جلسه ۱۷:

ته نشینی (۲)

درس: مهندسی تصفیه آب و فاضلاب

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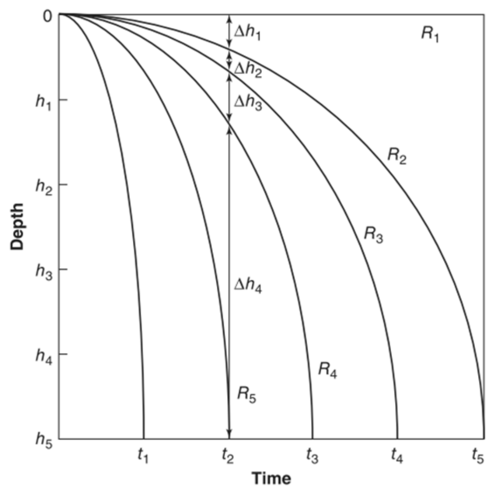
Sedimentation test (Type 2)

- To perform sedimentation tests, a flocculating suspension similar to the one in the settling tank is placed in the column
- Samples are withdrawn at different heights (from all the ports) at various time intervals and the amount of suspended solids contained in the samples is determined.
- The percent removals of suspended solids by sedimentation are then calculated.

Sedimentation test

- For example, if a suspension containing 500 mg/L of suspended solids was introduced into the column and the sample showed a concentration of 100 mg/L at a particular height after some time, then the percent removed would be 80% at that height.
- These percentages are plotted on a depth versus time graph. Points of equal percent removals are joined and a plot

Class 2



Class 2

- Overall removals of suspended solids at a certain detention time (t_2):

$$R_{t2} = \frac{\Delta h_1}{h_5}\left(\frac{R_1 + R_2}{2}\right) + \frac{\Delta h_2}{h_5}\left(\frac{R_2 + R_3}{2}\right) + \frac{\Delta h_3}{h_5}\left(\frac{R_3 + R_4}{2}\right) + \frac{\Delta h_4}{h_5}\left(\frac{R_4 + R_5}{2}\right)$$

where

R_{t2} = the percent removal at time t_2

$R_1, R_2, \ldots, R_5$ are percent removals

h_5 = the total depth of water in column

Δh_1, Δh_2, Δh_3, Δh_4 are depth increments to successive percent removal curves at time t_2

Example

- Find the detention time for a settling tank with 8 ft (2.44 m) effective depth to remove 75% of the suspended solids. The following settling column analysis has been carried out.
- Keep in mind that in order to obtain removals in settling tanks comparable to those indicated by a settling column analysis, it is recommend that the detention time be multiplied by 1.75–2.0 and the overflow rate or design settling velocity by 0.65.

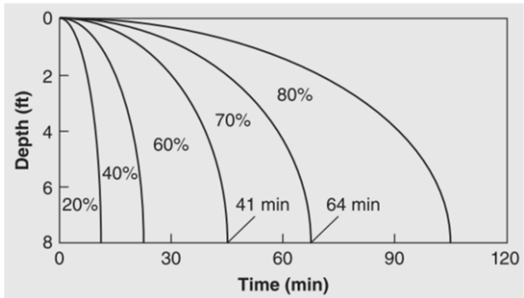
Example (cont.)

Suspended solids removal in %

Depth ft (m)	Time (min) 10	20	30	45	60	90	120
2 (0.6)	40	58	69	75	80	84	85
4 (1.2)	24	47	60	69	75	81	84
6 (1.8)	16	39	55	65	70	79	82
8 (2.4)	14	33	52	63	68	76	81

Answer

- First we must plot the data on a time–depth graph. Points of equal percentage removals are joined to obtain percentage removal lines like the figure



Answer (cont.)

- To obtain detention time for 75% suspended solids removal we calculate overall percent removals, at two different times, one which would give more than 75% removal and the other which gives less than 75% removal. The time required for 75% removal is then obtained by proportion.
- Examination of the percent removal curves indicate that overall removal at 64 min should be over 75% and that at 41 min should be less than 75%. So calculate overall removals at these two points only.

Answer

Overall removal at 64 min equals:

$$R_{t2} = \frac{\Delta h_1}{h_5}\left(\frac{R_1 + R_2}{2}\right) + \frac{\Delta h_2}{h_5}\left(\frac{R_2 + R_3}{2}\right) + \frac{\Delta h_3}{h_5}\left(\frac{R_3 + R_4}{2}\right) + \frac{\Delta h_4}{h_5}\left(\frac{R_4 + R_5}{2}\right)$$

$$= \frac{5.7}{8} \times \frac{70 + 80}{2} + \frac{2.3}{8} \times \frac{80 + 100}{2} = 79.3\%.$$

Overall removal at 41 min equals:

$$R_{t2} = \frac{4.9}{8} \times \frac{70 + 60}{2} + \frac{1.9}{8} \times \frac{80 + 70}{2} + \frac{1.2}{8} \times \frac{80 + 100}{2} = 71.1\%.$$

By proportion 75% removal will be obtained in

$$t = 41 + \frac{75 - 71.1}{79.3 - 71.1} \times (64 - 41) = 41 + \frac{3.9}{8.2} \times (64 - 41) = 51.94 \text{ min, say } 52 \text{ min.}$$

Safety factor of 2, so detention time = 52x2 = 104 min

Zone settling (Type 3)

- Concentrated suspensions have somewhat different settling characteristics than dilute suspensions.
- The particles settle as a zone or "blanket" leaving a relatively clear liquid above the zone-settling region. Some particles are invariably left behind which settle in the relatively clear water as discrete particles.
- A distinct interface is formed between the relatively clear liquid and the zone-settling region.

