Water waste water treatment
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Lecture -16
Design of primary settling tank

Hello everyone, welcome back to the latest lecture session. As is the norm a quick recap of what we have been up to. In the last couple of session we have been looking at or we have been discussing settling different types of settling in the context of primary treatment. Why were we trying to settle particles in such because, we have these bigger particles which can be removed with the assistance of gravity.

That we decrease the load on the biological process where we need to provide oxygen which does require money or resources. In that context, we looked at different types of settling type 1 discrete, discrete each one does not each particle does not interfere with the other. In this context we looked at gravity. We looked at three forces, gravity pulling it down buoyancy due to the relevant fluid there then the friction or the drag force.

When all these three what we say negate each other we have the particle reaching its terminal velocity or the settling velocity we looked at how we are people came up with the stokes law that was applicable when Reynold number was less than 1 or even is applicable when it is less than 100, but it is applicable in laminar flow when we have spheres let see, on wave when we are discussing spheres.

In that context, we moved on I mean we discussed some aspects then we moved on to looking at type 2 settling where in due to difference in velocities the fluid or a bigger particle a smaller particle having different velocities of settling then coming together. We were looking at flocs being formed then flocculation or flocculant settling which was type 2.

Then we looked at how to understand the system try to design it we looked at some data looked at one example. In that context, let us clear up some aspects or discuss them.

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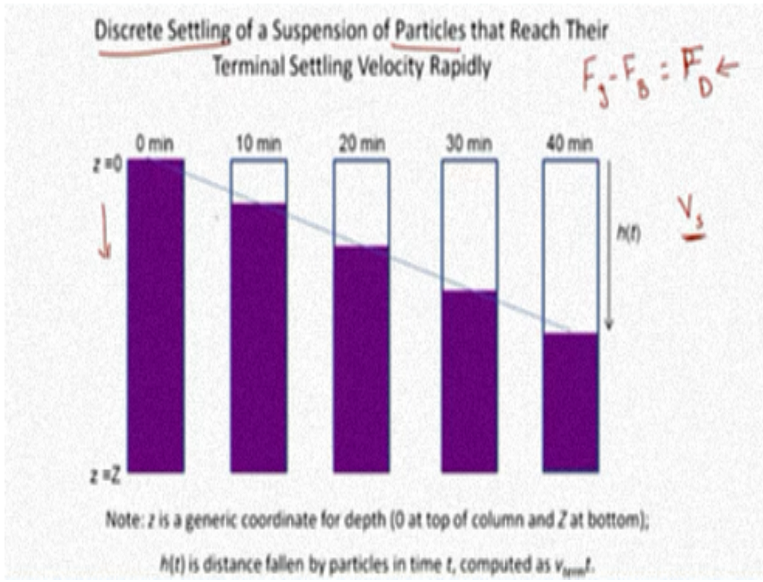

Here we have discrete settling of particles, where let say gravity minus buoyancy equal to drag force. The particle has reached its thermal settling velocity what do we see now if this is the settling column we see that with the depth it decreases. This line is going to be a straight line because now the velocity is constant it is discrete settling now, that is something that is not a no-brainer.

Here we are considering that all the particles are more or less are of the same size let see. That is why we have entirely clear liquid at the top particles being concentrated at the bottom out here.

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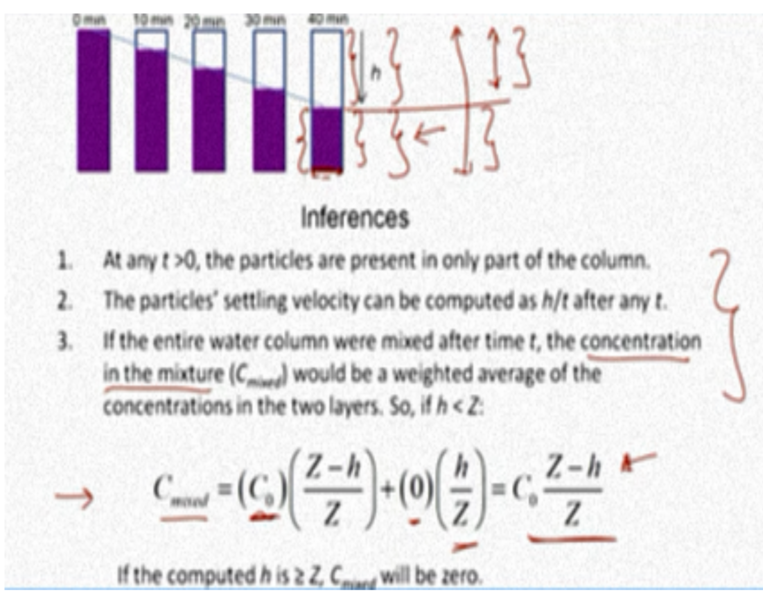

$$C_{mixed} = C_0\left(\frac{Z-h}{Z}\right) + (0)\left(\frac{h}{Z}\right) = C_0\frac{Z-h}{Z}$$

What we have here, so general inferences which we discussed earlier but I want to discuss one aspect which we will look at later let us see this is the aspect. If we want to calculate the concentration in the mixture which we are referring to as mixed calculate the concentration of the relevant suspended solids in the mixture. I need to understand that there are two zones. I need to look at weighted average as in for this zone.

I need to average it or weighted by the concentration of the tss in this zone for this zone I need to weighted by the concentration of the tss in this zone. Whatever has settled down at the bottom we are assuming that that is not present. For this particular zone let see what do we have we know let say or we assume that the concentration is C_0 let us see, which is the more or less the initial concentration.

What do we have C_0 into z – h, z is this we are subtracting h. We are looking at z - h by z into C_0 that gives us the concentration in this particular layer we are looking at weightage in the above layer h by z let say there is no suspended solids that is why we have 0. C mixture is equal to C_0 into z - h by z let see the concentration is uniform here that is what we always have.

Let us move on we will look at this later but please keep this in mind as in we are weighting it by the concentration in that zone or we are considering the concentration in that zone also weightages, we are looking at the height of that particular zone let see that is something to keep in mind.

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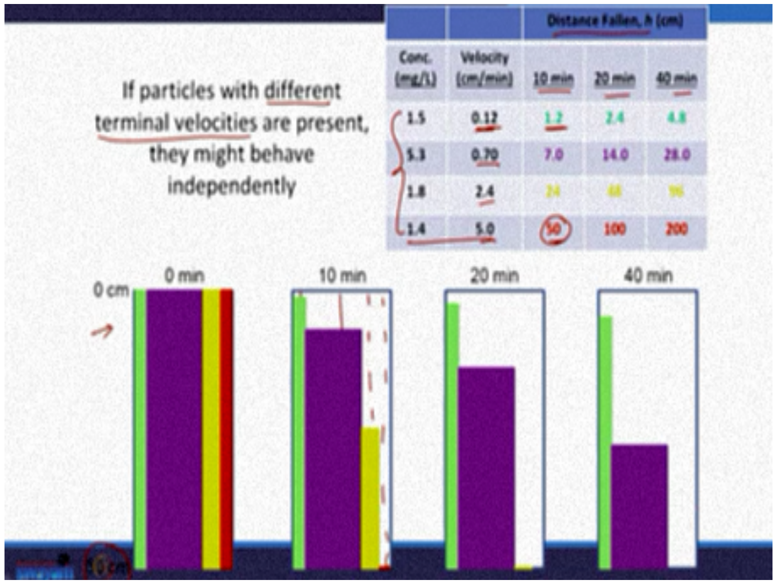

Unlike the previous case, if we have different particles with different terminal velocities. Here we have an example this is from professor mark m benjamin who wrote the book water chemistry he is pretty famous for that. We have different particles with different sizes thus terminal velocities let us see settling velocities different settling velocities the concentration of this settling velocity, I mean the compounds with these settling velocities is given out here.

Then we have data of how much distance they have fallen after different times. If a particular particle has a greater settling velocity that is going to travel a greater distance if it has a lesser settling velocity it is going to travel a lesser distance. Here we are still assuming that it is discrete what do we see settling. If this is the initial picture these thicknesses more or less indicate the concentration if I am not wrong,

After 10 minutes the one with the relatively slow settling velocity or less settling velocity only settles a bit the one with the greatest or highest settling velocity settles a lot here we are talking about what is your 50 centimeters. That was already reached for this particular particle so progressively the other particles to keep settling down. This is more realistic because in wastewater you do not have particles of just one size but particles of different sizes.

