CE 418 Homework II

Spring 2019 | Due March 8 | B.A. DeVantier

Problem 1

Design a mixing tank, giving width, length, and water depth as well as a motor size. The design flow is 8 MGD. The mixing tank should supply 5 seconds of hydraulic retention and a mean shear of 1000 s^{-1}. Take manufacturer information on efficiency as 90%.

Design $Q = 8\ MGD$, $t_R = 5\ s$, $G = 1000\ s^{-1}$

Since $t_R = \forall / Q$, $\forall = Q\,t_R = \left(8\times10^6 \frac{gal}{day}\right)(5\ s)\left(\frac{1\ day}{86{,}400\ s}\right) = 463\ gal$

$\forall = (463\ gal)\left(\frac{1\ ft^3}{7.48\ gal}\right) = 61.9\ ft^3$

Since volume should be nearly cubic $L = (61.9\ ft^3)^{1/3} = 4.0\ ft$ //

use square horizontal x-section (4' x 4')

∴ water depth $d = \frac{61.9\ ft^3}{(4\ ft)^2} = 3.9\ ft$ depth //

Actual volume, $\forall = 3.9(4)^2 = 62.4\ ft^3$

$G = \left(\frac{P}{\mu \forall}\right) \Rightarrow P = \mu \forall G^2$ use $\mu = 2.735\times10^{-5} \frac{lbf\cdot s}{ft^2}$ @ 50°F

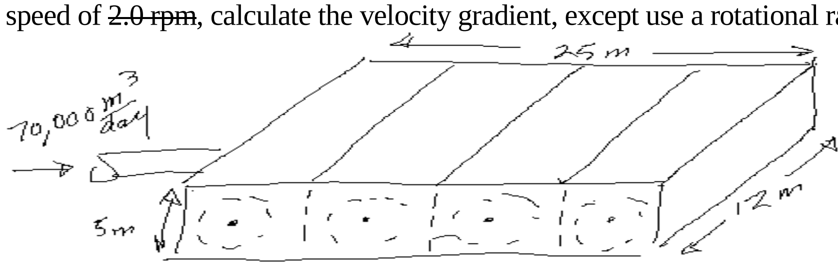
$P = \left(2.735\times10^{-5} \frac{lbf\cdot s}{ft^2}\right)(62.4\ ft^3)\left(1000 \frac{1}{s}\right)^2 = 1707 \frac{ft\text{-}lbf}{s}$

$P_{rated} = \frac{1707}{0.9} = 1896 \frac{ft\text{-}lbf}{s} = \frac{1896}{550}\left(\frac{hp}{\frac{ft\text{-}lbf}{s}}\right) = 3.45\ hp$

Use 5 hp // (rated) motor

Problem 2

Class Text Problem 10.9 (*changed* ~~value~~) A surface water treatment plant is being designed to process 70,000 m^3/d at a water temperature of 10°C has a four compartment flocculation tank with a total length of 25 m, width of 12 m, and a water depth of 5.0 m. The paddle flocculator in each of the four chambers between baffles has 4 blades, each 25 cm wide and 11.5 m long with the center line of the paddles at a radius of 1.8 m. Assume the velocity of the water is 30% of the paddle velocity and the drag coefficient is 1.8. At a rotational speed of ~~2.0 rpm~~, calculate the velocity gradient, except use a rotational rate of *2.3 rpm*.



