Ministry of Higher Education and Scientific Research
Southern Technical University
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Water Quality Control

For

Students of forth class
Department of Environment and Pollution Engineering
Basrah Engineering Technical College

By

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PRELIMINARY TO TREATMENT PROCESS

second modular unit

Rationale :-

To protect the main units of a treatment plant and to aid in their efficient operation it is necessary to remove the large floating and suspended solids which are often present in the inflow. These materials include leaves, paper, plastics, rags and other debris which could obstruct flow through a plant or damage equipment in the plant. Therefore, this modular unit has been designed for this knowledge to be understood.

Central Idea :-

1 - Introduction

2 –Screening

a - Purpose

b – Types of Screens

c – Design Consideration

3 – Grit Chamber (Sand Trap)

a - Purpose

b – Types of Grit Chambers

c – Design Consideration

4- Velocity Control Device.

4-1 Proportional Flow Weir

The Text :-

Screening:-

a- Purpose:

Screening of sewage is done for removing floating matter like pieces of wood, charcoal, leaves, etc. The problems appear from eliminating screen while treating sewage is:

1- Clog the pumps
2- Form ugly sludge banks at the disposal site if disposal done without treatment.
3- Clog the trickling filter bed.
4- Interfere in the activated sludge treatment units.

Screens mechanically or manually cleaned normally used for this purpose.

b- Type of screens:

Screens are classified into different categories as given below:
As per size of opening: fine, medium &coarse screens.
As per shape: disc, drum, cage, wing, bar….etc.
As per method of setting: fixed, moving, movable ….etc.
As per method of cleaning: manual cleaning or mechanical cleaning.

* The opening in coarse screen is 50 mm or above; medium screen is varying from 20-50 mm; fine screen is smaller than 20 mm.

** For large size sewage treatment plants mechanical screens are found more suitable. Wherever the average quantity of sewage exceeds $400 m^3/hr.$, mechanical screens are recommended. All mechanically cleaned medium screens should be preceded by a coarse screen which is manually cleaned.

C- Design considerations:

1- Horizontal velocity through a screen chamber:

$V_H > 0.6$ m/s (grit bearing sewage)

$V_H > 0.3$ m/s other sewage

2- Effective area of the screen should be such as to product a velocity through the screen opening not exceeding 1.2 m/s at maximum discharge.

3- Min. freeboard is 300 mm above the highest flow level.

4- The screen bars are provided with flats of 10 mm maximum thickness and not less than 50 mm deep.

5- Maximum screen width is 1.5 m and min. width is 0.6 m.

6- The angle of inclination of manually cleaned screen are 45^0 to 60^0 with the horizontal and 75^0 to 80^0 for mechanical screens.

7- Head loss:

$$h_L = 0.0729\,(V^2 - v^2)$$

in which ,

h = head loss in (m)

V = velocity through the screen (m/s)

v=approach velocity through the channel (m/s)

Allowable head loss , clogged 150 mm =15cm

Max. head loss , clogged 800 mm = 80cm

8- Length of screen channel:

$$L = (d_c + 0.3)\cot(\alpha) + 1.73\,(w_c + d)$$

Where:

L = length of screen channel ,(m)

d_c = depth of flow in screen chamber ,(m)

α = angle of the screen with the horizontal plane
w_c = width of screen chamber ,(m)
d = diameter of incoming screen sewer, (m)

The length of screen channel should be sufficient, so that the screen can be properly honest, working space should be available, flow can be stabilized and eddies are avoided.

Note: after computation of cross - sectional area of screen and fixing the size and spacing of bars ….etc , checking has to be done for determining the velocity of the flow.

