Water and Wastewater Engineering
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Sedimentation
(Continued)
Lecture # 9

Last class we were discussing about sedimentation. We have seen that sedimentation is a unit operation. It is utilizing the settling velocity of the particles to remove it from water and clean the water. So we can either go for settling or floatation for the removal of particles which is large enough. And based upon the properties of the suspension we can divide the sedimentation into different categories. Those are type one settling, type two settling, zone settling and compression settling.

And in water treatment most of the time we come across this type one settling and type two settling. Type one settling is for discrete dilute suspensions. And we have seen in detail what a discrete particle is. A discrete particle is the one whose size, shape, specific gravity or the properties will not change with respect to time. But a flocculent suspension is the one whose properties will change with respect to time.

In water treatment, most of the time in primary sedimentation tank it is type one settling and after the coagulation flocculation in clary flocculator we have flocculent settling. We have also seen in detail how to calculate the efficiency of a tank when it is a discrete particle settling or if it is for a flocculent particle settling, and we also saw how to conduct the settling column studies etc.

Today we will see in detail what are the different types of sedimentation tanks and what are the important components of the sedimentation tank and how to design a sedimentation tank and how can we find out the efficiency of a sedimentation tank in actual practice because theoretically we can achieve hundred percentage efficiency but in actual practice, in field we will not be able to get that much of efficiency. Therefore, we will discuss in detail; what are the factors that affect the efficiency of the sedimentation process and how we can find out the efficiency etc.

Coming to sedimentation tanks we can have different types of sedimentation tanks or we can classify the sedimentation tanks into different categories the first classification is either horizontal flow sedimentation tanks or vertical flow sedimentation tanks.

In horizontal flow sedimentation tank as the name indicates the flow is in horizontal direction that means water enters in one side and it flows horizontally so that is known as a horizontal flow sedimentation tank. And in vertical flow sedimentation tank the water flow direction is in the vertical direction that means water enters in the tank from the bottom portion and it comes up and it distributes. This is very common in circular sedimentation tank.

We can classify sedimentation tanks as either long rectangular tanks or square tanks or circular tanks. We will see them in detail. First we will talk about long rectangular basins. These are the best basins as far as hydraulics is concerned because these basins are hydraulically more stable. Moreover, flow control is very very easy in such basins. In long rectangular basins usually the length of the tank is 2 to 4 times and sometimes even 5 times, this is important. Sometimes the height of the tank is ten to twenty times is equal to the length of the tank. These are the parameters.

In this case the bottom is slightly a slope. The reason for this one is, if you want to remove the settled sludge it is very easy if you provide a slope in the bottom. So the bottom is slightly a slope. Usually the slope is around one percentage and the sludge removal is carried out by using a slow moving mechanical scraper.

Redwood pieces on a chain drive continuously pulls the settled material and all the settled material will be coming to a particular portion and from there we can pump it out, that is what is happening.

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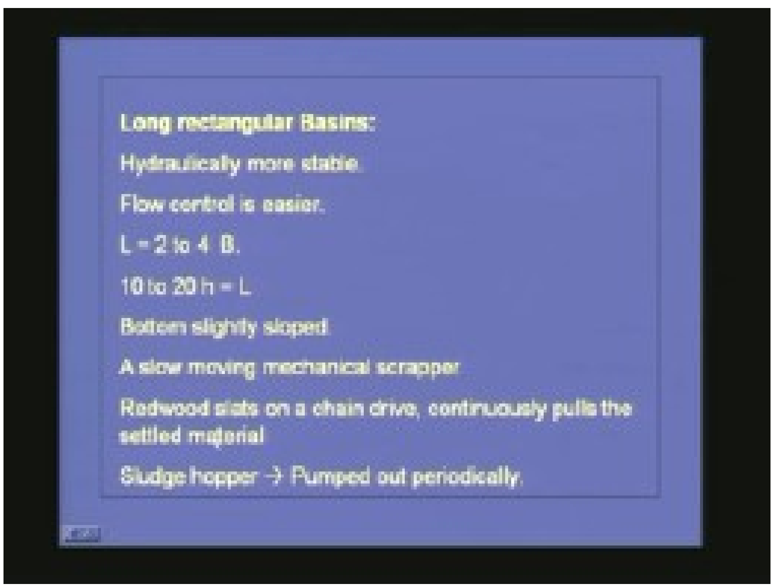

In the sludge hopper whatever sludge is accumulated is pumped out periodically. This is the property of a long rectangular basin. The most important one is, hydraulically it is more stable and we will see afterwards, what are the advantages of this long rectangular basin. The most important one is; it provides a plug flow. Plug flow is very very important to get maximum efficiency.

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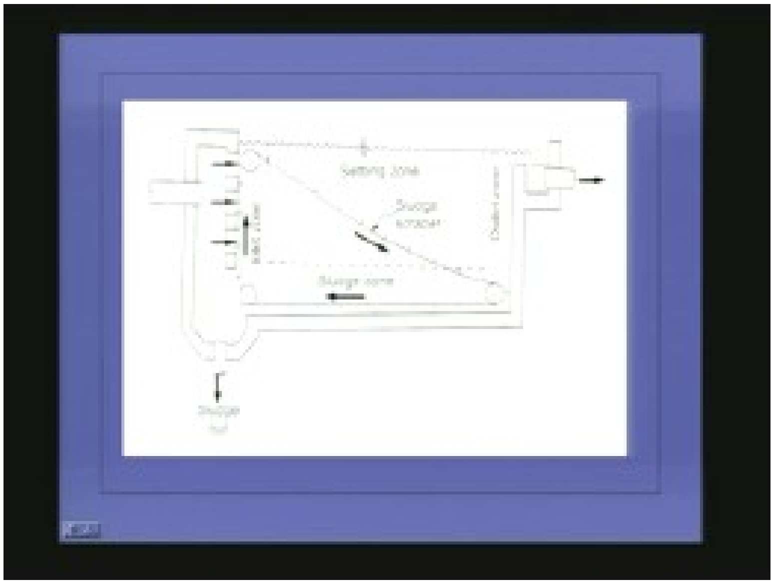

This shows the sketch of a rectangular sedimentation tank. This is the inlet zone (Refer Slide Time: 6:20) the water to be treated is entering here and this is the baffle, the inlet pipe should be facing a baffle and this baffle is having many openings as we can see here, these are the openings and this is the settling zone of the sedimentation tank whatever we are designing. This is the portion we are designing (Refer Slide Time: 6:43), this is the settling zone and this is the sludge scraper, we can see that it is connected in the pulleys and these are the scrappers, this is the wood scraper, a motor is attached to this one so this will be moving in this direction. Therefore, what will happen is, whatever sludge is settled in the bottom of the sedimentation tank which is here all those things will be scrapped. Here, this is the sludge hopper, so everything will be coming here and it will be pumped out using a pump.

This is the outlet zone. The outlet zone is designed in such a way that minimum disturbance will be provided for the settled sludge. If the turbulence is more here in the outlet zone then whatever sludge is settled in the bottom of the sedimentation tank will be getting disturbed and the particles will be escaping through the treated water in the effluent so we will not be getting the required treatment efficiency. So outlet zone should be designed properly to achieve proper efficiency or to achieve the required effluent quality.

Once again the important parts of a sedimentation tank are; first one is the inlet zone, second one is the settling zone and then the outlet zone then the sludge zone and sludge removal mechanism.

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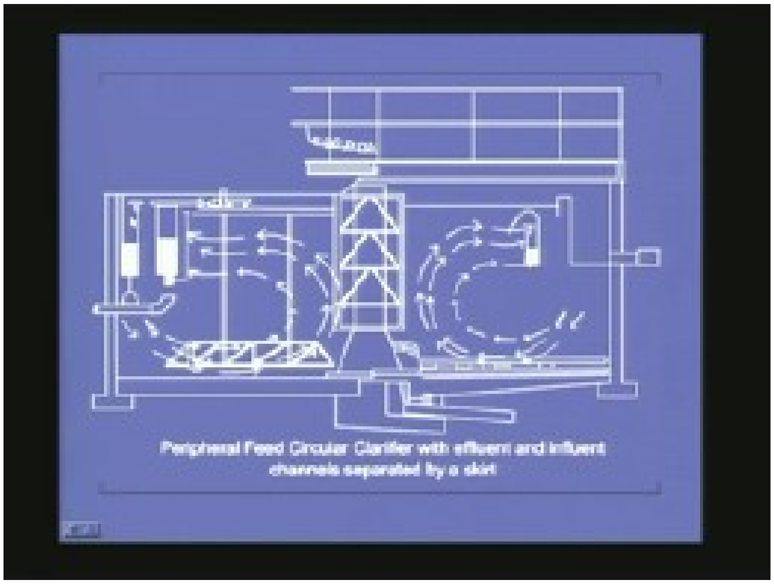

This is another picture which is showing a circular sedimentation tank. The earlier one was a rectangular sedimentation tank; this is the circular sedimentation tank with peripheral feeding. The inlet is here. Water is flowing here and it is taking a path like this and (Refer Slide Time: 8:33) this is the effluent collection weir so this portion will be acting as the settling zone. Similarly, here also this is the inlet zone, water takes a path like this, during this period whatever particle is present in water will be settling down and the clear water will be collected earlier, this is the effluent collection we have and here the slope is in this direction so whatever sludge is settled in the bottom of the tank everything will be coming here and from here it is taking away. This is the way a circular tank with peripheral feed is working.