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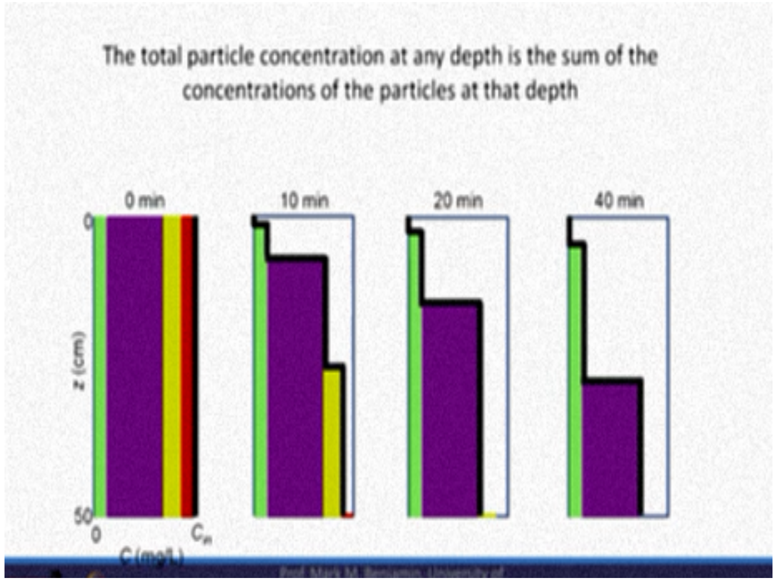

Here we are assuming different what we say are having some assumptions but we are not go into that now let see. What is the profile looking like, now it is the total concentration at any depth is the sum of the concentration of the particles at that depth pardon me. What is the profile looking like you see this profile?

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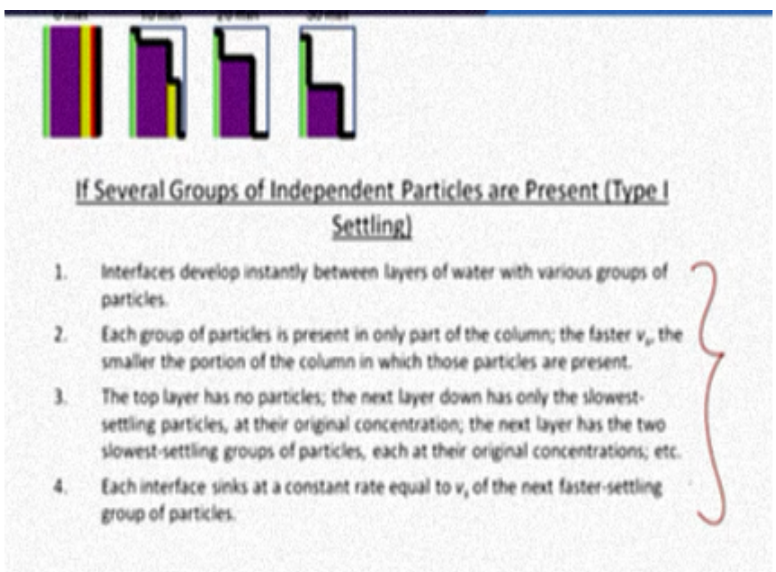

These are the assumptions or these are some of the inferences out here, but we are not going to look at that in detail but if you look at these inferences or such we see that it is typically not practical or it does not really happen in that way.

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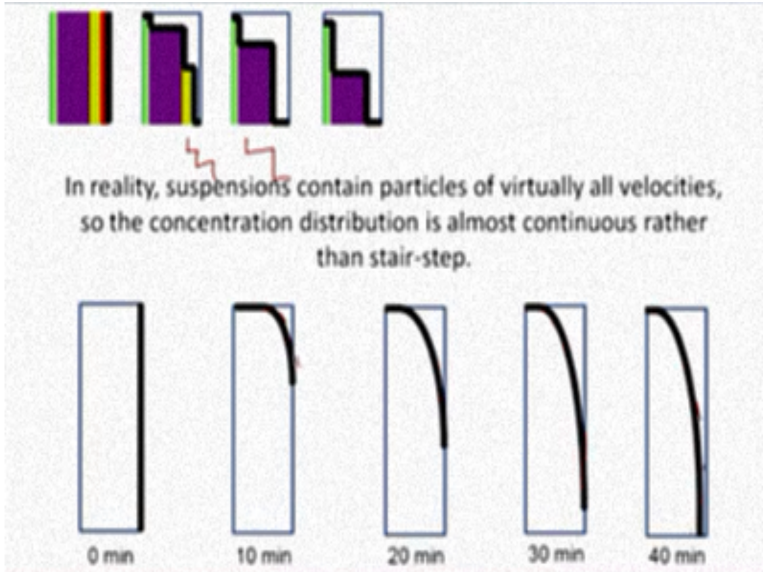

More realistic one would be when suspensions contain particles of virtually all velocities that rather than this step kind of distribution we see this step kind of distribution. We have a continuous distribution like this let see. That is one aspect fine.

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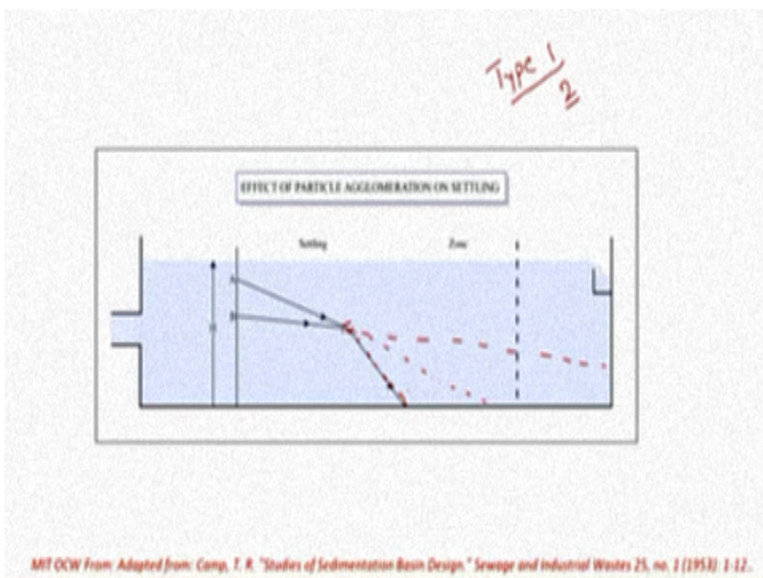

But all these aspects we were discussing were about type 1 discrete but we know that that is rarely the case mostly we come across type 2. Here we have a good figure effect of particle agglomeration or let say flocculation on settling. Particle a this is the profile, particle b this is the profile but because they came together due to let see either differential or different settling velocities or due to different fluid velocities there they came together.

Now, you see that the flocs settle fast relatives. Type 2 settling where we have flocculation settles.

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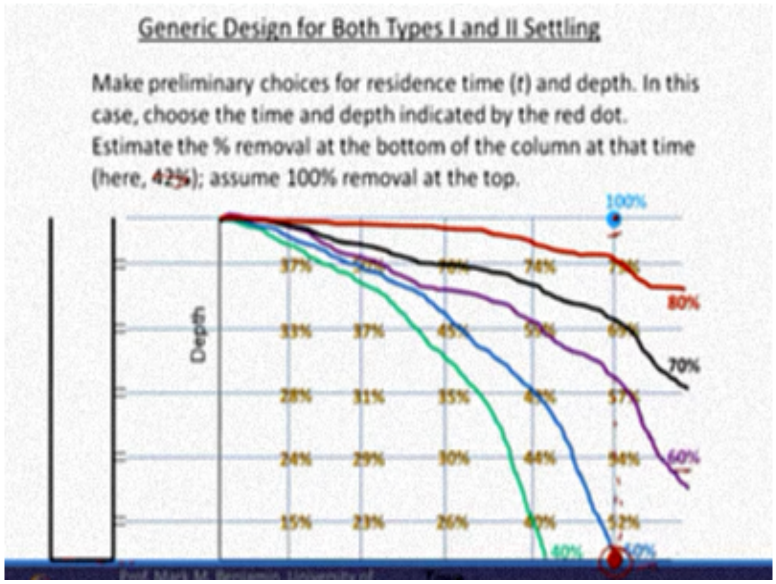

This is what we usually encounter we looked at one example but let us just look at it in some detail let us see; I rushed it the last time so I want to discuss this in detail. We got data we plot the percentages then from those percentage removals we can get the, what is it now what are they calling that isopleths, which are more or less are nothing but constant removals let us see.

This can be for 30 for 40 %, 50%, 60, 70, 8 this you will get based on interpolating the data which you measure at different depths. This is the actual data you are interpolating. I am going to choose a particular time depth. At this particular depth I can I know the time here that is how we have this is x axis time. At this particular depth what is it that we know here.

