Physico-Chemical Processes for Wastewater Treatment
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Lecture – 27
Settling and Sedimentation – VI

Good day everyone and welcome to these lectures on settling and sedimentation. So, we will be continuing today also with respect to these lectures. In the previous lectures, we studied that what are the different design conditions that we have to take care during the design of various settling or sedimentation basin and we found that there are different non-idealities also which are possible during actual operation and we have to take care of those, those non-ideal possibilities which may affect our operation.

So, these non-idealities included like the turbulence and then the wind effect and there are many other parameters that may account for the non-ideal behavior of the sedimentation basin. So, and also in addition to that, we tried to understand the various design considerations in the inlet zone, settling zone, outlet zone, and the sludge zone and we also understood typical values which are used in the design of the actual sedimentation basin.

So, today we are going to solve one problem, and then we are going to learn regarding high rate settlers, etcetera in today's lecture itself, so, we will start with the problem continuing with the previous lecture.

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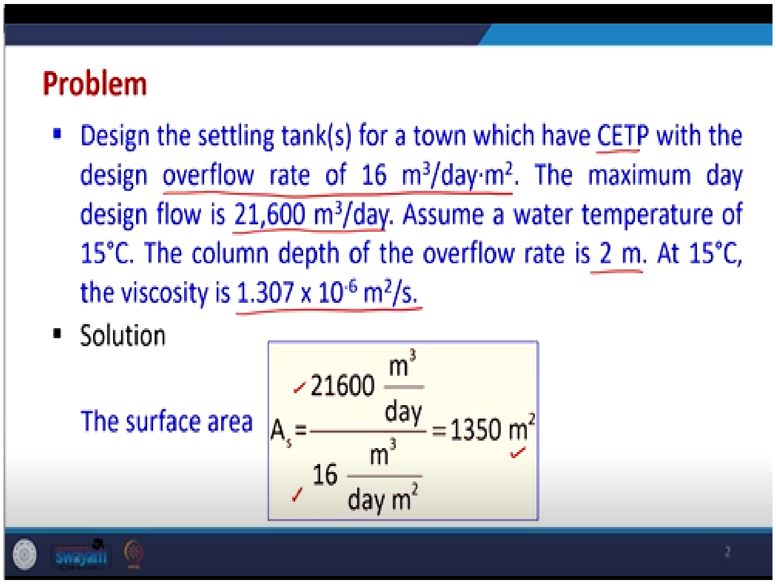

So, here the problem is given that we have to design settling tanks for a town which is having a common effluent treatment plants CETP with design overflow rate of 16-meter cube per day per meter square. So, we have tentatively the data is known to us that this is the overflow rate that we have to use.

Now, the maximum design flow which is possible as per the data available for that CETP is that we have to use the maximum value of 21,600-meter cube per day. Now, we are going to assume a water temperature of 15 degrees centigrade, the column depth of the overflow rate was 2 meter where the design was done and at 15 degrees centigrade, the viscosity of the water was found to be this.

So, this is all the, these are the parameters which are known to us. Now, let us start with the design of the tank so this will, will try to cover whole of the design mostly. So, we will start with the what is will be the surface area which will be required if we directly consider this 21,600-meter cube per day of the flow.

Now, the overflow rate is given and the total flow rate is given. So, the surface area we can find out by dividing that total flow rate with the overflow rate, and this is found to be 1350 meter square and this value is very high as per the surface area so, we cannot use a single design basin for this because this, this will be very, very huge otherwise.

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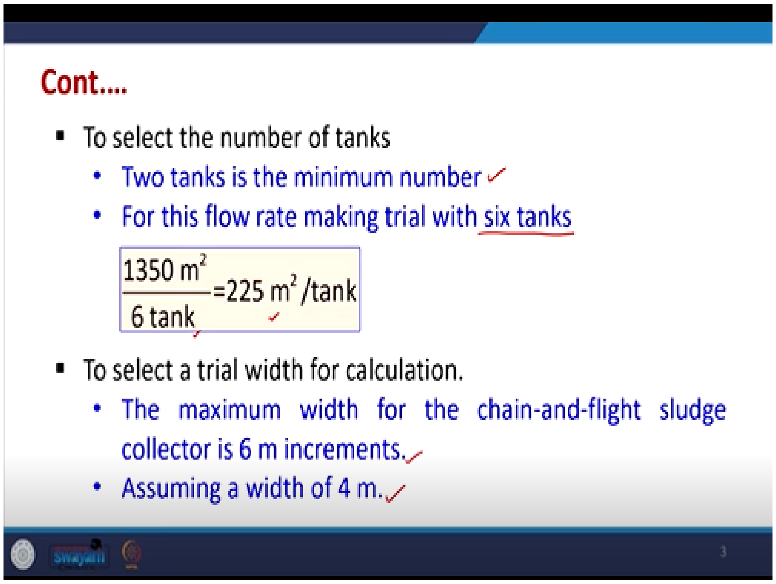

So, what we do is that we have to select the number of tanks we are going to use. So, the general criteria is two tank is the minimum number, but considering this much high surface area we are starting with six tanks as a trial basis. So for first six tanks suppose we have six tanks. So, divided by 6 we have 225 meter square will be the surface area for each tank. So, this is there. Now, we for this surface area, we have to select the trial width for calculation as well. So, the maximum width for chain-and-flight sludge collector is 6-meter increment and assuming a width of 4 meter.

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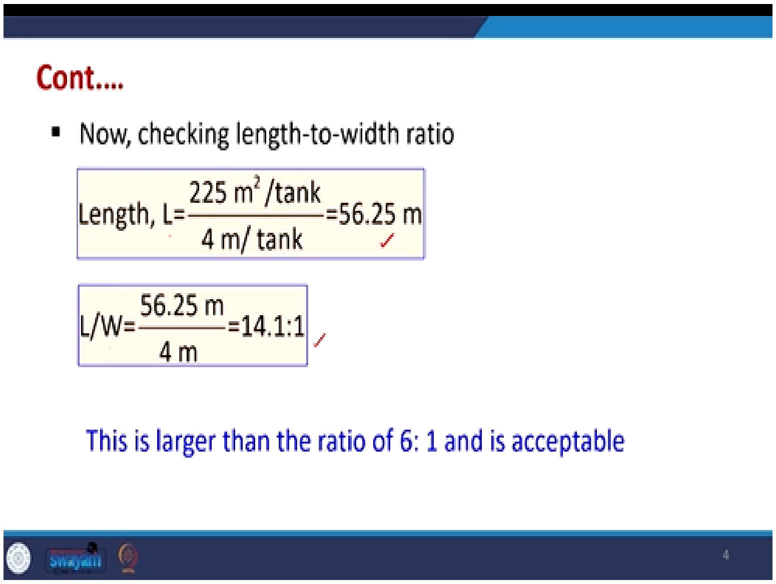

So, we are starting with the assuming a width of 4 meter we know with 4 meter the length will be coming out a total length will be coming out to be equal to 56.24 because 4 meter is the width if we assume the width to be 4 meters, this is there. Now, under this condition the L by W value because L is known and width is known. So this will come, come to 14.1 is to 1 so, that is the, this value is larger than the 6 is to 1 value which was given in the like previous lecture.