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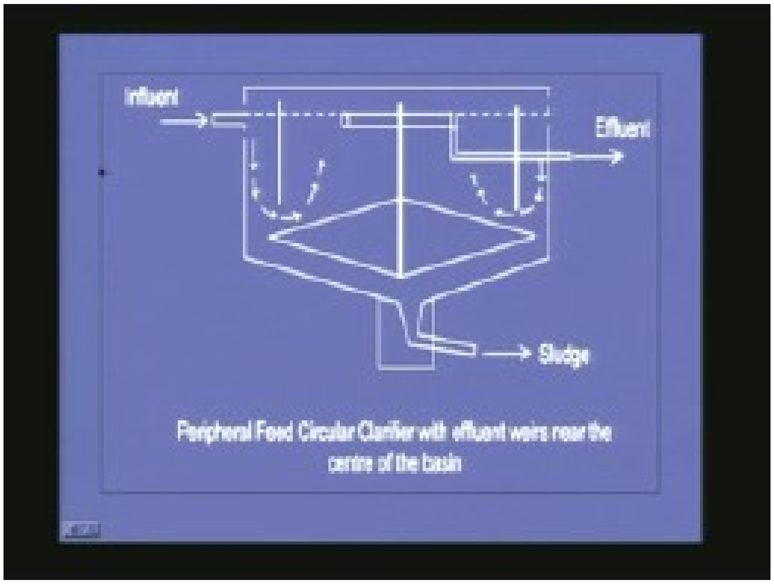

This is again another example. Here the outlet weir is situated in the center. in the previous case we have seen that the weir is also in the periphery and inlet and outlet both are located in the periphery, in this case the inlet is in the periphery, the outlet is in the center so water will be taking this type of a path and here we are providing a baffle wall in order to reduce the kinetic energy of the incoming water. Otherwise the turbulence will be very very high and that will be affecting the settling process so we will not be getting much removal. Here also whatever is settling here will be coming to this portion (Refer Slide Time: 10:10) and from here the sludge will be taking away.

I have already discussed that the sedimentation tank will be having various zones. The first one is inlet zone, then the settling zone, outlet zone and the sludge zone. The inlet zone is the one in which the baffles intercept the incoming water and spreads the flow uniformly. or the major purpose of the inlet zones are to uniformly distribute the incoming flow because there is only one incoming pipe and you will be having so much of width for the sedimentation tank so we have to distribute the flow uniformly throughout the sedimentation tank then only the entire area or the entire volume of the sedimentation tank will be effectively utilized. That is the most important purpose of the inlet zone; distributing the flow uniformly throughout the tank.

Second one is to minimize the turbulence created by the incoming flow. We know that the water will be entering into sedimentation tank with a high velocity
So if we allow that one to enter in the settling zone with the same velocity then it will be creating lot of turbulence in the sedimentation tank. If the turbulence is more then whatever sludge gets settled in the bottom of the tank will be coming out. Therefore, how should we design the inlet zone in such a way that the turbulence should be at minimum?

The third purpose is to train the flow so that it will be equally distributing and it will be uniformly flowing throughout the sedimentation tank. These are the purposes of inlet zone. Always the inlet pipe will be facing a baffle which will be reducing the kinetic energy of the incoming water. These baffles will be having many pores on them or many holes on the baffle wall therefore water will be uniformly escaping through these pores to the settling zone and when water enters the pores there will be a head loss. The pores are designed in such a way that the velocity through the pores should be around 0.2 to 0.3 meter per second and the head loss through the pores will be around 1.7 times the velocity head. These are the important things we have to consider when we design the inlet zone.

Once again, the inlet pipe should be face to a baffle wall to dissipate the kinetic energy of the incoming wall and most of the time the inlet zone will be made in such a way that the baffle wall will be having many pores or many holes and the water will be coming into the inlet zone and from the inlet zone through these holes of the baffles it will be entering into the settling zone. Therefore, the ports in the baffle walls will be distributing water equally to the inlet zone moreover it will be reducing the kinetic energy because there will be lot of head loss when the water passes through the holes.

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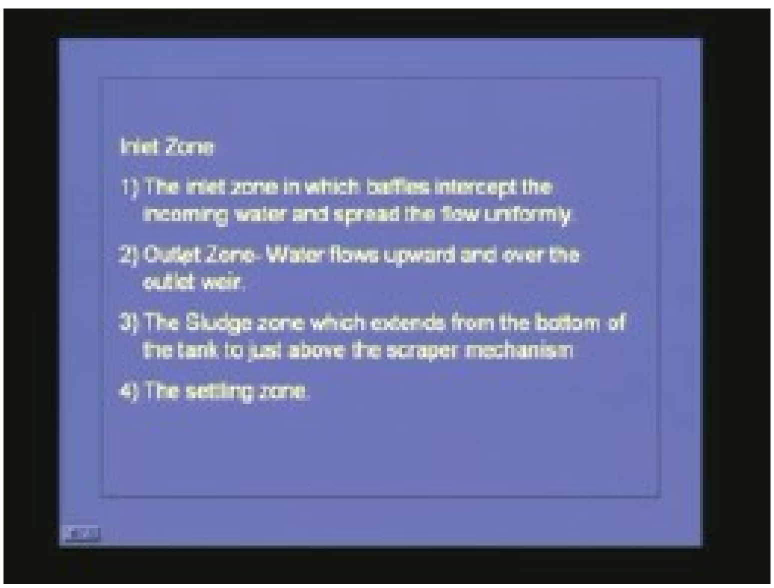

Now, in the outlet zone what is happening is, water flows upwards and over the outlet weir so it will be reducing the turbulence and it will be improving the quality of the treated water. The sludge zone which extends from the bottom of the tank to just above the scrapper mechanism, this is the sludge zone and the last one is the settling zone which is responsible for the settling process. In the inlet zone the opening must face a baffle, this I have already explained and we have seen the purpose. The purpose of this one is to dissipate the kinetic energy.

I will show you some of the inlet arrangements.

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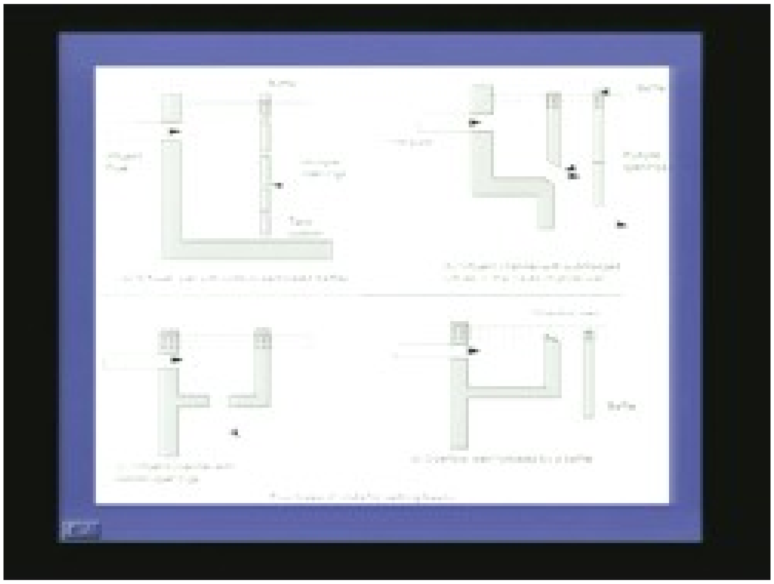

This is one of the inlet arrangements. Here (Refer Slide Time: 14:20) the influent pipe is coming and this is the inlet of the sedimentation tank and this is the baffle. Here we can see multiple openings and this baffle wall goes up to the bottom of the tank and the influent pipe brings the water here and the water will be stored here and from here the water will be going to the settling zone of the sedimentation tank. This portion will be the settling zone through these multiple openings. Hence, the velocity of the incoming water will be reduced and the water will be equally distributed throughout the width and depth of the tank so the settling zone will be completely utilized if you give this type of an arrangement for the inlet.

This is another type of inlet arrangement (Refer Slide Time: 15:19). this is the inlet pipe and here we have a submerged orifice so the inlet pipe brings the water here from here, it is passing through this orifice and this orifice will be having multiple openings because this is only a portion and throughout the cross section we can see many openings and afterwards to reduce the kinetic energy further we provide a baffle wall. So you will be having uniform distribution of water because of these multiple openings and because of the baffle wall the turbulence will be reduced or minimized to some possible extent.

This is another type of inlet arrangement (Refer Slide Time: 16:10) it is influent channel with bottom openings. Here what is happening is, water is coming through this pipe and this is your storage place and it will be having a bottom opening so what will happen is that water enters here like this and the direction will be changed and it will be coming to the settling zone like this. Here also multiple openings will be there throughout the width of the tank so there will be some uniform distribution of the water as well as energy destruction.

This (Refer Slide Time: 16:41) is another type of an inlet arrangement which is an overflow weir followed by baffle. We have a submerged orifice here and here we have an overflow and the inlet pipe is here, the entire water that is passing here will be overflowing through this weir, we have a baffle wall here and afterwards the water will be going to the settling zone. All these things are meeting the basic requirement that is uniform distribution of water as well as minimizing the turbulence and training the flow in the settling zone. These are the purposes of the inlet and these are the commonly used inlet arrangements in a sedimentation tank. So whenever we design a sedimentation tank it is very very important to design properly the inlet zone, outlet zone and sludge zone. Anyway we will be designing the settling zone properly based upon the principles whatever we have seen earlier.

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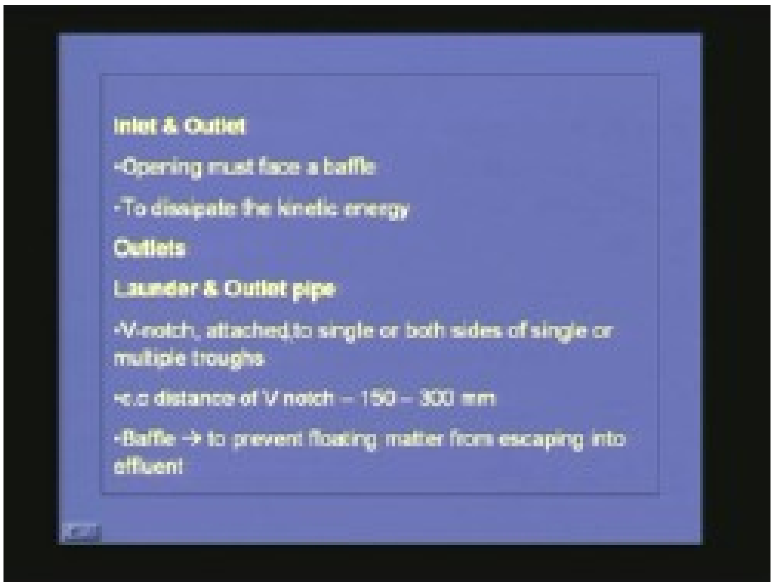

Now we will see how the outlet zones are designed in a sedimentation tank. Most of the time, the outlet zone consists of a launder and an outlet pipe. It consists of V notches attached to single or both sides of single or multiple troughs.