9- Slope of the channel :
It is computed using Manning's formula.

$$v = (1/n) . (R)^{2/3} . (s)^{1/2}$$

v = velocity through the channel, (m/s)
n = roughness parameter
R = hydraulic radius = A/P , P: wet parameter (m)
A: wet area (m^2)
s = slop of the channel

Grit Chambers (Sand Trap)

Grit chambers are constructed primarily to remove grit, consisting of sand, gravel, cinders and other inorganic heavy materials of course sizes, along with grit some heavier particles of organic maters get settled in the grit chamber.

a- Purpose:

i. Grit chamber is provided to protect mechanical equipment from abrasion and abnormal wear.
ii. To reduce formation of heavy deposits in pipe and conduits.
iii. To reduce the size or frequency of cleaning of digesters.

b- Type of grit chambers:

i. As per method of cleaning: manual or mechanical cleaning
ii. As per flow: horizontal flow spiral movement (Aerated grit chamber)
iii. Detritus tank: grit chamber with rotating arms for collection of grits in square tanks.

c- Design consideration:

i. Settling velocity:

Grit chamber may be designed on a rational basis by considering it as a sedimentation basin. The grit particles are treated as discrete particles settling with their own settling velocities. The minimum size of the grit to be removed is (0.15-0.2) mm.

a) Stock`s law

$$V_S = \frac{g}{18} \cdot \frac{(P_s - P)}{P} \cdot \frac{d^2}{V}$$

or

$$V_s = \frac{g}{18}(s_s - 1)\frac{d^2}{V}$$

Where:

V_s = settling velocity (m/s)
g = acceleration due to gravity, (= 9.81m/s^2)
P_s = mass density of grit particle, kg/m^3
P = mass density of liquid, kg/m^3
S_s = specific gravity of grit particle, dimensionless (=2.5)
d = size of the particle, m
V = kinematics viscosity of sewage, (= 1.01 * 10^{-6} m^2/s)

This relation corresponds to particles of sizes less than 0.1 mm. The flow conditions are laminar (Reynolds number is less than 1) where viscous forces dominate over inertia forces.

b) Transition law :

The design of grit chamber is based on removal of grit particles with minimum size of 0.2 mm or 0.15 mm and therefore, stock's law is not applicable to determine the settling velocity of the grit particles for design purposes.

The settling velocity of a disc rate particle is given by the general equation:

$$V_s = \sqrt{\frac{4}{3}.\frac{g}{c_D}.\frac{(P_S - P)}{P}.d}$$

Where, C_D is the Newton coefficient or drag which is a function of Reynolds number. The transition flow conditions held when Reynolds number is between 1 and 1000. In this range, C_D can be approximated by:

$$C_D = \frac{18.5}{R^{0.6}} = \frac{18.5}{(\frac{V_S.d}{V})^{0.6}}$$

Substituting the value of C_D in above equation and simplifying:

$V_S = [0.707(S_s - 1).d^{1.6}.V^{-0.6}]^{0.714}$ For grit particles in the range of (0.1mm&1mm).

The settling velocity of grit particles in the transient zone is also calculated by the Hazen`s modified formula:

$V_S = 60.6(s_s - 1)d.\frac{3T+70}{100}$ To remove particle size of 0.15 mm or 0.2 mm.

When d in above equation is in cm and T is the temperature in degree and V_S in cm/s.

c) Newton`s law:

When the particle size increases beyond 1mm and Reynolds number beyond 1000, the coefficient of drag C_D assumes a constant value of 0.4 and the following equation can be used to determine the settling velocity of grit particles.

$$V_S = [3.3g(S_S - 1).d]^{0.5}$$

ii. Surface over flow rate:

Efficiency of an ideal settling basin

$$(\eta) = \frac{V_S(settling\ velocity)}{surface\ over\ flow\ rate(S.O.R)}$$

$$(S.O.R) = \frac{Q(flow)}{A(Plan\ area\ of\ the\ Tank)}$$

In an ideal settling basin, all particles having settling velocity $V_S \geq$ S.O.R are completely removed. However, the behavior of a real grit chamber departs significantly from that of the ideal settling basin due to turbulence. The following equation could be used to determine the SOR for a real basin for a given efficiency of grit removal and basin performance.

