Water and Waste Water Treatment
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Lecture - 31
Flocculent Settling

Hello everyone, welcome back to the latest lecture session. A quick recap of or quick recap holistically, , let us take a step back and understand the bigger picture. We want to remove suspended solids, even those solids that are relatively small and will not settle down within a reasonable amount of time. And now, we coagulated them by adding a coagulant and we destabilise them and we let them flocculate.

And then we want them to settle down, we have big enough flocs and we want them to settle down.

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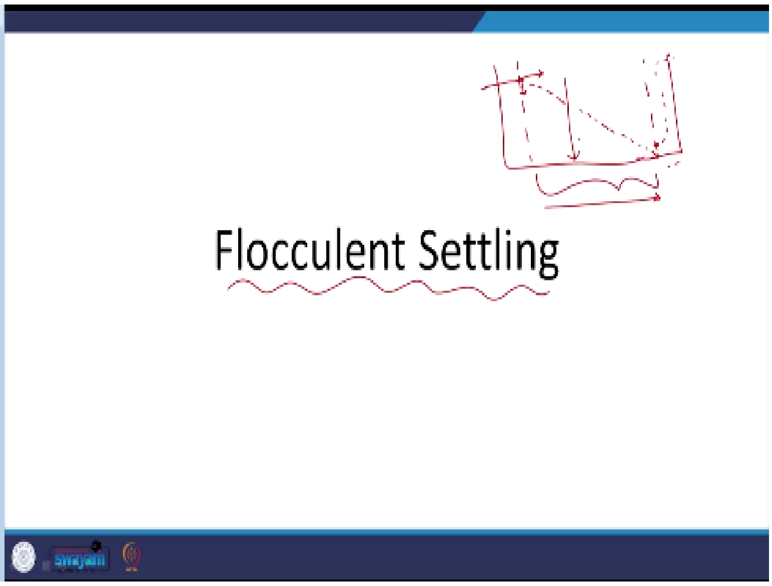

So in that context, we saw that it is flocculent settling or type 2 settling that is what is prevalent in the settling zone that we have. So, here, , we will come back to this later, but just the relevant aspects. So here we have, the inlet zone and then the settling zone and then the outlet zone or outflow zone. So, the assumptions in the models are the aspects that we are going to talk about is that if a particle can , settle down within the settling zone, it is assumed to be removed.

If it even comes here, we assume that the particle will flow out of the relevant tank or the sedimentation tank. So, that is one thing to keep in mind. Why? Because later, when we look at it, we will look at the particle coming through here, particle coming through here. And we will see, because this is the maximum time available. So, the particle will have 2 vectors in this direction and in this direction.

So, by the time it reaches this point or cover this horizontal distance, it should have covered this vertical distance. , we will look at this later, but we already looked at this briefly and not briefly in some detail and waste water treatment relevant aspects. Here, we will look at it briefly.

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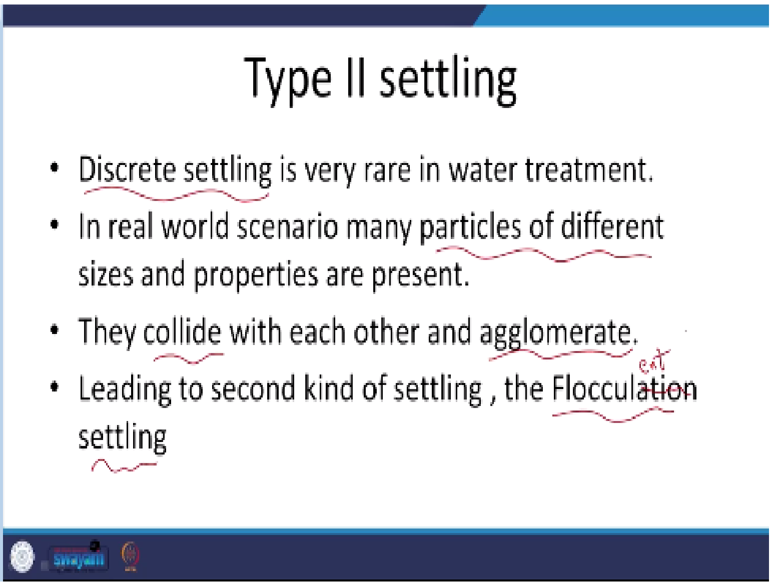

So, type 2 settling, as mentioned, type 1 is relatively rare. In general, you have particles of different sizes, more importantly and then they will have different settling velocities, they move at different velocities. And also you have water conditions that are typically rarely laminar. So, you are going to have what we say irrelevant Eddies out there or different gradients in velocities.

So, the particles will form flocs after colliding and thus, they will agglomerate. So, that is why we say that we have or we will see, this our experience this flocculent settling. It is not flocculation settling. It is flocculent settling, .

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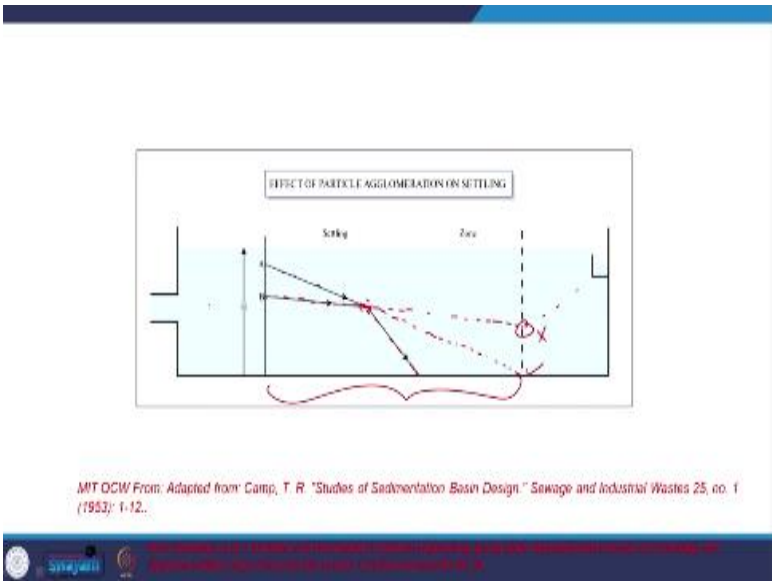

So, what does this mean? So, here we see a pretty good picture here. So, here, we have effect of particle agglomeration. So, we have 2 particles, relatively bigger particle coming out here. So, if I look at this, this bigger particle probably would have been removed within this settling zone. This is the settling zone. This is my settling zone, and this particle B which entered at a lower depth would have gone through or out of my particular settling zone.

And it would have been carried out meaning it would not have been removed. Particle A would have been removed; particle B would not have been removed. But, what happens different settling velocities and also even different fluid velocities there? And thus, you have A and B agglomerating colliding and agglomerating now a bigger particle. So, both settle down and that to at a much faster or earlier time, , within an earlier time.

So, this is the effect of particle agglomeration on settling and this is what we typically see, especially when water is coming into sedimentation tanks . That is one thing to keep in mind. Let us move on.