This I will explain in detail when we do the design problem.

Most of the time what will happen is the center distance of this V notch will be around 150 to 300 mm so in the outlet zone trough many V notches will be there, these V notches will be placed at a center distance of 150 to 300 millimeters and just before the outlet zone there will be a baffle. We have seen that in the inlet zone after the inlet pipe we will be providing a baffle but in the outlet zone what is happening is the baffle will be provided first then the outlet launder or the V notches will be coming.

The purpose of this baffle is to prevent floating matter from escaping into the effluent because there will be many floating materials as well as scum in the sedimentation tank. Whatever amount of water is entering in the sedimentation tank is having oil or grease or any floating material, it will not be removed by settling so definitely it will be present in the surface of the sedimentation tank so definitely if we do not provide any obstruction it will be coming and escaping through the effluent so naturally the effluent quality will be destroyed or effluent quality will be spoiled. So if you want to improve the effluent quality we have to remove the scum as well as floating matter from the sedimentation tank. So these baffles, whatever is provided in the outlet zone is serving that purpose.

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Another important factor which we have to consider when we design an outlet zone is weir loading rate. If we go for a high weir loading rate that means the rate at which the water escaping through the weir is very high then definitely the turbulence will be very high so that will be destroying or that will be reducing the efficiency of the tank. Hence, weir length relative to the surface area determines the strength of the outlet current. This point is very very important. The weir length is the one which decides the strength of the outlet current. To get maximum efficiency we have to keep the strength the minimum possible.

Usually whenever we design a sedimentation tank the weir loading rate we usually keep it at this value 300 meter cube per day for per meter but if the settling is very very good then we can go for a higher weir loading rate up to 1500 meter cube per day per meter. But usually we keep a value of 300 meter cube per day per meter.

How can we find out the weir loading rate?
It is nothing but the flow rate divided by the weir length. The flow rate per weir length will be giving you the weir loading rate that’s why we get this unit because your flow rate unit is meter cube per day so that much is the flow entering into sedimentation tank and your weir length will be given in terms of meter so weir loading rate will be in terms of meter cube per day per meter or meter cube per hour per meter.

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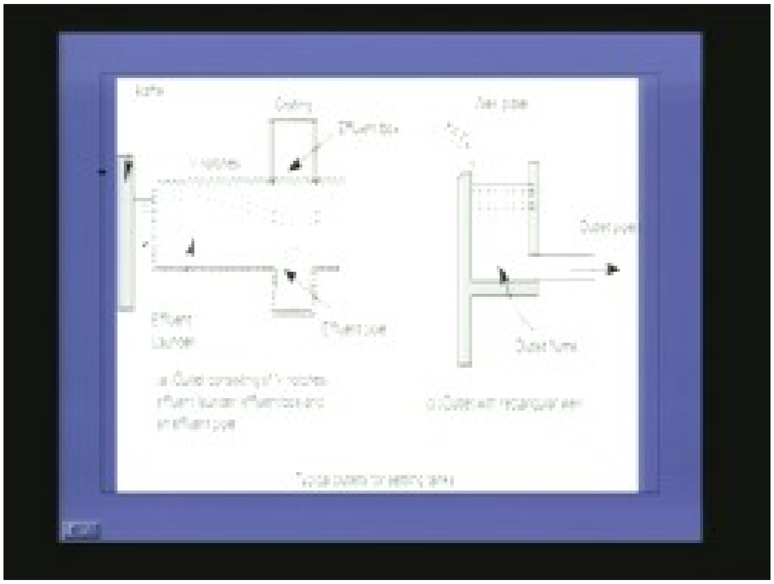

These are typical outlet arrangements. As we discussed earlier, we can see here, this is the baffle, this baffle will be preventing all the floating materials and scum materials to escape into the outlet zone. From here this is the treated effluent (Refer Slide Time: 21:47), and here we can see many V notches and the center to center distance between these two V notches is usually 15 to 30 centimeters. The treated water here will be escaping through the effluent launder through the V notches and from here it will be going to the effluent box and from the effluent box it will be collected through the effluent pipe. Therefore, an outlet zone consists of many V notches which collect water to the effluent launder and from there it is going to the effluent box and from the effluent box the treated water is collected through the effluent pipe.

This is another type of an effluent outlet zone (Refer Slide Time: 22:40). This consists of outlet with rectangular weir. Here we are having a weir and before this one we will be having a baffle wall to remove the floating materials as well as scum and the treated water is coming here which is free from floating matter and scum and it is passing through this weir, most of the time this weir length is adjustable and this is escaping here and what you see here is known as the outlet fume and from here the treated water is collected through this outlet pipe.

These are very very important. So, whenever we design a sedimentation tank we have to design the inlet zone and outlet zone properly.

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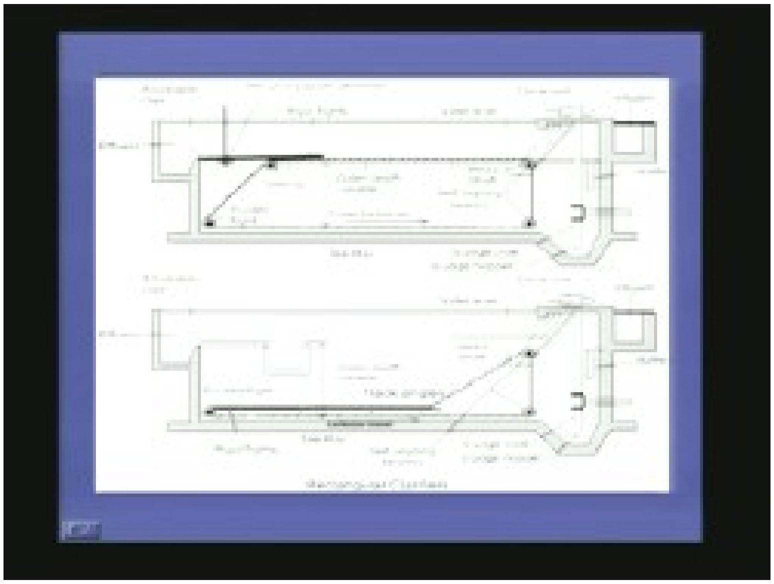

This is a sedimentation tank with all the details. This is the influent inlet arrangement (Refer Slide Time: 23:42) so influent is coming here and this is the baffle and this is the settling zone and we have the sludge scraper mechanism here. This is another important point; most of the time the sludge hopper will be situated near the inlet zone. The reason is, if you provide the sludge hopper here near the outlet zone then during heavy turbulence the entire sludge present in the sludge hopper would be disturbed and it can escape through the effluent or outlet arrangement so it is always advisable to keep the sludge hopper in the inlet zone so that the disturbance will be at its least and we will be getting a better effluent quality.

This is the inlet zone (Refer Slide Time: 24:36) and this is the settling zone, this is the sludge hopper and this is the outlet. So we are getting the outlet effluent from here and here an adjustable weir is used as the outlet arrangement.

This is another type of outlet arrangement (Refer Slide Time: 24:54). Here what is happening is, this is a weir and we are collecting the effluent here and finally whatever is collected is coming out through this one and here we can see that the sludge scraper is little different from the one whatever we have seen. So we can provide any type of sludge scraper but only thing is it should be able to remove the collected sludge effectively. We should provide proper sludge removing mechanisms. We should not allow the sludge to accumulate here in the sludge hopper so the pump should be operating periodically to remove the sludge whatever is collected in the sludge hopper.

Another important factor whenever we discuss about the sedimentation tank is surface loading and detention periods. We have seen what surface loading is in the last class.

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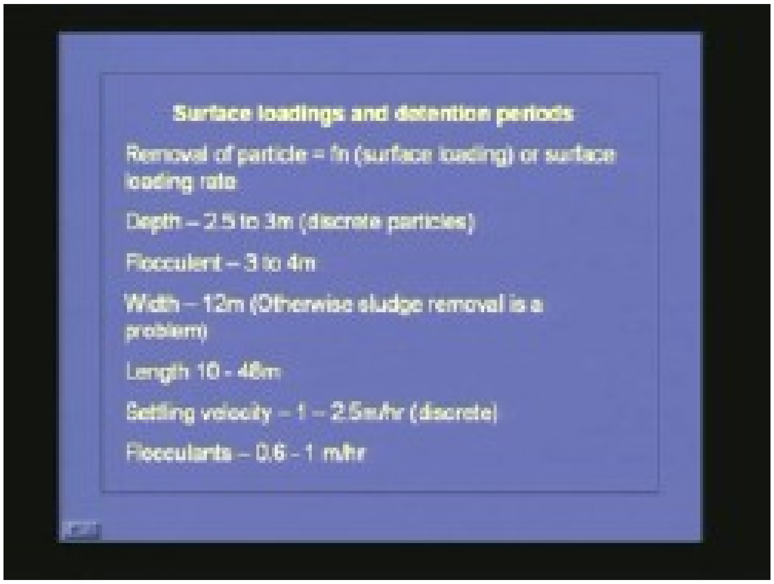

Removal of particle: we have seen that the time required for the removal of a particle is depending upon the settling velocity and we have seen how to calculate settling velocity in case of a discrete particle. We can use the Stokes' Law to find out the settling velocity and in flocculent particles we cannot use the Stokes' Law, the reason is, the particle size shape and the properties will be changing with respect to time. We have seen that the settling velocity of the discrete particle will be increasing with respect to time. The reason is, more and more particles will be agglomerating together with respect to time. So as the particle size increases the settling velocity also will increase. So removal of a particle is directly proportional to the settling velocity. And we have seen that the settling velocity of a particle in a sedimentation tank is numerically equal to the surface loading or surface loading rate or the removal of a particle is a function of surface loading or surface loading rate. This is very very important when we talk about high rate reactors also.

I will show you how to derive this one.

