# Hindered (Zone) Settling
# Type (3) Settling

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## Hindered ( Zone) Settling

In systems that contain a high concentration of suspended solids, both hindered or zone settling and compression settling occur in addition to discrete ( free) settling and flocculent settling . The settling phenomenon that occur when a concentrated suspension, initially of uniform concentration  throughout, is placed in a gradual cylinder, is illustrated on the presented figure of this lecture. Because of the high concentration of particles, the liquid tends to move up through the interstices of the contacting particles.

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As a result, the contacting particles tend to settle as a zone or (blanket), maintain the same relative position with respect to each other. The phenomenon is known as hindered settling. As the particles settle, a relatively clear layer of water is produced above the particles in the settling region.

## Hindered ( Zone ) Settking

The scattered, relatively light particles maintain usually settle as discrete or flocculent particles, as discussed previously. In most cases, an identifiable interface develops between the upper regions of the figure shown in the context of the lecture. The rate of settling in the hindered settling region is a function of the concentration of solids and their characteristics.

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As settling continues, a compressed layer of particles begins to form on the bottom of the cylinder in the compression settling region. The particles apparently form a structure in which there is close physical contact between the particles.

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As the compression layer forms, region containing successively low concentration of solids that those in the compression region extend upward in the cylinder. Thus, in actuality the hindered settling region contains a gradation in solids concentration from that found at the interface of the settling region to that found in the compression settling region.

# Hindered (Zone) Settling

## 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.

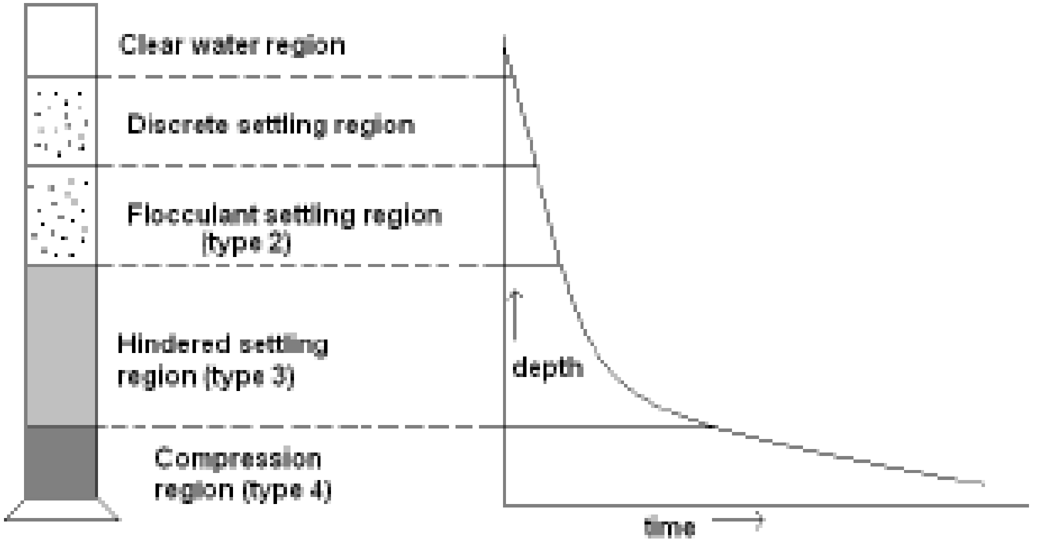


**Figure 20.1** Schematic diagram of settling regions for ASP

# Hindered (Zone) Settling

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

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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.

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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

$$A = \frac{Qt_u}{H_o} \tag{1}$$

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.

The critical concentration controlling the sludge handling capability of the tank occurs at a height $H_2$ (Figure 20.2), where concentration is $C_2$ ($C_2$ is determined by extending tangent and bisecting angle of intersection).

# Hindered (Zone) Settling

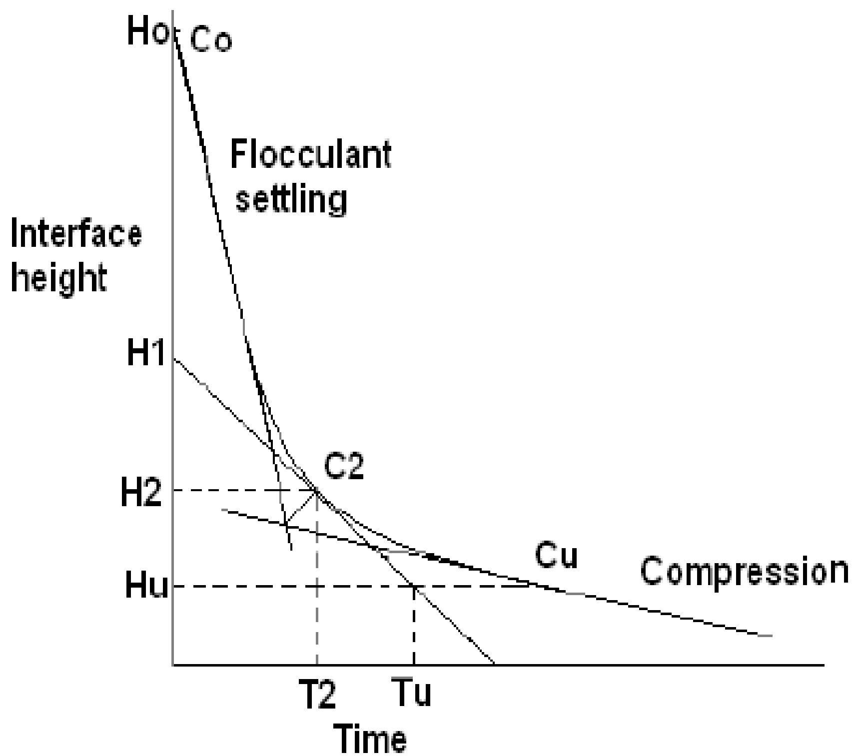


Figure 20.2 Analysis of the single batch test result

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

a. Construct a horizontal line at the depth '$H_u$' that corresponds to the depth at

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which the solids are at the desired underflow concentration, '$C_u$'.