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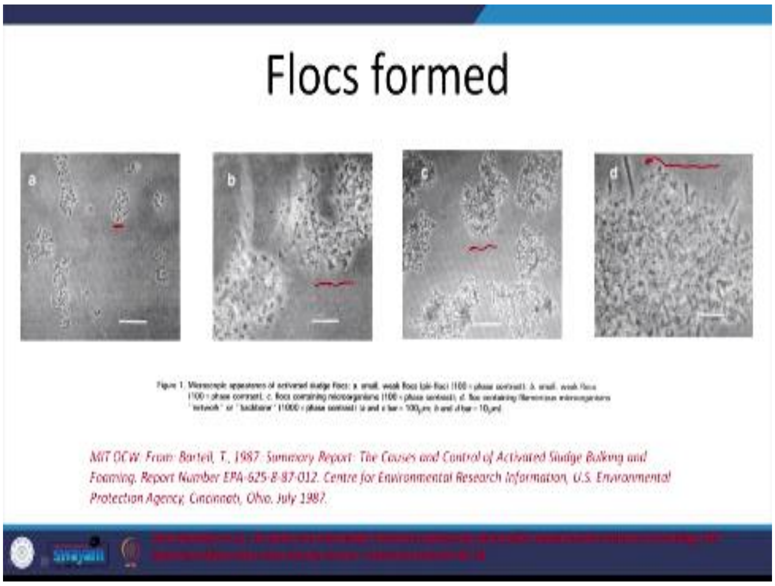

So, in the context of waste water, we did talk about different flocs. But here, the kind of flocs are going to be formed. Here in water, we are typically talking about inorganic particles or such. But , you can have some organic content to depending on the type of source of water. So, here we looked at waste water treatment, I think pin-flocs magnified and once with the flocs with the filamentous microbes in such, , different types of flocs. But , this is slightly out of context. But I wanted to have one picture about flocs, .

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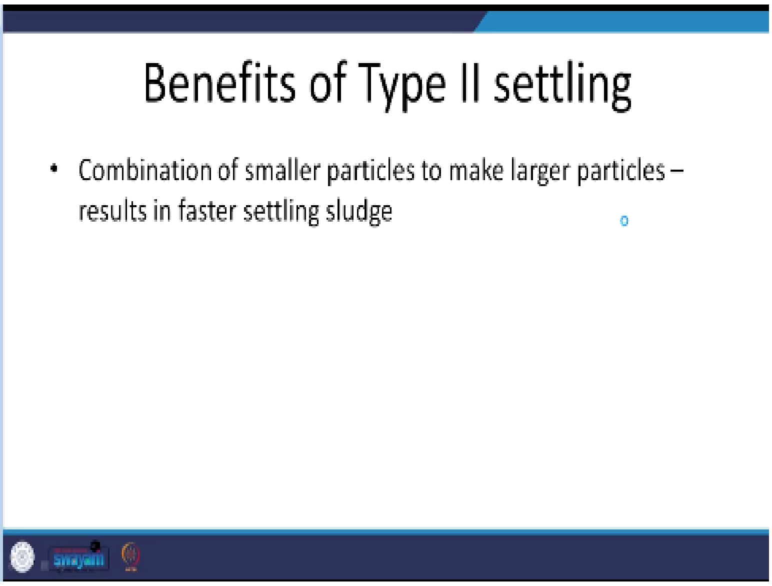

So, benefits of type 2 settling, this is what we just looked at in that other picture. The combination sees to it that the particle settles down earlier or those particles which would not have settled out would settle out.

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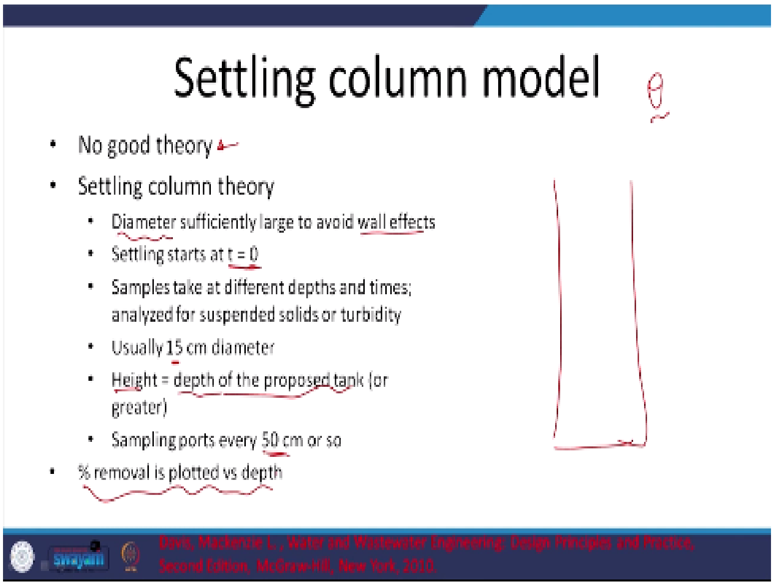

So, how do I look at it? Or how do I use this to be able to model my sedimentation basin or such? So, there are different models. Here, we have looking at one settling column model. So, in general, , it is difficult to really predict what is going to happen. Because, flow conditions are going to be different. The actual kind of waste water that you are going to experience in your not waste water, actual kind of water that you are going to experience in your particular process might be different than what is available to you.

That will typically be the case with waste water, but with water, with surface water as the source, typically you can get the water sample. So, , the issue is with respect to applying this model, there are aspects about correlating or , using the results from one sample and applying it to another sample. , but let us look at the most widely used one. So, as mentioned, no good theory. But the second best is the settling column theory.

And we want to choose a column which has a diameter long enough to avoid wall effects. Yes, that is one thing to keep in mind. And we are assuming that settling time starts at time equal to 0. So, this is a batch system. We will look at the figure, I think we have it here. So, this is what we have. So, when I say time equal to 0, how do I interpolate that or what information is that given to me in a continuous flow system.

In a continuous flow system, this time in a batch reactor will be similar to this theta, hydraulic retention time.

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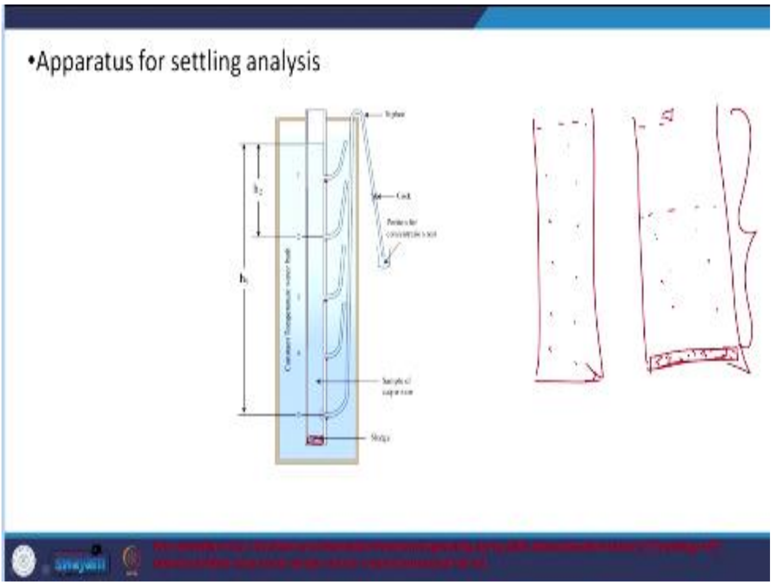

So, samples taken at different depths and times that is what we see here different depths and also a different the same depth at time 0, time 5 minutes, 10 minutes , we will look at that, usually 15 centimetre diameter that is fine. Height is equal to the depth of the proposed tank or greater that is that we typically try to do. Sampling ports every 50 centimetres or so. And we looked at these kinds of plots in detail in waste water relevant aspects, I request you to go back there and look at it but we only briefly look at it.