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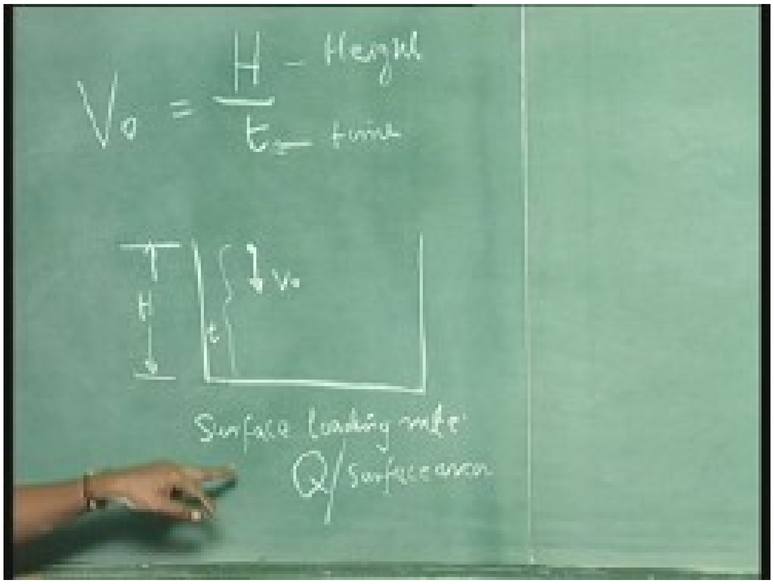

The settling velocity is nothing but V_0 where V_0 is H by t; H is nothing but the height of the tank and t is the settling time, this we have seen. If we have a tank this is having a height H and here one particle is there it is settling with a settling velocity of V_0 or we have a particle, it took around t seconds or t minutes to reach the bottom of the tank then we can find out what is the settling velocity. So the particle removal is a function of this settling velocity and we have seen now the settling velocity or the particle removal is a function of surface loading or surface loading rate. Surface loading rate is nothing but, this is the flow rate (Refer Slide Time: 28:32) divided by surface area.

How to show this one? We have this expression V_0 the settling velocity is equal to H by t and we have the sedimentation tank, and for any sedimentation tank we can find out the volume by multiplying length of the sedimentation tank by width by height so this is the volume of the sedimentation tank and if you want to find out the height of the sedimentation tank what is that one volume divided by surface area that will be giving you the height. So what is the surface area? Surface area is nothing but length into width. So we can write like this. Here we are finding out what is the height or depth of the sedimentation tank if you know the volume of the sedimentation tank and surface area.

So volume of the sedimentation tank is nothing but length into width into height and surface area is length into width (Refer Slide Time: 29:54). That is the surface area so you will be getting the height. We have seen that V_0 is nothing but H by t so we have the H value like this that means volume divided by surface area and t. So if you talk about a sedimentation tank what is the t or what is the time the water or any particle that is getting in the tank that is nothing but volume of the tank divided by the flow rate so this is nothing but the hydraulic retention time. This is the time the particle is getting inside the tank that means volume. So we have a particle volume and we know the flow rate so we can find out what is the time that water is going to stay inside the tank. So we can put this one so this expression we can write like this; V_0 equal to H by t so that is equal to L into B into H divided by L into B so that will be giving you the H value.

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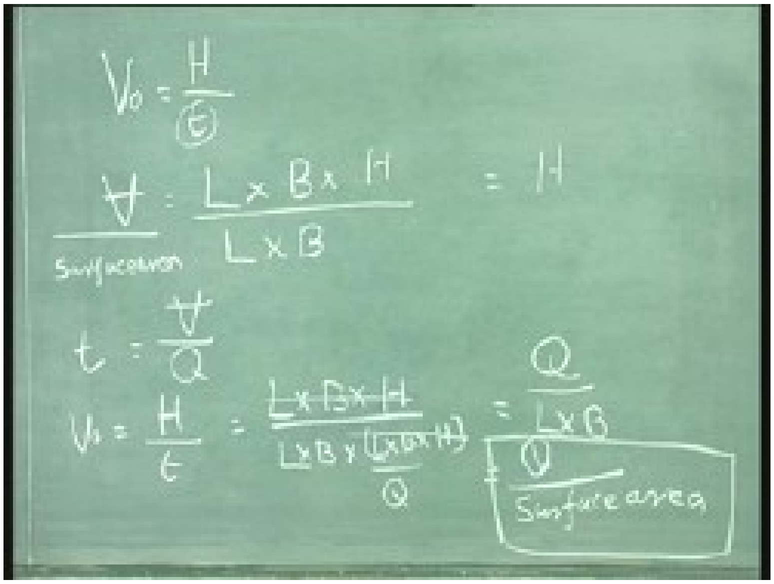

Now t is nothing but volume by Q so this volume we can again replace by L into B into H this is nothing but the volume of the sedimentation tank. Now these terms will be getting cancelled and you will be getting Q divided by L into B so this is nothing but Q divided by surface area so that is what we have seen in a sedimentation tank. The settling velocity or the removal of the particle or particle removal efficiency is a function of surface overflow rate. Surface overflow rate is nothing but the flow rate divided by the surface area and the particle removal is independent of the height of the tank or H. This is very very important when we talk about the high rate sedimentation tank. We will discuss this in detail towards the end of the class.

We have seen that the removal of a particle is a function of surface loading or surface loading rate. Usually in a sedimentation tank we provide a depth of 2.5 meters to 3 meters in case of discrete particle and flocculent particle we usually give 3 to 4 meter. Though we have seen that the depth of the tank is not an important factor what will happen is, even if the depth is too minimum whatever sludge gets settled on the bottom of the tank will be coming out because of the turbulence. That's why we are providing a depth of 2.5 to 3 meter.

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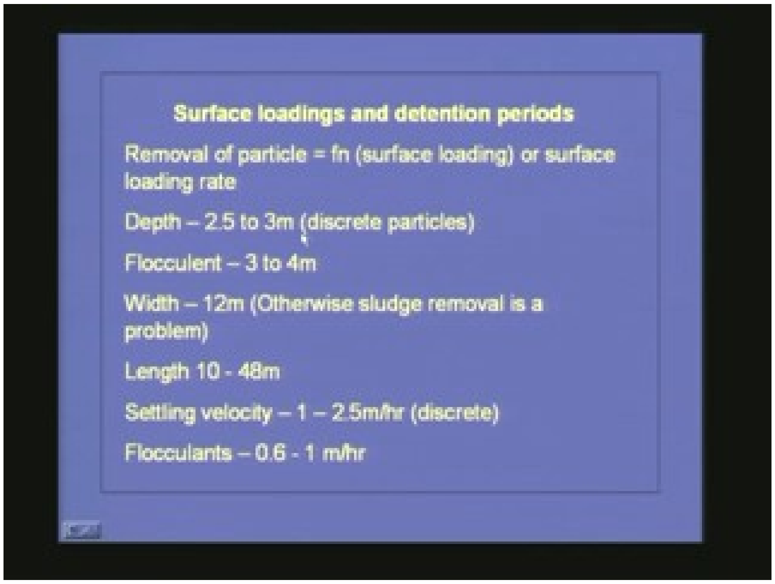

In case of flocculent particles what will happen as the particles travel downward direction with respect to time the particle size will be increasing, so if you provide large depth the removal efficiency will be high. Usually the width of the tank is 12 meters otherwise the sludge removal is a problem. When you install the sludge removal mechanism it is always advisable to provide a width of 12 meters or more. The length of the tank varies from 10 to 48 meters and the settling velocity of the particle if it is discrete it varies from 1 to 2.5 meter per hour and for flocculent particles the settling velocity varies from 0.6 to 1 meter per hour and these (Refer Slide Time: 33:47) are the typical surface loading rates and detention periods for various types of sedimentation tanks, for a plain sedimentation tank.

That means there is no coagulation flocculation and most of the particles are discrete in nature so the range is 0 to 6000. But typical values for design is 15 to 30 meter cube per day. So this is the surface loading rate usually we provide. And for horizontal flow circular sedimentation tanks the typical values for design is 30 to 40, this is for rectangular 15 to 30 and circular, 30 to 40.

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For vertical flow clarifiers here the flow direction is in the opposite from the bottom to the top most of the time so in such cases we can provide a surface loading rate of 40 to 50 meter cube per day; and for plain sedimentation we can give a detention period of three to four hours if the particles are sand, silt and clay; and for horizontal flow circular sedimentation tanks the detention period can be 2 to 2.5 hours; and vertical flow usually the detention time of 1 to 1.5 hours is provided.

Now we will see how to design a long rectangular settling basin for type two settling. Type two settling means it is flocculent particle settling.

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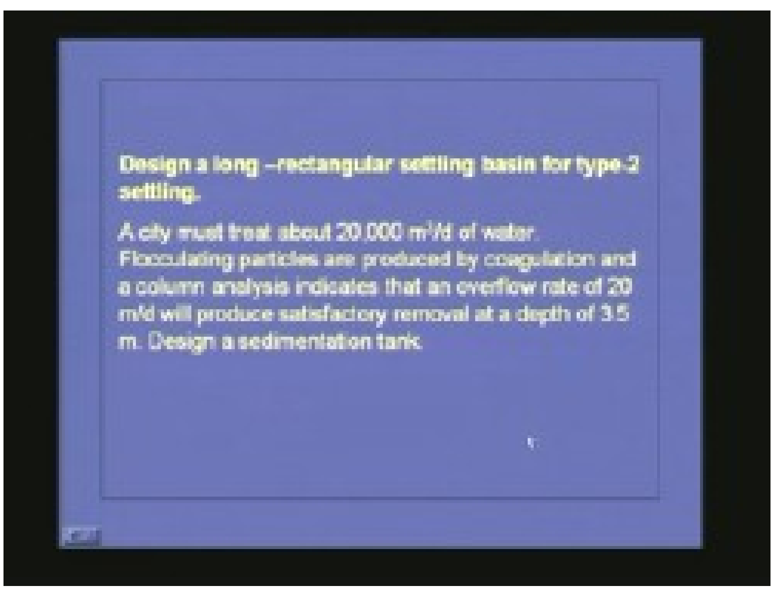

This is the problem: A city must treat about 20000 meter cube per day of water. Flocculating particles are produced by coagulation and a column analysis indicates that an overflow rate of 20 meter cube per day per meter square will produce satisfactory removal at a depth of 3.5 meter. Design a sedimentation tank.

