Physico-Chemical Processes for Wastewater Treatment

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Lecture 26

Settling and Sedimentation - V

Good day everyone and welcome to these lectures that we are continuing on settling and sedimentation and overall in the previous lectures we discussed about the various settling zones or behaviours which may be observed in a water or wastewater treatment plant. And we observed that there are different types of behaviours which are possible and that include discrete settling, hindered settling, flocculant settling or compressive settling. So, all these zones are possible and it is possible that within a wastewater treatment plant within a settling chamber, any one of the behaviour is also occurring.

And in addition to these behaviours, we tried to understand the different equations and the theories that are used for design of all these basins which may be operating under these behaviours. So, continuing with the previous lectures, in today's lecture, we will try to understand what are the various non ideal behaviours which are possible and which we have to take care during the design of actual settling or sedimentation basin.

So, there are many non ideals are there and that we have to account and then later on in the today's lecture itself will try to understand what are the basic design criteria which have to be considered in various zones of settling or various zones of sedimentation basin and all those important considerations we have to take care.

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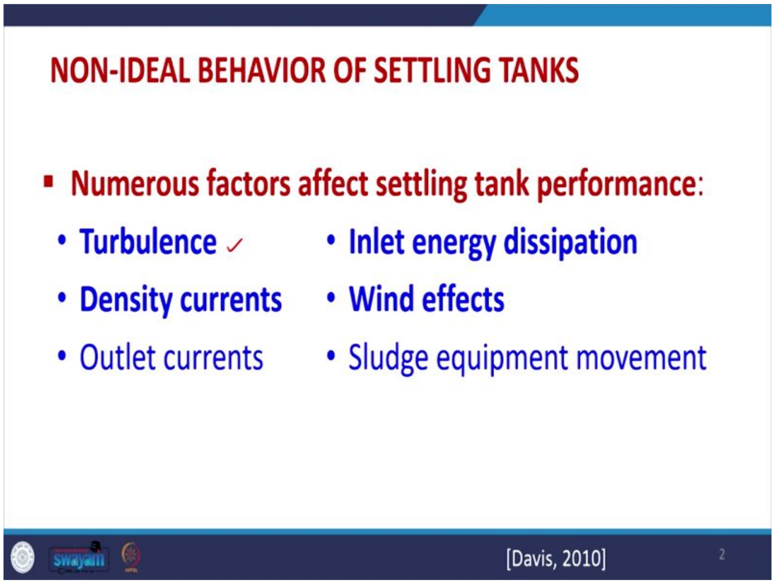

So, we will start with the non ideal behavior of settling tank. So, any settling tank it may be horizontal, it may be of flow type. So, all these settling tanks have different behaviors, non ideal behavior and which may be observed during the operation and these non ideal behavior maybe because of turbulence because of inlet energy dissipation because actually at the inlet, the amount of energy along with the flow is higher as compared to at the in the settling tank itself. So, that inlet energy dissipation.

Then the density currents so, because of density difference or otherwise some currents may be inside the inside the flow currents may be there inside the different zones, so, that density currents and wind effects these are the major effect reasons, which actually account for non ideal behavior of flow of the liquid inside various zones in the settling tank.

Along with these effects, outlet currents and sludge equipment movement also caused non ideality of the behavior in different zones. So, all these effects turbulence, inlet energy dissipation, density current and wind effects, all these non ideal behavior causing things we are going to understand a little bit more.

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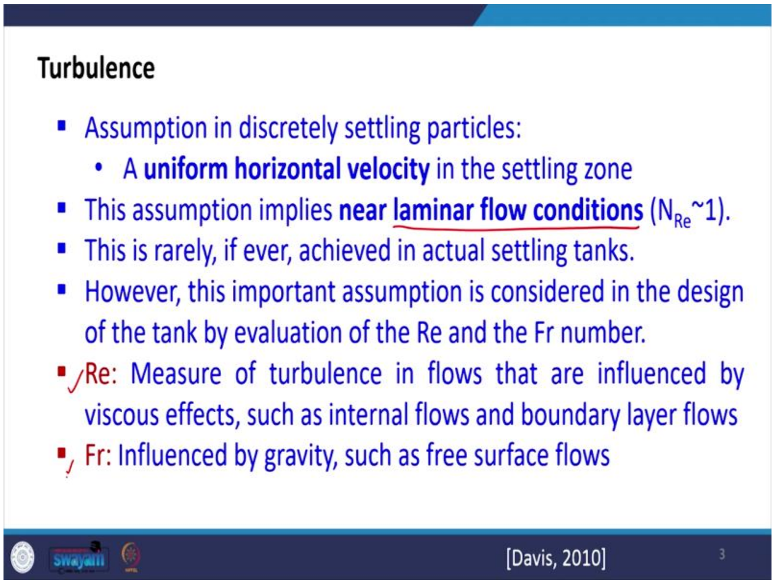

Now, starting with the turbulence, so, suppose, we are assuming a discrete settling particle and in this condition what we assume is that in the basin it has a uniform horizontal velocity in the settling zone. Now, this if we consider this assumption, this will this will be like assuming that laminar flow conditions are there inside that settling zone.

Now, laminar flow condition means that Reynolds number is in the range of 1. Now, in actual condition when the settling is actually occurring, this is rarely possible and it will be very difficult to achieve the Reynolds number equal to 1 condition. So, under this condition the assumption which is there, it may not be true.

So, what we have to do is that we should try to measure the turbulence by measuring the Reynolds number and that Reynolds number or the turbulence may be influenced by viscous effect, may be influenced by the internal flows or boundary layer flows. So, all these factors may account for variation in the Reynolds numbers.

So, turbulence may be there, the actual laminar flow condition may not be observed in most of the conditions. In addition to that, we should also measure the Froude numbers because it is influenced, Froude number is like factor which account for the gravity and it will be correct for free surface flows.

So, all these Froude's number and Reynolds number are very important parameters that should be measured, and they account for giving, like non ideal behavior and which may be observed by measuring these numbers. So, we will we will solve some problems and in that we will try to measure these Reynolds number and Froude number and understand their uses.