So, it may be considered acceptable and we may further go ahead and cross-check whether you are meeting all the criteria with respect to design of a sedimentation basin or not. So, this is these are the length values we are now going to take 56.25. The L by W is already given the area we have taken per tank is 225 and width is 4 meter.

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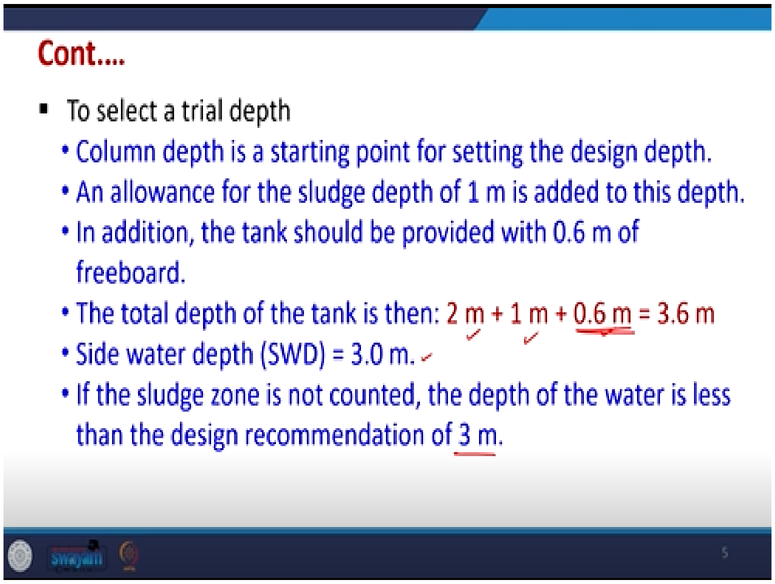

So, this is taken now, we have to take the trial depth, so, the column depth is a starting point for settling of the, for designing the settling basin. So, an allowance for sludge depth of 1 meter is recommended. Now, in addition the tank should be provided with 0.6 meter of the freeboard above, so, that also has to be taken care. So, since the depth was 2 meter for the column and we may start from there itself.

And the so, overall if you see it becomes 2 meter, 1 meter, 0.6 meter so, it that means, it is 3.6 meter is the total depth of the tank out of which the water depth is 3 meter because 0.6 meter is the freeboard region actual water depth is 3 meter. Now, if the sludge zone is now counted the depth of the water is less than the design recommendation of 3 meter. So, this is okay as per that so, because here we are taking care of the sludge depth as well.

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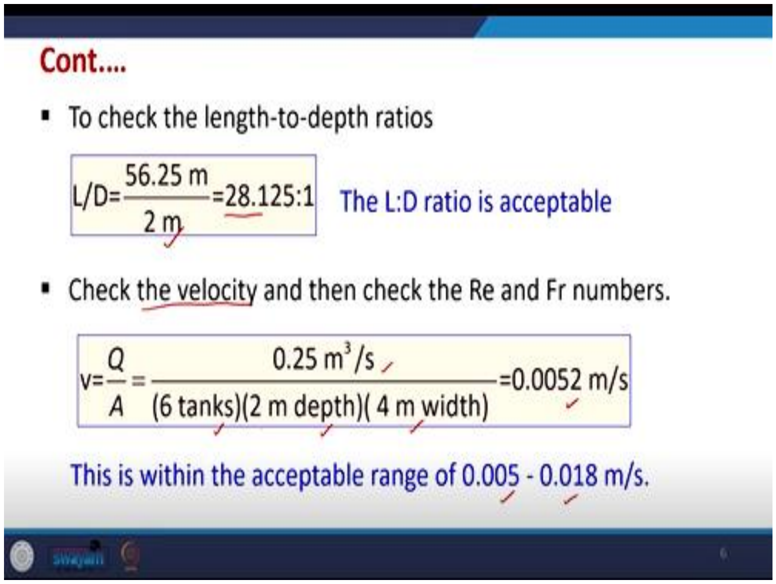

Now, the, now cross-checking with respect to length to depth ratio, it is 56.25 and 2 meter because actual water depth is only 2 meter, 1 meter is for the sludge depth. So, side water depth was 3 meter, now, the actual depth is where the water or settling etcetera is occurring is 2 meter. So, under that condition the ratio is 28.125 is to 1 and this may be considered as acceptable.

Now, what we do is that we go ahead and try to cross check that what is the velocity that is occurring when we are taking these values. So, depth is known, width is known, length is known, we have taken area is known. So, every parameter is now known to us now checking the velocity, so, what will be the lower velocity that is there.

So, if we perform calculation we will be finding that in terms of meter cube per second the value is 0.25 is the Q and the area which is there which may take in, which may give you the idea with respect to velocity is we have 6 tanks, each are having 2 meter depth and 4 meter width, the first the total flow rate is divided by 6. Now the, whatever is the flow rate after that in the each tank that is divided by the depth and the width.

So, that we have the cross section is known to us. Now, cross section is 2 meter and 4 meter. So, it comes out to be 0.0052 meters per second. So, this is within the acceptable range of 0.005 to 0.018 meter per second. So, we are at a condition where the velocity is 0.0052 and it is also within the acceptable limit.

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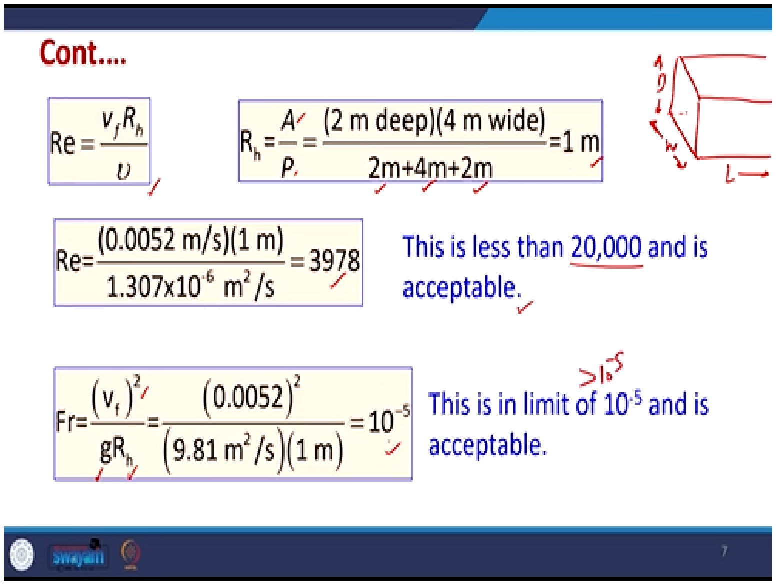

Now, going further we calculate the Reynolds number. So, this is very important that we calculate the Reynolds number, Froude number and cross check that these values are within the acceptable limit or not. So, Reynolds number in the previous lecture we had studied is given by this equation.