We will see what information is available. We have the Q the flow rate 20000 meter cube per day and we have the surface loading rate that means this much meter cube per meter squared per day and the depth of the tank is also given 3.5 meter so we will see how to design the tank.

First we have to find out what is the surface area required because we know the depth of the tank so how can we find out the surface area. We have the flow rate and since the flow rate is very very high we are providing two tanks where each tank will be taking care of 10000 meter cube per day so Q is 10000 meter cube per day and this is equal to Q_0 into A_s where A_s is the surface area and this Q_0 is nothing but the surface overflow rate.

The surface overflow rate is already given as 20 meter cube per meter square per day so we can find out the area required. So just divide this one by the surface overflow rate and we will be getting 500 meter square.

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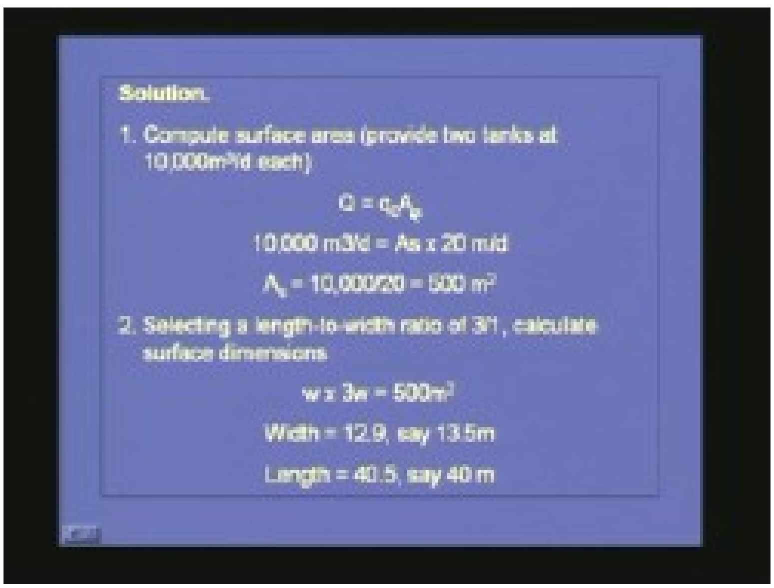

Now we have to find out how much is the length and width we have to provide. So we are assuming the length to width ratio as 3 is to 1 so we have seen that we the length of the tank is around two to five times the width of the tank so we are assuming three times so we can find out the width like this w into 3w that means this is the L with a value of 500 meter square so width is 12.9 meter so either we can go 13 or 14 meter, I have taken 13.5 meter because we have to satisfy other conditions so the length will be around three times this one so we are providing a length of 40 meters.

Now we have to check for the retention time. How to find out the retention time? it is nothing by V by Q that is a retention time. So we can find out the volume because we know the width, we know the length, we know the height so this is the volume divided by the flow rate so it is coming around 0.189 days or 4.5 hours so we have seen that in the discrete settling we can go up to four hours this is higher than [……..38:12]

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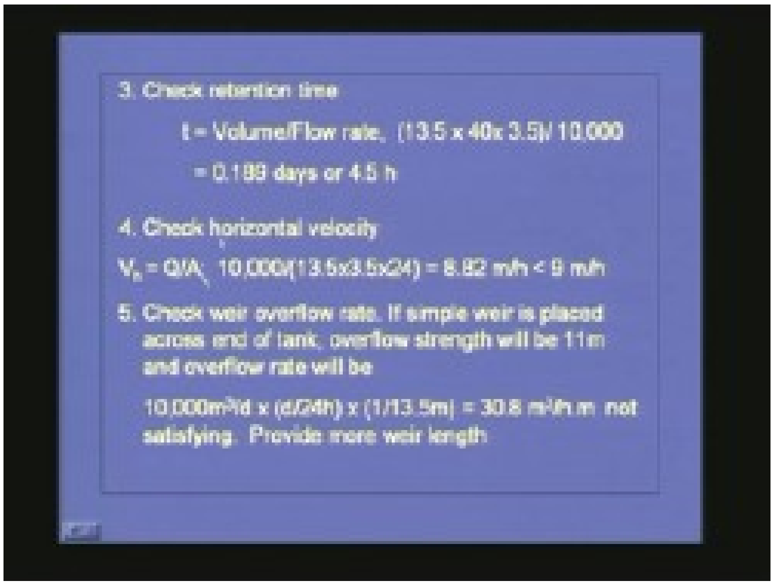

Now we will check for the horizontal velocity because if the horizontal velocity is high more turbulence will be generated and that will be affecting the efficiency of the system. The horizontal flow velocity is nothing but Q divided by the cross sectional area which we can find out using this expression; 10000 divided by width and depth so you are getting 8.82 meter per hour and for discrete particles it should be less than 9 meter per hour so it is satisfying that condition.

Now we have to see the weir overflow rate. The weir overflow rate should be less than 300 meter cube per meter square per hour. Here we are getting around 30.8 meter cube per hour per meter and this is not satisfying that condition so how can we achieve the condition. What we can do is, instead of proving only one layer of weir in the end we can provide multiple weirs. I will show you this.

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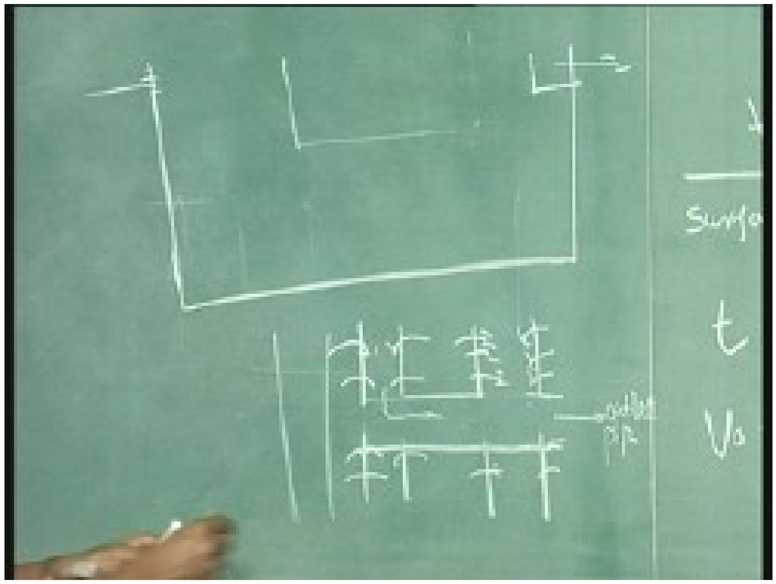

This is a sedimentation tank and this is your inlet and this is your outlet and this is the settling zone. Usually what we give is we will be having a weir here and this is the outlet zone. So instead of providing one weir here what we can do is we can provide multiple weir as something like this (Refer Slide Time: 39:45) so water will be coming to this one from both sides like this and this one we can connect through a pipe as something like this. So whatever amount of water that is collected here will be entering here and it will be going to the outlet pipe. Therefore, instead of providing a single row or single weir length we can provide two or three weirs here so that will be taking care of the weir loading rate. This is what we usually provide in the rectangular tanks. But when we talk about the circular tanks this weir loading rate will not be a problem.

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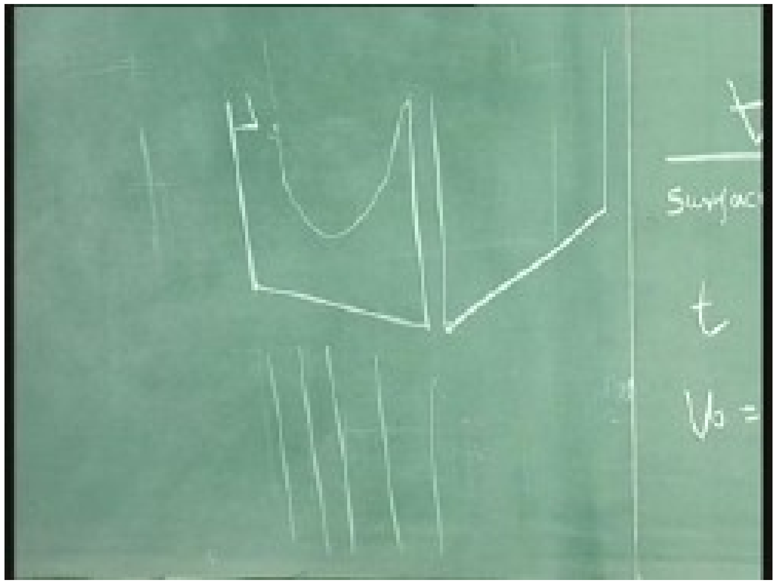

This is the cross section of a circular tank so the inlet will be most of the time in the center so it will be coming like this, (Refer Slide Time: 41:00) this is the outlet so entire periphery of the tank will be available for this weir so the weir loading rate will not be a problem in circular tanks. But in rectangular tank if you provide only one line of weir it may not be meeting the weir loading rate requirement so in such cases we have to provide parallel weirs. This point is very very important.

Hence, if you want to draw the picture whatever we have designed so for it comes like this. So whatever dimension we have got, that 40 by 13.5 is for the settling zone and we have to provide the inlet zone, we have to provide the outlet zone depending upon the weir loading rate and we have to provide the sludge zone. Usually we provide a slope of one percentage and this is the sludge hopper which is situated in the inlet zone.

