5 points total for entire homework

CEE 371 Fall 2009

Homework #7. Filtration

1. Determine the effective size (d_{10}, in mm) and the uniformity coefficient (UC) for the sand filter media characterized by the sieve analysis results presented in the following table. Include a plot of % Weight passing versus media size in your analysis.

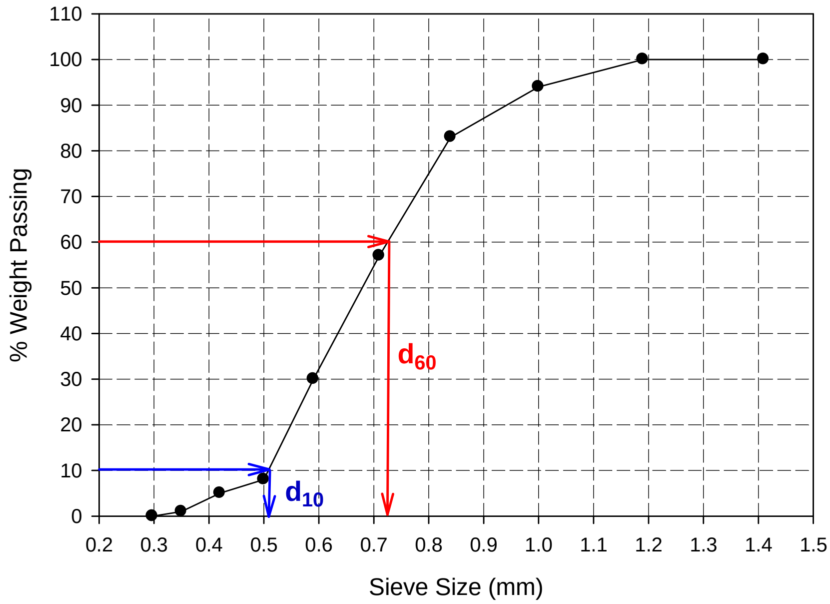
Sieve Number (mm size opening)	% Weight Passing
14 (1.41)	100
16 (1.19)	100
18 (1.00)	94
20 (0.84)	83
25 (0.71)	57
30 (0.59)	30
35 (0.50)	8
40 (0.42)	5
45 (0.35)	1
50 (0.297)	0

1 point for #1

Answer:

First plot % weight passing vs size of sieve opening in mm

Size (mm)	% Weight Passing
1.41	100
1.19	100
1.00	94
0.84	83
0.71	57
0.59	30
0.50	8
0.42	5
0.35	1
0.297	0



Therefore from the graph we estimate:

d_{10} = size @ 10% weight passing = ~0.51 mm

and the d_{60} appear to be about 0.73 mm, so

$$UC = \frac{d_{60}}{d_{10}} = \frac{0.73mm}{0.51mm} = 1.43$$

From Fig 7-13 in your text (pg 222), the typical media for sand in a dual media filter has an effective size of 0.45-0.55 mm and a uniformity coefficient of less than 1.7

Therefor, these d_{10} and UC values are typical for silica sand used in a dual-media filter

2. Consider the design of granular media filters for a water treatment plant with a design flow of 24 MGD:

   a) For a filtration hydraulic loading of 4 gpm/ft^2 determine the total filter area required for filtration (in square ft). Next, select the number of parallel filters needed, and their length and width (even foot increments), if each filter is square with area between 450 and 650 square feet.

1 point for #2a

Answer:

$$A_{total} = \frac{Q}{V_o} = \frac{24MGD\left(\frac{10^6 gal}{MG}\right)\left(\frac{60x24min}{day}\right)}{4\frac{gal/min}{ft^2}} = 4164ft^2$$

Number needed will be in the range of

$$\frac{4164ft^2}{650\frac{ft^2}{filter}} = 6.4\ filters\ or\ nominally\ 7$$

To

$$\frac{4164ft^2}{450\frac{ft^2}{filter}} = 9.25\ filters\ or\ nominally\ 10$$

If you select 8 filters, each will be $4164ft^2/8$ or $520ft^2$ in area.