The percentage removal is plotted versus depth. Percentage removal is plotted versus depth. But before that, we have to interpolate and I think we did spend quite some time in that particular context here. So, operators for settling, , this is what we have. And this is the sludge. And in the next slides, we will look at some pieces of information or some figures.

And that context, when we are looking at concentration, we assume that this sludge that has settled down is no more part of the mass of the solids that in the column. For example, if this is the one initially, I know the concentration. How? The mass of the solids, mass by volume of this particular system. , after some time and the column, now it is at this height, the water is here.

But , this is relatively more clear here. And here, I have particles and here, most of it has settled down, . So, when I am trying to calculate it, it meaning the concentration of the solids in this particular system, I am assuming that whatever has settled down is removed from the system. And I will only consider the mass of the particles that is out here, . That is something to keep in mind.

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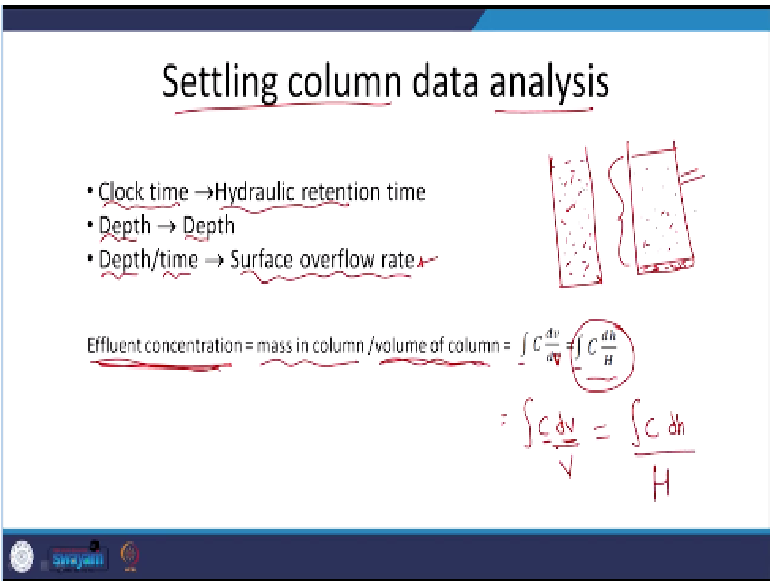

So, , as I mentioned, the clock time in your particular settling column is going to be similar to your hydraulic retention time. And the depth is similar, the depth is the same as the depth in your sedimentation basin and the depth per time, that will give me an idea about the surface overflow rate. So, the depth per time will give me an idea about the surface overflow rate.

, surface overflow rate , we just discussed this earlier. Let me see I think I plan to discuss this after a few slides, . , in general surface overflow rate will give me an idea about that critical velocity if I may say so, beyond which, depending upon the type of tank, if it is up flow or horizontal, , either no particles will be removed or rarely a fraction of the particles will be removed . We will come back to this.

In general, the effluent concentration we are now looking at our settling column analysis, . Effluent concentration will be equal to the mass in the column by the volume of the column that is what we understand, . So, after some time, , earlier it was different particles of different sizes. So, initially, this is after some time, .

So, maybe here, I have the smaller particles and here, I have the bigger particles or mixer and here I have my sledge. So, what is my effluent concentration going to be? So, it is going to be equal to this mass in this column, not in this zone, mass in this column by the volume of the column that is going to be my effluent concentration. How do I get that? I will have to get that by integrating C dv by dt or dv by V, this is not t, if I am not wrong, or C dh by H, . So, that is something to keep in mind. Yes.

Let us move on. Because keep this in mind, we will use this later. So, as I just mentioned, it is integral C dv differential volume/V. Yes, you have different concentrations at different volumes that is what we are looking at, . So, mass in column will be the concentration into that particular in that particular volume, . And by the total volume of column will give you mass by volume.

Because cross sectional area here, relatively uniform throughout the column, it will turn out to be integral C dh/ H; H is the total height here. So, in the last, what we set, when I say set, I am talking about the set related to the sedimentation, we discussed how it came through, I think using the information given by Professor Mark and Benjamin, we looked at discrete settling and then use that to understand how to interpret and maybe use the data for the type 2 column settling.

Here, from Dr. Bachelor, Bill Bachelor, my advisor, we will look at the numerical integration method.

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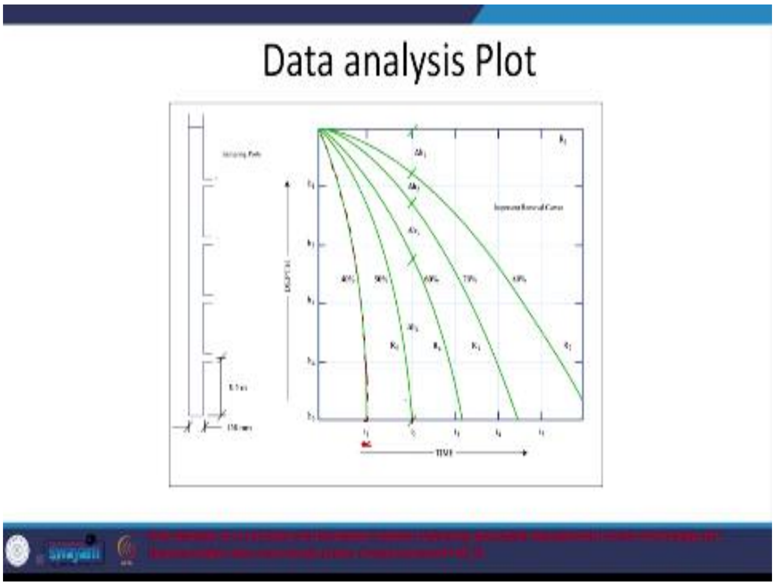

So, from taking the samples at different ports at different times, we can, we will first have a table. From the table, you will interpolate it and , we will get this graph. So, 40% graph or 40% removal graph, different times 50%, 60, 70 and 80, . So, here, , , based on this time and relevant height, I will be able to calculate the relevant surface overflow rate.

So, that is something that we already looked at; yes, as we already looked at. Depth by time will give me the surface overflow rate depending on which time . But as you can see, at this time, , it is not that. It is only 50% removal, you have different fractions of removal at different stages, . So, how do I take this into picture? So, how the equation came about. Yes.