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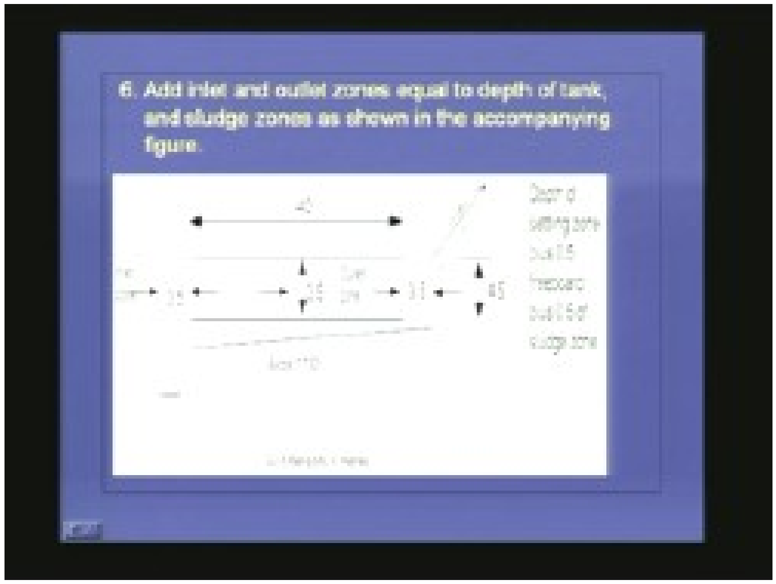

Then the total height of the tank will be coming around 4.5 meter the reason is, 3.5 is the depth of the settling zone and we have to provide around 0.5 meter for the sludge zone and 0.5 meter as the free Bourne so that's why it is coming as 4.5 meter.

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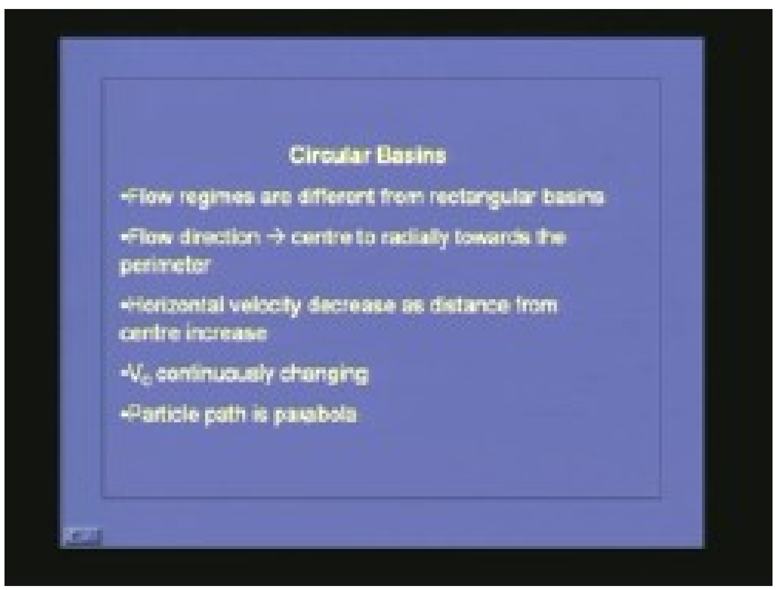

In circular basins the flow regions are different from rectangular basins. In most of the cases the flow direction is from the center to radially towards the perimeter. Here what is happening is the horizontal will velocity will not be a constant it decreases as distance increases from the center. The reason is, if you take any section the cross sectional area will be increasing as we go towards the perimeter of the circle that's why the horizontal velocity will be keep on decreasing so you will not be getting a linear velocity change it will be in parabolic. So V_0 is not a constant it will be continuously changing and if you find out the particle path it will be following a parabola.

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And here if you go for circular tanks the major advantages are; sludge removal mechanism is simpler and weir overflow rate will not be a problem as I have already mentioned because entire perimeter is available for the weir and usually when we go for tanks in circular shape the d should be less than 30 meters. It is easy for construction and all those purposes that's why we are restricting the diameter as 30 meter.

This is the same problem if you design a circular settling basin (Refer Slide Time: 43:43). Here what I have done is I have taken three tanks instead of two tanks so we will be getting the cross sectional area in the same way as 333.33 meter squared so we can find out the diameter. The diameter is coming as 20.6 meters or we can provide as 22 meters and it should also have the inlet and outlet arrangements and sludge collection systems.

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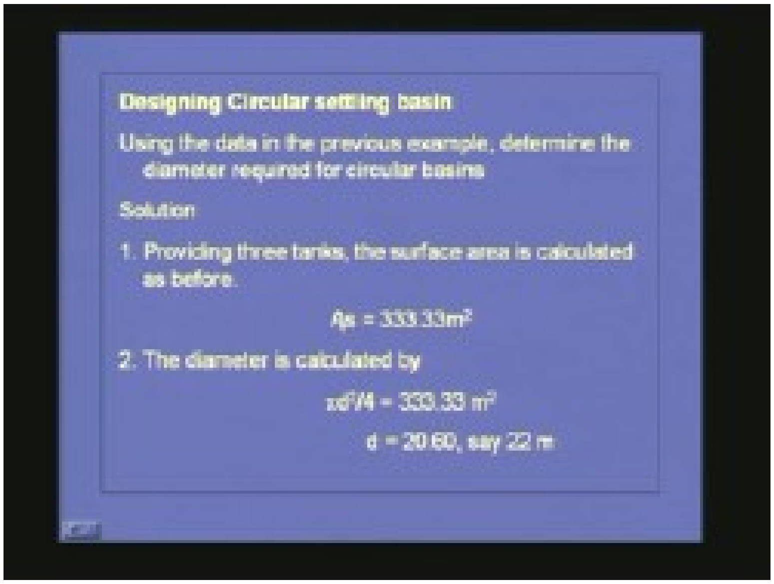

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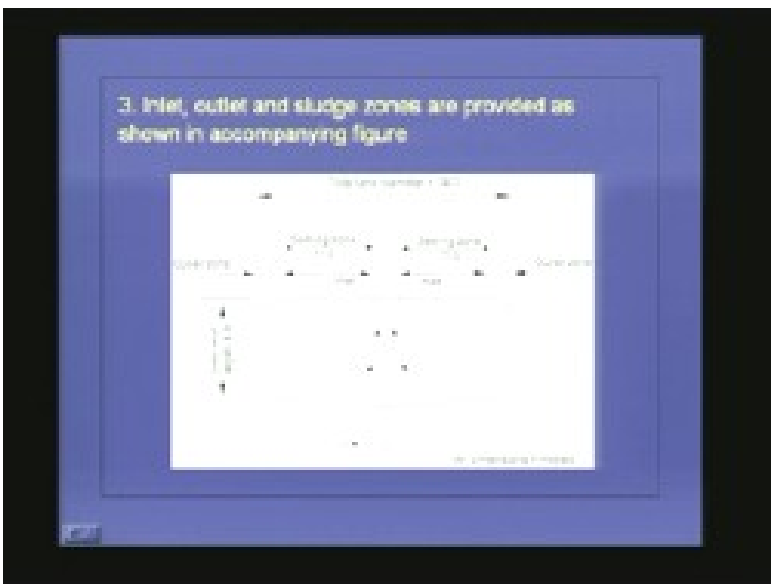

This is the settling zone, this is the inlet zone and this is the outlet zone (Refer Slide Time: 44:19) so if you provide the inlet zone and outlet zone along with the settling zone then you will be getting a total diameter of 34 meter though the inlet zone itself requires only 22 meters.

Now we were discussing about the discrete particle settling. We have seen that the depth of the tank is not very important in discrete particle settling. Based upon this principle high rate sedimentation tanks are being designed. Tube settlers or inclined plate settlers are examples of high rate settlers. Here what we are doing is we are providing excess surface so that the surface overflow rate will be decreased. We have sedimentation tank like this say some 3.5 meters depth so if you provide many plates parallelly in the settling zone so what will happen is the effective surface area will be increasing because many surfaces are available for the settling or many planes are available for settling. So, effectively what will happen is it will be considerably reducing the surface overflow rate or in other words it will be increasing the efficiency of the tank. That is the principle of these tube settlers.

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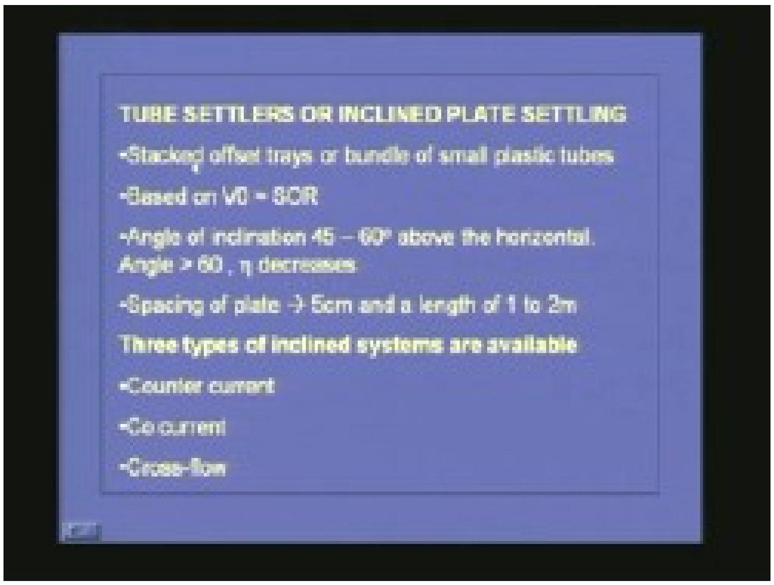

Here the design is based upon the surface overflow rate so here we are providing many tube or inclined plates at an angle of 45 to 60 degree above the horizontal. Why we are providing this 45 to 60 degree angle is because the particles will be settling on the plates or the tubes so if you provide an angle 45 to 60 degree then whatever the particle that is settled on the tubes or the plates will be sliding back to the system with the self weight so cleaning will be very very easy.

Therefore, people have shown that if you provide an angle of 45 to 60 degree the efficiency of the system will be at maximum. And in such cases the spacing of the plates will be around five centimeter and length of the plates will be around 1 to 2 meters. When we talk about these tube settlers it can work in three different modes either counter current mode or co current mode or cross flow.