$$\eta = 1 - \left[\frac{1 + n.V_S}{(S.O.R)}\right]^{-(\frac{1}{n})}$$

Where,

η = desired efficiency of removal grit particle

V_S= settling velocity of the minimum size of grit particle to be removed

(S.O.R) or (Q/A): design surface over flow rate

n: an index which is a measure of the basin performance

n = 0.125 (very good)
= 0.25 (good)
= 0.5 (poor)
= 1.0 (very poor)

iii. Detention period:

A detention period between 45 to 60 sec is usually adopted for horizontal flow grit chamber and between 3 to 5 minutes for aerated grit chamber is adopted.

iv. Bottom scour and flow through grit chamber:

Bottom scour is an important factor effecting grit chamber efficiency. The scouring process itself determines the optimum velocity of flow through the unit. This may be explained by the fact that there is a critical velocity of flow V_c beyond which particles of a certain size and density once settled, may be again placed in motion and reintroduced in the stream of flow. The critical velocity of scour may be calculated from modified schield`s formula:

$$V_C = \sqrt{\frac{8k}{f}(S_S - 1).g.d}$$

k=0.04

f= 0.03

Note: Horizontal velocity V_h should be less than V_c

Velocity Control Device

Numerous devices have been designed in an attempt to maintain a constant horizontal velocity of flow through grit chamber in the recommendation range of 0.15 to 0.30 m/s is used at peak flows.

A satisfactory method of controlling velocity of flow through grit chamber is by:

i. Using a control section which placed at the end of channel.
ii. Varies the cross-sectional areas of flow in the section in direct proportion to the flow.

Each grit chamber should provide with separate control device:

i. Throat control weir
ii. Proportional flow weir
iii. Parshall flume

Proportional Flow Weir

The proportional flow weir is a combination of a weir and an orifice. It maintains a nearly constant velocity in the grit channel by varying the cross-sectional area of flow through the weir so that the depth is proportional to flow.

i- The general equation for determining the flow through weir, Q, is:

$$Q = c.b.\sqrt{2ag}.(H - \frac{a}{3})$$

Where,

c: a coefficient which assumed 0.61 for symmetrical shape – edge weirs.

a: dimension of weir usually assumed between 25 mm and 50 mm

b: base width of the weir

H: depth of flow

ii- To determine the shape of curve forming the outer edges of the cut portion, the following equation of curve forming the edge of the weir may be used:

$$x = \frac{b}{2}\left(1 - \frac{2}{\pi}\tan^{-1}\sqrt{\frac{y}{a} - 1}\right)$$

The weir shall be set 100mm to 30mm above the bottom of grit chamber to provide grit storage or for operation of mechanical grit chamber.

v- Number of units:

In case of manually cleaned grit chambers at least two units should be provided. All mechanically cleaned units should be provided with a manually cleaned unit to act as a bypass. (At least two units provided).

vi- Dimensions of each unit:

i. The width of tank is fixed with reference to the control device adopted.
ii. The length is worked out on the basis of the select over flow rate.
iii. The depth of the flow is determined by the horizontal velocity and the peak flow.

$$Total\ Depth = Computed\ water\ depth + Free\ board + Depth\ due\ to\ grit\ storage\ space$$

$$(0.15 - 0.3m) \quad (0.25\ of\ water\ computed\ depth)$$

Illustrated Problems

Problem 1:- Design a bar screen for 35 MLD sewage flow so that velocity through the screen does not fall below 0.8 m/s. Assume (i) depth of flow = 0.9 m (ii) diameter of incoming sewer = 0.5m (iii) roughness parameter=0.024 (iv) angle of inclination=60^o (v) screen with bars of flat size 10mm * 50mm and 20mm clear opening. Find the followings:

1- Calculate the width and length of screen.
2- Calculate the head loss and check for half plugged flow.
3- Calculate the slope of the channel.