Removal at the bottom of the column here it is 42. Maybe I am looking at this, is it okay it is 100% at the top let see. Maybe this has to be corrected it is not 42 that is it. That is what we have but I know that it is 50 or other relevant point of intersection here at the bottom 100% about at the top, but here you see that there are still particles with varying levels of removal or at different depths we have different levels of removal.

How do I get the total concentration here? Similar to what we did in discrete settling we are going to look at giving the weights as in terms of depth. We know the depth here the average removal will be 60 + 50 by 2, 55%. Here this is what we have for this zone or height we will say it is 70 + 60 by 2.

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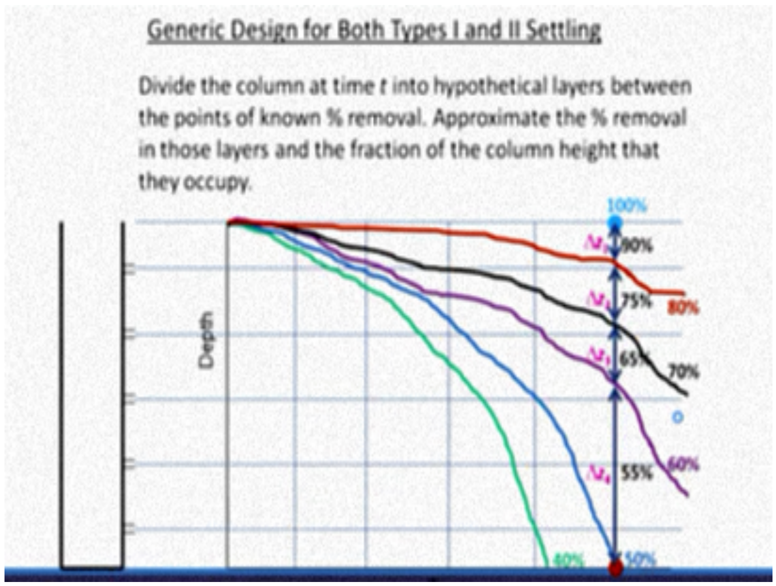

That is what we have 55%, 65%, 75%, 90% corresponding to this height let see in the relevant column or the sedimentation tank from that we got that relevant removal if you remember the total removal was nothing but removal at this point, our total removal at this point plus what now this particular what we say height where we look at the midpoint, then we looked at the average of these two particular values 60 + 50 by what is it now 60 + 50 by 2.

Then into this h if I say our delta z 4 by the total here total depth let say is h. In this way we looked at it earlier so in the same case you can analyze it for any system.

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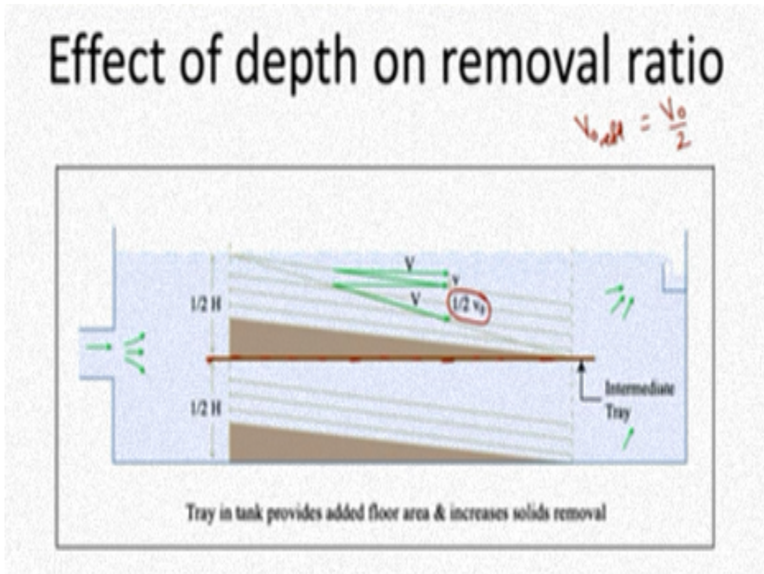

We also looked at effect of depth we know that let us understand this figure we calculated the overflow velocity. Such that the particle if it just comes out at the top has this a settling velocity equal to this overflow velocity, it will just be removed. This settling velocity is in the downward direction but the water is taking it in this direction. The net will be in this direction that is what we have out here.

This velocity is due to the relevant fluid flow this is due to the settling of the particle. If a particle has settling velocity equal to V_0, it will just be removed that is what if we see but if the particle coming in at the same location has a settling velocity less than V_0, it is not going to be removed that is what you see out here. That is something we already discussed then we looked at the depth.

For example, if I decrease the depth, what is going to happen here the overflow velocity if you remember is how did we calculate that I think we calculate that by looking at q by the top area let see our surface area apart me here we have q by length into width we do not have height out here. Mathematically we can see that height does not affect your overflow rate this is your removal efficiency.

Let us just try to understand here, if I decrease the height the flow rate is still the same. This velocity of the fluid will now be twice you can look at the relevant algebra that is pretty simple

Now the height is lesser you will see that it is still the same though V_0, still we so the lesser height lesser time available. That is what you will have.
Even though we have less height you will now have lesser time for the particle to spend in this reactor settle down the whole point comes down to whether the settling velocity is greater than or less than what is this V_0. If it was twice though instead of h to 2 h, it might seem like there is more time though that is true but then the particle also has to settle down for twice the distance let see or twice the height.

Both ways you see that height does not affect your removal efficiency. Only way is to increase that surface area which can be done by putting in a tray here. In effect you are decreasing the surface or increasing the surface area thus in effect decreasing the V_0, or effective V_0, here V_0 effective will be the previous V_0 by two because here I am providing a tray here.

You will have increased removal efficiency for the same volume but here the case is that we have an intermediate

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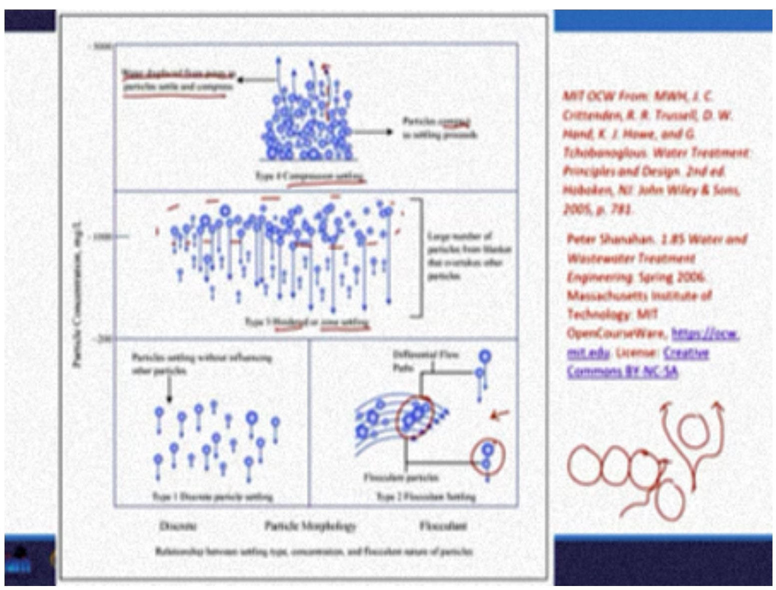

These were the aspects that we looked at, let us look at some of the other aspects. Here we have what do we see on the y-axis the particle concentration here different types of settling were mentioned discrete settling when the particles do not influence or interact with the other particles then type 2 or flocculant settling when particles interact form flocs.

The next one will be hindered or zone settling, we have better figures here but let see just try to briefly look at it. What happens is after certain level of settling actually what do you see you see particles coming together now water would not say trapped but it has to or it does not have a clear path to go around. For example, earlier water could go around like this or this now.

But now you have something like this water finds it difficult to go out only in these interstices between the particles the water will go out also, because the particles are so close to each other they also repel them repel each other in effect you will have what we say decreased settling velocities beneath these particles. That is hindered or zone, why do we say zone? Because more or less you see that all these particles are entrapped out here.

As these particles settle down you clearly see a zone above below above relatively clear below where you have the suspended matter. That is what you see out here compression settling, here it is not as if particles settle down but let say because of if I may use this layman's term the weight of the overlying particles the water in these pores will be squeezed out.

Then you see more or less compaction or particles compacting that we are calling as compression settling. Water displays from the pores as particles settle compress the layers beneath it, so discrete floc length, hindered settling compression settling.