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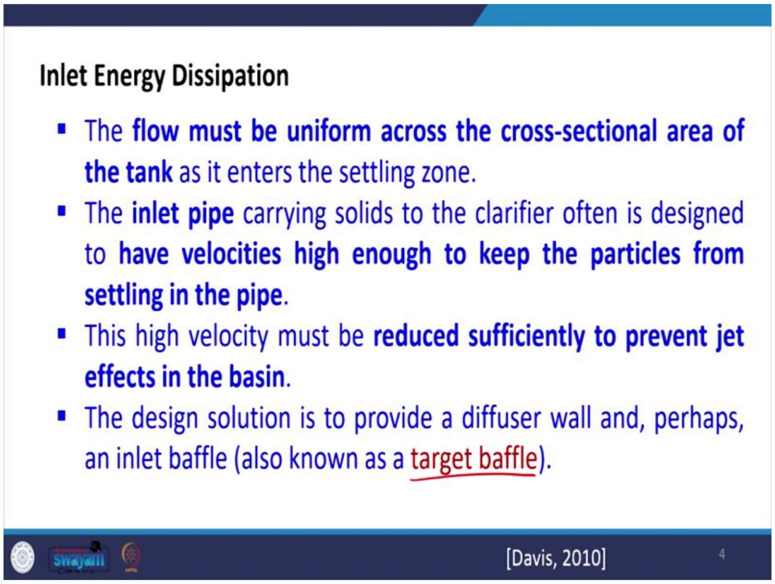

Now, then, the second parameters, which affects the non ideal behavior or ideal behavior is inlet energy dissipation. Now, the flow must be uniform across the cross sectional area of the tank as it enters the settling zone. So, this is a one of the essential requirements in the settling zone. Now, the inlet pipe which carries the solids to the clarifier is often it is designed at much higher velocities, so, that the particles do not settle in the pipe itself. So, that means the inlet pipe always have very high velocity as compared to that in the settling zone or settling chamber.

Now, this high velocity has to be reduced and to prevent the jet effect in the basin otherwise the non ideality will be more but this cannot be reduced very sufficiently and most often we use like Target baffle and this is used as a solution to provide a diffuser wall or something diffuser wall which is considered as the target baffle or inlet baffle may be there.

So, diffuser wall or inlet baffle may be used to reduce the velocity and made the flow uniform, but it may not be effective up to a level which is desirable and because of that, non ideality happens in the settling basin.

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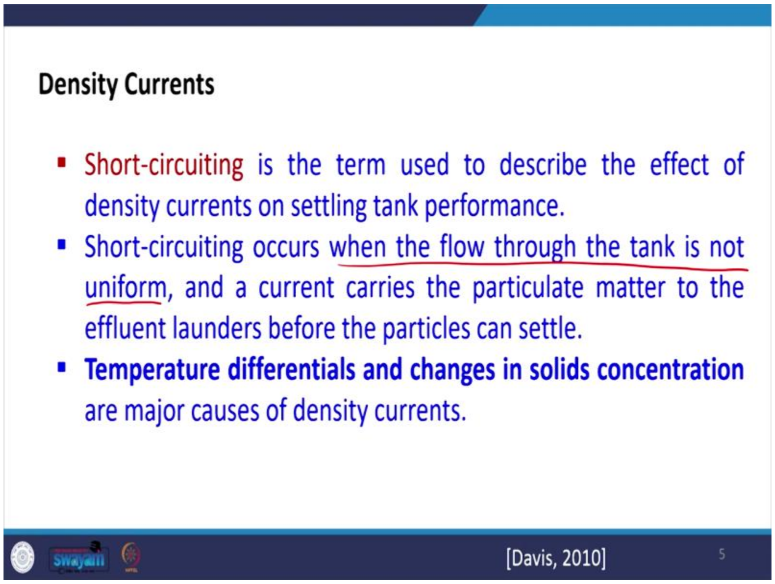

Then the second parameter is the density current. Density current is like it happens because of the effect of various effects, it may be because of the variation in the density, it may be also because of the variation in temperature. So, temperature variation changes in solid concentration all may cause the variation in density and that density may lead to density current and density current actually leads to the short circuiting.

So short circuiting is the term which is used to describe the effect of density currents on the settling tank performance and short circuiting occurs when the flow through the tank is not uniform. So, we do not have the flow through the tank is not uniform. And under that condition short circuiting may happen.

A current carries the particle matter to the effluent launders before actually particle can settle. So, in place of that means, for that particulate matter or that particle which is getting short circuited it has, it does not have that much detention time that it can settle, actually it leads the effluent launders before actually settling down. So, density currents short circuiting they have a lot of effect and these may be because of temperature differentials and changes in solid concentrations as well.

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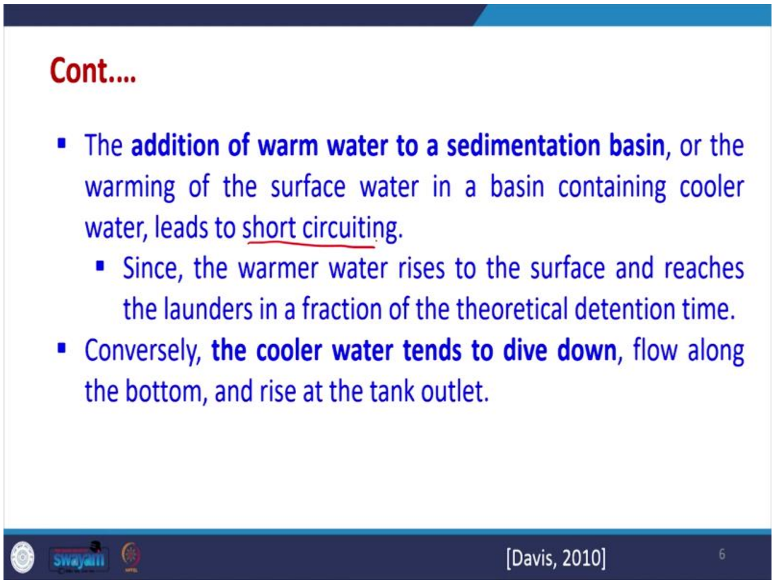

Now, suppose we add a warm water to a sedimentation basin. So, it is possible that somehow that there is a difference at some time it is only colder conditions are prevailing and now we are adding a warm water to the sedimentation basin or the warming of the surface water in the basin containing cooler water may occur because of various reasons. And if any of these occurs, then always be short circuiting since the warmer water will always rise to the surface and reach the launders in the fraction as compared to the theoretical detention time so whatever is the theoretical detention time it will reach the launders before that. So that means the settling will not occur.

Similarly if the cooler water is added somehow, so cooler water will tend to dive down and flow along the bottom and rise at that tank outlet only. So, this is possible. So, both warm water and cooler water may lead to density differentials and because of that differential currents, density currents may be there.