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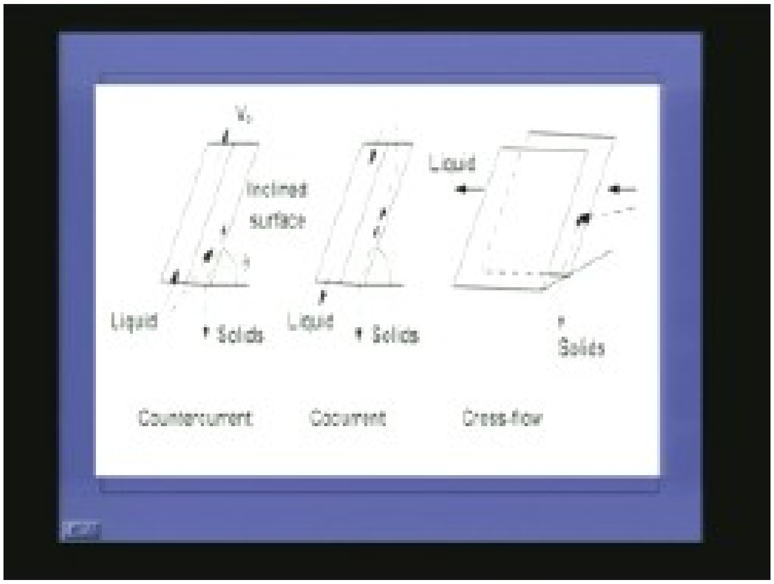

This shows how the three systems are functioning. This is an example of counter current mode. Here what is happening is, the plates or the tubes are placed at an angle theta degree to the horizontal and it is an inclined plate so what will happen is the liquid will be entering through the plate like this. If it is a tube what will happen is, water or the particle will be going and touching the top portion of the tube and afterwards it will be coming down and it will get settled and if it is a plate the same thing will be happening.

So what will happen is, here the liquid flow is in this direction (Refer Side Time: 47:24) we can see that the velocity V_0 is going in this direction and particle settling will be in the opposite direction, it will be settling and particle will be coming back to this system because the plates are inclined like this. That is what is known as counter current. That means the flow is in one direction and particle settling and removal is in the opposite direction that's why it is known counter current. this is co current (Refer Slide Time: 47:50) so in co current what is happening is, this is the liquid flow direction and this is the solid removal direction so both are in the same direction. That means water is entering like this and as it enters the particles will be following this trajectory and it will be coming and settling here and it will be getting removed and clear water will be going like this. Hence, both are in the same direction, this is co current and this is cross flow. That means here the flow is in this direction (Refer Slide Time: 48:20) the plates are placed parallelly and flow is in this direction and solids will be settling in this direction that is why it is known as cross flow.

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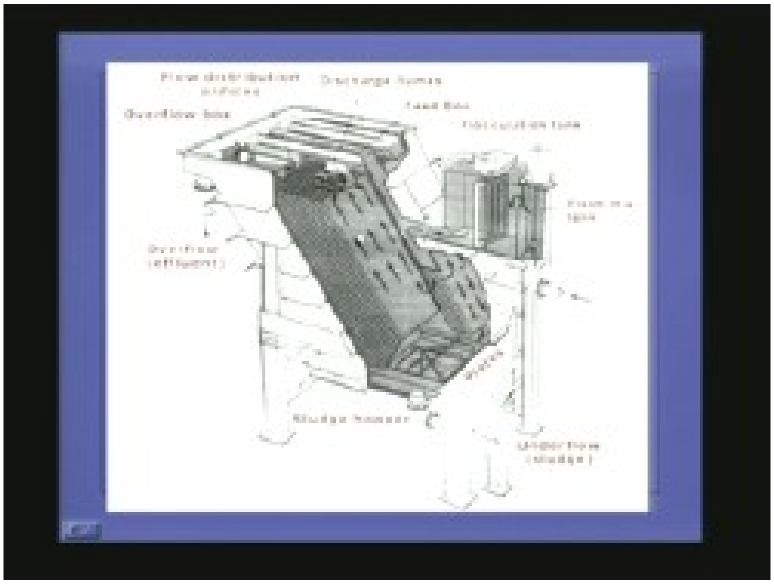

This is a typical cross section of a plate settler. Here we can see many plates are provided so all these things are plates and this is a coagulation flocculation and clarification so this is the flocculation tank and from here the water is coming here and this is the underflow sludge (Refer Slide Time: 48:53) the water flow direction is like this, you can see that one, and as it comes here we will be getting the clean clear water. This is the overflow box and from here we can see that the clear effluent is collected. This is the feed box (Refer Slide Time: 49:11) and this is the sludge hopper and from here the sludge is collected through this pipe. This is how a tube settler is functioning.

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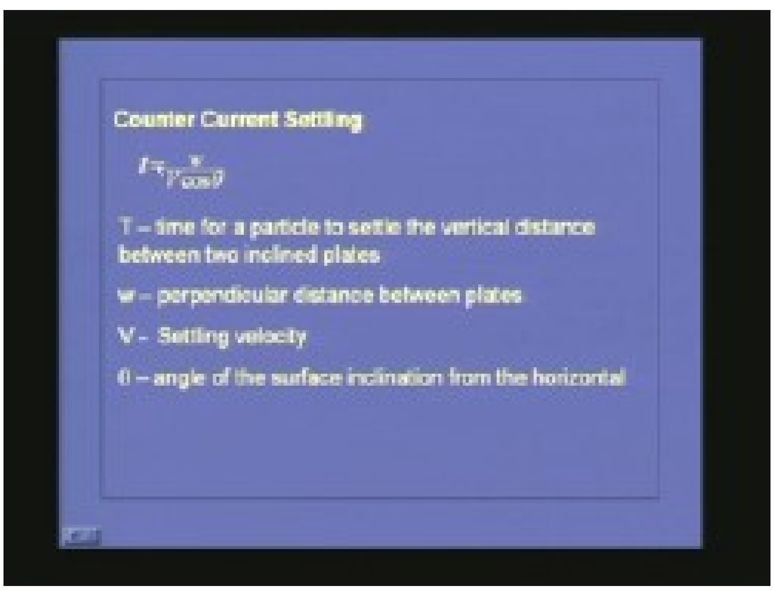

We are having many parallel plates. So here what we are doing is by utilizing a small area we are increasing the efficiency of the tank so that is the major principle of tube settlers. In counter current settling how can we find out the time required? The time required is nothing but what is the time taken by the particle to travel the perpendicular distance between the plates. That is nothing but w by V cos theta this is the velocity component; t is the time for a particle to settle the vertical distance between two inclined plate and w is the perpendicular distance between the plate and V is the velocity and theta is the angle of the surface inclination from the horizontal.

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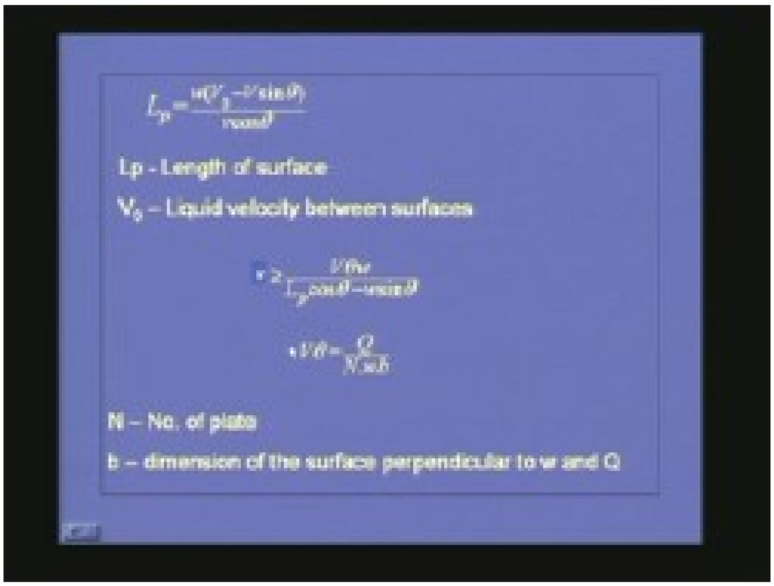

Similarly we can find out what is the length of the plate required. It is equal to w into V_0 minus V sin theta by V cos theta where Lp is the length of the plate or length of the surface and V_0 is the liquid velocity between the surfaces and n is the number of plates; b is the dimension of the surface perpendicular to w and Q and we can find out what is the V theta it is equal to Q the flow rate divided by number of plates divided by (Refer Slide Time: 50:51) this is the perpendicular distance and this is the width so the flow rate divided by the cross total cross sectional area will be giving you the velocity.

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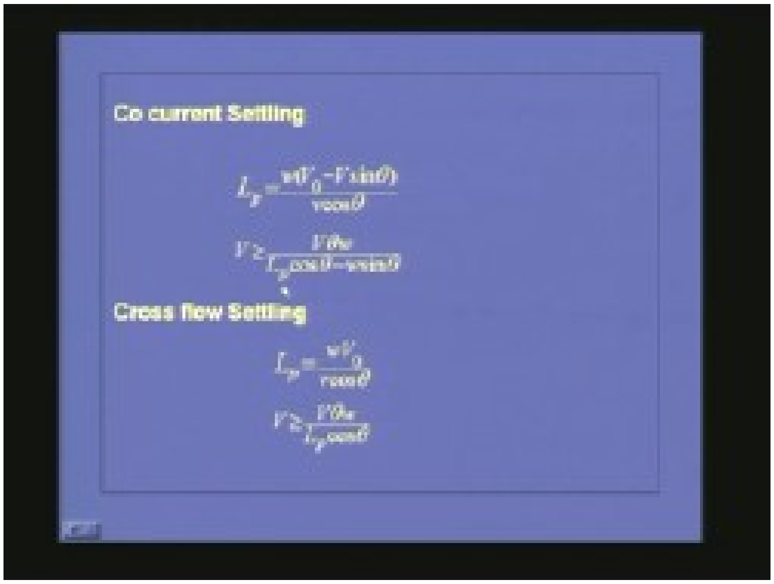

In co current also similarly we can find out what is the length of the plate that is equal to w by V_0 minus V sin theta by V cos theta and V is equal to the settling velocity should be greater than or equal to V theta into w by Lp cos theta minus w sin theta. These things we can get by just analyzing the velocity components, it is nothing difficult. And in cross flow settling the length of the plate required is wV_0 by V cos theta where V_0 is the flow velocity and settling velocity should be greater than or equal to V theta into w by Lp cos theta. So depending upon the flow regime or depending upon the arrangement the length of the plate required and the settling velocity will be varying.

Till now we were discussing about the settling tank efficiency theoretically. but in practical condition the settling tank efficiency will be varying because of the inertia of the flow, because always the flow will be having a tendency or the particles will be having a tendency to continue the same flow regime so that is the inertia.