So, v as the flow velocity is already known to us, Rh is the hydraulic radius which is given by the area divided by perimeter. So, area is 2 meter deep, 4 meter wide and the perimeter is so, we can tentatively cross check like this. So, this is like and this is the length. So, this is what we are designing tentatively this is the length and this is the depth and this is the width. So, this is known to us.

Now, within this, the perimeter will be width plus height plus height, so, 2 depth plus 1 width, so, we have 2 depth plus 1 width, which is 4 meter. So, this way the hydraulic radius comes out to be 1 meter for each of the settling basins, which are six in number, so, Rh comes out to be 1 meter. Now, once this Rh is known, we can calculate the Reynolds number, because we know the flow velocity, we know the Rh and we know the viscosity also which is given in the problem itself or which has been found separately we can find it out separately by knowing the density and viscosity parameters.

So, this is known, now, this value is 3978 if you put all the values will calculate it to be 3978 and which is less than 20,000 and may be considered acceptable. So, this is there. Now, similarly, we have to calculate the Froude number also, the Froude number everything is known, velocity is known, hydraulic radius is known, and the gravity is also known. So, under that condition, we have if we put all the values, this comes out to be very similar to 10 raise to minus 5 and it can be considered acceptable the acceptable limit is that the Froude number has to be greater than 10 raise to minus 5 and this is tentatively coming in the same range so this is there.

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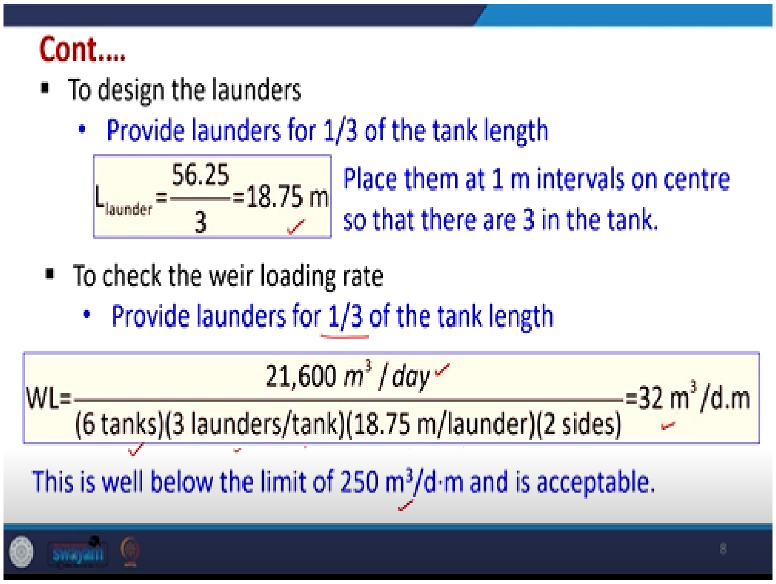

Now, we have to go for the design of the launders also. So, the basic design condition which was given in the previous lecture was that we have to provide launders for 1/3 of the tank length. So, the tentative length of the launders is 1/3 of the tank length. So, we calculate it, it is 18.75 and we can place them at 1 meter intervals on centers, so, that we have there are 3 in the tank. So, this is possible now, to check the weir loading that the weir loading should be below 250 meter cube per day per minute. And so, we have to cross-check that what is the weir loading which is coming.

So, provide since we have provided launders 1/3 of the tank length and flow rate was this. So, we have 6 tanks and 3 launders in each tank and we have 18.75 is the length of the launders upper launder and we have 2 sides. So, taking all these things the launder weir loading, which will coming out which is 32 meter cube per day per meter and this is below 250 meter cube per day per meter. So, this is also acceptable within the acceptable limit so, this is there.

So, if we consider all the parameters that we have taken, when we considered six number of tanks, they are coming within the all the parameters or within the acceptable limit. So, we can go ahead with the design of this, we can optimize by this design by taking care of the cost factors. So, that is a possibility, but overall these designs seems to be logical and all the tick marks are there with respect to design criteria.

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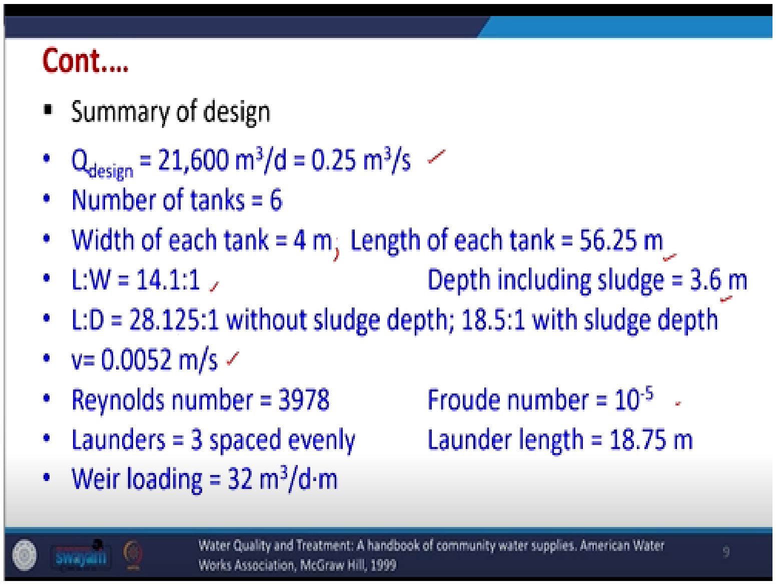

So, overall design was that, that the flow rate was this 21,600-meter cube per day or 0.25-meter cube per second, the number of tanks were 6 and the width of each tank has been taken as 4 meter, length has been taken as 56.25 meter, the L by length width ratio was this and depth including the sludge zone etcetera was 3.6 meter and the overall without considering the sludge depth.