The value of $H_u$ can be determined as:

$$H_u = \frac{C_o . H_o}{C_u} \qquad (2)$$

b. Construct a tangent to a settling curve at point $C_2$.

c. 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,

$$A = \frac{Q t_u}{H_o}$$

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.

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## 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, $C_0 = 4300$ mg/L. Determine the area to

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yield a thickened sludge concentration $C_u$ of 20 g/L with an inflow of 500 $m^3$/day. In addition, determine the solids loading in kg/$m^2$.day and the overflow rate in $m^3$/$m^2$.day.

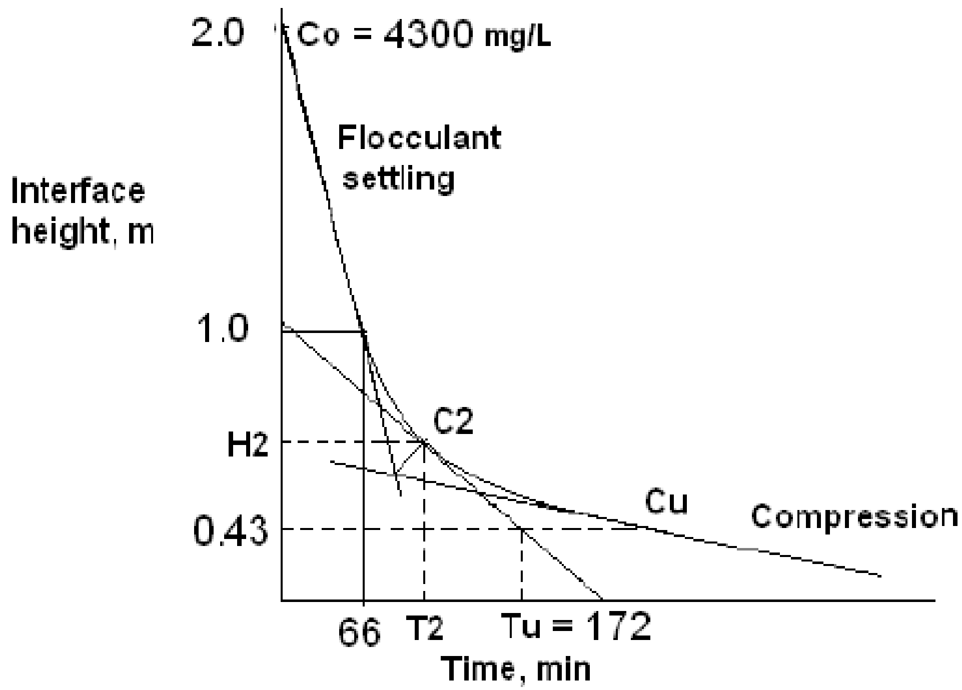


**Figure 20.3** Results of the batch settling test

**Solution:**

1. The area required for thickening,

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

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

2. Draw a horizontal line at height $H_u$ =0.43 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 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 settling portion of the curve, (considering velocity of particles present at the interface).

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

b. Determine overflow rate:

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

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

c. Determine area required for clarification:

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

$$A = \frac{Q}{v} = \frac{392.5}{0.91}\ x\ \frac{1}{24} = 17.97\ m^2$$

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:

$$\text{Solids loading (kg/day)} = \frac{500\left(\frac{m^3}{day}\right) x4300(g/m^3)}{10^3\ (gm/kg)} = 2150\ kg/day$$

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

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7. Determine hydraulic loading rate:

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

## 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, $m^3/m^2.d$ | | Solid loading rate, $kg/m^2.d$ | | 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 |

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Weir loading rate for the secondary sedimentation tank is kept less than or equal to 185 $m^3/m.d$. 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 $m^3/m^2.d$ at average flow.

Therefore surface area required = 10000/20 = 500 $m^2$

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

*Check for solid loading*

At average flow solid loading rate = 10000 x 3/500 = 60 $kg/m^2.d$

At peak flow solid loading rate = 20000 x 3/500 = 120 $kg/m^2.d$ (less than permissible)

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

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Provide detention time of 2 h, hence volume = 10000*2/24 = 833.33 $m^3$

Hence depth of the tank = 833.33/500 = 1.67 m

Provide depth of 2.0 m + 0.3 m for sludge accumulation and 0.4 m free board. Hence total depth = 2.7 m

*Check for weir loading*

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

# Hindered (Zone) Settling

**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 MLVSS in aeration tank is 3500 mg/L and average annual wastewater flow rate is 500 $m^3$/d. However in summer the wastewater generation is 1.5 times the annual average. Consider MLVSS/MLSS = 0.8.

**Answer:**

Q. 5. Provide surface loading rate of 20 $m^3/m^2$.d at average flow. Diameter 5.64 m and total depth = 2.7 m.

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