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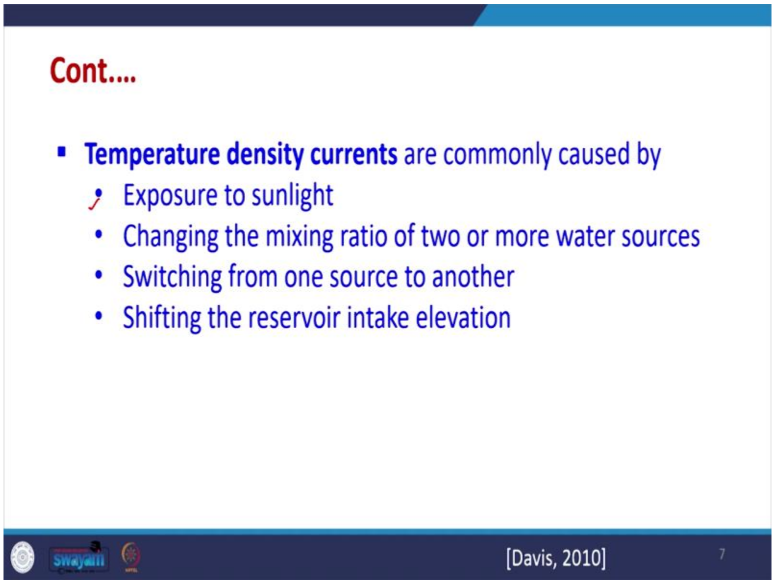

Similarly, because of the variation in like cooler water, warmer water the temperature density currents can be caused by other measures also like exposure to the sunlight. So, I would like during night time it may be different, during daytime it may be different. Similarly, changing the mixing ratio of two or more water sources. So, it may be possible that there are two or more water sources and one, two have difference in temperature also. So, if the mixing ratio changes, so, that this temperature density current will arise now, there is a possibility that we are changing the water from one source to another.

So, then also because the concentration difference may be there, temperature difference may be there and because of that also temperature density currents may arise. Similarly, shifting the reservoir intake elevation, that at what elevation we are taking the water into the reservoir. So, all those parameters affect the temperature density currents and they have a lot of effect on the non ideality behavior.

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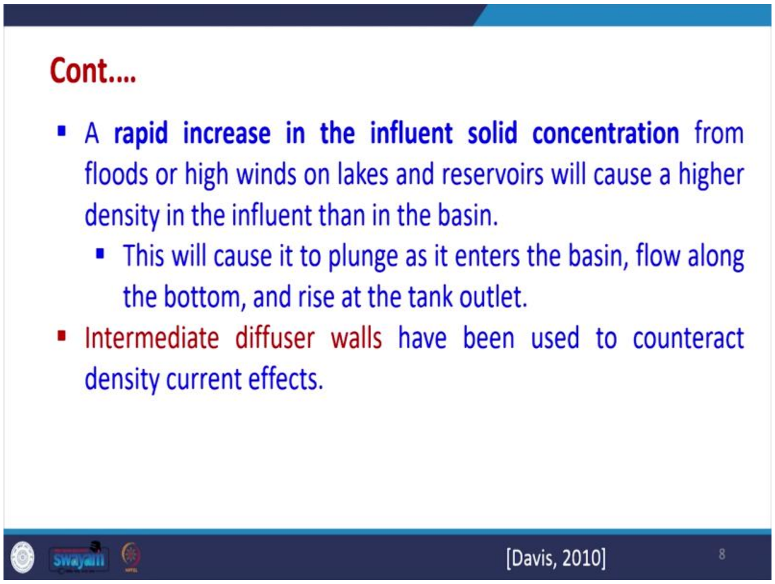

Now, similarly, a rapid increase in the influent solid concentration from floods, this may occur from floods or high winds on the lakes and reservoirs will cause a higher density in the influent then in the basin. So, it is possible that suddenly very high solid concentration is coming in the influent and that is with respect to what is present in the basin. So, this will cause it to plunge as it enters the basins all the solids will try to settle down very quickly and flow along the bottom and rise at the tank outlet. So, this will again create a differential.

Now, similarly, for taking care of this intermediate diffuser walls have also been used many times. So, we will discuss these things more in the design considerations. Now, in addition to density differentials, we have wind effects also. So, large open tanks which may be there, they are always susceptible to induce the currents and in sufficiently strong winds waves may also occur at the top of the tank.

So, this is possible and if this happens or otherwise also and underflow current in the opposite direction to the surface current gets created and this will cause the short circuiting in addition to that the short circuiting it may lead to scouring of the already settled particulate matter from the sludge zone because the wind effect so, at the top there may be a wave at one direction. So, at the bottom of the lake, there will be some movement in the opposite direction.

So, that underflow current may cause scouring of that settled particulate matter from the sludge zone. So, this is there. So, one of the design solutions that is taken care is that limiting the length of the tank and placing some wave breakers along the tank surface. So, these are some of the design solutions which are there with respect to taking care of the wind effects.

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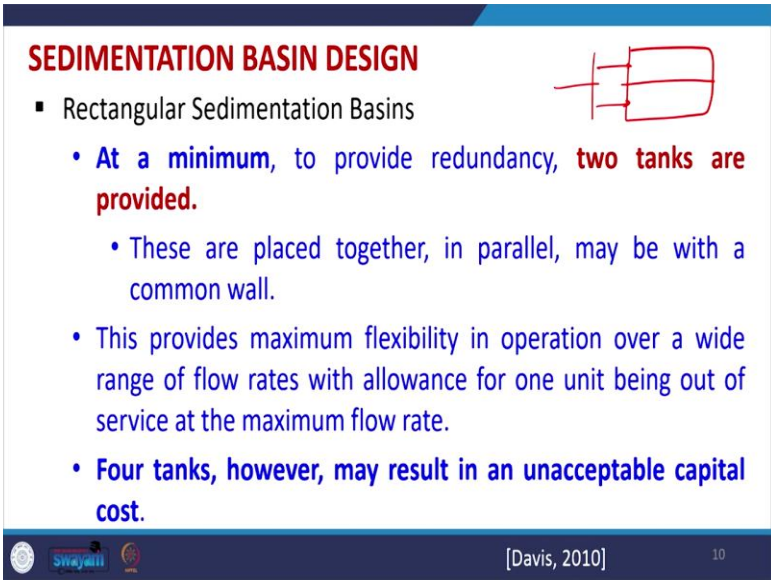

Now, we will start with the actual design and what are the parameters that we have to take care in a like a rectangular sedimentation basins. So, some of the important design considerations now, we are going to discuss one by one in each and every zone. Now, generally what will happen that for removing the redundancy of one of the if suppose we are using only one tank, so, to take care we always design any settling basin with two tanks minimum. So, two tanks are always provided, they may be placed together in parallel.

So, they maybe like two basins maybe there, so like this is a bigger basin. So, two basins with a common wall maybe there so, this is one basin this is second basin, so we are having two basins in parallel. So this is always we take care that we actually design in most often at least two tanks are used. Now, this helps in providing flexibility in operation over a wide range of flow rate, so, if flow rate is very less, so, we can use only one basin.

Also, suppose at any time one of the basins is out, so, we can take, use the second basin at least. So, this all these redundancy factors may be taken care of, if we use at least two tanks, four tanks or higher may be used, but this will result in an acceptable capital cost etcetera. So, certainly cost is the most important factor based upon which we design that how many tanks we are going to use for the actual settling.

