Module 15 : Grit Chamber

Lecture 19 : Grit Chamber

Grit chamber is the second unit operation used in primary treatment of wastewater and it is intended to remove suspended inorganic particles such as sandy and gritty matter from the wastewater. This is usually limited to municipal wastewater and generally not required for industrial effluent treatment plant, except some industrial wastewaters which may have grit. The grit chamber is used to remove grit, consisting of sand, gravel, cinder, or other heavy solids materials that have specific gravity much higher than those of the organic solids in wastewater. Grit chambers are provided to protect moving mechanical equipment from abrasion and abnormal wear; avoid deposition in pipelines, channels, and conduits; and to reduce frequency of digester cleaning. Separate removal of suspended inorganic solids in grit chamber and suspended organic solids in primary sedimentation tank is necessary due to different nature and mode of disposal of these solids. Grit can be disposed off after washing, to remove higher size organic matter settled along with grit particles; whereas, the suspended solids settled in primary sedimentation tank, being organic matter, requires further treatment before disposal.

15.1 Horizontal Velocity in Flow Though Grit Chamber

The settling of grit particles in the chamber is assumed as particles settling as individual entities and referred as Type – I settling. The grit chamber is divided in four compartments as inlet zone, outlet zone, settling zone and sludge zone (Figure 15.1)

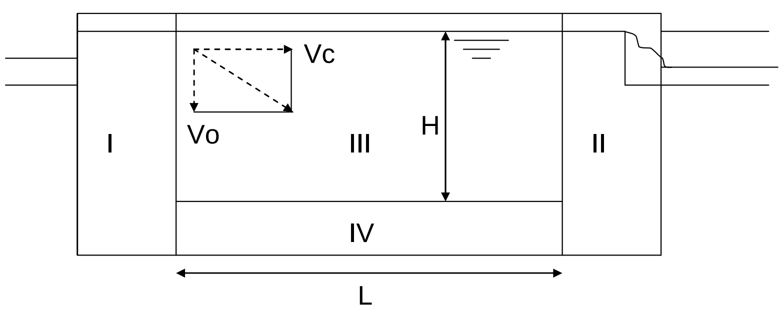

Figure 15.1 Compartments of grit chamber

Zone – I: Inlet zone: This zone distributes the incoming wastewater uniformly to entire cross section of the grit chamber.

Zone – II: Outlet zone: This zone collects the wastewater after grit removal.

Zone – III: Settling zone: In this zone settling of grit material occurs.

Zone – IV: Sludge zone: This is a zone where settled grit accumulates.

L – Length of the settling zone

H – Depth of the settling zone

v – Horizontal velocity of wastewater

Vo – Settling velocity of the smallest particle intended to be removed in grit chamber.

Now, if Vs is the settling velocity of any particle, then

For Vs ≥ Vo these particles will be totally removed,

For Vs < Vo, these particles will be partially removed,

Where, Vo is settling velocity of the smallest particle intended to be removed. The smallest particle expected to be removed in the grit chamber has size 0.2 mm and sometimes in practice even size of the smallest particle is considered as 0.15 mm. The terminal velocity with which this smallest particle will settle is considered as Vo. This velocity can be expressed as flow or discharge per unit surface area of the tank, and is usually called as 'surface overflow rate' or 'surface settling velocity'. Now for 100 percent removal of the particles with settling velocity Vs ≥ Vo, we have

Detention time = L/v = H/Vo

Or L/H = v/Vo (1)

To prevent scouring of already deposited particles the magnitude of 'v' should not exceed critical horizontal velocity Vc, and the above equation becomes

L / H = Vc / Vo

The critical velocity, Vc, can be given by the following equation (Rao and Dutta, 2007):

$$Vc = \sqrt{\left[\frac{8\beta}{f} g(S-1)D\right]} \quad (2)$$

where, β = constant

= 0.04 for unigranular sand

= 0.06 for non-uniform sticky material

f = Darcy –Weisbach friction factor = 0.03 for gritty matter

g = Gravitational acceleration,

S = Specific gravity of the particle to be removed (2.65 for sand), and

D = Diameter of the particle, m

The grit chambers are designed to remove the smallest particle of size 0.2 mm with specific gravity around 2.65. For these particles, using above expression the critical velocity comes out to be Vc = 0.228 m/sec.

15.2 Settling Velocity of the Particles

Settling velocity of any discrete particle depends on its individual characteristics and also on the characteristics of the fluid. Assuming particles to be spherical, the settling velocity of any particle, Vs, can be given by the following formula:

$$Vs = \sqrt{\left[\frac{4}{3}\frac{g}{C_D}(S-1)D\right]} \qquad (3)$$

where, C_D = Newton's drag coefficient

$$= \frac{24}{R} + \frac{3}{\sqrt{R}} + 0.34 \quad \text{for } 0.3 < R < 10^4$$

= 24 / R, when R < 0.3

R = Reynold's Number = Vs.D/ν

ν = Kinematic viscosity of the fluid

For the value of R < 0.3, C_D = 24/R and the above equation becomes (Stoke's Law)

$$Vs = \frac{g}{18}\left[\frac{S-1}{\nu}\right]D^2 \qquad (4)$$

For the value of R > 0.3, the value of Vs should be worked out by trial and error.

