they increase in size and settle at a faster velocity. Examples of Type II settling:
  - Primary settling of wastewater
  - Settling of chemically coagulated water and wastewater
- A batch settling tests are performed to evaluate the settling characteristics of flocculent suspensions.

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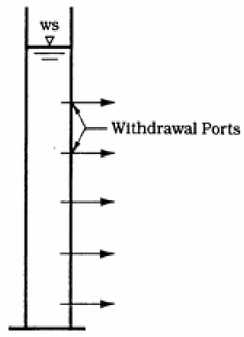
Type II settling (Batch settling test)

- **Batch settling tests:**
  - Suspension is poured into column.
  - Samples are removed from the ports at periodic time intervals.
  - The samples suspended solids concentrations are determined.
  - The percent removal is calculated for each sample.
  - The percent removal is plotted on a graph as a number vs time and depth.
  - Interpolations are made between the plotted points and curves of equal percent removals are drawn as shown in the next figure.



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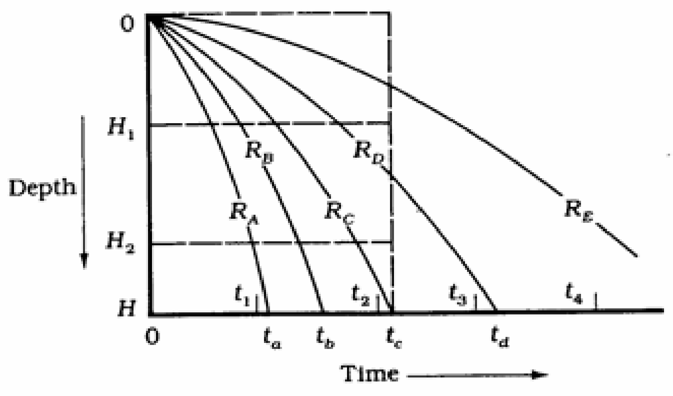
Type II settling (Settling diagram)



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Type II settling (Settling diagram)

- **Determining overflow rate and fraction removed:**

The overflow rates, V_o , are determined for the various settling times (t_a, t_b, and so on) where the R curves intercept the x-axis. For example, for the curve R_c, the overflow rate is:

$$V_o = \frac{H}{t_c} \times \text{proper conversions}$$

The fractions of solids removed, R_T, for the times t_a, t_b, and so on are then determined. For example, for time t_c, the fraction removed would be:

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

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Type III settling (zone or hindered settling)

- Is the settling of an intermediate concentration of particles
- The particles are close to each other
- Interparticle forces hinder settling of neighboring particles
- Particles remain in fixed position relative to each other
- Mass of particles settle as a zone

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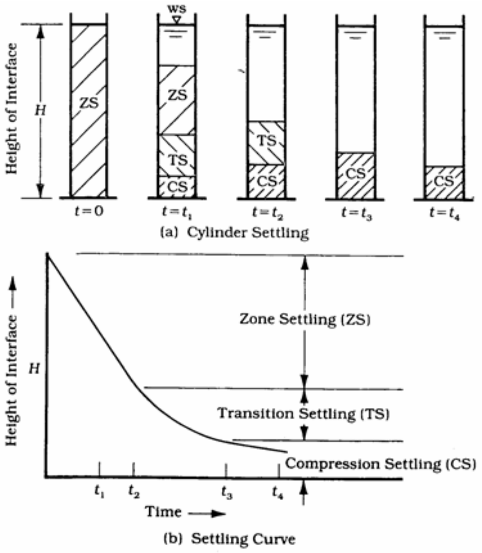

FIGURE 9.20 *Settling of a Concentrated Suspension*

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Type IV settling (compression settling)

- Settling of particles that are of high concentration
- Particles touch each other
- Settling occurs by compression of the compacting mass
- It occurs in the lower depths of final clarifiers of activated sludge

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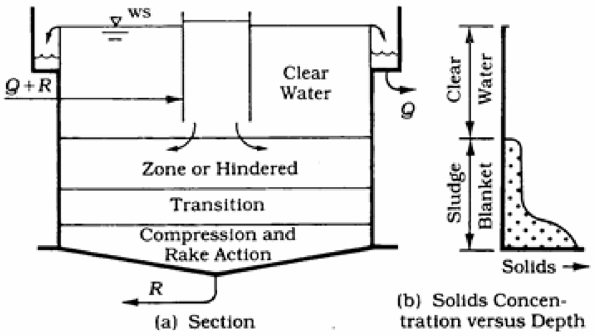

FIGURE 9.21 *Settling in a Final Clarifier for the Activated Sludge Process*

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Sedimentation in Water Treatment

- Settling characteristics of floc depend on:
  - Water characteristics
  - Coagulant used
  - Degree of flocculation

- For water coagulated with alum or iron salts
  - Overflow Rates
    - 20.4 to 40.8 $m^3/d\text{-}m^2$
  - Detention Times
    - 2 to 8 hours

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Sedimentation in Water Treatment

- In lime-soda softening plants
  - Overflow Rates
    - 28.6 to 61.2 $m^3/d\text{-}m^2$
  - Detention Times
    - 4 to 8 hours

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Example of Sedimentation in Water Treatment