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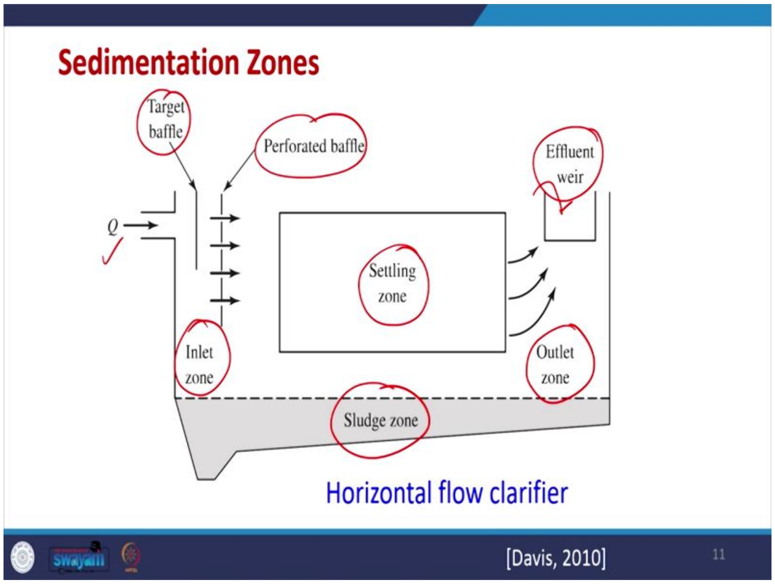

Now, this figure we have already previously in the previous lectures also we have seen, so, we will be discussing each of the zones. So, when the flow enters and when it leaves from the effluent weir, So, under this condition now, there are four zones which are possible. One is inlet zone, then we have a settling zone, then we have outlet zone and then the sludge zone.

So, now, we are going to discuss each of these zones and their design considerations, important design considerations in detail. Now, within this we have perforated baffle, we have target baffles also which are very important, then we have weir also So, all these factors we are going to discuss little bit in detail.

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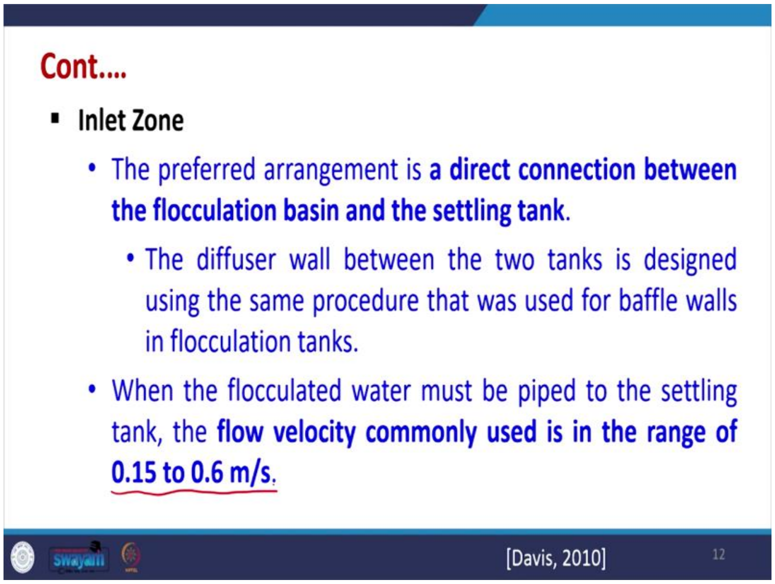

Now, in Inlet zone the preferred arrangement is that a direct connection is there between the flocculant basin and the settling tank. So, this is what is the preferred arrangement. A diffuser wall between the two tanks is designed using the same procedure that is used for baffles walls in a flocculant tank. So, we can use the same technique. Now, when the flocculated water is piped to the settling tank, the common flow velocity which is used is in this range from 0.15 to 0.6 meters per second.

So, this is the common flow velocity in the pipe which is connected from flocculant tank to the settling tank. So, this is possible so, this is the flow velocity range generally we use. In addition, this velocity must be reduced and the flow has to be spread evenly over the cross section of the settling tank. So, this is one other important parameter if we can do it, well, we can reduce the non ideal behavior.

Now, that diffuser wall is the most effective way to accomplish this and the diffuser wall is placed approximately two meter downstream of the inlet pipe. So, this is the diffuser wall which is placed. So, already we have seen the diffuser wall or percolated baffles. So, this is there now, the head loss through the holes. So, therefore, this also it is generally taken care that it should be four to five times the velocity head of the approaching flow. So, this is tentatively kept in this range. So, this is there.

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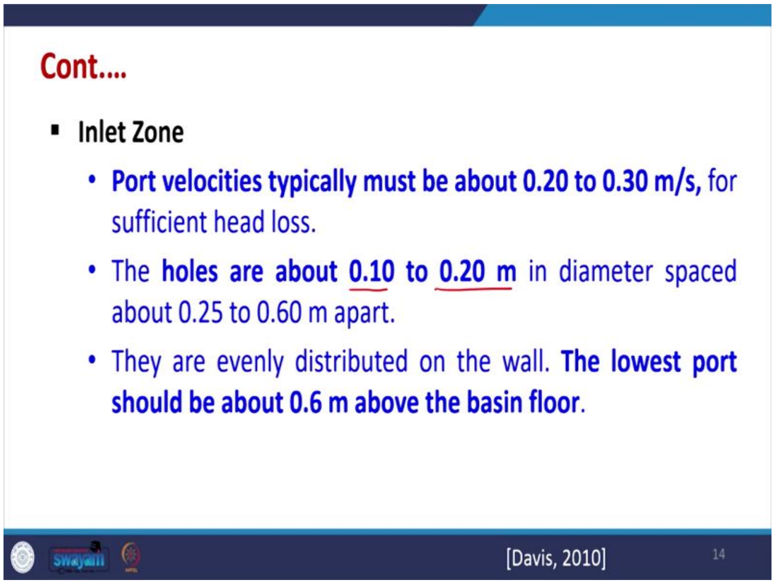

Now, in addition the port velocities typically must be around 0.2 to 0.3 meter per second for sufficient head loss, the holes are in the range of 0.1 to 0.2 meter in diameter and they are spaced at a distance of 0.25 to 0.60 meter apart. So, this is there and so, these are the some of the important things that are taken care of and there are evenly distributed all these holes are evenly distributed on the wall. The lowest port or hole should be around 0.6 meter about the basin flow, so this is also taken care and so, that the flow becomes more uniform.