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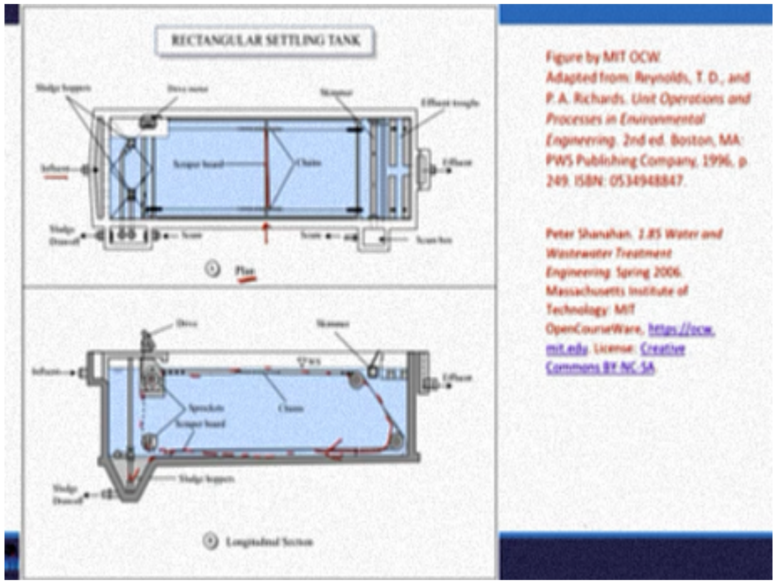

Let us look at some figures so rectangular tank if narrow rectangular tanks anyway as you can see here. This is the plant top view this is the side view. Narrow rectangular plants not plants sedimentation tanks are typically much better with respect to removal efficiency let see, but the issue here is that if you have long narrow tanks the area beside it you cannot really use it.

It is typically uneconomical for the plant or with respect to the construction efficiency let say even though the removal efficiency might be high. That is one thing to keep in mind. We have figures for this for these chains we will look at that. Let us just look at it so influent out here so sludge hoppers that is fine idea you see the sludge hoppers from here too we will not look at that.

The water is flowing in this direction particles that are settled out will be removed by the scraper board. You will have I have a better figure later we will look at that. That will scrape the sludge bring that out here. Let us see you have this you can see that from the side view. What is going to happen these chains moving in this direction they will scrape the sludge at the bottom bring it down here that is what you see maintaining these kinds of scrapers is always an issue.

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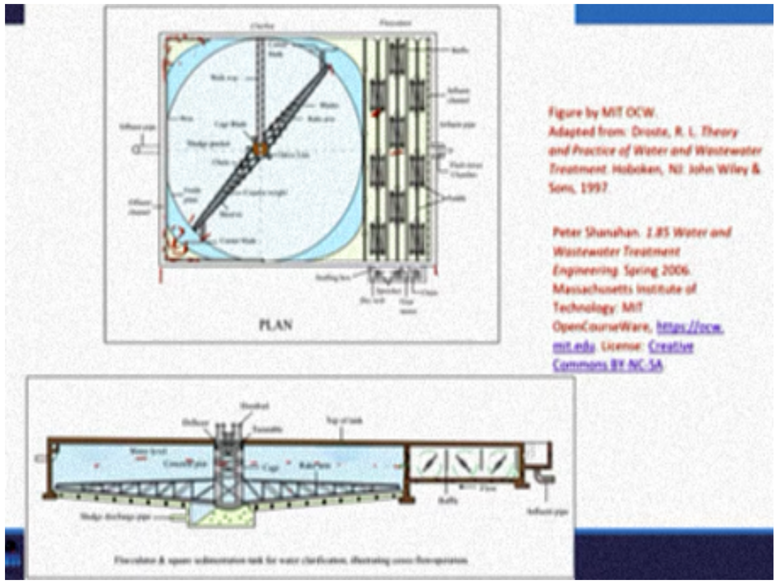

People typically what we say go for this rotating or circular types of scrapers let see. Please note that here we still have a rectangular sedimentation basin. What is happening here? We have water coming in we have baffles out here to distribute the flow bring down the velocity then you have a rectangular segmentation tank, but here we do not have scrapers like the earlier case but we have what we say circular scraper.

If I may say so flocculator square segmentation tank for water clarification one issue here is that you see you have dead zones out here so removal of the sludge or particles that have settled out here is an issue looks like due to the wear length along this particular edges sludge you can have radial flow or non-uniform flow affecting your removal efficiency. That is one aspect to consider.

Side view as you can see water coming in you have baffles here mixing to provide flocculation then it comes in. Then it settles down as it goes through you hear you have these what is it tray calm circular tray calm that get the job done with respect to scraping the sludge.

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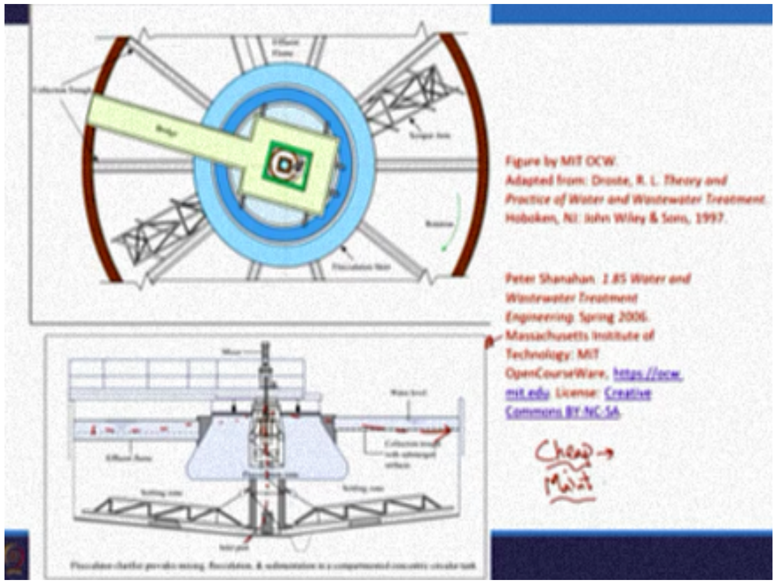

But the most widely used ones are going to be this circular sedimentation tanks, where the water comes in from the bottom here you have flocculation then it flows radially with respect to efficient usage of area within the tank for sedimentation this is not as good a design as the relevant rectangular tanks or sludge. But why is it that people go for it? Because they are cheap maintenance is easier even I mean when I say cheap the capital costs are pretty less maintenance is always better.

, that is why people typically go a lot for these particular these kinds of circular segmentation tanks. That is something to keep in mind.

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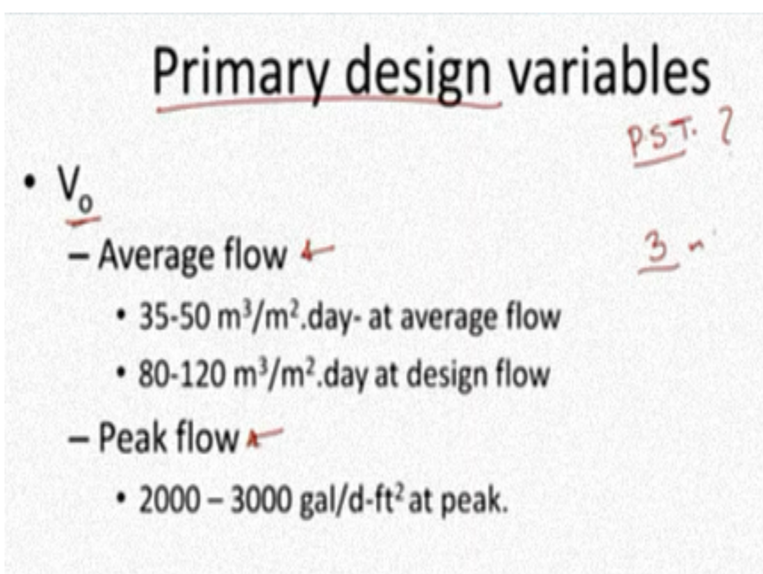

Let us move forward, so when we are designing primary sedimentation tanks. we need to look at some variables but the primary variables are the volume of your tank. But that needs to take into account the average flow also the peak flow one reason why we have let say sedimentation tanks of depth three meters or so even though theoretically the depth can be much lesser is that.

Let say I design it for average flow have a depth of let say 30 centimeters or so let see then you have the peak flow coming in then everything is going to scout up you are going to have what we say tuck blends in the system everything being scouted up. You want to prefer or situate that you can tackle these peak flows you want to avoid turbulence in your primary sedimentation tank also, you want to promote floc formation.

You always want to or that is the reason why people go for sedimentation tank depths of around 3 meters or so even though the design for from point of view of just sedimentation let see are the stokes velocity will tell you otherwise let see.