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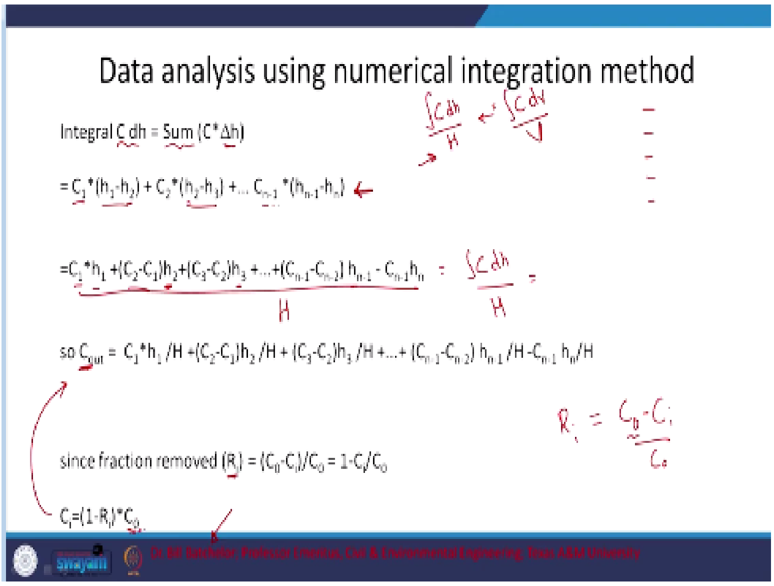

So, as I mentioned, data analysis using numerical integration method from my advisor, so, we have this the mass or effluent concentration is equal to integral of C dh/ H. This is what we saw earlier, this is from integral of C dv mass of the relevant particles and that relevant volume into the relevant concentration by the total volume that is equal to this particular aspect.

I am looking at the numerator here. Integral C dh is equal to some of C into delta H, . I have different heights. Yes. So, some of C into delta H. So, what is that equal to? C into h1 – h2, h2 – h3, so on, C_n – 1 to this and that I can rearrange, I am going to take out the term h common, height will be common. So, C1 h1 + C1 minus or C2 minus C1 into h2 , it is just rearranging the terms, so that the common variable is the height here, .

So, that is something I have. So, C out will be equal to, so I know that the concentration is going to be given by this. And this is nothing but integral of Cdh. So, if I divide this by H that is the effluent concentration, so I will have to divide this by H. So, that is what I have C out is equal to this. So, it is going to be divided by H that is what we have. And that is what we saw earlier, .

So, now I know that my graph is going to be something like this, it will have the different removal percentages and different removals at different heights , . So, how do I get this removal percentage in the picture? So, here I am going to say that fraction removed is equal to C_0, this is not out, C_0 or C initially present minus Ci/C_0 or initially present. So, from this, I can rearrange and get Ci in terms of the fraction removed and the initial concentration.

So, this I will go back here and plug it into this particular equation, . So, for each case, I can plug this. Ci is equal to 1 minus Ri into C initial, . So, this is C initial. Keep that in mind. So, C out to, I can put that in here. Let us plug that in.

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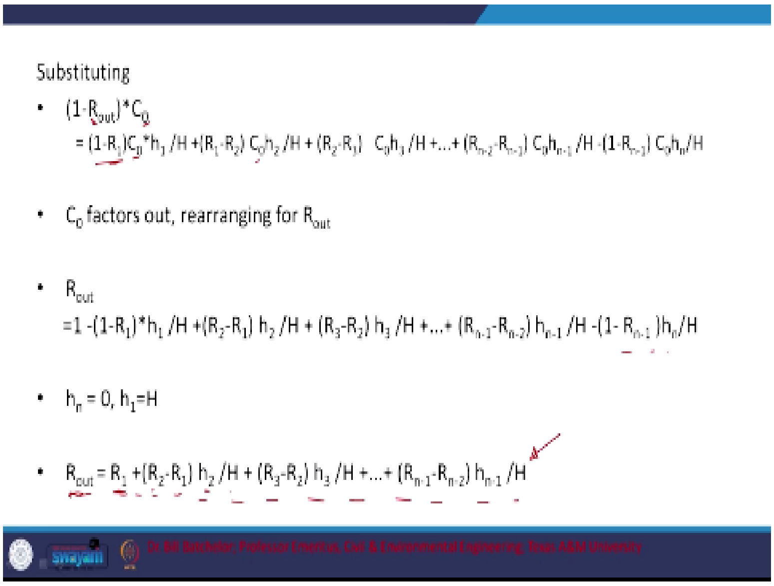

So, 1 minus R out into C_0, this is not out, this is initial, is equal to the same case, I am going to plug it in and then we can cancel out C_0. Yes. And then rearranging for R out, I see that R out is equal to this particular set of terms. , C_0 cancel out and we are just rearranging that is why it is 1 minus of this set of terms. Bring this R out to the hand side and this term to the left hand side. So, that is what you C out here, . And hn is 0, h1 is H. And so, thus, we get this equation of the H, hn is 0 and h1 is H. So, this equation simplifies to be this. And so, this is what you will use, , R out will be this R 1. Let me see where the equation is R 2 – R 1 by into h 2 by H, R 3 – R 2 into h 3 by H .

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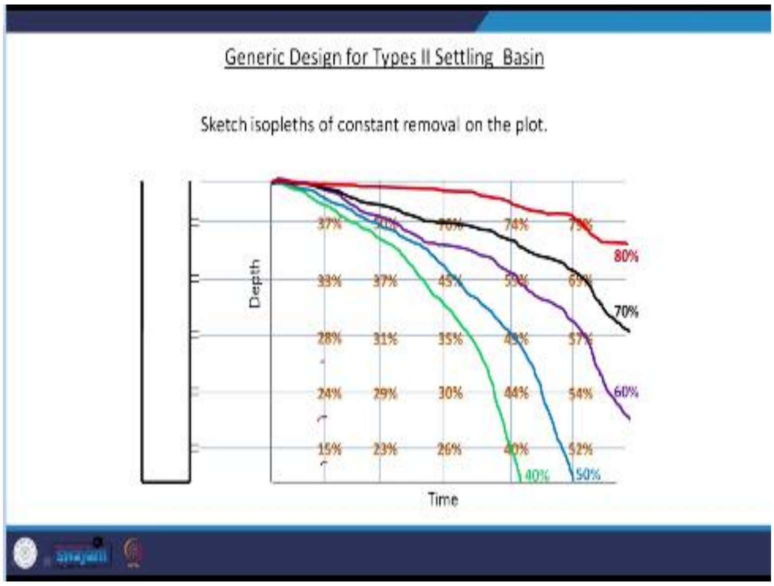

So, this. So, for example, here, we will have this curve, after getting this data, we will have this curve by interpolation, you can see that this curve will represent the 40% removal, this curve will represent the 50% removal. if I am looking at this, this R 1 is this 50% removal across the whole H.

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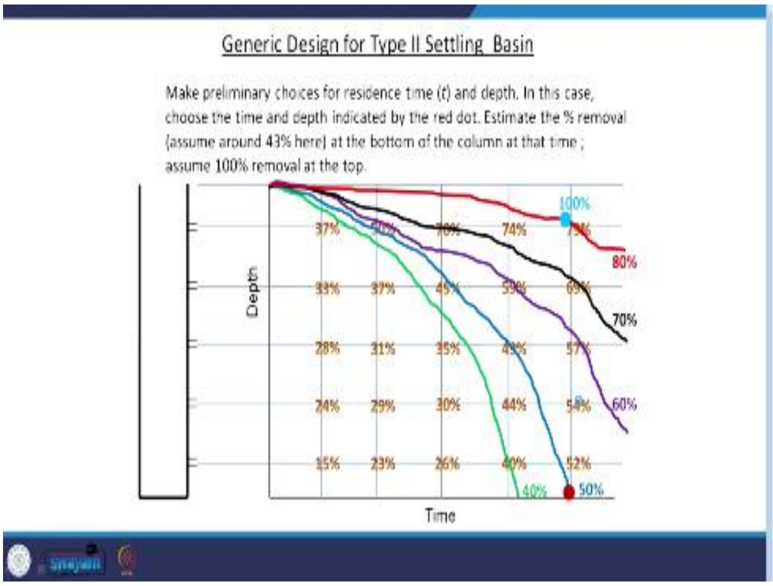