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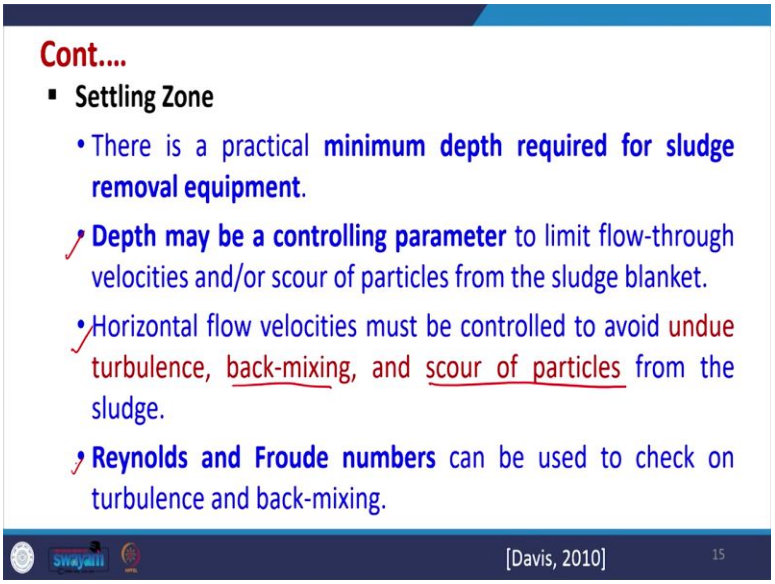

Now, after the inlet zone the flow will come to the settling zone. So, these are the important considerations which are there for settling zone. Now, there is a practical minimum depth which is required for sludge removal and equipment. So, that depth may be calculated from the previous lectures we can tentatively calculate from that also and the settling velocity is one of the parameters we have to also take care of the horizontal velocity. So, all those things are taken into account in calculating the depth.

Depth is a controlling parameter to limit flow through the velocity and scour of the particle from the sludge blanket so, both have to be taken care that what should be their depth so that the scouring of the particle is stopped, the horizontal flow velocity must be controlled to avoid undue turbulence. So, this undue turbulence, back mixing and scouring of the particle from the sludge zone. This we have to take care, so, horizontal flow velocity and depth, these become very important parameters for settling zone.

Now, for this checking whether these are under the limit and we do not have all these issues, we have to check the Reynolds number and Froude number that can be used for checking whether turbulence and back mixing is occurring or not occurring. So, all these can be checked.

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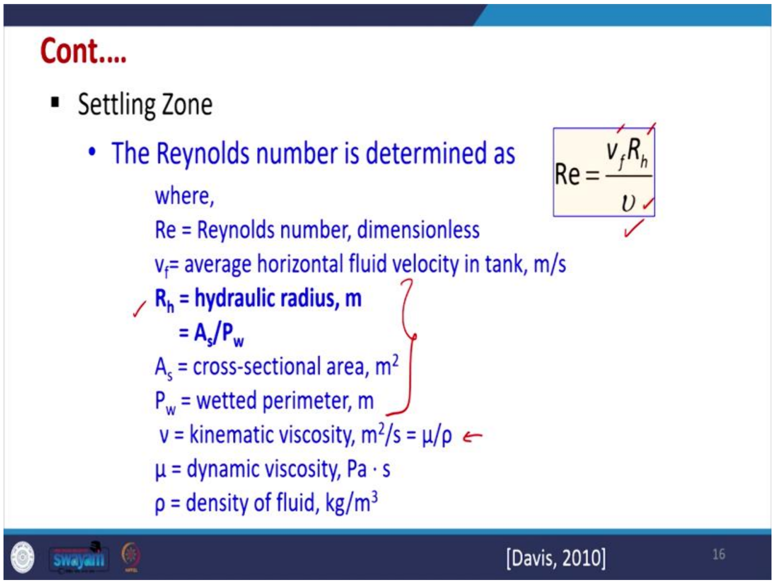

The Reynolds number is determined as

$$\mathrm{Re} = \frac{v_f R_h}{\upsilon}$$

where,

Re = Reynolds number, dimensionless

v_f= average horizontal fluid velocity in tank, m/s

R_h = hydraulic radius, m = A_s/P_w

A_s = cross-sectional area, m^2

P_w = wetted perimeter, m

ν = kinematic viscosity, $m^2/s = \mu/\rho$

μ = dynamic viscosity, Pa · s

ρ = density of fluid, kg/m^3

Now, within this the Reynolds number can be determined by this equation and which is like Reynolds number is equal to Vf into Rh divided by mu and where Reynolds number itself is dimensionless Vf is the average horizontal velocity fluid velocity in the tank in meter per second and Rh is the hydraulic radius, the hydraulic radius is the ratio of cross sectional area divided by the weighted perimeter. So, this we have to understand then kinematic viscosity is there and kinematic viscosity itself can be found out from dynamic viscosity divided by the density of fluid. So, this is also one of the parameter here. So, through this we can find out the Reynolds number.

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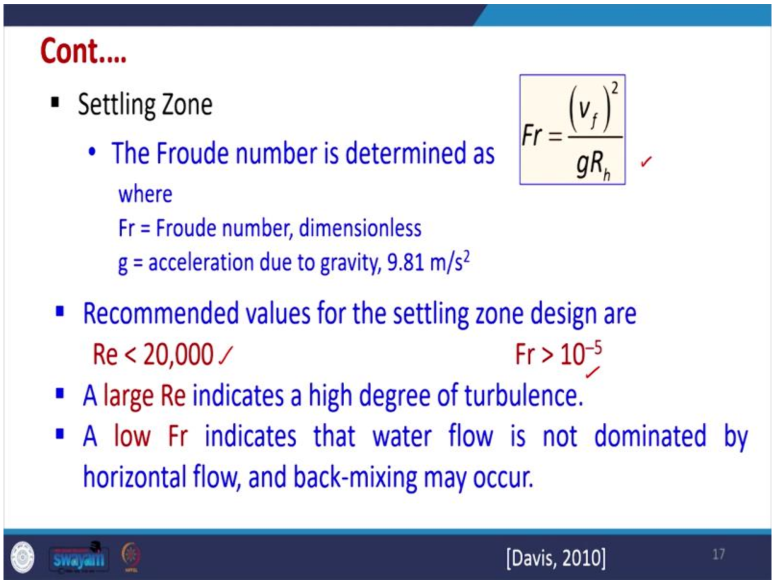

The Froude number is determined as

$$Fr = \frac{(v_f)^2}{gR_h}$$

where

Fr = Froude number, dimensionless

g = acceleration due to gravity, 9.81 m/s^2

Similarly, we can find out the Froude number also and which is given by this equation which is like Vf squared divided by gRh, the Vf and Rh already have been defined in the previous. So, Vf is redefined and Rh is also defined, so, we have this and g is the acceleration due to gravity. Now, recommended values are this Froude number, Reynolds number are given here, so Reynolds number should always be less than 20,000.

So this is there and the Froude numbers should be greater than 10 raise to minus 5 a large Re indicates high degree of turbulence, but it has to be limited within. The lower the Reynolds number better it is and the low Froude number indicates that water flow is not dominated by horizontal flow and by mixing may be occurring. So, this we have to take care that this Froude number has to be greater than 10 raise to minus 5. So, this is there.