This was the ratio which was there the velocity was also within the 0.005 to within the limit, Reynolds number was 3978, Froude number was 10 raised to minus 5, the launders 3 launders were used which are spaced similarly, and the launder length is 18.75 meter, the weir loading is 32 meter cube per day per meter and which is also within the limit. So, overall this is the design and we can use for this design. So, this is the one typical design of a sedimentation basin for some flow rate and this sedimentation basin has to be used in a CETP common effluent treatment plant.

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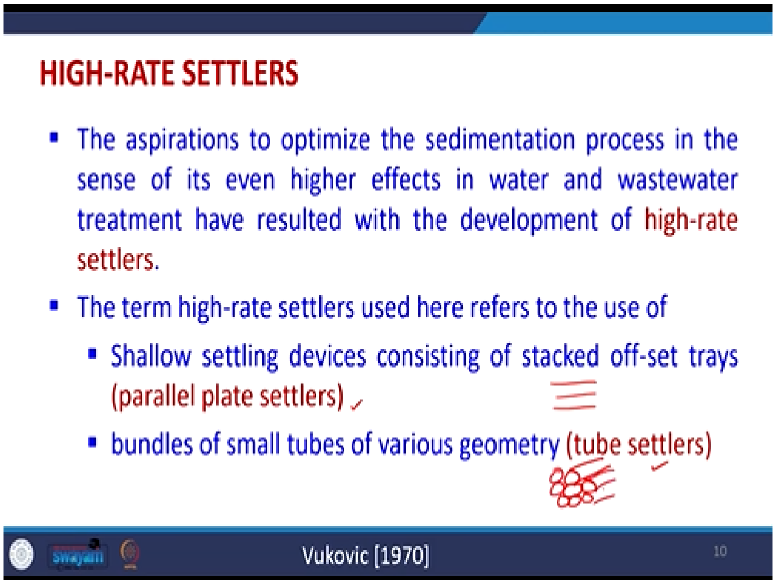

And now going further now, the high rate settlers have coming into picture a lot in all the industries common effluent treatment plant, effluent treatment plant. So, what are these high rate settlers, why they are used, what are their advantages as compared to traditional settlers? So, this we are going to understand now, the sediment, to optimize the sedimentation basin it is very important that the flow how much amount of water we can process through the sedimentation basin within certain time limits. So, that has to be taken care.

Now, the term high rate settlers is actually meaning that we have very high amount of water can be processed within a specified time. So, there are two basically two types of settlers which are coming as the high rate settlers, these are like parallel plate settlers and tube settlers.

So, in the parallel plate settlers shallow settling devices, they are consisting of stacked off-set trays are there so, we have parallel plate we can tentatively we have one plate, second plate, third plate etcetera., and then tube settlers certainly, where we have different tubes which may be there they are all closely space and the flow rate is all through these tubes. So, these tubes settlers are there, so basically, two types of high rate settlers are very common tube settlers and parallel plate settlers. So, we are going to learn regarding both of them now.

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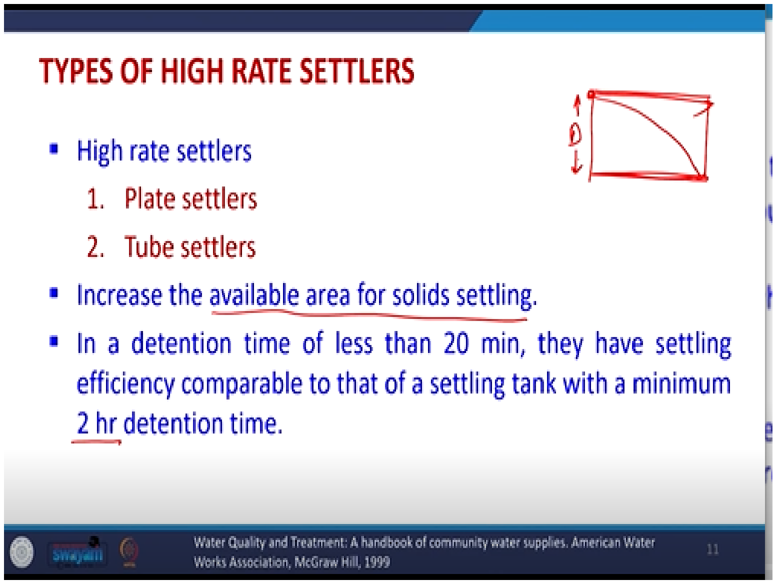

Now already discussed high rate settlers are two types, plate settlers, and tube settlers, what they do is that they increase the available area for solid settling, this is one thing then there is a second thing when what they do is that they decrease the depth. So, that means that depth that has that the particle has to settle while moving through the settler is very less so, that means they can settle quickly.

Actually, the earlier the design was that suppose this is the simple horizontal flow settler. Now, any particle which is entering here, the earlier consideration was that that it should settle down, it should settle down before actually, it leaves. So, this is there. So, that means, the time this if that this depth is less.

So, that means under that condition that time of settling will be much less so, more amount of and the time of settling will be much less and under that condition if that time of settling is lower, we can increase the flow rate because we want the target to reach the surface area on which the settling is occurring. As soon as it reaches this particular area, we can increase the flow rate so, that the particle is not coming out still the flow rate is very high that is possible.

So, by decreasing this depth, we are able to increase the horizontal flow velocity also that means, we are able to increase the throughput also of the water which can be processed through these high rate settlers. So, this is there. So, one of the key thing is that they have very high available area for solid settling.

In a detention type of less than 20 minutes, they have settling efficiency comparable to that of a settling tank which may have, be having a detention time of 2 hours. So, that means there and this is because that depth for which the settling has to occur is much lower here in this settlers so, this is there.

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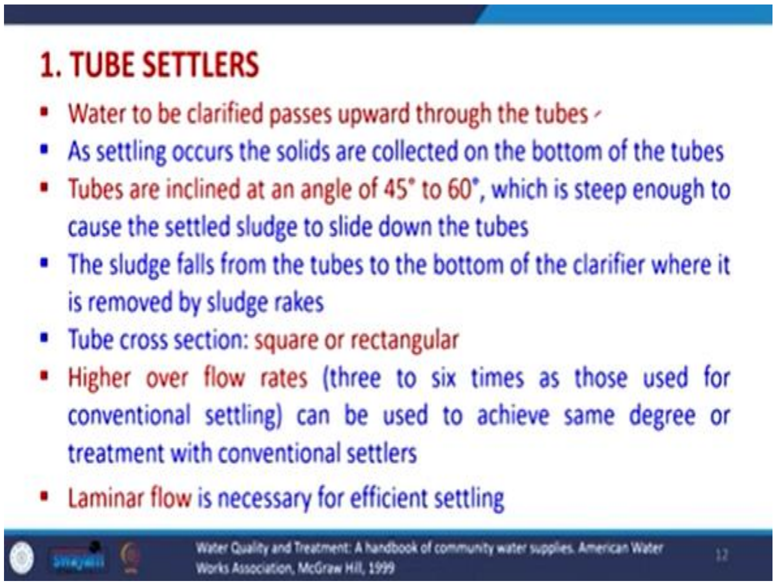

Now, understanding each of them one by one so, first is the tube settler. So, water to be clarified passes upwards through the tube.