Solution :-

Q= 35 MLD = 0.405 m^3/s

Velocity through the screen = 0.8 m/s

Area of opening = $\frac{0.405}{0.8}$ = 0.506 m^2

Width of clear opening = $\frac{0.506}{0.9}$ = 0.562m

No. of openings=(0.562*1000)/20=28

No. of bars = 28-1=27

Total width of the screen = 0.562 + $\frac{27*10}{1000}$ = 0.832m

V= $\frac{0.405}{0.506}$ = 0.8m/s

v=$\frac{0.405}{0.832*0.9}$ =0.54m/s

h_L = 0.0729 ($(0.8)^2 - (0.54)^2$) = 0.0225m

For half plugged screen

h_L = 0.0729 ($1.6^2 - 0.54^2$)= 0.165m = 16.5 cm

Calculation of the length of the channel

L= (d_c+ 0.3) cot$\propto$ +1.73 (w_c + d)

L= (0.9+0.3) $\frac{1}{tan60}$ +1.73 (0.832+0.5) = 2.997m $\approx 3m$

Calculation of the slope of the channel

V= $\frac{1}{n}$. $R^{2/3}$. $S^{1/2}$

v= 0.54m/s , R = A/P = 0.285

0.54=$\frac{1}{0.024}$.$(0.285)^{2/3}$. $(S)^{(1/2)}$ $\longrightarrow$ S= 0.0009

Problem 2: Design grit chamber to treat peak design flow of 150MLD (3X average waste water flow of 50 MLD) of waste water to remove grit particles up to size 0.15mm and the specific gravity of 2.65. The grit chamber is equipped with proportion flow weir as control devise. $\nu = 1.14*10^{-6}$ m^2/s. Determine the following:

- i- Settling velocity.
- ii- Surface over flow rate, assuming that η = 75% , n=1/8.
- iii- Dimension of grit chamber.
- iv-Proportional flow weir.

Solution:-

i) Computation of settling velocity

Applying Stocke`s law

$V_s = \frac{g}{18} (S_S - 1) \frac{\delta}{\nu}$

Given S_S = 2.65, d= $0.15*10^{-3}$ m

$V_s = \frac{9.81}{18}(2.65 - 1)\frac{(0.15*10^{-3})^2}{1.14*10^{-6}}$ = 0.018 m/s

Check for Reynolds Number, R

$R = \frac{V_s\, d}{\nu} = \frac{0.018*0.15*10^{-3}}{1.14*10^{-6}} = 2.37 > 1.0$

Hence Stocke`s law does not apply

Applying transition law for $1.0 < R < 10^3$

$V_s = [\, 0.707 (S_s - 1) d^{1.6} \nu^{-0.6}]^{0.714}$

$= [0.707(2.65-1)(0.15*10^{-3})^{1.6}(1.14*10^{-6})^{-0.6}]^{0.714} = 0.0168 m/s$

ii) Computation of surface overflow rate, SOR

The surface overflow rate = settling velocity of the minimum
For 100% removal efficiency size of particle to be removed
in an ideal grit chamber

$= \frac{V_s}{SOR} = 1$

V_S = SOR = 0.0168m/s = 1451.5 $m^3/m^2/day$

$\mu = 1 - (1 + n \frac{V_s}{\frac{Q}{A}})^{-1/n}$

When η = efficiency of removal of desired particle n=measure of settling basin performance

=1/8 for very good performance

Assuming η = 75% , n=1/8

$$\left(\frac{Q}{A}\right) = \frac{V_s\ n}{[1-0.75]^{-n}\ -1} = \text{SOR}$$

$$= \frac{1451.5*\frac{1}{8}}{(1-0.75)^{-0.125}\ -1} = 959 m^3/m^2/d$$

iii) Determination of the dimensions of grit chamber

Plan area of grit chamber = [Q / (Q/A)]

$959=\frac{Q}{A} \longrightarrow A=\frac{Q}{959} \longrightarrow A=\frac{150*10^3}{959}=1564 m^2$

H.W:- Check the dimension with the design criteria

Provide 4 channels of 2.5m wide and 16m long

The critical displacement scouring velocity to initiate re-suspension of grit is given by $V_c=[\frac{8k}{f}(S_s-1)gd]^{0.5}$

For k=0.04 , f=0.03 , S_s=2.65 , d=0.15*10^{-3}m V_c=0.161m/s

The horizontal velocity of flow V_h should be kept less than critical displacement velocity V_c

Assume V_h=0.158 m/s <0.161 m/s O.K.