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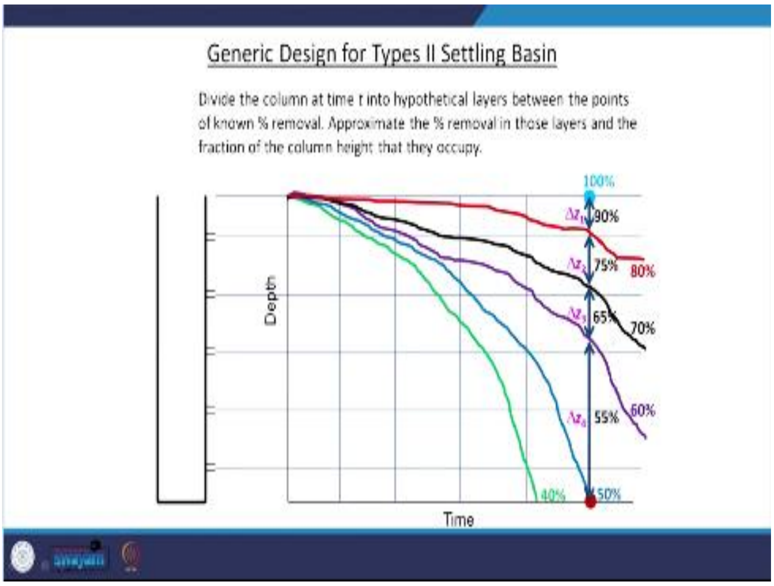

And so here, we see this 55% removal across this and this midpoint will be your, what, h 2 or not h 2; this H, . This H will be the midpoint. And h 3 will be the midpoint out here and so forth, . And R 2 – R 1, we have the percentage removals out here. And we will use that to get it out of there. Yes. So, that is how it comes in. , you have 50% removal and different levels of removal, . Let us move on.

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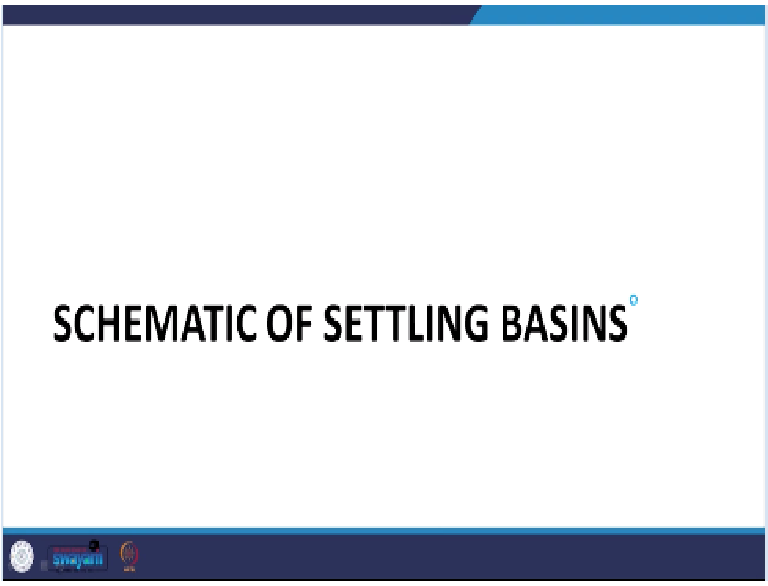

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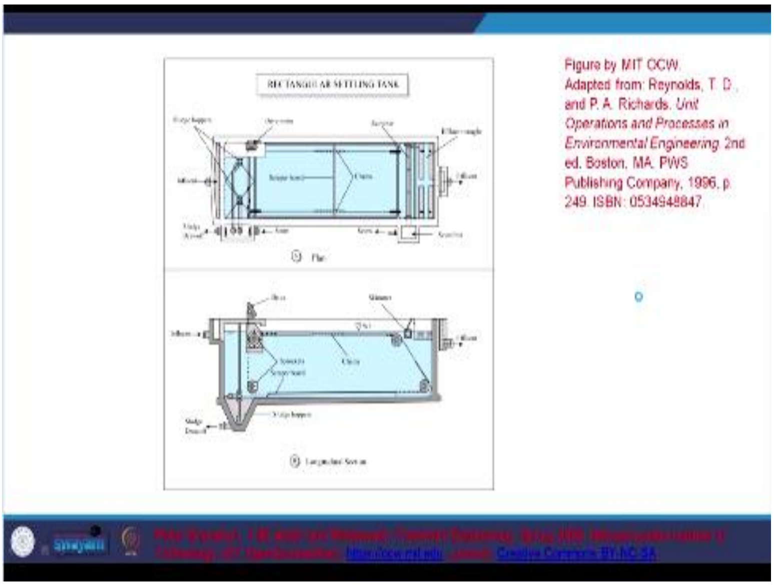

So, different types of settling basins, this is what we have. We already looked at this typically rectangular settling tank, but as we know, people would not typically prefer rectangular settling tanks because of maintenance relevant issues. Think of this, you need long and narrow tanks. So, all this area beside it relatively difficult to use or utilise. So, that is the relevant aspect.

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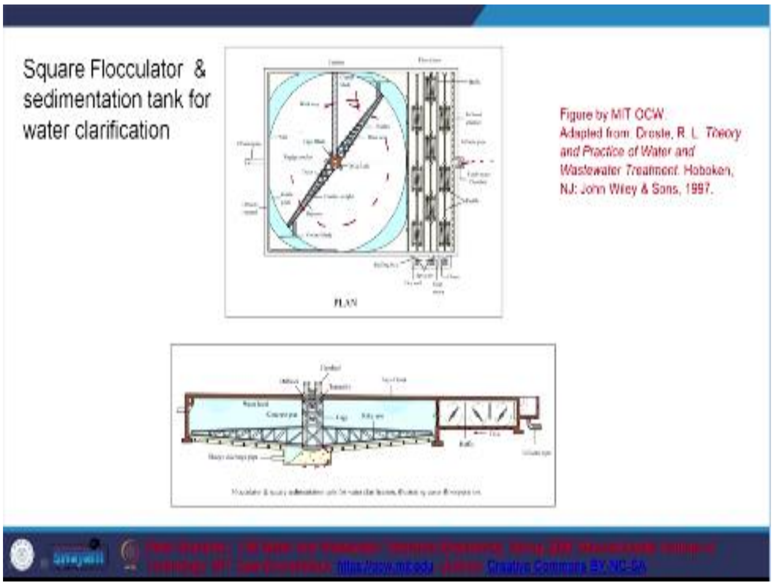

So, because of the type of scraper, yes, here you have the side view, which will give you a better view. Let us understand this water is coming in. You have influent channels, and then the paddles. And then you have this sedimentation zone. And this arm (17:43) which is going to rotate like this. It is going to rotate like this. Yes. And from the side view, you see this and here you see this sludge hopper or sludge collection, .

And here , you are going to have see baffles all around because you want to promote laminar flow conditions. , we talked about this dead zones here.