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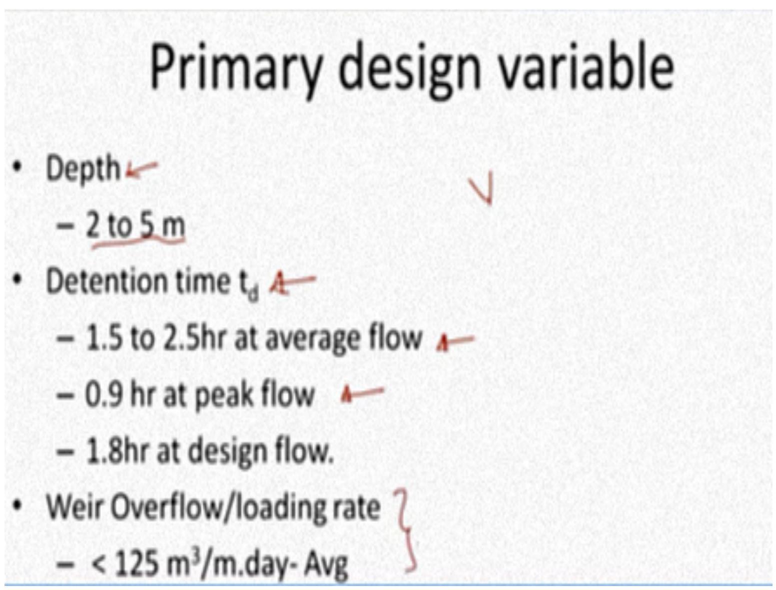

What else I also need to look at the depth as I mentioned typically 3 meters once, I can get the volume depending on the flow rate I will have the detention time or hydraulic retention time. We have different ranges around 2 hours at average flow what is that peak flow a design flow. But you do not need to mug these up where overflow rate or overflow rate is something that we need to be looking here. These are the primary design variables.

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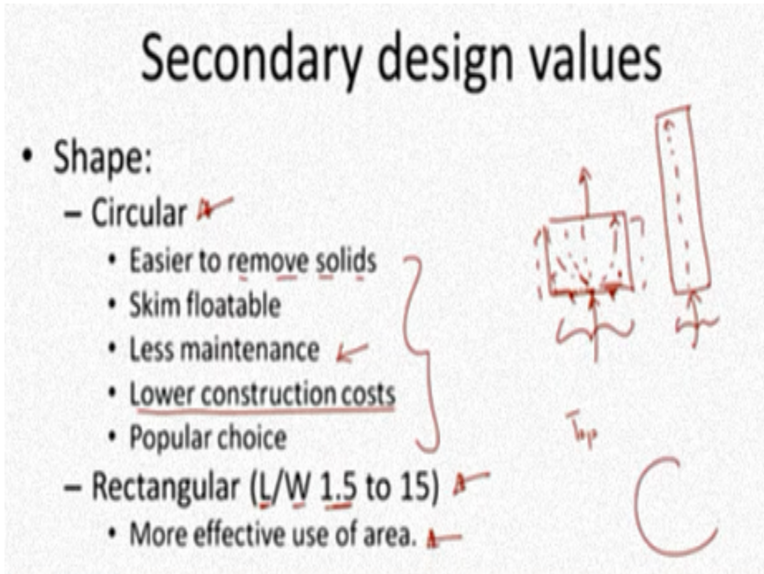

What else do I need to look at as in I need to look at whether you want to go for circular or rectangular, why we already discussed it easier to remove solids at the bottom, less maintenance cost more importantly the construction costs are pretty less, the capital costs are pretty less. But rectangular more effect to use of area here we see typically that the length to width or length is typically more or less.

Because think of this if you have this assume that this area or top view this is the top view this here you can have a lot of short circuiting occur. For example, you want the particle to settle down but here you can have short circuiting occurring as in not every particle that comes in at the influent or you are not going to design it so well that you are going to have very good distribution saturation.

Here energy dissipation depending on the design pretty good you have longer paths for the what is it settling of the relevant particle but here people can use the side area more effectively that is why people prefer rectangular to long narrow rectangles or these kinds of rectangular sedimentation tanks to long narrow sedimentation tanks but from the point of view of maintenance cost people go for circular sedimentation tanks.

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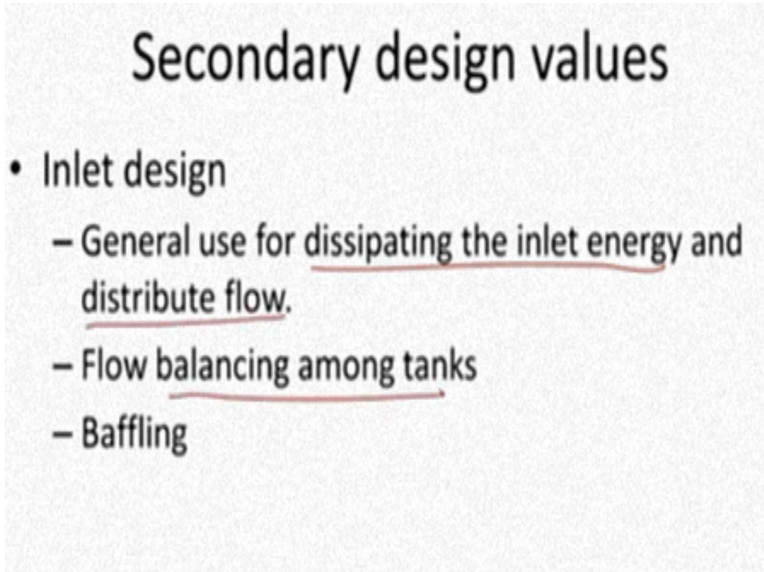

Inlet design part of secondary design values. What are we concerned with? We as I mentioned we want to decrease the energy or dissipate the inlet energy you want to prevent cross circuiting you want to distribute the flow. Flow balancing among tanks also baffling which is more or less a part of what we just discussed earlier let see.

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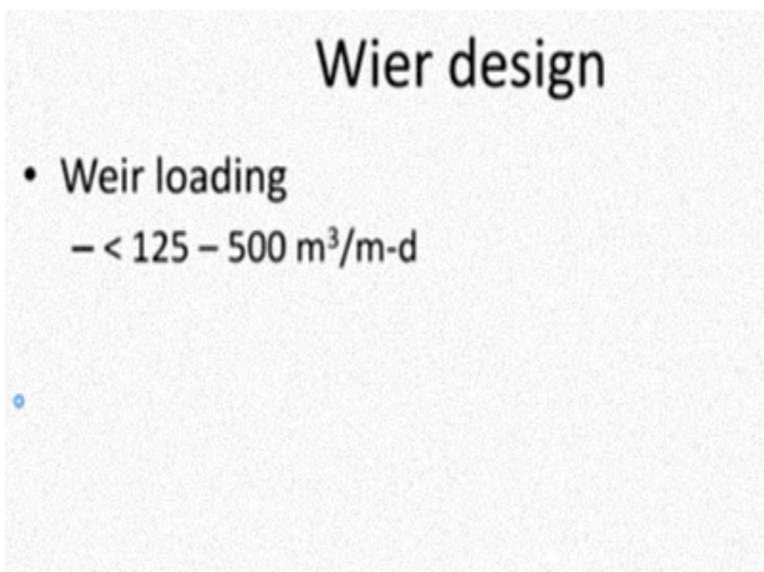

Weir design, you want to have as, quotient flow conditions or laminar flow conditions as possible then you are going to have it but we are not going to go into design here. But you can look at the relevant loadings here.

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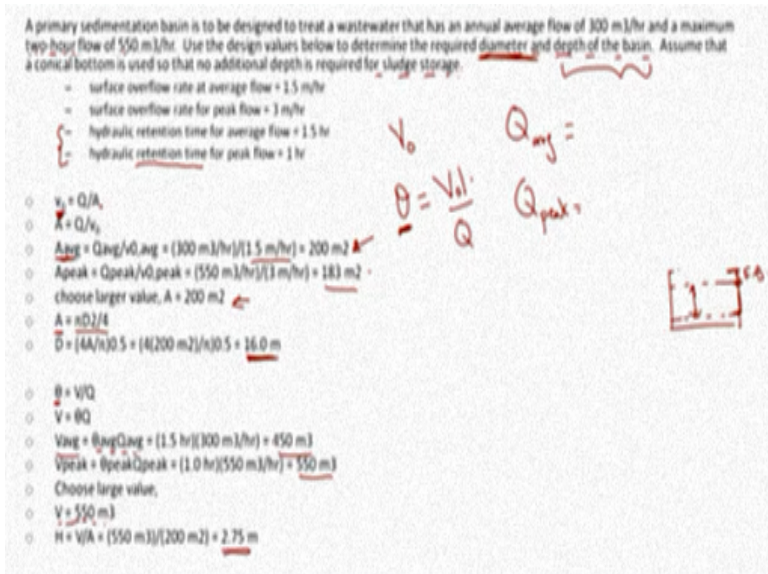

Let us just look at one example out here. A primary sedimentation basin is designed to treat a wastewater that has an annual average flow q average is 300 meter cube per hour maximum 2 hour flow q peak. We will look at this 2 hour flow meaning for over this year. The maximum flow which continuously which was observed continuously over a 2 hour period was 550-meter cube per hour.

