

20. SECONDARY SEDIMENTATION

The secondary sedimentation facility is provided after the biological reactor to facilitate the sedimentation of the cells produced during biological oxidation of organic matter. If these cells produced are not removed, complete treatment will not be achieved as these cells will represent about 40 to 60% of the organic matter present in untreated wastewater in aerobic treatment. Depending on the type of reactor used fraction of these settled cells is returned back to the reactor and remaining cells are wasted as excess sludge for further treatment.

20.1 Analysis of hindered settling (Type 3)

In systems that contain high concentration of suspended solids, both hindered (zone) settling (type 3) and compression settling usually occur in addition to discrete and flocculent settling. The settling phenomenon that occurs when a concentrated suspension, initially of uniform concentration throughout, is placed in cylinder as shown in Figure 20.1.

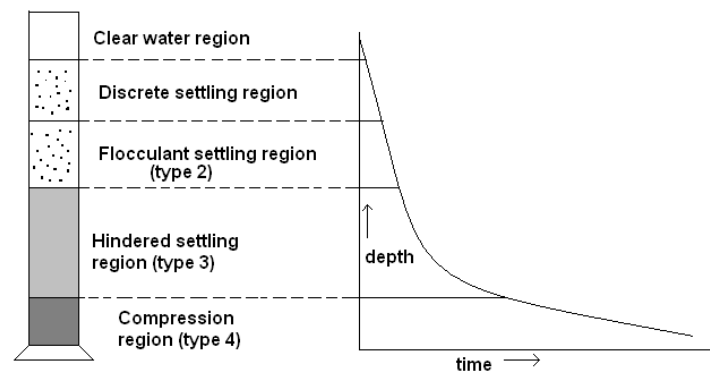


Figure 20.1 Schematic diagram of settling regions for ASP

Due to high concentration of particles the liquid tends to move up through the interstices of contacting particles. As a result, the particles settle as a zone or 'blanket', maintaining the same relative position with respect to each other. This is known as 'hindered settling'. As the solids settle as a zone, a relatively clear layer of water is produced above the particles in the settling region. The rate of settling in the hindered settling region is a function of concentration of solids and their characteristics.

As settling continues, a compressed layer of particles begins to form at the bottom of the cylinder in the compression settling region. Thus in hindered settling region a gradation in solid concentration exists from interface of settling region to that found in the compression settling region. Due to variability of nature of solids and concentration, settling test is

necessary to determine the settling characteristics. Two different approaches can be used for conducting the laboratory test.

1. Single (batch) settling test, or
2. Solid flux method (based on series of tests at different suspended solids concentration).

20.2 Area Requirement Based on Single Batch Test Result

The final overflow rate selected for design of sedimentation tank is based on the following:

- Area needed for clarification,
- Area needed for thickening,
- The rate of sludge withdrawal.

Since the area needed for the free settling region is less than the area required for thickening, the rate of free settling is rarely the controlling factor. In case of activated sludge process where light, fluffy floc particles may be present, it is conceivable that the free or flocculent settling velocity of these particles could control the design.

For a column of height = H_o , and uniform solid concentration = C_o , the position of interface as the time elapses is given in Figure 20.2. The rate at which interface subsides is equal to slope of the curve at that point in time.

The area required for thickening

$$A = \frac{Qt_u}{H_o} \quad (1)$$

- Where,
- A = Area required for sludge thickening, m^2
 - Q = Flow rate in the tank, m^3/sec
 - H_o = Initial height of interface in column, m
 - t_u = Time to reach desired underflow concentration, sec.