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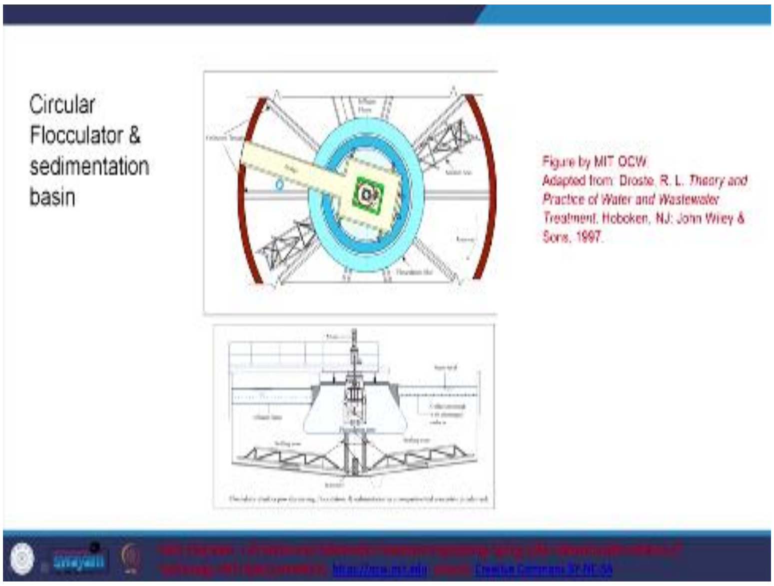

Because ease of maintenance, people will go for circular flocculation and sedimentation basins.

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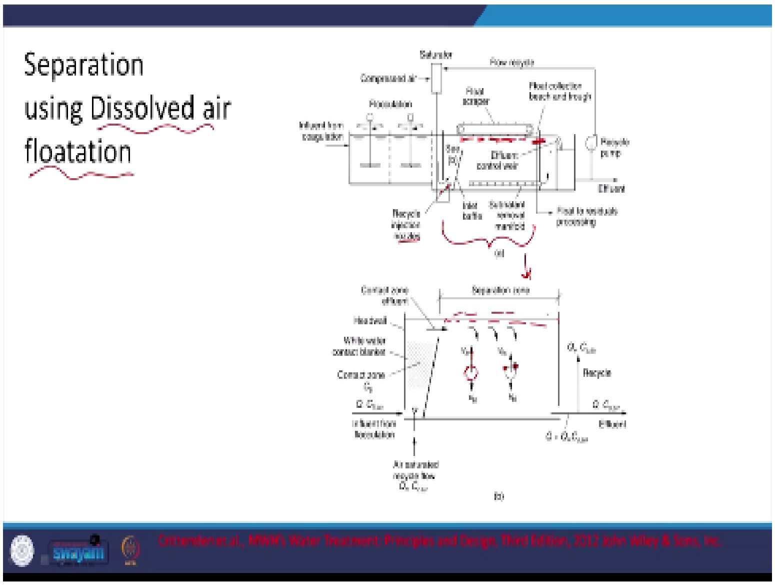

And recently people have also been looking at dissolved air floatation. Well, this seems a bit counter intuitive, I want to see to it that there are decent conditions, stable conditions, no mixing such that heavier particles come out but what is this about dissolved layer? Why will I pump in air? Does not that create an additional element air and maybe some turbulence initially.

So, , here, we want to look at the cases when we have particles of relatively less density, . And rather than settling them down, we are going to pump in air initially such that these particles, which are relatively less density, alkaline, some organic matter , well rise up , here you can call that scum. So, that is what you have here flocculent or flocculation.

And then here from the saturated, you see that you have the recycle or injection nozzles for the air. And we will see this in here, this particular zone, we are going to look at it here. So, here you have the contact zone and here you have the effluent zone. So, this is my 8 particle dissolved air as it goes up, , relatively less dense particles, will be taken up along with it and it is going to move up here.

So, it is not really settling here and then the floor will be scraped. , this case if there is any vent (19:38) when you are going to have issues with scraping so, that is why typically it is going to work in the covered kind of setup. Earlier, we used to remove it at this water, at this particular level supernatant but here we will remove it as supernatant. , here this area will be less but it depends upon the kind of system and which which you are using, .

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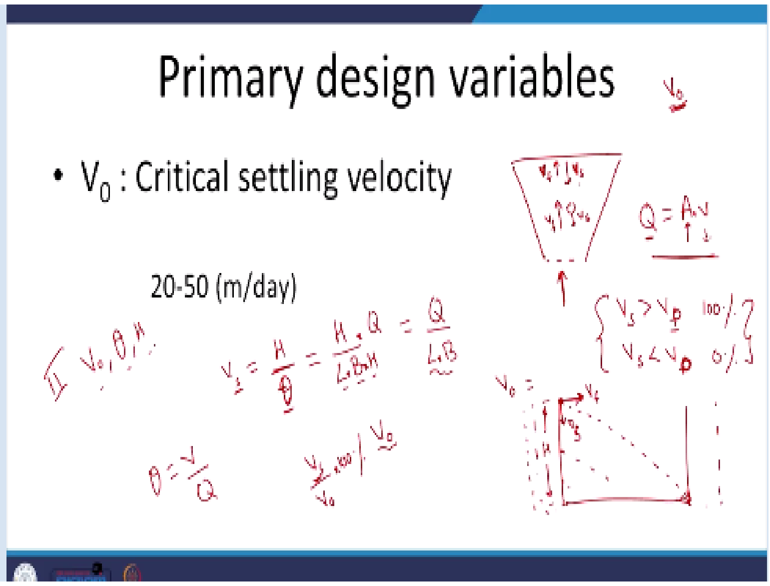

So, primary design variables, always primary design. So, if it is discrete, I am just concerned with what is the surface overflow rate or the critical settling velocity. Before we go further, , I should certainly talk about this overflow rate. So, I think we looked at this upflow and so forth. So, if my particle is coming in through here, along with my relevant water, so, because of this increasing cross sectional area as I go up and Q is equal to area into velocity.

Q is the same and the area is increasing then velocity will decrease. So, if this dimension , I find using the length here, so here it will be relatively lesser, but we know that gravity will be pulling the particle down. So, here , it is like this and as you see the velocity of flow of the fluid is decreasing as we go up. So, here, we see this is the settling velocity of the particle which we calculated from the Stokes law earlier and this is the velocity of flow of the fluid, .

So, here, we see that the settling velocity is higher than the fluid flow that is velocity that is going out or taking the water out, . Then , the particle will settle down. So, if Vs is greater than V_f, , the relevant particles will be removed 100% removal. If Vs is less than V_f, 0% will be removed. But, what is this V_f concerned with? Not the V_f here, but at this particular location.

So, that is the V not or the surface overflow rate, . So, surface overflow rate. From here, you can calculate the surface overflow rate. This is fine with our upflow. But, what about our horizontal flow? So, in this case, if this is the settling zone, this is the inlet zone, this is the outlet zone, we are only concerned with this particular case and my particle is coming through here, my assumption is that if the particle settles by the time it reaches here, I am fine.

So, the particle will be under 2 vectors. One the horizontal one and the downward or vertical one. So, this is due to the settling. Settling, this is due to the velocity of that fluid, . So, how to go about that or what is the critical one that is required. So, it has to be such that. What is the height? This is the height. It has to cover this and this particular time, but what is the time or this theta, I should have mentioned theta there.

Theta, I know, is equal to V by Q. So, here, , I will use theta. Why is it? This particle is spending a total of theta minutes in this particular system. Within that time particular time, it has to cover a distance of H in the vertical direction. Only then will it be removed or just be removed. So, H is to equal to H /ɵ is V by Q with V is equal to length into breadth into height by Q.