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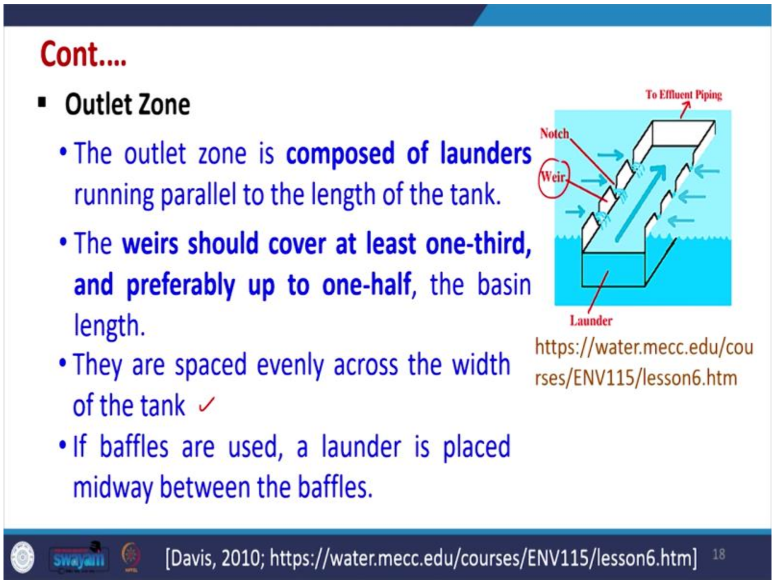

Now, after settling we have outlet zone, the outlet zone is composed of like launders running parallel to the length of the tank. So, this is there and the weirs after the settling zone, they should cover at least one third or one half of the basin length. So, that has to be taken. So, we can see that we are here and we have the notch here.

Now, this has to be there and these weirs are evenly spaced across the width of the tank. So, this we see okay and if the baffles are used, suppose a launder is placed midway between the baffle, so, that this is another consideration that has to be taken care in the outlet zone during the design.

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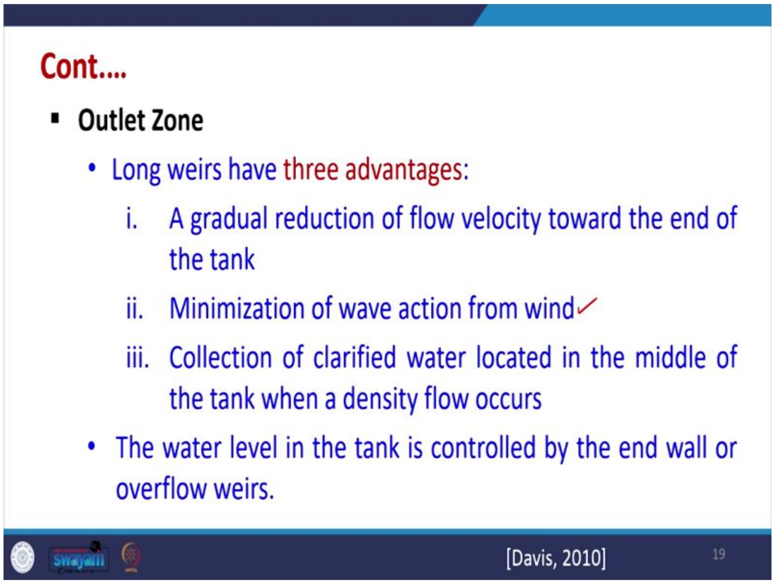

Now there are other there are certain advantages of using long Weir's. So, these advantages are like a gradual reduction of flow velocity towards the end of the tank. So, this is possible. So, that is if we use long weir it is possible then we have we can minimize the wave action from wind. So, we are taken care of the wind also by using the long weirs.

Also, we can collect the clarified water in the middle of the tank when the density flow occurs if anything like this occur, so, this is also taken care of the long weirs, the water level in the tank is controlled by the end wall or the overflow weir. So, this is also one of the important things that we should remember while designing the settling basin.

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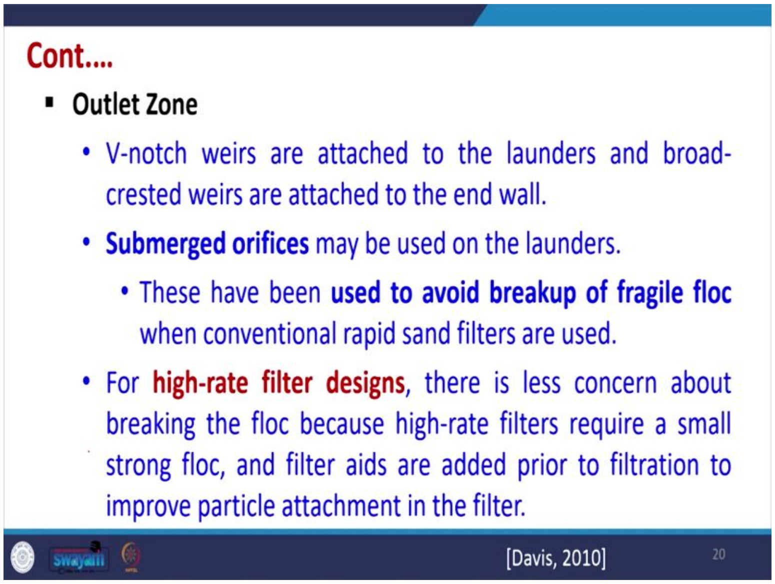

Now, in the outlet zone, we have V notch weirs, which are attached to the launders and they and broad crested weirs maybe attached at the end wall. So, this is there. Sometimes we use submerged orifice may be used on the launders and they have been used to avoid the breakup of fragile flocs, when conventional rapid sand filters have to be used later on. So this is good if the suppose we have a fragile floc and in the floc is bigger.

So, we have more chances of filtering it in the rapid sand filter. So, this is possible to avoid this we can use the submerged orifice also a for high rate filter designs which had to be used after the settling basin, there is a less concern about the breaking the flocs because the high rate filter will require a small strong flock and so, it this concentration may not be there for high rate filter design, but for simple rapid sand filter etcetera submerge orifice may be preferred.

Now, in addition to this at the bottom we have sludge zone. So, in selecting the depth sludge zone is the most important thing after the settling basin. Now, in selecting the depth of the sedimentation basin an allowance of 0.6 to 1 meter is made for the sludge accumulation and sludge removal equipment.

So, that will be there at the bottom if the overflow rate is design is based upon the pilot studies, then the depth of the pilot settling tank column used to develop the data may be selected as the depth of the tank. So, that may be taken from the directly from the pilot settling column itself.