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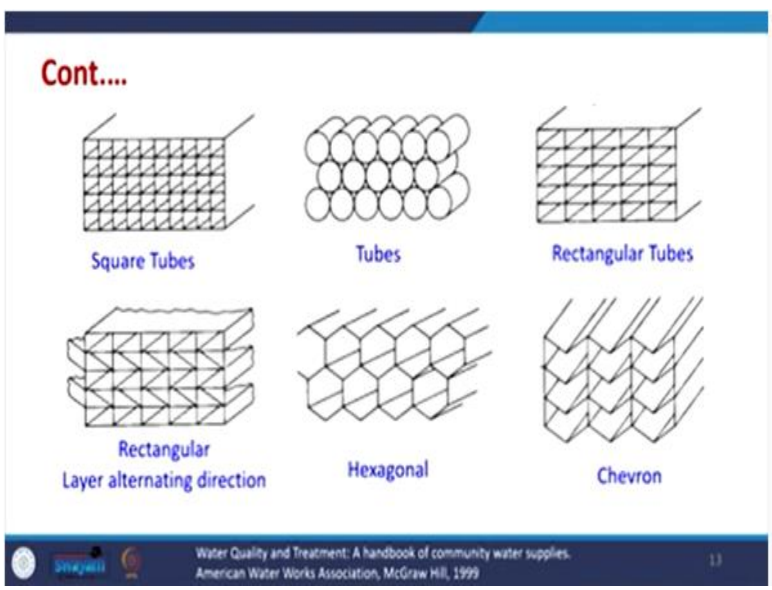

So, you can see the pictures here. So, through this the water to be processed will pass in any of these tube settlers and they may be of different dimensions. So the water has to pass through them.

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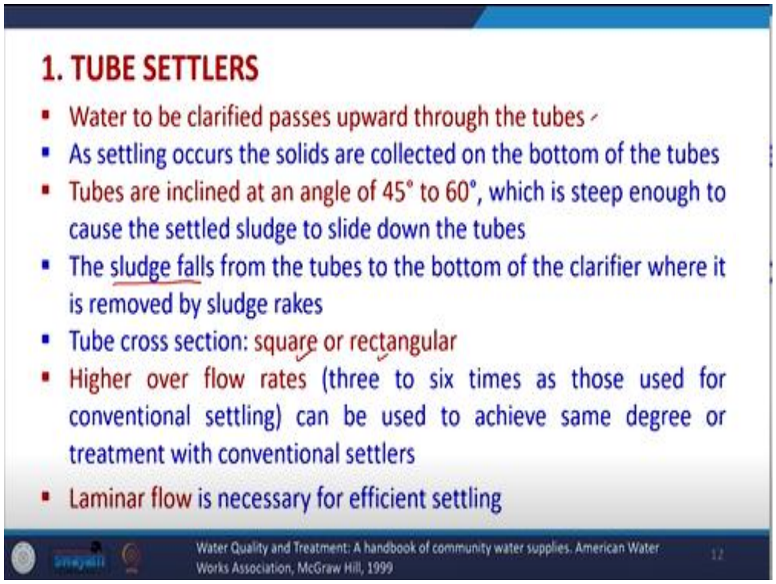

Now, as settling occurs the solids are collected on the bottom of the tube. So, all the solids will get settled on the bottom of the tube in each of the tube. Now, tubes these tubes are inclined at an angle of 45 to 60 degree and which is actually a steep enough to cause the settled sludge to slide down the tube. So, this is possible and because of this steepness they are able to settle and they slide down also. The sludge falls from the tube to the bottom of the clarifier where it is removed by the sludge rakes. So, this is there, so, the sludge will fall from the tube to the bottom of the clarifier and which is further removed.

Now, the tube cross-sections may be square rectangular or other shapes are also possible. The high overflow rates three to six times as those used for conventional settling can be used to achieve the same degree or higher degree of treatment, so, this is possible. Laminar flow is one of the important considerations in the tube settler for efficient settling that is true for other settlers also.

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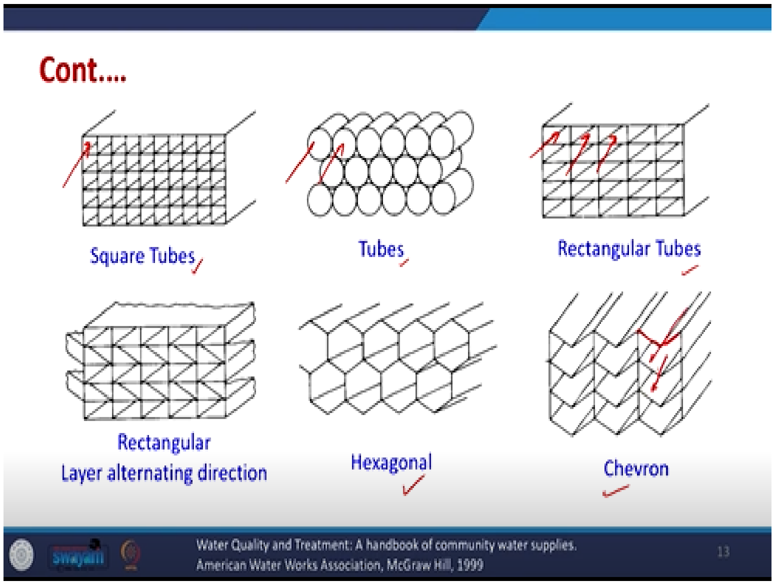

So, these are the different cross-sections which are possible square tubes, these are simple circular tubes, then we have rectangular tubes, rectangular with layers alternating the direction so, we can see here some layers are also there in between we have hexagonal or chevron type where there is some inclination is there so the sludge may easily settle and come out here in chevron tubes, these are all possible.