So, the Q will go up, . So, this is going to be equal to, after I cancel it out, Q by length into breadth; Q by the surface area. So, , this is similar to this surface overflow rate. So, if the Vs is greater than surface overflow rate, then it will be removed. If Vs is less, , depends here unlike 100% and 0%, there is going to be a different aspect it depends upon which height it is coming at.

So, a fraction will be removed, it is no such thing as 100% removal or such. Why are we assuming fraction or this? We are assuming that whatever particle is coming in, it is not concentrated, but it is uniformly distributed throughout the height. So, that is why it is going to be fraction removal, , Vs by V_0 into 100%. So, that is the percentage removed that is going to take place.

Unlike this upflow, where we get 100 or 0%. It is Vs by V_0 into 100%, . That is the relevant percentage removal for a particular particle, . So, in general, what are the different cases? So, for type 1, we are only concerned with V_0. For type 2 settling, we are concerned with V_0 and also how much time it is also spending, theta or H. So, it has to be combination of at least 2 of these 3 variables, .

So, what is the critical settling velocity or such that we typically look at? It is 20 to 50 metres per day.

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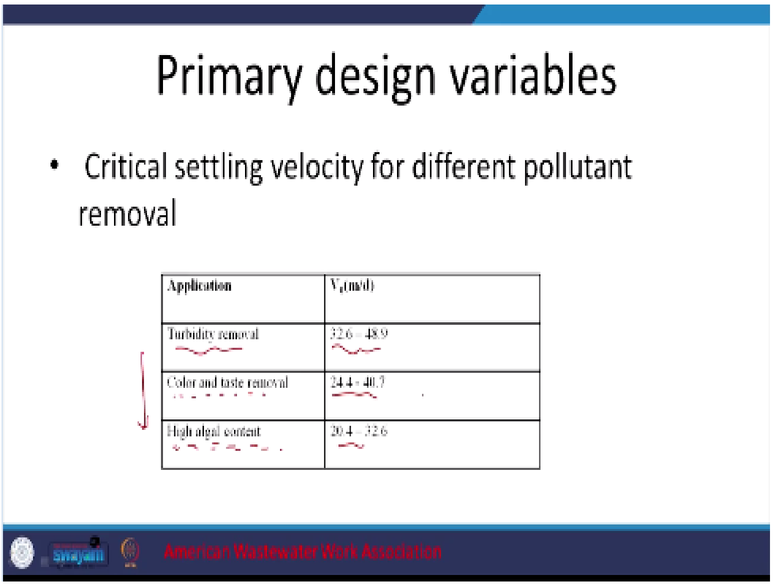

So, one is V_0 and let us look at it for different pollutant removal. If we are looking at only turbidity, this is the relevant value and if we are looking at colour and taste removal and high algal content, so, we see that we are decreasing the V_0, . So, that is something to keep in mind, depending on the relevant density . So, let us move on.

, although content, you can look at removal by dissolved air floatation. , as you can see the density is decreasing in this way. And thus, it is also affecting the V_0 here. Let us move on.

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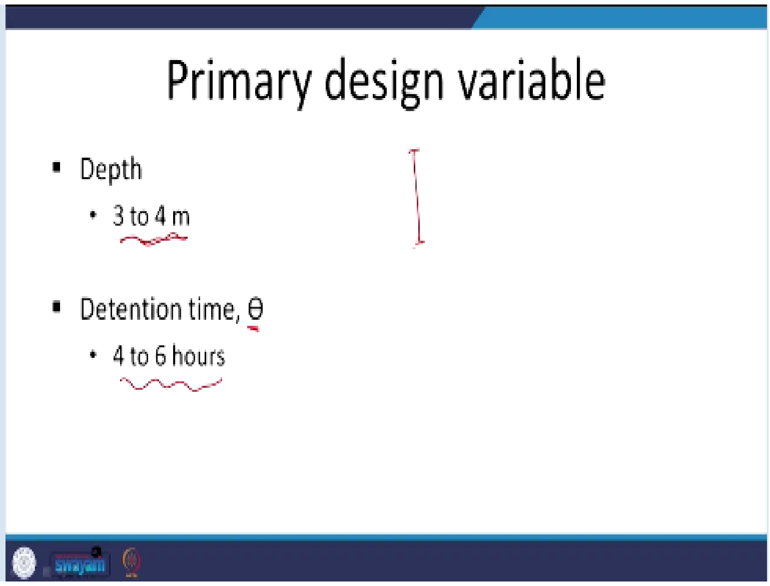

So, primary design variable. As we mentioned, it is also depend upon the time. So, typical time and sedimentation basin will be 4 to 6 hours and depth, depth or theta, or we are going to talk about H, , so that is what we have out here. Why is it? Because it has to be able to travel this particular depth in that particular time, typically 3 to 4 metres, . Let us move on.

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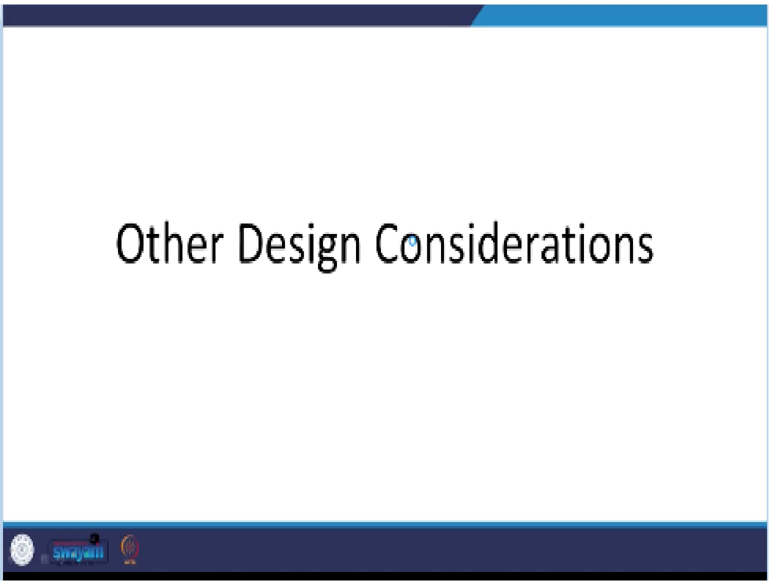

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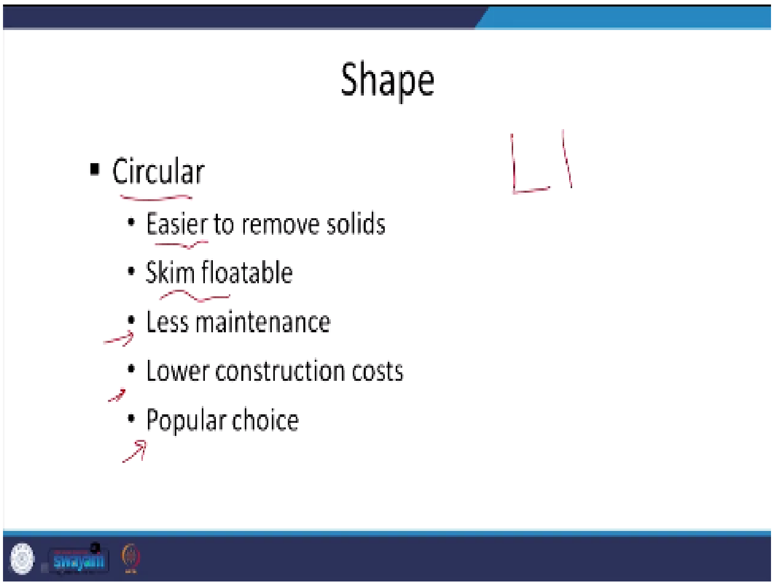

So, other design considerations. Typically circular is better, because it is easier. And skim floatable main aspect is less maintenance and less construction cost that is why it is universally much more use, compared to the rectangular one, even though here in the rectangular one. According to the sedimentation theory, we make better use of the area, .