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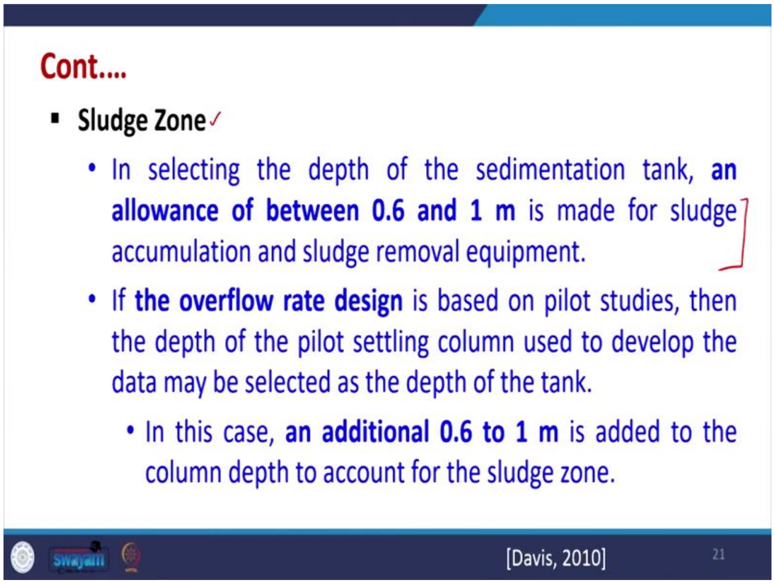

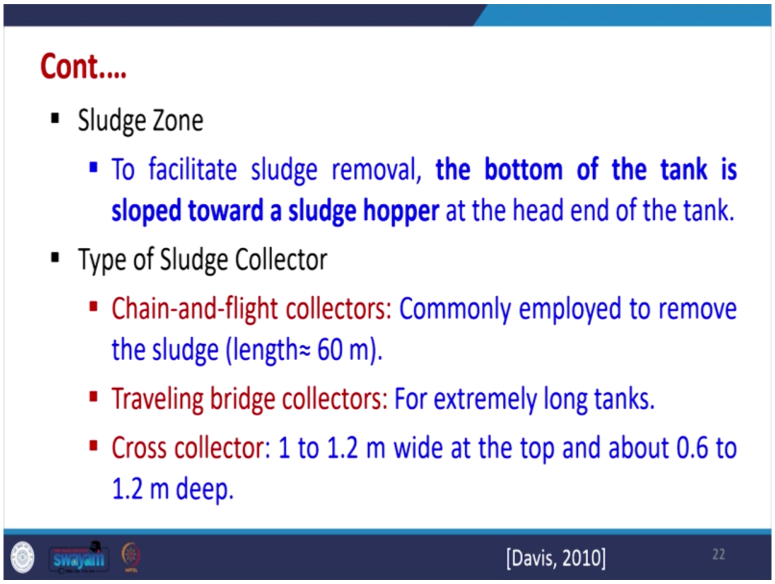

Now, sometimes we may use an additional 0.6 to 1 meter to the column depth to account for the sludge zone. So, this is also possible so sludge zone is very important. And to facilitate easy sludge removal, the bottom of the tank is sloped towards the sludge hopper and head end of the tank.

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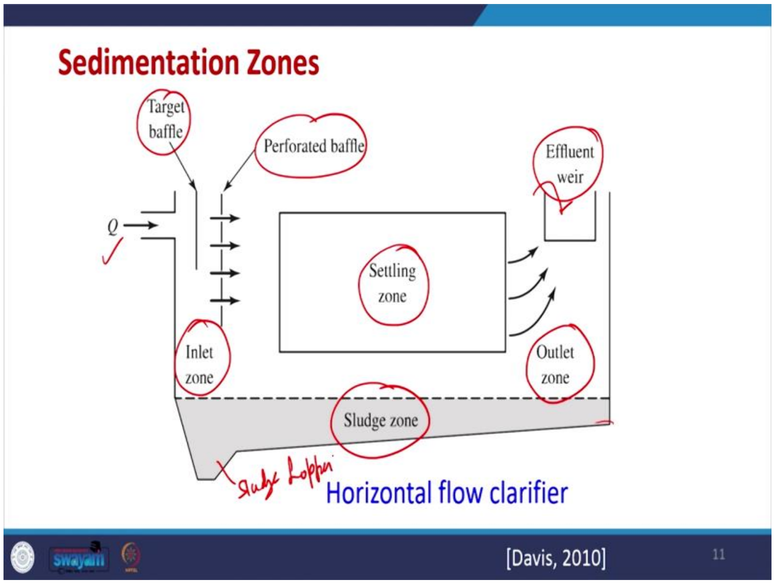

So, we can like here in the figure you may have seen this is slanted and this is the sludge hopper which is there. So, we have to see that this is slanted and we can easily remove the sludge whenever desirable. So, this is there. So, this is what is written here in the.

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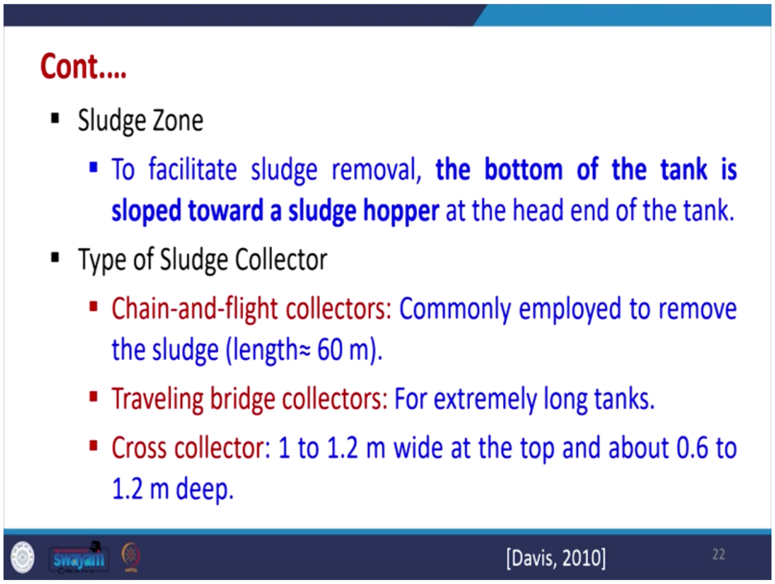

Now there are different types of sludge collectors. So, once it moves to the sludge collector, we may have different types of sludge collector. So, chain and flight collectors are there, so they are commonly applied to remove the sludge, the length is approximately 60 meter or maybe others also, the traveling bridge collector is for extremely long time, then the cross collectors 1 to 1.2 meter wide at the top and 0.6 to 1.2 meter deep at the bottom. So, any of these types of collection systems may be used depending upon the design.