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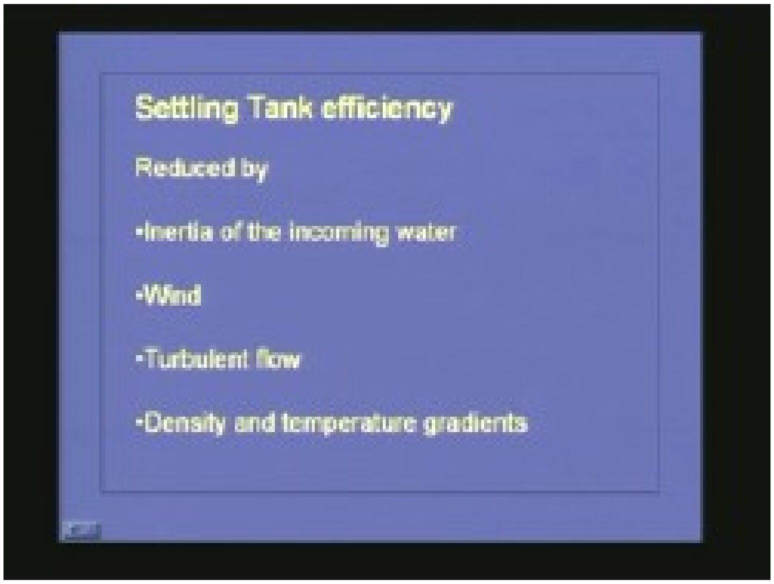

Second one is the wind effect, third one is because of the turbulence created in the system because of temperature variations all these things affect the efficiency of the tank. So we will see one by one in detail. The factors that affect the efficiency are inertia of the incoming water because the water will always be having the tendency to follow the same condition; the second one is wind effect; third one is because of the turbulence. Though we are trying to minimize the turbulence there will be still some turbulence and because of that one the efficiency will be reducing.

The last one is density and temperature gradients. How the temperature gradients effect the flow conditions? We will take two cases. For example, you have a sedimentation tank, the sedimentation tank water temperature is higher than the influent water so what will happen is, though the water is getting distributed equally in the inlet zone what will happen is, since the density of water whatever is present in the sedimentation tank will be less compared to the incoming water. Thus, the incoming water will be always flowing to the bottom of the tank by which your settling zone will not be effectively utilized. That is happening during summer time.

But during winter if we are having an open sedimentation tank, the sedimentation tank temperature will be lower so naturally the density of the water will be more but if the incoming water temperature is more compared to the existing water, the water will be flowing in the top portion of the tank and the bottom portion of the tank will not be utilized completely so we will not be getting a complete plug flow regime in the sedimentation tank. So naturally if the settling zone is not completely utilized then definitely your efficiency will be decreasing.

Similarly, it is with the wind effect. Most of the time you will be having a wide rectangular tank as the sedimentation tank, so if the tank length is larger then there will be wind effect and because of that wind effect there will be turbulence in the top portion of the tank and because of the turbulence your settling will not be proper because for settling quiescent condition is a must. So if lot of turbulence is there the settling efficiency will be decreasing. These are the factors that affect the sedimentation tank efficiency.

So if you want to find out what is the actual efficiency we can conduct tracer studies. What we are doing in a tracer study is we are injecting a color, we are injecting a dye or some chemicals which can be analyzed easily so we find out the concentration of the dye or the chemical at the effluent with respect to time and we can plot the concentration and from that one we can find out the flow regime in the sedimentation tank and how much tank volume is utilized and what is the dead volume in the tank. So based upon that one we can find out the efficiency of the system.

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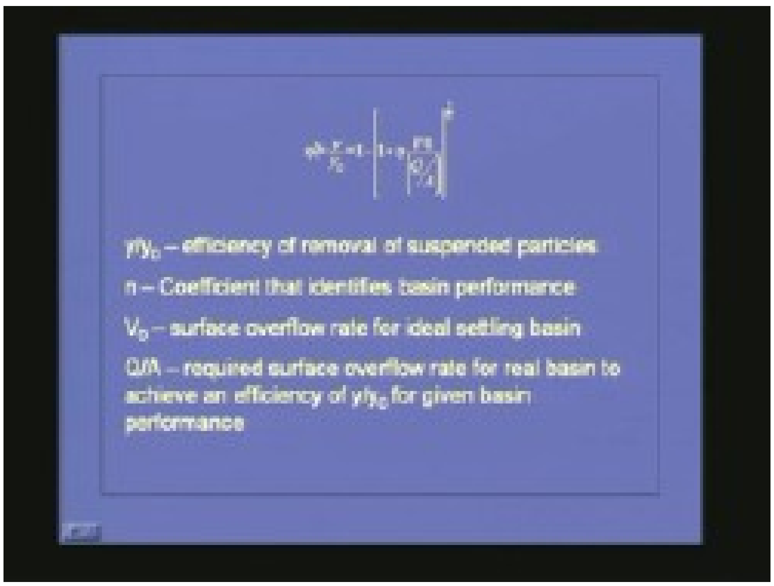

This is the formula usually we use to find out the efficiency of the tank that is equal to y by y_0 which is equal to 1 minus 1 plus n into V_0 by Q by A raised to 1 by n. Once again the efficiency of the tank is y by y_0 which is equal to 1 minus 1 plus n into V_0 by Q by A raised to 1 by n where y by y_0 is efficiency of removal of suspended particles n a coefficient that identifies basin performance and V_0 is the surf surface over flow rate for ideal settling basin and Q by A is the required surface overflow rate for a real basin to achieve an efficiency of y by y_0 for a given basin performance. This formula is very very important.

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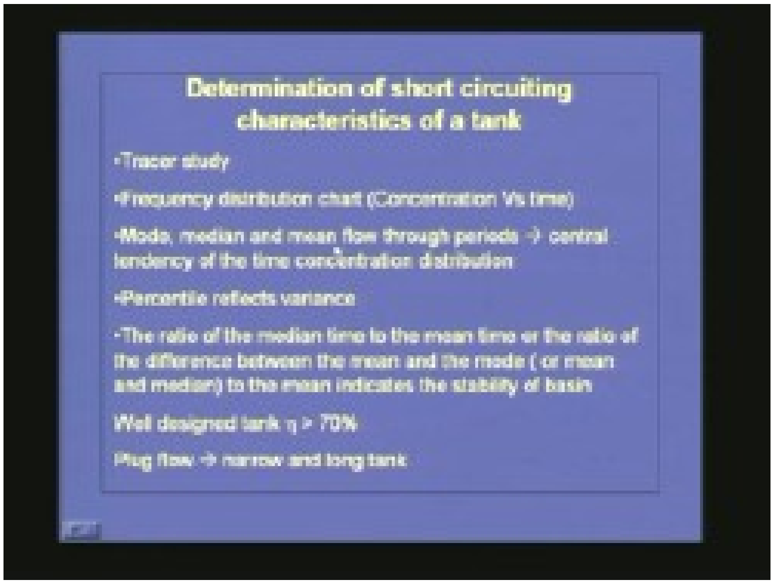

We will see how to find out this n value. for finding out this n value or to determine the short circuiting we can go for tracer study and we can make the frequency distribution chart; from the mode, median and mean flow through periods we can find out the central tendency of the time concentration distribution. And using this one we can find out the efficiency of the tank and a well designed tank usually gives an efficiency of 70 percentage and if it is a complete plug flow regime that means a very narrow long tank we will be getting maximum efficiency.

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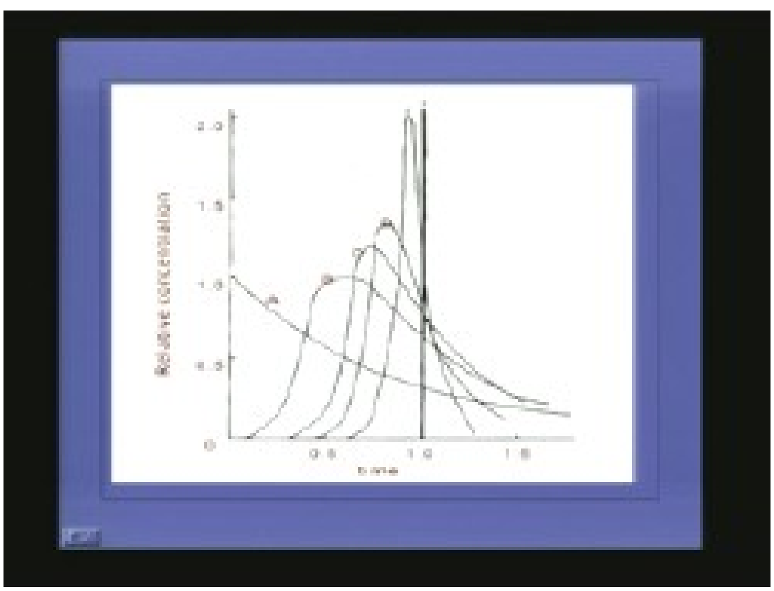

This shows the tracer study. Here we are floating the relative concentration with respective time. If it is a plug flow regime we will be getting the concentration like this and if it is a completely mixed tank we will be getting a flow regime like this. So most of the time the sedimentation tanks will be in between a CSTR and a plug flow regime so as it flows to the plug flow we will be getting more efficiency. it is the best one. It is almost approaching a plug flow regime; b is more close to CSTR; c is less; then d is approaching plug flow and e is almost a plug flow.

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For best possible the n value is 0 that means it is ideal and for very good performance the n value is 1 by 8; good performance it is 1 by 4; average performance it is half and for very poor performance it is 1, 1 means it is completely [t…….58:20] it is almost acting as a CSTR reactor.

We will see the things we have discussed today. We have seen what are the important components of a sedimentation tank. Those are inlet zone, outlet zone, sludge zone and the settling zone. And we have seen in detail how to design the inlet zone, outlet zone and the settling zone and we have seen about high rate reactors that means the tube settlers or plate settlers which will be increasing the efficiency of the settling. We have also seen that in ideal case we may be able to get 100 percentage efficiency but in actual case the efficiency will be less.