Compression settling (Type 4)

- In the compression zone, particles come into complete physical contact and are supported by layers below
- The approximate rate of consolidation is proportional to the difference in sludge depth at time *t* and the final depth of sludge after a long period of settling:

$$-\frac{dH_t}{dt} = K(H_t - H_\infty)$$

H_t = depth of sludge at any time (t), ft (m)

H_∞ = final depth of sludge after a long period of settling, ft (m)

K = constant for a given suspension

Compression settling (Type 4)

$$-\int_{H_{t_1}}^{H_{t_2}} \frac{dH_t}{H_t - H_\infty} = K \int_{t_1}^{t_2} dt$$

$$\ln\left(\frac{H_{t_1} - H_\infty}{H_{t_2} - H_\infty}\right) = K(t_1 - t_2)$$

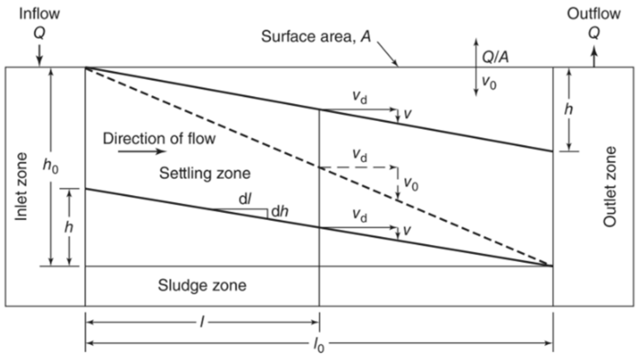
$$H_{t1} - H_\infty = \left(H_{t2} - H_\infty\right) e^{K(t_1 - t_2)}$$

- Note: *gentle* disturbance (such as mechanical rakes) allow for more compaction by breaking flocs and permitting water to escape

Ideal settling basin

- A continuous-flow basin can be divided into four zones:
  - (1) an inlet zone, in which water and suspended matter disperse over the cross-section;
  - (2) a settling zone, in which the suspended particles settle within the flowing water;
  - (3) a bottom zone, in which the solids accumulate and from which they are withdrawn as underflow; and
  - (4) an outlet zone, in which the flow and remaining suspended particles assemble and are carried to the effluent conduit

Ideal settling basin



Ideal settling basin

- All particles with a settling velocity $v_s \geq v_0$ are removed, v_0 being the velocity of the particle falling through the full depth h_0 of the settling zone in the detention time t_0
- Also, $v_0 = h_0/t_0$, $t_0 = V/Q$, and $V/h_0 = A$, where Q is the rate of flow, V the volumetric capacity of the settling zone, and A its surface area.
- Therefore, $v_0 = Q/A$ is the surface loading (in) or overflow velocity (out) of the basin.

Settling efficiency

- If y_0 particles possessing a settling velocity vs $\leq v_0$ compose each size within the suspension, the proportion y/y_0 of particles removed in a horizontal-flow tank becomes:

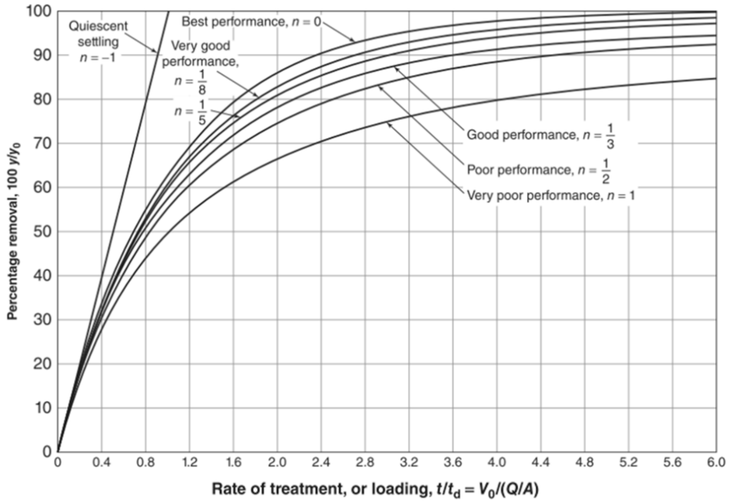
$$y/y_0 = h/h_0 = (v_s t_0)/(v_0 t_0) = v_s/v_0 = v_s/(Q/A)$$

- So in an ideal settling tank, the efficiency is hence independent of basin depth and or detention period!!!

Basin performance

- Currents can harm the settling process, including eddy currents, surface currents (induced by wind), vertical convection currents, density currents (hot water rises), current induced by inlet and/or outlet structure etc.
- We define "basin performance coefficient" n between 0 and 1

$$y/y_0 = 1 - [1 + n v_0/(Q/A)]^{-1/n}$$



Example

- Find the settling velocity and size of particles of specific gravity 1.001, of which 80% are expected to be removed in a very good settling basin (n=1/8) at an overflow rate of 40.8 $m^3/d.m^2$, if the water temperature is 10∘C (50∘F)

Answer

$$Q/A = 40.8\,\text{m}^3/\text{d}/\text{m}^2 = 40.8\,\text{m/d} = 4{,}080\,\text{cm}/\,(1{,}440 \times 60)\ \text{s}$$
$$= 0.0472\,\text{cm/s}$$
$$= 4.72 \times 10^{-2}\,\text{cm/s}.$$

From graph on next slide:

$$v_0/\,(Q/A) = 1.8 \text{ for } n = \frac{1}{8} \text{ and } y/y_0 = 80\%$$
$$v_0 = 1.8\,(Q/A) = 1.8\left(4.72 \times 10^{-2}\,\text{cm/s}\right)$$
$$= \mathbf{8.5 \times 10^{-2}\ cm/s}.$$

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