Q=150 MLD=1.736 m^3/s

Depth= 1.736/(0.158*2.5*4)= 1.1m

$\frac{V_h}{V_s} = \frac{0.158}{0.0168} = 9.4$ closer to 10 hence (O.K.)

The hydraulic residence time at peak flow is

$$HRT = \frac{volume}{peak\ discharge} = \frac{4*2.5*16*1.1}{1.736} = 101.38\ second$$

Total depth of grit chamber = water depth +free board +grit storage space

=1.1+0.25+(0.25*1.1)=1.625m

Provide 4 channel of grit chamber , each 16m*2.5m*1.625m

iv) Design of proportion flow weir

Peak flow for each weir= (1.736/4) = 0.434m^3/s
Flow through a proportional flow weir is given by

$$Q=Cb\sqrt{2ag}[h-(a/3)]$$

For symmetrical sharp – edged weir , c=0.61
Assuming a=35mm(usually between 25-50mm)
h=1.1m at peak flow

$0.434=0.61*b(2*0.035*9.81)^{0.5}(1.1-0.035/3)$
b=0.79 say 0.80m

To determine the coordinates (x,y)of the curve forming the edge of the weir assume suitable four values of y and compute corresponding values of x using equation

$$x=b/2[1-\frac{2}{\pi}\tan^{-1}\sqrt{y/a}-1]$$

The coordinates for proportional flow weir are listed below

SI.NO.	Y,m	x,m
1	a=0.035	0.400
2	5a=0.175	0.12
3	10a=0.35	0.082
4	20a=0.7	0.057
5	30a=1.05	0.047
6	40a=1.40	0.040

<u>H.W. :- Draw the proportional weir</u>

Test 1:-

Circle the correct answer:-

1. **Screening of sewage is done essential for removing:-**

a-Floating matter b- Suspended solid

c- Bacteria d- All of above

2. **Screens are classified as per:-**

a-Size of opening b- Shape

c- Method of seating d- Method of cleaning

e- All above

3. **Horizontal velocity through screen chamber ranges from:**

a- 0.3- 0.6 m/s b- 0.15-0.5m/s

c- More than 0.6m/s d- Less than 0.1m/s

4. **The width of screen ranges from :**

a- 0.3-2.5 m b- 0.6-1.5m

c- 0.6-2.0m d- 1.0-2.0 m

5. **Slope of screen channel governed by:**

a- Darcy's equation b-Hazen Willam's eq.

c- Manning formula d- Newton formula

6. **Grit chamber is provided to :**

a- Protect mechanical equipment b- Reduce size of digester

c- Reduce formation of heavy deposit d- All of above

7. **Settling velocity of laminar flow is computed by :**

a- Stock's law b- Newton's law

c- Hazen modified formula d- Transition law

8. **The efficiency of ideal grit chamber basin is equal to:**

a- S.O.R b- Settling velocity

c- 100% d-All of above

9. **Detention period of aerated grit chamber ranges :**

a- 45-60 sec b- 3-5 minutes

c- 90-120 sec d- 15-20 minutes

10- **The velocity of scouring should be :**

a- Greater than horizontal velocity b- Less than horiz. velocity

c-Greater than or equal d- Equal to horiz. velocity

Test 2:-

Design a screen chamber for a peak discharge of 0.5 m^3/s if the following data are given:

i) Diameter of incoming sewer = 0.65m

ii) Inclination of bar screen= 45°

iii) Clear opening of screen =20mm

iv)Bars made of 15mm *50mm of flats.

v) Velocity through the screen =V=0.8m/s

Calculate the length of the screen chamber and the hydraulic loading for peak flow.

key Answer :-

1- Test 1 :-

1. a
2. e
3. a
4. b
5. c
6. d
7. a
8. d
9. b
10. a

If you :-

- got 9 or more you do not need to proceed .
- got less than 9 you have to study this modular unit well .