Then the linear dimensions for a square filter box will be:

$$x = \sqrt{520ft^2} = 22.8ft\ , nominally\ 23\ ft$$

So the options include this one as well as those selecting 7 and 9 filters as follows:

# filters	Length (ft)	Width (ft)
7	25	25
8	23	23
9	22	22

Note that selection of 8 filters at the slightly larger size of 25x25 ft would allow you to meet the design filtration rate with one filter off line.

b) Choose a dual media filter consisting of 20 inches of anthracite with an effective size (ES) of 1.1 mm over 12 inches of sand with an ES of 0.45 mm. The porosity of the anthracite layer is 0.40 and the sand porosity is 0.36. Determine the superficial filtration velocity and the pore velocities in both the anthracite and sand layers in both ft/min and m/hr units.

1 point for #2b

Answer:

First calculate superficial velocity which will be the same for both filters

$$V_o = 4\frac{gal/min}{ft^2}\left(\frac{1ft^3}{7.48gal}\right) = \boxed{0.53\ {}^{ft}/_{min}}$$

and

$$V_o = 0.53\ {}^{ft}/_{min}\left(\frac{60min}{hr}\right)\frac{1m}{3.28ft} = \boxed{9.7\ {}^{m}/_{hr}}$$

Now recall that the pore velocity is just the superficial velocity divided by the porosity, so:

Media	Porosity	Pore Velocity	
		(ft/min)	(m/hr)
Anthracite	0.40	1.33	24.3
Sand	0.36	1.47	26.9

c) Calculate the detention time (in minutes) through the entire depth of the filter.

Answer:

For the anthracite media:

$$t = \frac{bed\ depth}{pore\ velocity} = \frac{L}{V_o/_\epsilon} = \frac{20in\frac{1ft}{12in}}{1.33\frac{ft}{min}} = 1.25min$$

For the sand media:

$$t = \frac{bed\ depth}{pore\ velocity} = \frac{L}{V_o/_\epsilon} = \frac{12in\frac{1ft}{12in}}{1.47\frac{ft}{min}} = 0.68min$$

So the total detention time is the sum:

t = 1.25 min + 0.68 min = 1.9 min

0.5 points for #2c

d) Calculate the clean bed head loss (in feet) for the filter using the Carmen-Kozeny equation. Assume a water temperature of 68 ºF and the design hydraulic loading rate. Also assume a value of 5 for the constant "k" in the Carmen-Kozeny equation (slides for Lecture #19). Use the media effective size for media diameter in the calculation.

0.5 points for #2d

e) What is the clean bed head loss if the filtration rate was 6 gpm/ft^2? What is the clean bed head loss if the water temperature is 40 ºF at the design loading rate?

0.5 points for #2e

f) If the entire filter depth was sand of the same size as the sand used in the dual media, and the total filter media depth was also the same, what would the clean bed head loss be for the conditions of part (d)?

0.5 points for #2f

These three all involve the Carmen Kozeny Equation, so I answer all three together.

$$\frac{\Delta H}{L} = \frac{36k(1-\varepsilon)^2 \nu V_0}{\varepsilon^3 d_c^2 g}$$

Also note that the kinematic viscosity is

1.664 x 10^{-5} ft^2/s @ 40ºF

1.091 x 10^{-5} ft^2/s @ 68ºF

You can find this information from many textbooks and web sources, such as:
http://www.engineeringtoolbox.com/water-dynamic-kinematic-viscosity-d_596.html

				Prob (d)	Prob (e)		Prob (f)
				68ºF	68ºF	40ºF	68ºF
Media	Depth (ft)	Porosity	Dia (mm)	4 gpm/ft^2	6 gpm/ft^2	4 gpm/ft^2	4 gpm/ft^2
Anthracite	1.67	0.40	1.1	0.39	0.59	0.60	
Sand	1.00	0.36	0.45	2.19	3.28	3.34	5.85
			Total	2.58	3.87	3.94	5.85