15.3 Horizontal Flow Rectangular Grit Chamber

A long narrow channel is used in this type of grit chamber (Figure 15.2). The wastewater moves through this channel in more or less plug flow condition with minimal mixing to support settling of the particles. Higher length to width ratio of the channel is used to minimize mixing. For this purpose a minimum allowance of approximately twice the maximum depth or 20 to 50% of the theoretical length of the channel should be given for inlet and outlet zones. The width of this channel is kept between 1 and 1.5 m and the depth of flow is normally kept shallow. A free board of minimum 0.3 m and grit space of about 0.25 m is provided. For large sewage treatment plant, two or more number of grit chambers are generally provided in parallel. The detention time of 30 to 60 seconds is recommended for the grit chamber.

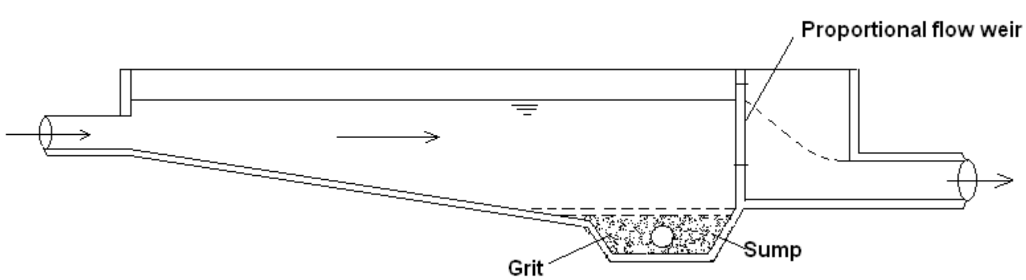

Figure 15.2 Horizontal flow grit chamber

15.4 Control of Velocity Through the Grit Chamber

With variation in sewage flow received at treatment plant, it is important that velocity of the wastewater in the grit chamber should be maintained nearly constant. Otherwise when flow is lower, deposition of not only inorganic solids but also organic solids will occur in grit chamber due to lowering of velocity. With flow higher than average, when the velocity will exceed the critical velocity, scouring of already deposited grit particles will occur leading to failure of performance. Hence for proper functioning, the velocity should not be allowed to change in spite of change in flow in the grit chamber. This can be achieved by provision of proportional weir (Figure 15.3) or Parshall flume (Figure 15.4) at the outlet end of grit chamber. The shape of the opening between the plates of a proportional weir is made in such a way that the discharge is directly proportional to liquid depth in grit chamber. As a result the velocity of water in the chamber will remain constant for all flow conditions.

The discharge through proportional weir can be given by the following equation (Rao and Dutta, 2007):

$$Q = C.b\sqrt{2ag}.\left[H - \frac{a}{3}\right] \tag{5}$$

where, Q = Discharge, m^3/sec[1]

C = constant, 0.61 for symmetrical sharp edged weir

a = 25 to 35 mm as shown in the Figure 15.3.

b = base width of the weir

H = Height of water above the crest of weir

The equation of the curve forming the edge of the weir is given by the following formula:

$$x = \frac{b}{2}\left[1 - \frac{2}{\pi}\tan^{-1}\sqrt{\left(\frac{y}{a} - 1\right)}\right] \tag{6}$$

The sharp edges generated by the curve at the bottom are curtailed on both the side, because such small opening will not contribute for flow due to deposition of solids. These edges are curtailed from the side wall at a distance of minimum 75 mm and height of the vertical edge 'a' is in the range of 25 to 35 mm. To compensate this loss of area the edge of the weir is lowered by a/3 than the theoretical level.

[1] $Q = Cd\,(2g)^{1/2}\,L\,H^{3/2}$ for normal sharp crested weir, where as in proportional weir $Q \propto H$ instead of $H^{3/2}$

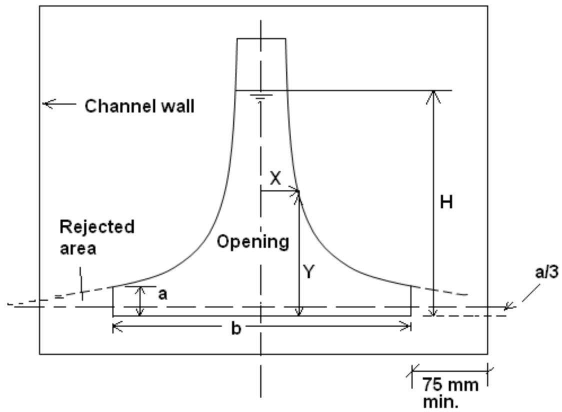

Figure 15.3. Proportional Weir

Alternatively, Parshall flume can be placed at the end of the grit chamber (Figure 15.4). The design details for Parshall flume to meet different discharges are provided in the CPHEEO manual (1993). With appropriate arrangement this will also facilitate recording of the discharge received at the sewage treatment plant.