Use these to determine the required diameter depth meaning a circular segmentation basin assume that it is a conical bottom. That no additional depth is required for sludge storage as in typically you are going to have some free board. We did not discuss this or we did not mention this free board because you are not going to plan it such that the water is up to the brim then you are going to have your effective zone then your sludge zone.

You will have to take into account all these heights but here we are only looking at this particular height out here. How do, we go about it, what do, we have we have the surface overflow rate V_0 , we have the hydraulic retention time theta equal to volume by what is this q; v by q let see. How do we get this or what does this tell me? This tells me the time that this particular water or the particle will spend in this reactive hydraulic retention time for how long is the particle being retained in the relevant reactor.

It is pretty straightforward let us go through this we now we have our surface overflow rate but there are two overflow rates given. We will have to look at it from both points of view. We will calculate the, case when we look at the average values. 300 meter cube per hour average flow by what we say the relevant overflow rate at the average flow, we get 200 meter square.

Similarly, for the peak we will calculate that we get 183 meter square. It seems fine in that context but we will end up choosing the higher value because the one that we are going to choose needs to meet the design from both the average peak flows. Thus, we are going to look at what is it now the higher or take the higher what do we see area here, this is the plan area that is something to note here.

Always the plan area at least with respect to the overflow rate then what next we have the area then the diameter depth well that is a pretty easy aspect. We know that area is equal to pi d square by 4. From that I can get the relevant diameter let see here we are done with diameter the next aspect is depth. Depth we have other values here as in we have the hydraulic retention time.

This will give us an idea about how much time the water molecule will spend in the system. Theta is equal to v by q; so we have v is equal to theta q average volume or volume required based on average flow conditions I get 450 meter cube based on peak flow conditions I get 550 meter cube. From that I am going to choose the larger volume of the relevant tank.

Because you cannot have overflow or you do not want to have overflow of your particular tank, so, I choose the big higher value I am trying to calculate the diameter I have the volume I have the area somewhere, I have the area now I can calculate the height let see, I am now able to calculate both the what is the diameter the relevant height of my particular sedimentation tank. That is a general aspect it is just algebra out here.

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	Retention time (hr)	Overflow rate (m^3/m^2-day)
Water Treatment	2-4	20-40
Wastewater		
Grit chamber	0.75-1.5	~60
Primary clarifiers	1.5-2.5	30-50
Secondary clarifiers	2-3	16-28

Let us just look at typical values, retention time, theta or t r some people look at t r some people say t d but theta is a better one because of obvious reasons. For water treatment retention time is 2 to 4 hours overflow rate is our typical overflow rate is around this particular around this particular value. Overflow rate we know that it is going to be equal to q by cross sectional area.

That is why you have the units meter cube per day for the flow rate volume of water per time by the cross sectional area not cross sectional pardon me, surface area that is meter square. That is what you see here in wastewater treatment we have different sedimentation tanks. For grid chamber when we are where we are trying to remove only the bigger inert particles retention time is less surface overflow rate is higher.

Particles with what we say lower settling velocities will not be able to settle down to the bottom. Primary clarifiers we increase the time retention time look at the concurrent decrease in the overflow rate let see, secondary clarifiers where we which are going to come into the picture after the biological process where we remove the organic content you have flocs forming bacteria which settle down to the bottom.

Time is higher the particles are much lesser the overflow rate also is pretty less. Just an idea here let see.

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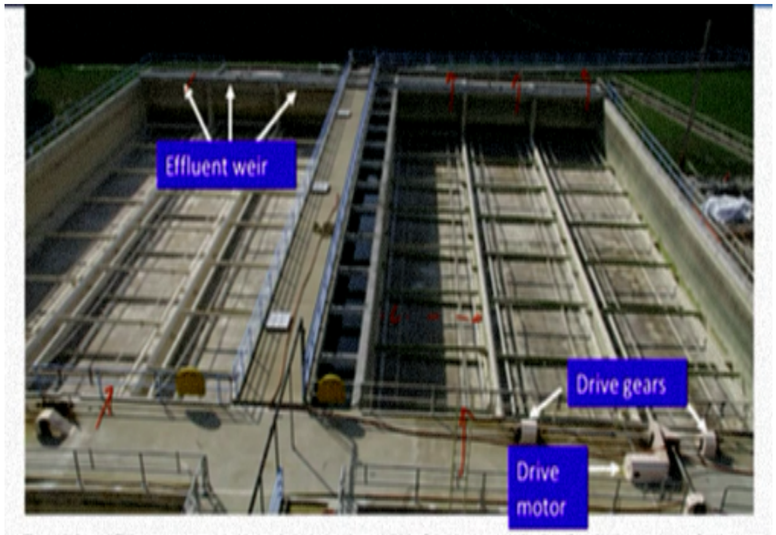

Three chain-and-flight scrapers are provided to limit the maximum width of a train to somewhat less than 6 m because the softening sludge is quite heavy. The end weir is not very effective because the up flow current carries sludge over the weir onto the launder.

Let see just look at some pictures wrap up this particular session. Here we have long narrow rectangular basins if I may say so. But it is not that narrow, ideally let see say if I have something like this each one was an individual what we say tank that would have been better. But here as you can see this is the inlet, inlet two tanks in parallel then you have the effluent wear all out here, effluent weir along here.

But here they did not have just one chain because as is mentioned out here the sludge is pretty heavy. They have only not only more chains drive gears motors let say.

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Head end of sedimentation basin showing baffle boards and direct connection to

Baffle walls. Not a great design here, head end of sedimentation basin showing the baffle boards then you can see these; what is that scrapes or such you see the chain. It is going to rotate in this direction come down scrape it like this or depending on where they have their collection it can be the other way too, that is one aspect.

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Scraping sludge is going in this, this is the bottom one is going out there this one towards here let see. So it was going in this direction. It is going out like this then rotating up then coming back. That is what we see out here.

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There are other kinds of settling basins but where the design is of crucial aspect, we know that you do not really require a lot of depth if you design it. But typically, to provide for floc formation more or less to have your what we say sludge settle down well you sometimes provide depth as high as 3 meters but theoretically if you look at sedimentation you do not need to do that. The way to do it, as in provide more surface area.

More surface area bring down the v 0 is by providing these plate settlers or tube settlers. This is one particular picture here two plate settler modules, one two.

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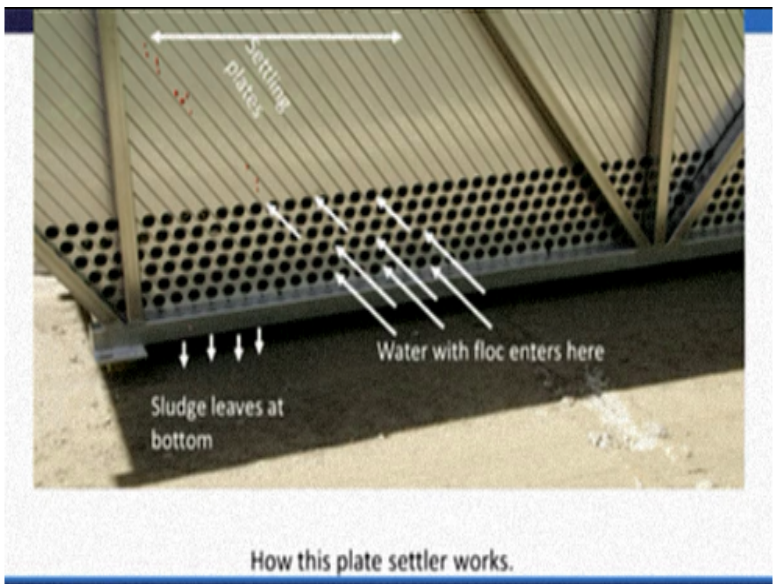

Let just see how it works. Water with flock enters here you have these plates you have these plates out here. You have this flocs settling down here then coming down so this is counter current then the sludge leaves at the bottom let see. These are all the settling plates.

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How this plate settler works.

We looked at picture earlier then the water comes out in the settled water or the water clear of the suspended that particles will come out at this top at this part I think, okay.