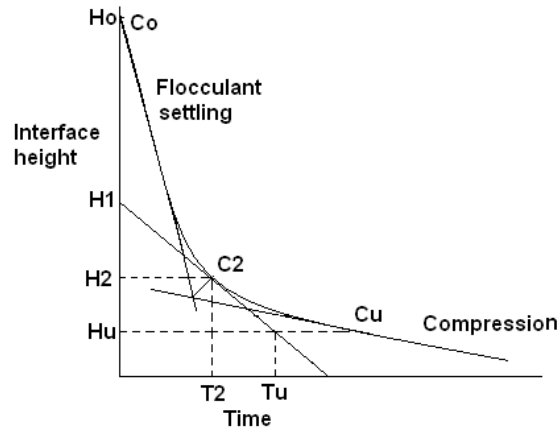


Figure 20.2 Analysis of the single batch test result

The critical concentration controlling the sludge handling capability of the tank occurs at a height H_2 , where concentration is C_2 (C_2 is determined by extending tangent and bisecting angle of intersection).

The time t_u can be determined as follows (Metcalf and Eddy, 2003):

- Construct a horizontal line at the depth ' H_u ', that corresponds to the depth at which the solids are at the desired underflow concentration, ' C_u '.

The value of H_u can be determined as:

$$H_u = \frac{C_o \cdot H_o}{C_u} \quad (2)$$

- Construct a tangent to a settling curve at point C_2 .
- Construct a vertical line from intersection of tangent and horizontal line from ' H_u '. This vertical line will determine ' t_u '.

With this value of ' t_u ' the area required for thickening is computed using relation,

$$A = \frac{Qt_u}{H_o}$$

The area required for clarification is then determined. The larger of the two areas is the controlling value. Although ' C_u ' in settling test will occur at longer time, due to continuous withdrawal from the bottom of tank this time may not reach in settling tank, hence ' t_u ' is worked out from tangent.

Example: 1

Calculate the size of SST for ASP. In a settling cylinder of 2.0 m height the settling test was performed, and the settling curve as shown in Figure 20.3 was obtained for an activated sludge with initial solids concentration, $C_o = 4300$ mg/L. Determine the area to yield a thickened sludge concentration C_u of 20 g/L with an inflow of $500 \text{ m}^3/\text{day}$. In addition, determine the solids loading in $\text{kg}/\text{m}^2 \cdot \text{day}$ and the overflow rate in $\text{m}^3/\text{m}^2 \cdot \text{day}$.

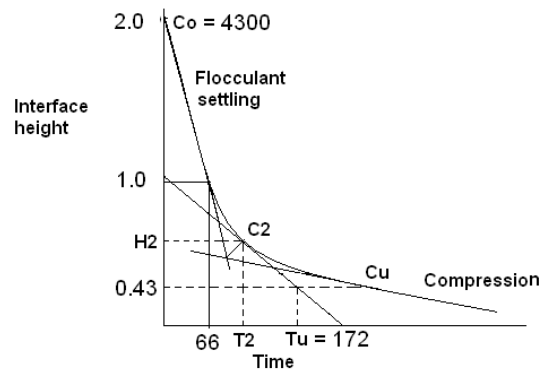


Figure 20.3 Results of the batch settling test

Solution:

1. The area required for thickening,

$$H_u = \frac{C_o \cdot H_o}{C_u}$$

$$= \frac{4300 \times 2.0}{20000} = 0.43 \text{ m}$$

2. Draw a horizontal line at height $H_u = 0.43 \text{ m}$
3. Construct a tangent to the settling curve at C_2 , the midpoint of the region between hindered and compression settling. The intersection of the tangent at C_2 and horizontal line is at $t_u = 172 \text{ min}$.

Hence, the required area

$$A = \frac{Qt_u}{H_o} = \frac{500}{24 \times 60} \times \frac{172}{2.0} = 29.86 \text{ m}^2$$

4. This area should be adequate for clarification also.
 - a. Determine subsidence velocity ' v ' from the beginning of the hindered settling portion of the curve, (assuming the particles present at the interface are those of concern).

$$v = \frac{2.0-1.0}{66} \times 60 = 0.91 \text{ m/h}$$

- b. Determine overflow rate:

The overflow rate is proportional to the liquid volume above the critical sludge zone (sludge is drained from bottom).

$$Q = 500 \text{ (m}^3\text{/day)} \times \frac{2.0-0.43}{2.0} = 392.5 \text{ m}^3\text{/day}$$