4 boards

0.25m x 11.5 m

all @ radius 1.8m

$n = (4\ \text{chambers})(4\ \text{boards/chamber}) = 16$

$P = \frac{n}{2} C_d A \rho (1-k)^3 (2\pi N)^3 r_1^3$

$C_d = 1.8$

$r_1 = 1.8\ m$ $N = 2.3/60\ rev/s = 0.0383\ rev/s$

$k = 0.3$ $A = (0.25\ m)(11.5\ m) = 2.88\ m^2$

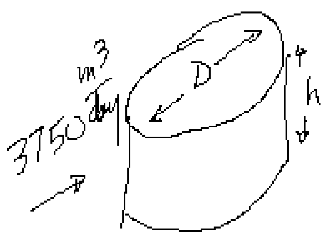
$$P = \frac{16}{2}(1.8)(2.88\, m^2)\left(1000 \frac{kg}{m^3}\right)(1-0.3)^3(2\pi)^3\left(0.0383 \frac{1}{s}\right)^3(1.8m)^3$$

$$= 1156 \frac{N \cdot m}{s} \qquad \mu = 1.307 \times 10^{-3} \frac{N \cdot s}{m^2} \text{ @ } 10^\circ C$$

$$G = \sqrt{\frac{1156 \frac{N \cdot m}{s}}{(5m)(12m)(25m)\left(1.307 \times 10^{-3} \frac{N \cdot s}{m^2}\right)}} = 24.3 \frac{1}{s} //$$

Problem 3

Class Text Problem 10.17 Calculate the diameter and depth of a circular sedimentation basin for a design flow of ~~3800 m^3/day~~ based on an overflow rate of 0.00024 m/s and a detention time of 3 hr, except use design flow of *3,750 m^3/day* and assume that construction dimension specifications will be in English units. Additionally, find the overflow and weir overflow rates in daily metric units.



$$V_o = 0.00024 \frac{m^3}{m^2 \cdot day} \qquad t_R = 3 hr$$

$$A = \frac{Q}{V_o} = \frac{3750\, m^3/day}{0.00024 \frac{m^3}{m^2 \cdot day}}\left(\frac{1\, day}{86{,}400\, s}\right) = 180.8\, m^2$$

$$A = \frac{\pi D^2}{4} \Rightarrow D = \left(\frac{4A}{\pi}\right)^{1/2} = \left(\frac{4(180.8\, m^2)}{\pi}\right)^{1/2} = 15.17 m = 49.77 ft$$

Round up to 50ft $\Rightarrow D = 15.24 m$ or $r = 7.62 m$

$$t_R = \frac{\forall}{Q} \Rightarrow \forall = Q\, t_R = \left(3750 \frac{m^3}{day}\right)(3 hr)\left(\frac{1\, day}{24 hr}\right) = 468.8\, m^3$$

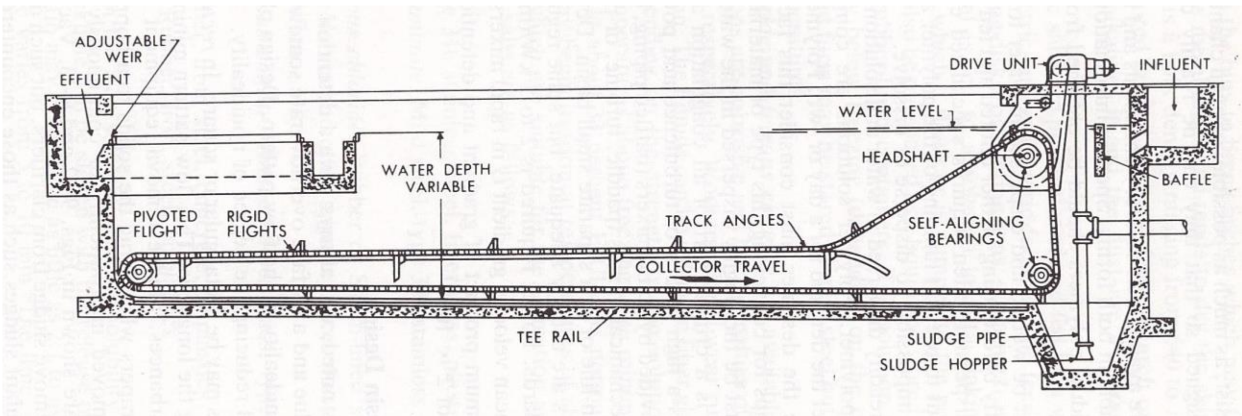
$$h = \frac{\forall}{A} = \frac{468.8\, m^3}{\pi (7.62 m)^2} = 2.57 m = 8.43 ft \text{ water depth}$$