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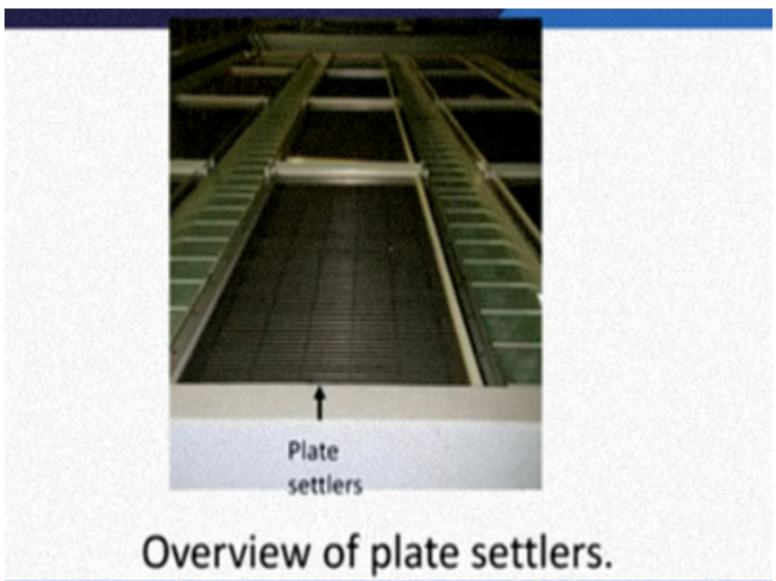

Overview of plate settlers.

When it is installed this is how it will look like plate settlers from the top view they are installed.

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Details of water discharge system from plate settlers. Water moves up between the plates, over the pipes, turns down through the flow control orifices, and discharges at the end of the pipe to flow over the weir plate

Now you see that details of the water discharge system from the plate settlers. It moves up from the plate settlers over the pipes down through the control orifices here you see pretty clear water.

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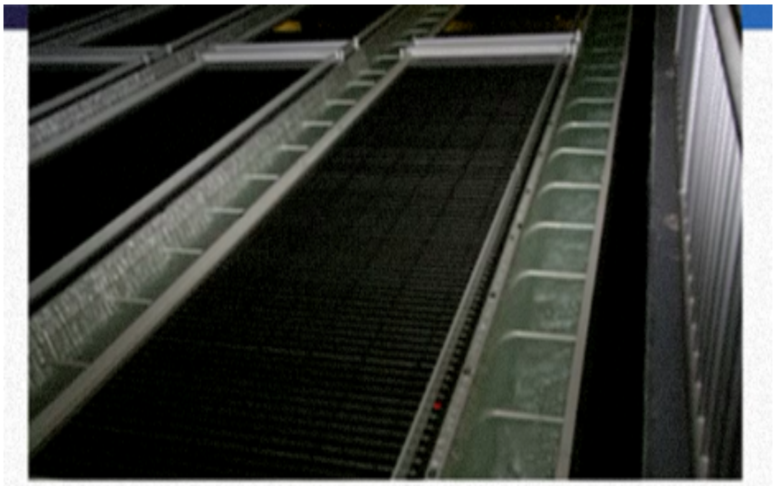

Settled water discharging into the launders.

Water comes in comes up through the plates goes through these particular circular orifices then is discharged into the laundry.

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That is one particular you can see the clear what do we see water coming up from the tube settler out here. Tube settlers you are more or less what is increasing the surface area also making the process more efficient because you have compact systems now.

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Wares will not go into that. Primary design variables we looked at that. I am going to skip this for now.

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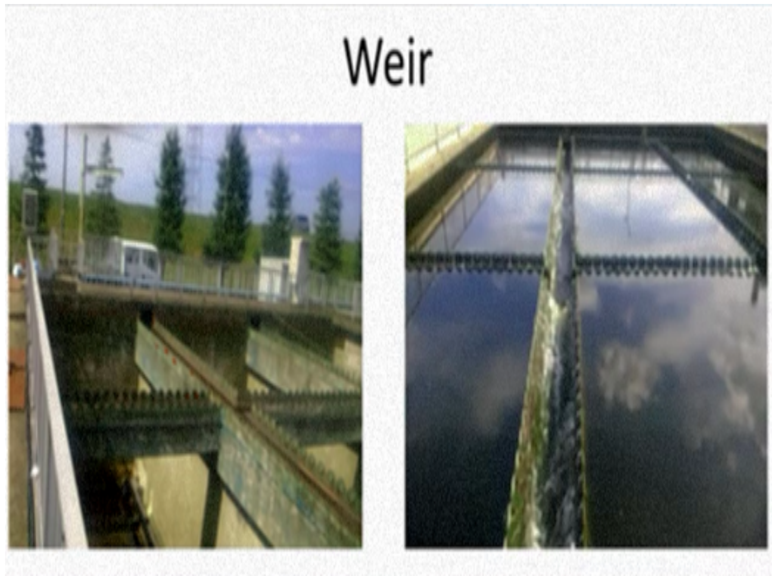

In india people are still learning we are still turning to what we say improve ourselves. This is the typical what we say old-fashioned weirs not wears sedimentation tank the weirs out here wheels. Not great design looking at what we have but I do not know the situation on the ground there. That is what we have then water overflowing out here. That is something to consider.

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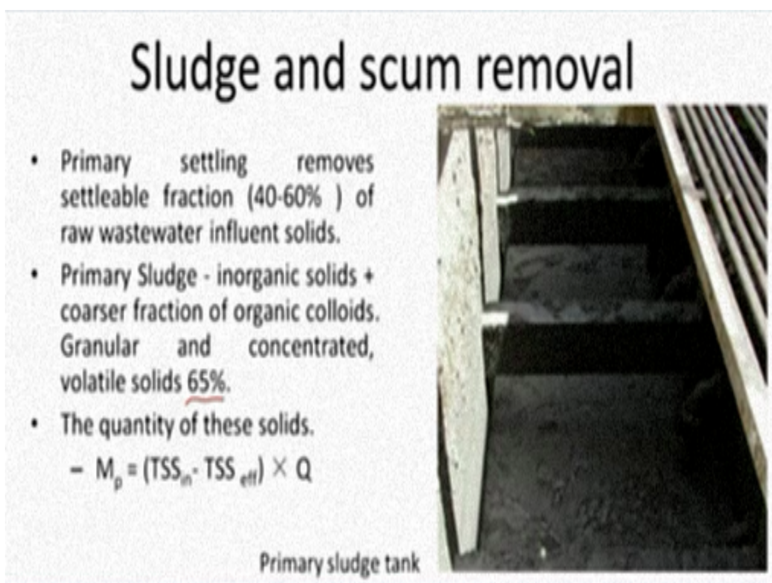

Then sedimentation tanks what is it that we are trying to do. We are primarily trying to remove the suspended particles. But along with suspend particles some organic content which is suspended are adsorbed on to these suspended particles will also be removed. Will we have removal of all the suspended particles not really so we have typically fraction being removed.

Indian aspects the issue is that people do not maintain it run the systems well design is always also not great. But that is what we are trying to change by learning here.

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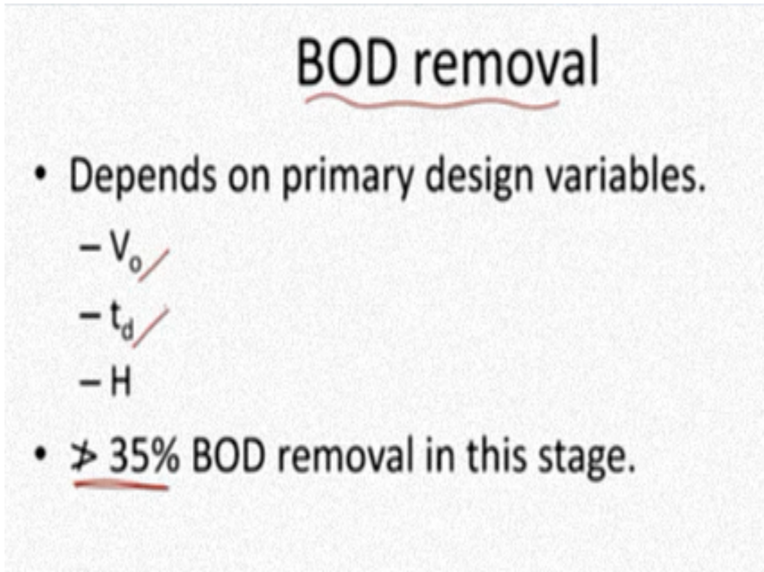

Primary aspects or another aspect to consider is that bod will also be removed. But you will typically not absorb more than 35 bod removal as mentioned earlier we are primarily concerned with overflow rate then the hydraulic retention time or the detention time the height of the relevant sedimentation basic.