2- Test 2:-

Solution:-

Area of screen opening $w_s = \frac{0.5}{0.8} = 0.625\ m^2$ (1 mark)

Submerged length of screen = $l_s = \frac{Q}{Ws.V} = \frac{0.5}{0.625*0.8} = 1.2m$ (1mark)

Depth of flow = $d_c = l_s\ .\sin\propto = 1.2 * \sin 45 = 0.85m$ (1 mark)

Number of screen opening = $\frac{0.625*1000}{20} = 31$ (1 mark)

Number of bar= 31-1=30 (1 mark)

Width of screen chamber= $w_c = 0.625 + \frac{30*15}{1000} = 1.075m$ (1 mark)

Approach velocity of chamber

$V = \frac{Q}{Ws*dc} = \frac{0.5}{1.075*0.85} = 0.547 m/s$ (1 mark)

Length of screen chamber

$L = (d_c+0.3)\cot\propto + 1.73\ (w_c+d)$

=(0.85+0.3)cot45+1.73 (1.075+0.65)=4.31m (1 mark)

Discharge = $0.4 m^3/s$=43.2MLD

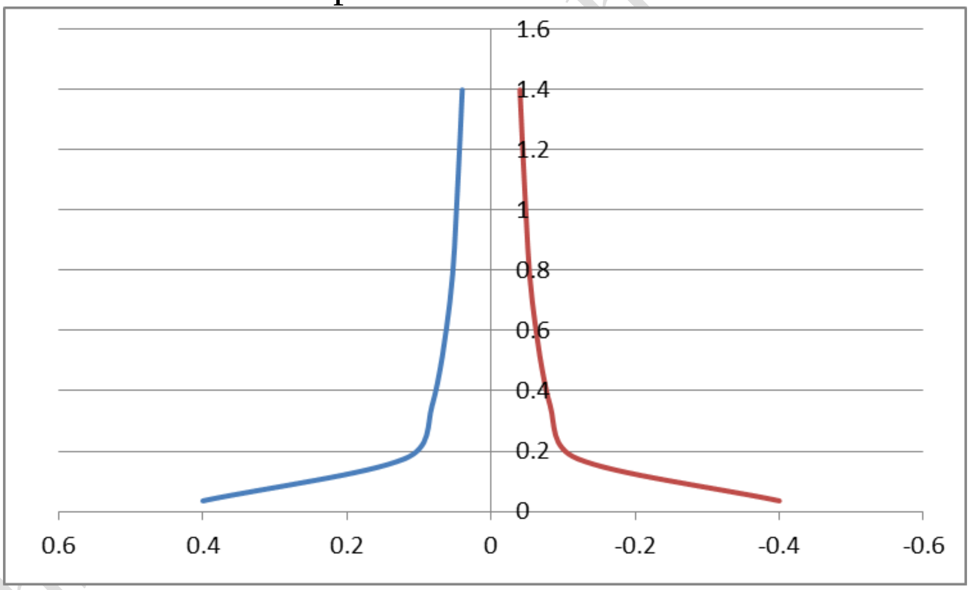
Hydraulic loading for beak flow

$= \frac{Q}{Wc*dc} = \frac{43.2}{1.075*0.85}$ = 47 $Ml/m^2/d$ (2 mark)

If you :-

- got 9 or more , so congratulation your performance , go on studying modular unit three .
- got less than 9 , go back and study the second unit ; or any part of it ; again, and then do the post test again .

H.W. Solution: Proportional Flow Weir



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