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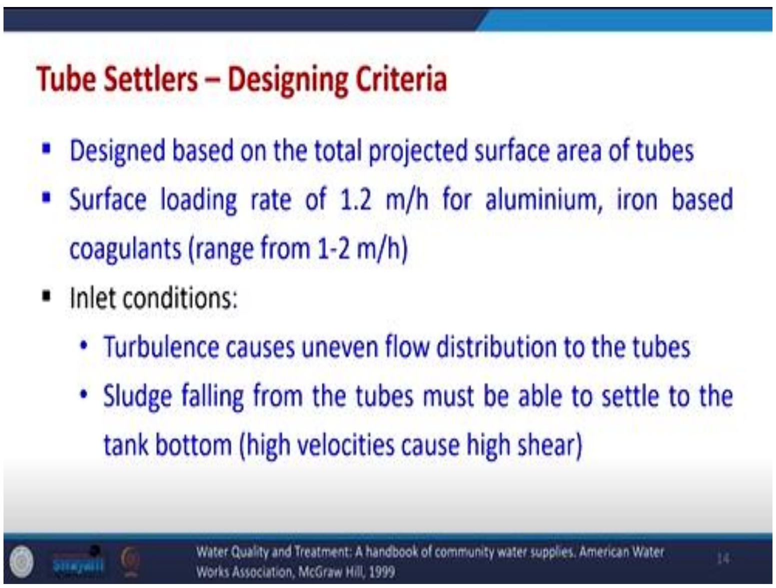

Some design criteria for tube settlers are there is that the design is based upon the total projected surface area of the tube. So, this is important already we do this. The surface loading rate of around 1.2 meter per hour for aluminium, iron based coagulants can be used. So, it may be 1 is to 2 is the range for this surface loading rate for tube settlers, the inlet condition turbulence causes uneven flow distribution to the tube. So, this has to be avoided and the sludge falling from the tubes must be able to settle to the tank bottom. So, high velocities may cause high shear rate this is there. So, this also has to be taken care of.

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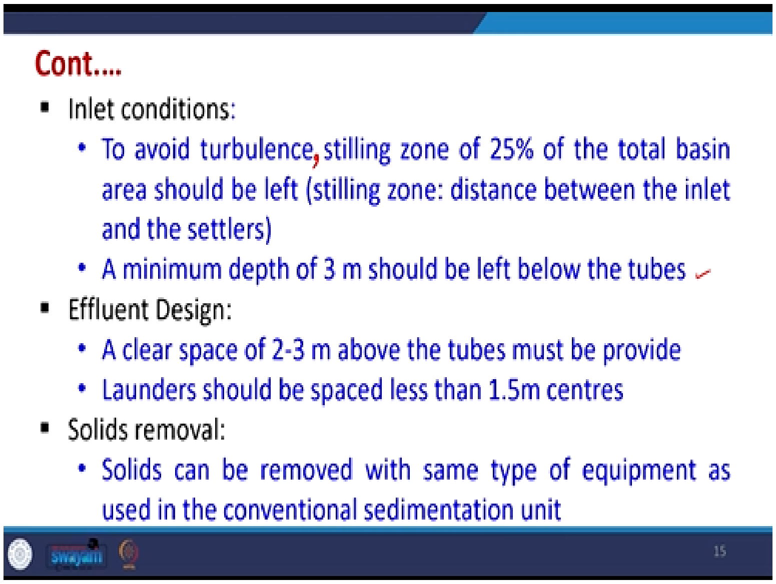

Now, in the inlet condition to avoid the turbulence stilling zone of around 25 percent of the total basin area should be left. So, this is there. So, to avoid this turbulence we had to take care of this and minimum depth of 3 meter should be left below the tubes. So, this is another one of the from experience this criteria has come. Now effluent design a clear space of 2 to 3 meters above the tube must be provided. Launder should be placed less than 1.5 meters on the center. So, this is there.

Solids removal, solids can be removed from the same type of equipment as used in the conventional sedimentation unit. So, these are the some important criteria for tube settler. So, they have very designed equations very similar to earlier not very difficult to design, but there are some key design elements that we have to take care.

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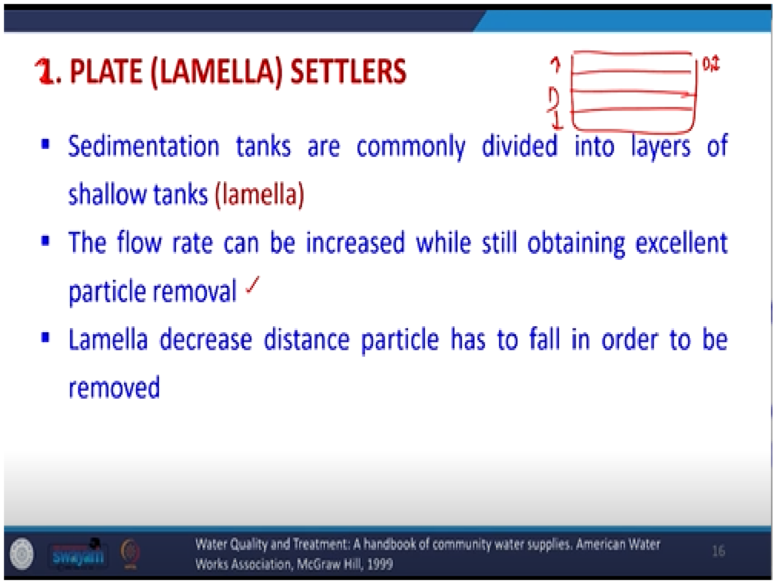

Now, second of the, this high rates settler is the plate or lamella settler the sedimentation tanks are commonly divided into layers of shallow tanks so, what is done is that? Overall the sedimentation basin may be like this, D is the depth now, what is done is that, this is divided into a number of layers, so, depth has decreased. So, it is now D1 only if you consider like this, so, the depth will decrease.

So, we have layers of shallow tanks. So, this is there. So the settling depth is decreased tremendously, the flow rate can be increased while still obtaining the excellent particle removal and this is because the time of the settling has decreased. So, that means we can have higher flow rate. So, that the still the water, still the particle cannot go out of the length and if they can reach to the end also this is okay.

So, that can be taken care by choosing a higher flow rate in such a manner that the sludge does not leaves the system, but still the particle settles down. So, that is there, the flow rate can be increased while still obtaining the excellent particle removal efficiencies. A lamella decrease the distance particle has to fall in order to be removed so, this is the, this is what is the key thing in the plate settlers as well as in the tube settlers.