- c. Determine area required for clarification:

The area required is obtained by dividing overflow rate by settling velocity.

$$A = \frac{Q}{V} = \frac{392.5}{0.91} \times \frac{1}{24} = 17.97 \text{ m}^2$$

5. The controlling requirement is the thickening area of 29.86 m^2 because it exceeds the area required for clarification.
6. Determine the solids loading:

$$\text{Solids (kg/day)} = \frac{500 \left(\frac{\text{m}^3}{\text{day}} \right) \times 4300 \text{ (g/m}^3\text{)}}{10^3 \text{ (gm/kg)}} = 2150 \text{ kg/day}$$

$$\text{Solids loading} = \frac{2150 \text{ kg/day}}{29.86 \text{ m}^2} = 72 \text{ kg/m}^2 \cdot \text{day}$$

7. Determine hydraulic loading rate:

$$\text{Hydraulic loading rate} = \frac{392.5}{29.86} = 13.15 \text{ m}^3\text{/m}^2 \cdot \text{day}$$

20.3 Design of secondary sedimentation tank

The design guidelines for secondary sedimentation tank for different biological processes as recommended by CPHEEO manual (1993) is presented in the Table 20.1.

Table 20.1 Design parameters for SST

Parameter	Overflow rate, $\text{m}^3\text{/m}^2 \cdot \text{d}$		Solid loading rate, $\text{kg/m}^2 \cdot \text{d}$		Depth, m	Detention time, h
	Average	Peak	Average	Peak		
SST for TF	15 - 25	40 - 50	70 - 120	190	2.5 - 3.5	1.5 - 2.0
SST for ASP	15 - 25	40 - 50	70 - 140	210	3.5 - 4.5	1.5 - 2.0
SST for extended aeration ASP	8 - 15	25 - 35	25 - 120	170	3.5 - 4.5	1.5 - 2.0

Weir loading rate for the secondary sedimentation tank is kept less than or equal to $185 \text{ m}^3/\text{m.d}$. Other guidelines for the dimensions of the tank are similar to as described earlier in primary sedimentation.

Example: 2

Design secondary sedimentation tank for treatment of 10 MLD effluent coming from conventional ASP. The MLSS in aeration tank is 3000 mg/L and peak flow factor is 2.0

Solution

Adopt surface loading rate of $20 \text{ m}^3/\text{m}^2.\text{d}$ at average flow.

Therefore surface area required = $10000/20 = 500 \text{ m}^2$

Then surface overflow rate at peak flow = $20000/500 = 40 \text{ m}^3/\text{m}^2.\text{d}$ (within 40 to 50)

Check for solid loading

At average flow solid loading rate = $10000 \times 3/500 = 60 \text{ kg/m}^2.\text{d}$

At peak flow solid loading rate = $20000 \times 3/500 = 120 \text{ kg/m}^2.\text{d}$ (Less than permissible)

Diameter of the tank for 500 m^2 area = 25.24 m

Provide detention time of 2 h, hence volume = $10000 \times 2/24 = 833.33 \text{ m}^3$

Hence depth of the tank = $833.33/500 = 1.67 \text{ m}$

Provide depth of $2.0 \text{ m} + 0.3 \text{ m}$ for sludge accumulation and 0.4 m free board. Hence total depth = 2.7 m

Check for weir loading

Weir loading = $10000/(\pi * D) = 126.18 \text{ m}^3/\text{m.d}$, hence safe.

Questions

1. Describe different types of settling.
2. Explain hindered settling. How the area required for sedimentation is worked out on the single batch test result?
3. Prepare notes on different types of settling occurring in treatment of wastewaters.
4. Explain the purpose of providing secondary sedimentation.
5. Design secondary sedimentation tank for the industrial effluent treatment plant employing completely mixed ASP. The MLSS in aeration tank is 4500 mg/L and average annual wastewater flow rate is $500 \text{ m}^3/\text{d}$. However in winter the wastewater generation is 1.5 times the annual average.