$$V_o = \frac{Q}{A_s} = \frac{3750\, m^3/day}{\pi (7.62 m)^2} = 20.6 \frac{m^3}{m^2 \cdot day}$$

$$q_w = \frac{Q}{L_w}, \text{ but } L_w = \pi D \qquad q_w = \frac{3750\, m^3/day}{\pi (15.24 m)} = 78.3 \frac{m^3}{m^2 \cdot day}$$

Problem 4

Class Text Problem 10.19 A rectangular sedimentation basin will have a flow of ~~1 MGD~~ using a 2:1 length/width ratio, and overflow rate of 0.00077 fps, and a detention time of 3.0 hr. What will the dimensions of the basin be using 2.5 *MGD* flow and also give the overflow rate in units of gpd/ft^2, weir overflow rate for one double sided cross-trough and one single sided end trough, then compare both to typical values tabulated in the class text for activated sludge secondary settling units. Figure below is cross-section of tank



Perspective view

$L = 2W \qquad t_R = 3\text{ hr}$

$V_o = 0.00077 \frac{ft^3}{ft^2 \cdot s}$

$Q = \left(2.5 \frac{MG}{day}\right)\left(\frac{1.547\ ft^3/s}{MG/day}\right) = 3.87\ ft^3/s$

Since $V_o = \frac{Q}{A}$, $A = \frac{Q}{V_o} = \frac{3.87\ ft^3/s}{0.00077 \frac{ft^3}{ft^2 \cdot s}} \leq 5023\ ft^2$

but $A = LW = (2W)(W) = 2W^2$

$5023\ ft^2 = 2W^2$, so $W = \sqrt{\frac{5023}{2}} = 50.1\ ft$ //

$L = 2W = 2(50.1) = 100.2\ ft$ //

$\forall = Q t_R = \left(3.87 \frac{ft^3}{s}\right)(3\text{ hr})\left(\frac{3600\ s}{hr}\right) = 41800\ ft^3$

$h = \frac{\forall}{A} = \frac{41800\ ft^3}{5023\ ft^2} = 8.3\ ft$ //

Comparing to Table 10.2 for Final clarifier 4.5.

$V_o = 400 - 800 \frac{gpd}{ft^2} \qquad q_{0W} = 10{,}000 - 20{,}000 \frac{gpd}{ft}$

$V_o = \frac{2.5 \times 10^6\ gal/day}{5023\ ft^2} = 498 \frac{gal}{day - ft^2}$ OK, between 400-800

$L_W = 3W = 3(50.1\ ft)$

$q_{0W} = \frac{2.5 \times 10^6 \frac{gal}{day}}{3(50.1\ ft)} = 16{,}633 \frac{gal}{day \cdot ft}$ OK, between 10,000-20,000

Problem 5

Text Problem 10.35 *Use English units* Calculate the head loss through a clean sand filter with a gradation as given by the sieve analysis below. The filtration rate is ~~2.7 L/(m²-s)~~ 3*.0 gal/(ft²-min)* and the water temperature may be taken as a worst case scenario of 10˚C *50˚F*. The filter depth is 0.7 m *28 in* with a porosity of 0.45, and the sand can be estimated to have a sphericity of 0.77.