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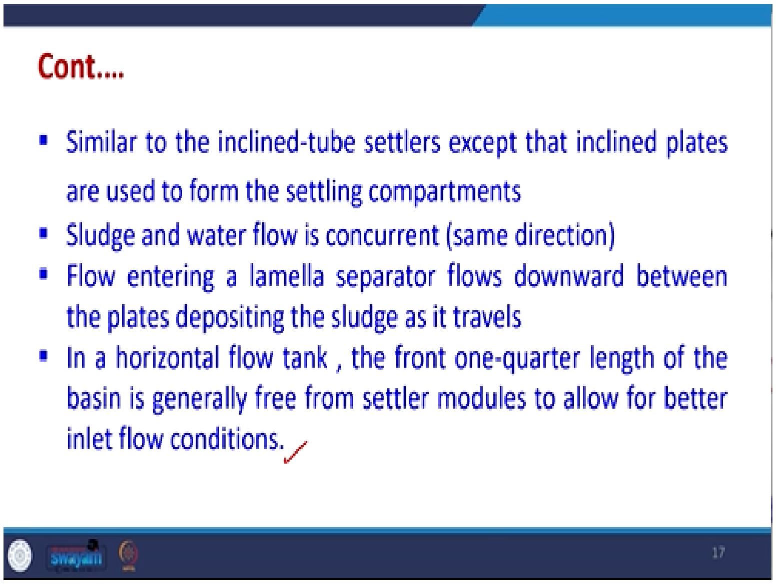

Now similar to the inclined tube settlers, except that the inclined plates are used to form the settling compartments. Here again the inclination is there, sludge and water flow is concurrent in the same direction the flow entering a lamella as separator flows downwards between the plates depositing the sludge at it travels.

So, it is in the same direction we are moving the flow the sludge and water both move in the same direction. Now, in a horizontal flow tank, the front one quarter length of the basin is generally free from settler modules to allow for better inlet flow conditions. So, we have to take care of this important criteria while designing the lamella or plate settler.

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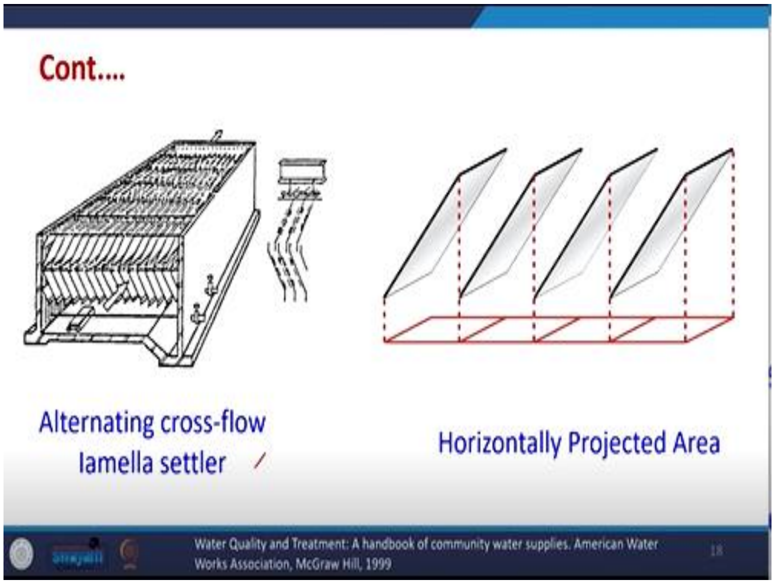

Now, this is this is how it is shown we can see here they are inclined also in one of the direction. So, this way the flow may there, alternating cross-flow lamella settlers is there. So, we can see the difference is there, then horizontally projected area, this area which is there. So, this is the key thing we remember that the top area is one of the important parameters in the design of the sedimentation basin. So, we can see here, so, the area has been reduced because of this inclination that helps in the overflow rate.

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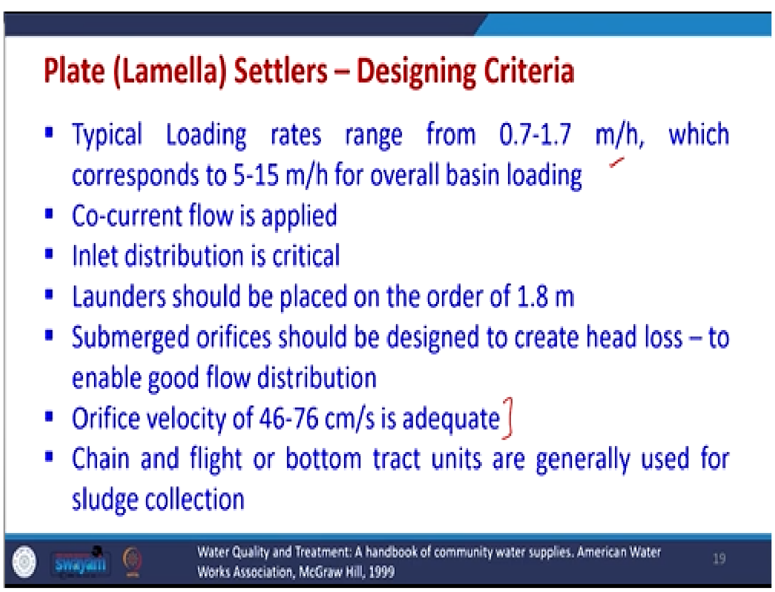

Now, some design criteria is that the typical loading rate range from 0.7 to 1.7 meter per hour which corresponds to 5 to 15 meter per hour for overall basin loading. So, we have to take care this. Co-current flow is applied, then inlet distribution is very critical and that has to be taken care.

Launders are placed on the order of 1.8 meters. Submerged orifice may be used to design to create head loss to enable proper good flow distribution out of the system. Then orifice velocity may be in the 46 to 76 centimeter per second range and chain and flight or bottom tract units are generally used for sludge collection, so this is there.

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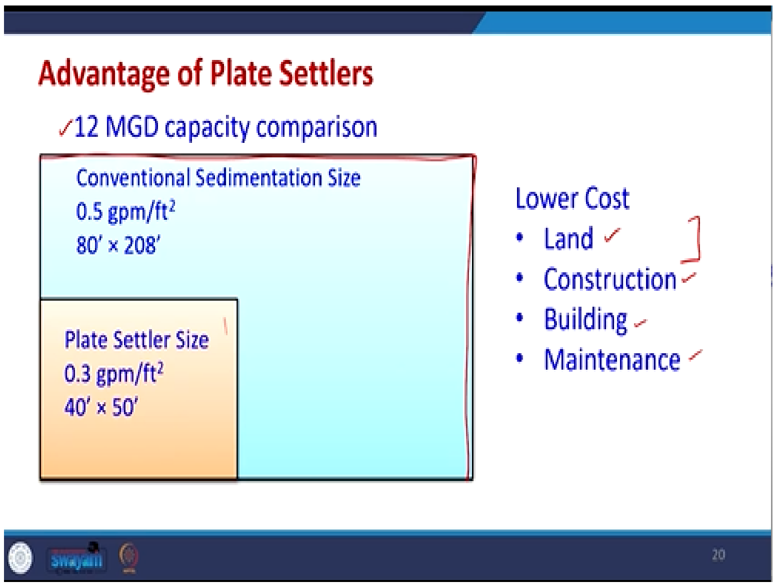

Now, suppose the, we have 20 million gallon per day capacity of the water has to be treated. So, conventional sedimentation basin will require area which is given here. So, this is the area which will be required by conventional sedimentation basin. Whereas, if we use the plate settler, only this much area will be required. So, we can see clearly lot of land space can be saved in the same, for same capacity or if the land space is same, we can use very high amount of water can be treated in the plate settler in place of the conventional sedimentation basin.