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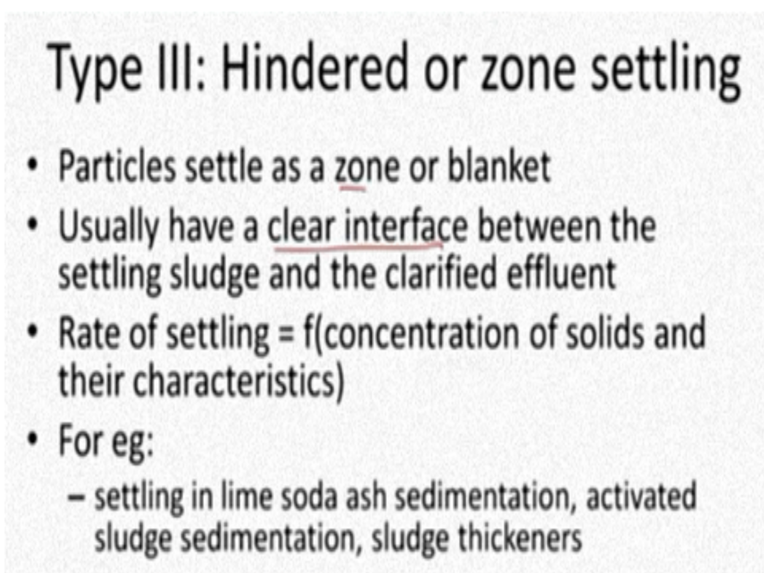

Then hindered zone let us wrap it up particles settle as a zone or blanket. That is, something that we already look at one aspect here is that now the settling velocities are going to be relatively less.

Water has to find its way out from under these or through these particles through the interstices between the relevant particles. Because you have a zone you are going to have a clear interface between the sludge the above effluent. That is, something to keep in mind.

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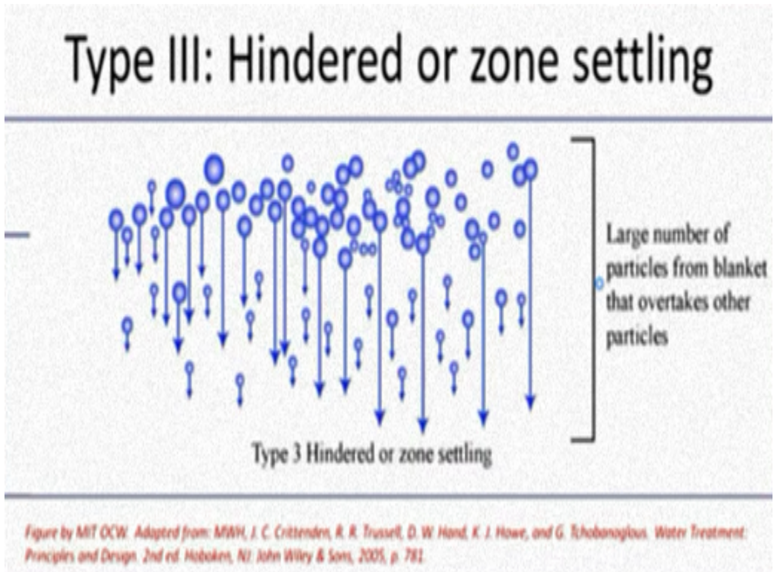

Hindered settling we already looked at this, I will move on from here.

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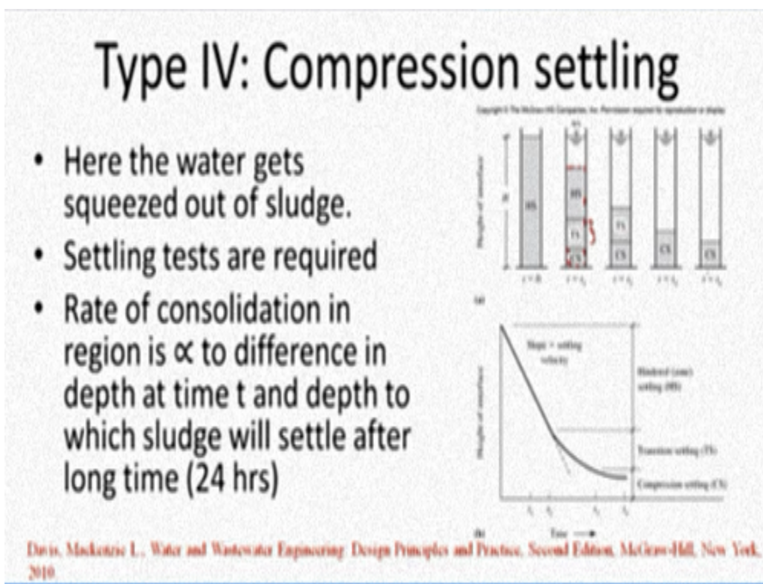

Compression settling, we have a good picture out here. Here the water is squeezed out of the sludge as I mentioned. It is not really particle settling down but the weight sees of the particles above seeing to it that the water is squeezed out from the particles underneath. That is why we call it as compression setting here we see. Let say, first now it is hindered settling then our zone what we say settling.

We see clear water then the hinder settling out here but now already the sludge out here is experiencing compression settling the transition zone in between then all the hindered settling is done we just have the transition the compression settling then we end up out here.

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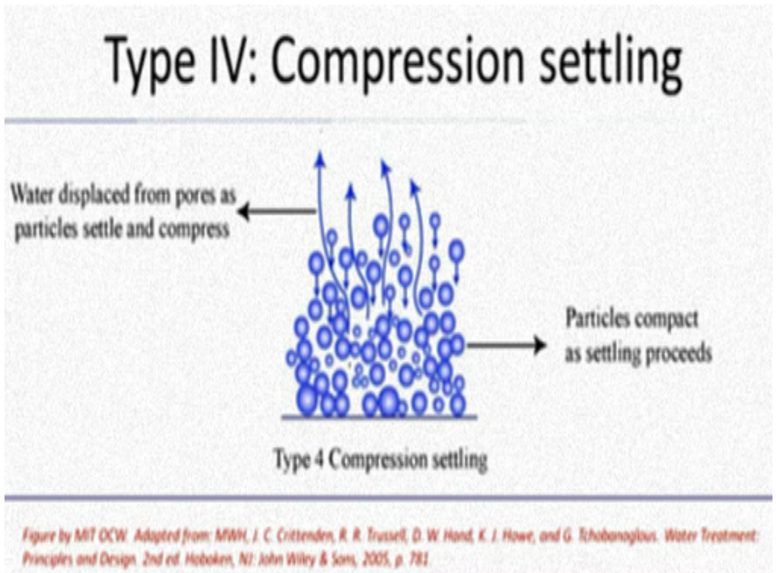

That is pretty much obvious as you can see the weight then all the water trapped out here is being compressed released.

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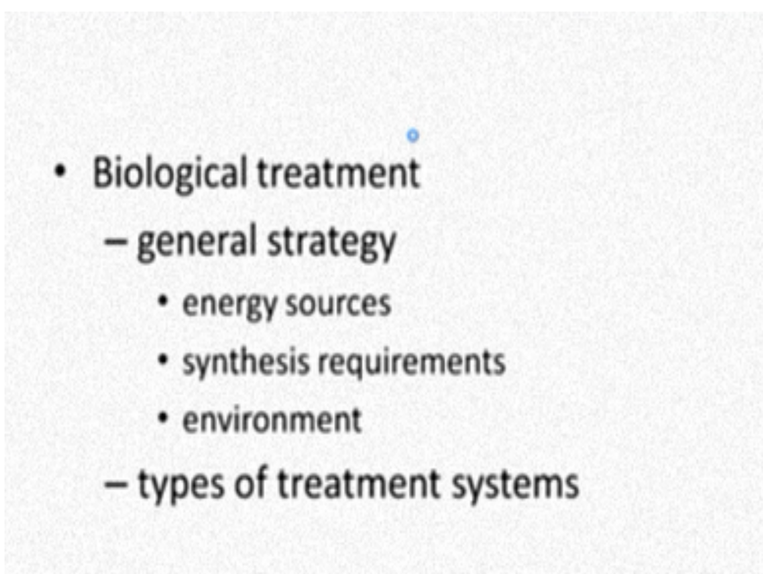

I am almost done with my time we are also done with looking at primary segmentation. What next I remove the suspended particles some dissolved organic content most of the suspended organic content. Next, I want to remove the soluble organic content or the dissolved organic content that I am going to do by the aid of microbes. With that I will end my session we will take continue this in the next session. Thank you.