US Sieve Series #	12	16	20	30	40	50
Cumulative fraction retained	*0*	*0.06*	*0.27*	*0.78*	*0.97*	*1.00*

Spread sheet below uses class text Table 10.4 to take US Sieve numbers 12 to 50 to calculate geometric means

porosity	0.45				
Sphericity	0.77	v(gpm/ft^2)=	3	v(ft/s)=	0.00668278
		v (m/s) =	0.0020374		
				nu (m^2/s)	nu (ft^2/s)
				1.306E-06	1.405E-05

Sieve(mm)	Geomean (ft)	Cum.Fraction	P_i	$P_i/d_i/d_i$			
1.68		0					
1.19	0.00463769	0.06	0.06	2789.63459		h/l=	0.6218303
0.84	0.00327934	0.27	0.21	19527.4421			
0.59	0.00230908	0.78	0.51	95651.3692			
0.42	0.00163277	0.97	0.19	71269.6476			
0.297	0.00115845	1	0.03	22354.6476			
				211592.741	(1/ft^2)		

Table 10.4

Sieve #	Opening Size (mm)
200	0.074
140	0.105
100	0.149
70	0.21
50	0.297
40	0.42
30	0.59
20	0.84
18	1
16	1.19
12	1.68
8	2.38
6	3.36
4	4.76

depth $l = 0.7 m\left(\frac{3.28 ft}{m}\right) = 2.33 ft$

$$\left(3\frac{gal}{min \cdot ft^2}\right)\left(\frac{1 min}{60 s}\right)\left(\frac{1 ft^3}{7.48 gal}\right) = 0.00668 ft/s$$

$$\frac{h}{l} = \frac{5(36)(1.405\times10^{-5} ft^2/s)(1-0.45)^2(2.116\times10^{5}\frac{1}{ft^2})}{(32.2 ft/s^2)(0.45)^3(0.77)^2}\left(0.00668\frac{ft}{s}\right)$$

$$\frac{h}{l} = 0.622 \Rightarrow h = (0.622)(2.33 ft) = 1.45 ft$$

Problem 6

The Carbondale water treatment plant is designed to treat a maximum of 8 MGD with 6 dual media filters using 30 inches of sand and 18 inches of anthracite. The specification sheet provided by the firm which designed the plant defines the design loading to be 3.64 gpm/ft^2 at the minimum loading (based on maximum area at the bottom) and 4.63 gpm/ft^2 at the top. What is the loading at the top and bottom of one filter in gpm/ft^2 at the current operating rate of 6.0 MGD, assuming five of the six filters are in operation at any time?

For 1 filter @ design flow $Q = 8\,MGD/6 = 1.3\bar{3}\ MGD$

Using loading at top $V_{o,top}$; $A_{top} = \dfrac{Q}{V_{o,top}} = \dfrac{1.333\times10^6\ gal/day}{\left(4.63\ \frac{gal}{min\cdot ft^2}\right)\left(\frac{1440\ min}{day}\right)}$

$A_{top} = 200\ ft^2$

Similarly at bottom $A_{bot} = \dfrac{1.333\times10^6}{\left(3.64\ \frac{gal}{min\cdot ft^2}\right)(1440)} = 254.3\ ft^2$

Actual operating flow $Q = \dfrac{6.0\ MGD}{5} = 1.2\ MGD$ per operating filter

$$V_{o,top} = \frac{\left(1.2\times10^6\ \frac{gal}{day}\right)\left(\frac{1\ day}{1440\ min}\right)}{200\ ft^2} = 4.17\ \frac{gpm}{ft^2}$$

$$V_{o,bot} = \frac{\left(1.2\times10^6\right)\left(\frac{1}{1440}\right)}{254.3} = 3.28\ \frac{gpm}{ft^2}$$

Problem 7

The Carbondale water plant backwashes only one filter at a time. Design backwash loading is 20 gpm/ft^2 at the bottom of the filter. What is the backwash loading at the top of the filter based on the filter areas which can be determined from data in Problem 6?

Calling backwash rate V_o, $V_{o,bot} = 20\ \frac{gal}{min\cdot ft^2}$

$$V_{o,top} = \left(20\ \frac{gpm}{ft^2}\right)\left(\frac{254.3\ ft^2}{200\ ft^2}\right) = \underline{\underline{25.4\ \frac{gpm}{ft^2}}}$$