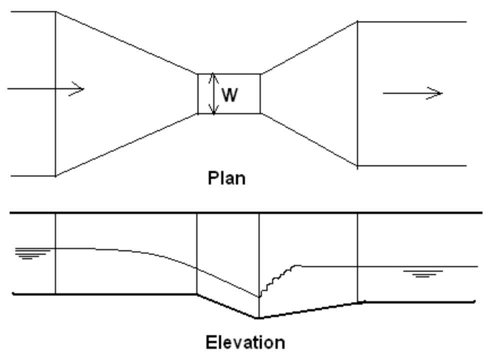

Figure 15.4 Parshall flume

15.5 Disposal of Grit

Considerable quantities of grit will be collected at the sewage treatment plant, about 0.004 to 0.2 m^3/ML. Quantity of grit will be more particularly for combined system. Necessary arrangement should be made at the treatment plant for collection, storage and disposal of this grit matter. The grit collected can be disposed in the following manner:

- In large treatment plant, grit is incinerated with sludge
- In the past, grits along with screening was dumped into sea.
- Generally, grit should be washed before disposal to remove organic matter.
- Land disposal after washing is most common.

Example:1

Design a grit chamber for population 50000 with water consumption of 135 LPCD.

Solution

Average quantity of sewage, considering sewage generation 80% of water supply, is

= 135 x 50000 x 0.8 = 5400 m^3/day = 0.0625 m^3/sec

Maximum flow = 2.5 x average flow

= 0.0625 x 2.5 = 0.156 m^3/sec

Keeping the horizontal velocity as 0.2 m/sec (<0.228 m/sec) and detention time period as one minute.

Length of the grit chamber = velocity x detention time

= 0.2 x 60 = 12.0 m

Volume of the grit chamber = Discharge x detention time

= 0.156 x 60 = 9.36 m^3

Cross section area of flow 'A' = Volume / Length = 9.36/12 = 0.777 m^2

Provide width of the chamber = 1.0 m, hence depth = 0.777 m

Provide 25% additional length to accommodate inlet and outlet zones.

Hence, the length of the grit chamber = 12 x 1.25 = 15.0 m

Provide 0.3 m free board and 0.25 m grit accumulation zone depth, hence total depth

= 0.777 + 0.3 + 0.25 = 1.33 m

and width = 1.0 m

Example :2

Design a horizontal flow grit chamber with rectangular cross section for treating maximum sewage flow of 10 MLD at maximum temperature of 34 ^oC during summer and minimum temperature of 15 ^oC in winter.

Solution

The settling velocity of the grit particle will be minimum at lower temperature, i.e., 15 ^oC. At this temperature kinematic viscosity = 1.14 x 10^{-2} cm^2/sec

In *first trial* assume Reynolds number 'R' less than or equal to 0.3.

$$Vs = \frac{g}{18}\left[\frac{S-1}{\nu}\right]D^2$$

$$Vs = \frac{981}{18}\left[\frac{2.65-1}{1.14x10^{-2}}\right]0.02^2$$

= 3.15 cm/sec

Reynolds Number R = v.D/ν = 3.15 x 0.02 / 1.14 x 10^{-2}

= 5.53 > 0.3

Therefore, Vs is not equal to 3.15 cm/sec because the equation for Vs is valid only for R < 0.3. Using Vs = 3.15 cm/sec, calculate R and C_D and then again Vs till it converges.

Subsequent Trial

Vs = 2.4 cm/sec

R = 2.4 x 0.02 /(1.14 x 10^{-2}) = 4.21

$$C_D = \frac{24}{4.21} + \frac{3}{\sqrt{4.21}} + 0.34$$

= 7.50

From equation

$$Vs = \sqrt{\left[\frac{4}{3}\frac{981}{7.50}(2.65-1)0.02\right]}$$

Vs = 2.4 cm/sec Hence, O.K. (2074 m/d)

Now for β = 0.06, f = 0.03, and D = 0.02 cm

$$Vc = \sqrt{\left[\frac{8\beta}{f}g(S-1)D\right]}$$

$$Vc = \sqrt{\left[\frac{8x0.06}{0.03}981(2.65-1)0.02\right]}$$

= 22.76 cm/sec

Now Q = 10 MLD = 0.116 m^3/sec

Therefore, C/S Area A = Q/V = 0.116/0.227 = 0.51 m^2

If width of 1 m is provided, the depth required = 0.51 m

Provide total depth = 0.51 + 0.3 (free board) + 0.25 (space for grit accumulation)

= 1.06 Say 1.1 m

Now Vo/Vc = H/L = 2.4/22.7

Therefore theoretical length L = 22.7 x 0.51 / 2.4 = 4.824 m

Provide 2 m extra length for inlet and outlet

Therefore total length = 2 + 4.824 = 6.824 m say 6.9 m

Total working volume = 0.51 x 6.9 x 1 = 3.52 m^3

Hence, Overall detention time = 3.52 / 0. 116 = 30.34 sec (within 30 to 60 seconds)