Clarifier for Water Treatment

A rectangular sedimentation basin is to be designed for a rapid filtration plant. The flow is 30,300 m^3/day, the overflow rate or surface loading is 24.4 m^3/d-m^2, and the detention time is 6 hours. Two sludge scraper mechanisms for square tanks are to be used in tandem to give a rectangular tank with a length to width ratio of 2:1. Determine the dimensions of the basin

Solution

The plan area required = (30,000 m3/d) / (24.4 m^3/d-m^2) = 1242 m^2
Since the length (L) is twice the width (W)
Then (2W)(W) = 1242 m^2
W = 24.9 m and thus L = 49.8 m
Therefore, the plant dimensions are:

Width = 24.9 m
Length = 49.8 m

Since the depth (H) is equal to the settling rate times the detention time
H = (24.4 m^3/d-m^2)(d/24)(6 h) = 6.10 m

Depth = 6.10 m

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Sedimentation in Wastewater Treatment

- Primary sedimentation
  - To remove settleable solids from raw wastewater
- Secondary sedimentation
  - To remove MLSS in activated sludge process
  - To remove biological growth sloughing off trickling filters
- Tertiary and advanced treatment
  - Remove coagulated-flocculated SS
  - Remove chemical precipitates

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Primary Sedimentation

Type of Treatment	Overflow Rate ($m^3/d\text{-}m^2$)		Depth (m)
	Average	Peak	
Primary Settling followed by Secondary Treatment	32.6 – 48.9	81.5 – 122	3.0 – 3.7
Primary Settling with Waste Activated Sludge	24.5 – 32.6	48.9 – 61.1	3.7 – 4.6

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Example on Primary Sedimentation

A primary clarifier for a municipal wastewater treatment plant is to be designed for an average flow o 7570 m^3/d. The peak overflow rate is 89.6 $m^3/d\text{-}m^2$, average overflow rate is 36.7 $m^3/d\text{-}m^2$, minimum side water dept is 3 m. The ratio of the peak hourly flow to the average hourly flow is 2.75. Determine:

1. the diameter of the clarifier
2. the depth of the clarifier

Solution

Using average flow, the required area = (7570 m^3/d) / (36.7 $m^3/d\text{-}m^2$) = 206 m^2

Using peak flow, the required area = (7570 m^3/d) (2.75) / (89.6 $m^3/d\text{-}m^2$) = 232 m^2

Therefore, the peak flow controls. So, 232 m^2 = $(\pi/4)\ D^2$; D = 17.2 m

The depth of the clarifier = 3.0 m

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Criteria Used in Design of Secondary Sedimentation Basins

Type of Treatment	Overflow Rate (m3/d-m2)		Solids Loading (kg/d-m2)		Depth (m)
	Average	Peak	Average	Peak	
Activated Sludge (except extended aeration)	16.3 – 32.6	40.8 – 81.6	98 – 147	244	3.7 – 4.6
Activated Sludge, Extended Aeration	8.15 – 16.3	32.6	98 – 147	244	3.7 – 4.6
Activated Sludge, Pure Oxygen	16.3 – 32.6	40.8 – 81.6	122 – 171	244	3.7 – 4.6
Trickling Filters	16.3 – 24.5	40.8 – 81.6	--	--	3.0 – 3.7

Criteria Used in Design of Secondary Sedimentation Basins

Tank Diameter (m)	Side Water Depth (m)
Up to 12.2	3.35
12.2 – 21.3	3.65
21.3 – 30.5	3.96
30.5 – 42.7	4.27
> 42.7	4.57

Criteria Used in Design of Secondary Sedimentation Basins

- Detention Time is 1.0 to 2.5 hours (based on average daily flow)
- Overflow rates, solids loadings and depths should control in design of final clarifiers
- Basins should be provided with baffles and skimmers to remove floating objects

Example on Final Sedimentation

A final clarifier is to be designed for an activated sludge treatment plant. Peak overflow rate = 57.0 m3/d-m2, average overflow rate = 24.4 m3/d-m2, Peak solids loading = 244 kg/d-m2, peak weir loading = 373 m3/d-m, and depth = 3.35 m. The flow to the reactor basin prior to the junction with the recycle line = 11,360 m3/day. The maximum recycled sludge flow is 100% of the influent flow and is constant throughout the day. The MLSS = 3000 mg/l, and the ratio of the peak hourly influent flow to the average hourly flow is 2.50. Determine:

1. **the diameter of the tank**
2. **the depth of the tank**

Solution

The recycle = (100%)(11,360 m^3/day) = 11,360 m^3/day

Average mixed liquor flow = 11,360 + 11,360 = 22,720 m^3/day

Peak mixed liquor flow = (2.5)(11,360) + 11,360 = 39, 760 m^3/day

Area of basin (based on average flow) = (11,360 m3/day) / (24.4 m^3/d-m^2) = 466 m^2

Area of basin (based on peak flow) = (28,400 m^3/day) / (57.0 m^3/d-m^2) = 498 m^2

Peak solids flow = (39,760 m^3/day)(1000 l/m3)(3000 mg/l)(kg / 10^6 mg) = 119,280 kg/day

Area of solids loading = (119,280 kg/day) / (244 kg/d-m^2) = 489 m^2

Thus the peak overflow rate controls

Since 489 m^2 = $(\pi/4)(D^2)$ the diameter of the basin, D = 25.2 m

From the Table, for a clarifier with D = 25.2 m, the suggested depth of the basin = 3.96 m