Now, so this is the benefit we have lower costs with respect to land, certainly construction cost maybe comparable, building and maintenance costs are important criteria. So, they will depend upon various parameters, but land cost is certainly saved, so this is there and maintenance is also not that difficult as compared to others.

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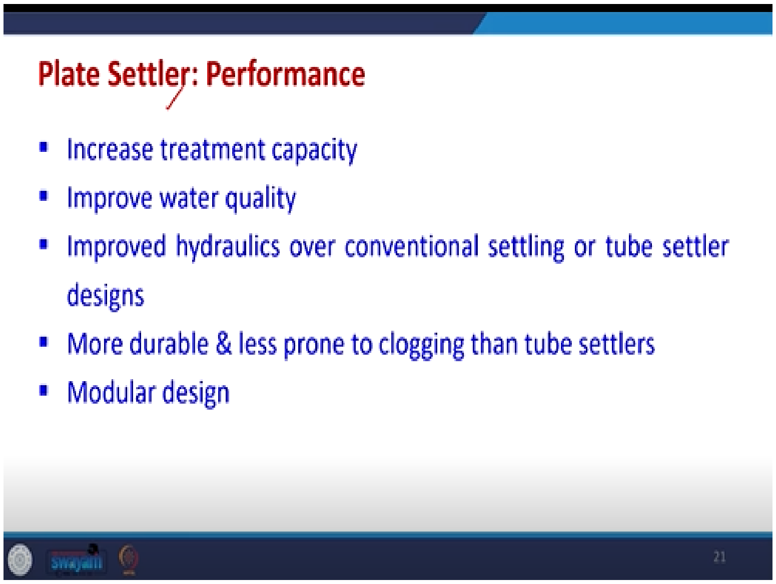

So, the performance we have increased treatment efficiency in the plate settler, they improve the water quality, they improve the hydraulics over conventional settling or tube settler design. So, this is the importance of plate settlers have these advantages which are there, and they are more durable and less prone to clogging then the tube settlers because tube settler the sludge moves in the opposite direction, it moves in the sludge direction so, we can easily remove the sludge also.

And there are modular designs which are available. So, we can always just by basic calculation, we can tentatively cross see that which is good enough, though it is like a modular design are already available. So, cost has been already reduced a lot.

So, we can always go for plate settler very quickly okay until unless we have very high throughput which is required under that condition we can go for tube settlers as well. All these possibilities are there. There are many design considerations; many design options also in both tubes settlers, plate settlers, etcetera. And based upon that, we can select the plate settler or tube settler.

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Now plate settler has been used for in potable water treatment, backwash water recovery, wastewater treatment in most of the industries, in new construction also they are being used, they are also being retrofitted to the existing basin where we have to take more water and they are coming in a package treatment systems also, so they have lot of advantages and they are now highly being used in the industry.

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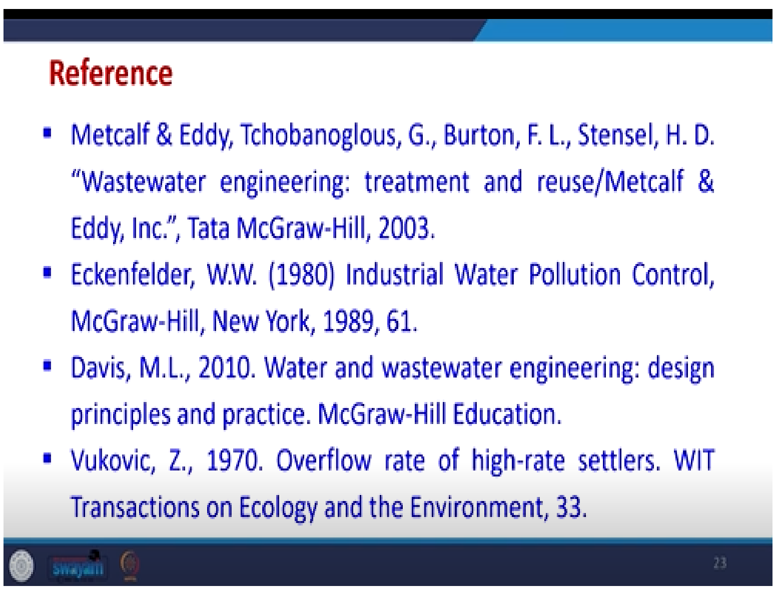

So, these are the references that we have used all throughout this settling and sedimentation section. And in this sedimentation and settling section, we have understood that after coagulation and flocculation, sedimentation basins are very important and they have to be used to settle out all those particles which cannot settle normally or during less time. So, normally they will take very high time. So, in the sedimentation basin, they can be settled down quickly.

Now, there are different types of behaviors which are possible and that depends upon the concentration of the particles in the water. So, there may be discrete settling, there may be flocculent settling, they may be, there may be hindered settling, there may be compressive settling. Now, for all these conditions, there are different design equations, different theories have been given and basic methods by which we can tentatively get the basic design data has been shared in these lectures.

So, we have understood all those things after that we came to know that, there are different types of settling basins which are used in wastewater treatment plant that may be in the grit removal, that may be in the primary treatment that is there in the secondary treatment after the biological treatment. These type of settlers are very common in anaerobic digesters which are used in our common residences also which are far away from any, any city or otherwise.

So, all these places we have settling operation which is going on. So, we should have a basic understanding of settling basin or sedimentation basin and based upon the, the ideas, the theories and the design considerations which have been discussed, we can tentatively design the sedimentation basin and we can use it as per our requirement. So and the behavior is very important that what is the solid concentration we are going to treat in that sedimentation basin.

So, we will end the sedimentation section with these lectures, after sedimentation because the smaller size particles or less denser size particles still cannot be settled out, because we always design the sedimentation basin to a particular diameter of settled, diameter of the particle. Suppose 100 microns, 50 microns, we always decide that which is the key diameter we are going to target for removal. So anything below that will be carried over and that has to be separated in a, if the turbidity is not within the our requirement.

If still the separation has not been good enough, we have to further treat the water via the filtration mechanism. So we will start with the filtration mechanism in the next lecture onwards. So today will end this the sedimentation section. We will continue with the filtration sections in the next lecture onwards. So thank you very much.