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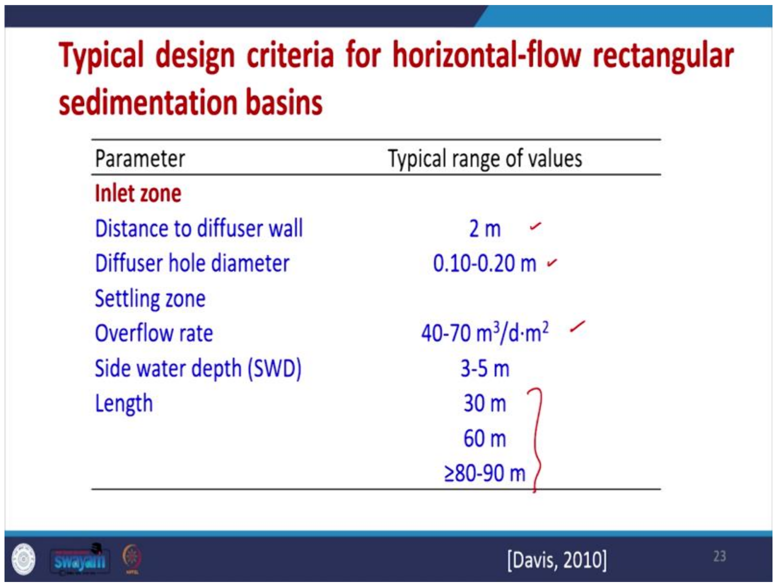

Typical design criteria for horizontal-flow rectangular sedimentation basins

Parameter	Typical range of values
Inlet zone	
Distance to diffuser wall	2 m
Diffuser hole diameter	0.10-0.20 m
Settling zone	
Overflow rate	40-70 $m^3/d \cdot m^2$
Side water depth (SWD)	3-5 m
Length	30 m
	60 m
	≥80-90 m

[Davis, 2010]

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Now, going further, there are some typical design criteria which are used for horizontal flow rectangular sedimentation basins. So, that we have to these values are given here. So, these values are highly helpful in design of any sedimentation basin in particular the rectangular sedimentation basin, which is having a horizontal flow.

Now for the inlet zone some of the parameters are like distance to diffuser wall should be two meter approximately, diffuser hole diameters should be 0.1 to 0.2 meter in the settling zone, the overflow rate should be around 40 to 70 meter cube per day per meter square, the side water depth may be 3 to 5 meter, the length maybe 30 meter, 80 meter it varies a lot. So, there are different types. So, we may use a fixed type of also and we may increase that length also.

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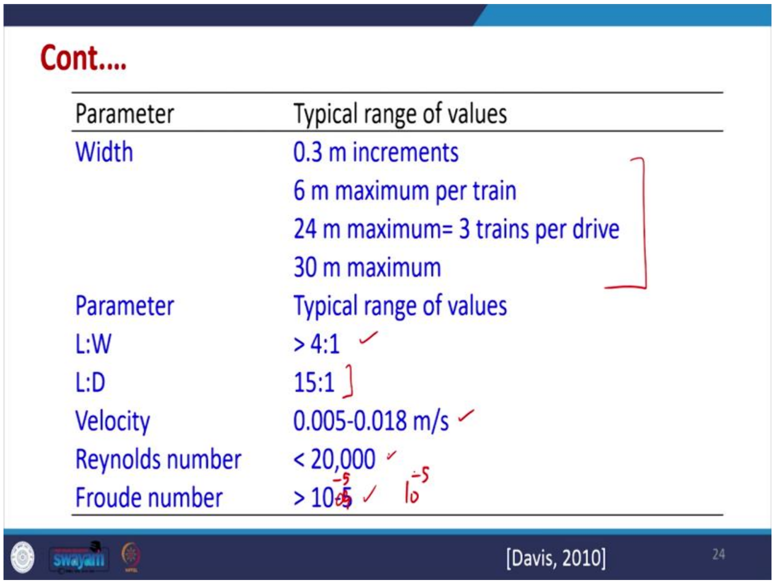

Now, the width is in 0.3 increments generally it is taken so 6 meter is maximum per train. So for 24 meter like three trains per drive. So, these are some of the ideas which have been used in the sedimentation basin, then the parameter L by W and L by D ratio. So, generally L by W is taken more than 4 is to 1 and L by D maybe 15 is to 1 or something like this, the velocity is in the range of 0.005 to 0.018 meter per second, Reynolds number, sorry this is 10 raise to minus 5. So, the Reynolds number has to be less than 20,000 and Froude number has to be more than 10 raise to minus 5. So, this is there.

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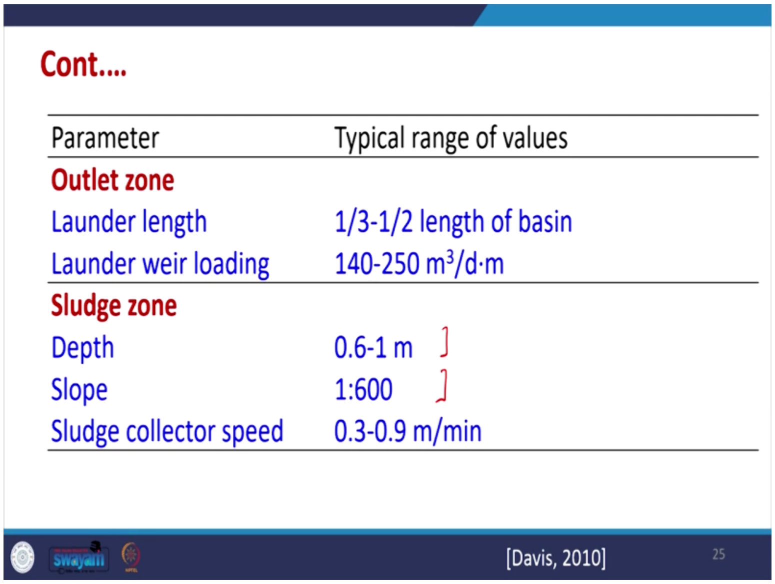

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Parameter	Typical range of values
Outlet zone	
Launder length	1/3-1/2 length of basin
Launder weir loading	140-250 $m^3/d \cdot m$
Sludge zone	
Depth	0.6-1 m
Slope	1:600
Sludge collector speed	0.3-0.9 m/min

[Davis, 2010] 25

And in the outlet zone we have some considerations which are there, the launder length has to be around one third to one half of the length of the basin. And weir loading maybe around 150 to 250 meter cube per day per meter this is there. In the sludge zone the depth is 0.6 to 1 meter, the slope is 1 is to 600 and the sludge collector speed is from 0.3 to 0.9 meter per minute. So, these are the some of the parameters or the typical design values which are used in the actual design of the sedimentation basin and all these parameters. If we take care of these parameters, generally a good, very good sedimentation basin can be designed.

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There are in this today's lecture we studied regarding the non ideal behavior which is possible in any sedimentation basin. So, we found that there are four parameters which will be there and it may include like wind effect, turbulence and the density difference. So, there are many parameters which are possible and which may cause non ideality of the behavior in different zones in the settling tank. And in addition, we tried to learn some of the basic aspects of the design in various zones including inlet zone, settling zone, outlet zone and sludge zone.

So, in the next lectures, we will be continuing with the design and we will try to solve some problems with respect to design and then there are new types of filters which have come into picture and these include like high rate settlers. So, now the requirement of filtration has high rate settlers. So, the requirement of high rate settlers has increased because we have to, we have to treat more amount of water in lesser time. So, new types of settlers have come into picture. So we will study those in the next lecture. So we end today's lecture. Thank you very much.