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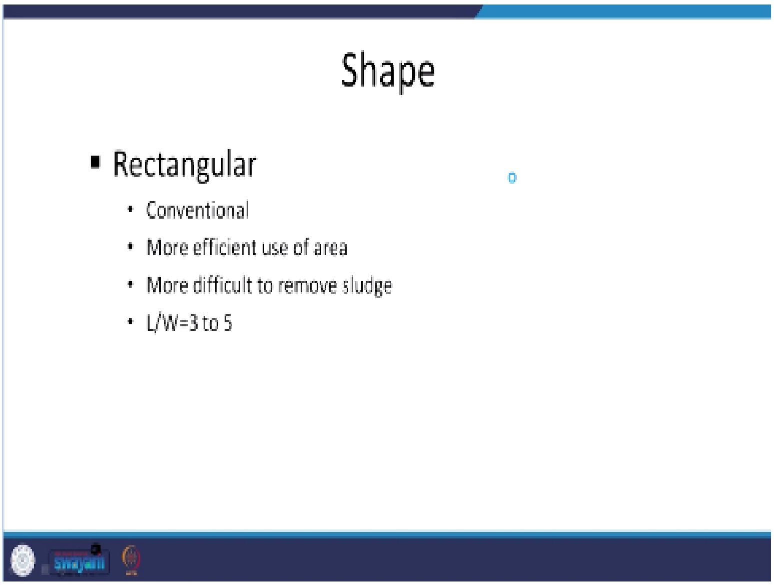

So, that is the thing that we look at. From the figure, we saw that it is relatively more difficult to remove the sludge.

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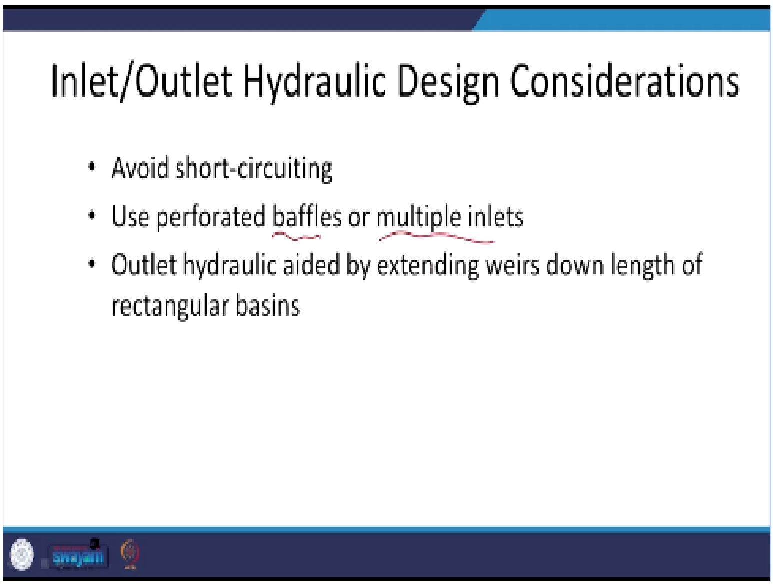

And inlet/outlet as we saw from some of the figures, I want to have uniform distribution. I do not want short circuiting. If I have short circuiting, that particular flow path we will have particles that are spending less time. , if they spend lesser time, these particles will not be removed as efficiently as the particles in the other flow paths, . So, that is something to keep in mind.

How will I do that? I will have baffles or multiple inlets, . Outlet hydraulic aided by having weirs along the length of the rectangle basis, even along the circular removal basins. You might have seen weirs all along, . So, that is something to keep in mind.

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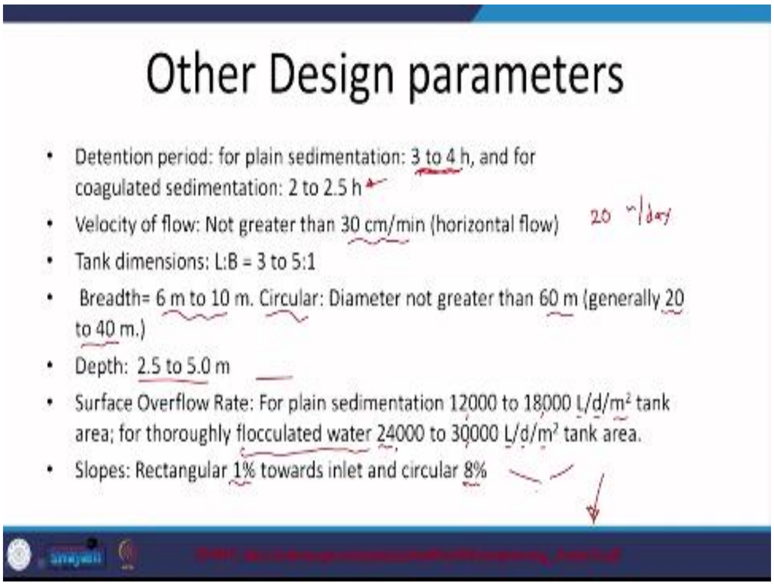

What other design parameters? This is from CPHEEO manual. They give more generic information but we looked at the basics, but because we are in India and need to be aware of what is happening here. We will also look at this aspect. Detention period 3 to 4 hours, Yes. For plain sedimentation, more time; for coagulated sedimentation this, but we are not going to use only these thumb rules.

We also, we actually have to calculate and then you can look at the relevant thumb rules. Velocity of flow not greater than this. Here, the units are different. I think there we saw 20 metres per day or some such value from the American Water Works Association relevant data. Tank dimensions , we will design. We will not take the thumb rules. So, breadth, fine. Circular diameter not greater than 60 metres, generally 20 to 40. These are good , practical aspects to keep in mind, .

Depth as you mentioned 3 to 4 there and here 2.5 to 5 metres, you do not want to have a very low depth. Even though the design says that your sedimentation will occur within a relatively less depth. You do not want to have very low depth, especially in rectangular tanks. Why is that? So, the flow comes in relatively higher , then what is going to happen? You can have scouring that is not what you want.

Also, if you have greater depth, what can happen is that the particles will experience more flocculated settling. So, that is one aspect to keep in mind flocculated settings. So, that is what you want to do. So, surface overflow rate, , based on the above aspects, you can get that so 12,000 to 18,000 litres per day per metre square and for flocculated one 24,000, you can have higher values 24,000 to 30,000 litres per day per metre square, .

Flocculated so, they settle (28:43) or efficiencies relatively better and slope rectangular is towards percentage towards the inlet and circular, 8% slope here. We are talking about this slope here. So, with that, I will end this session. Why? Because in the next one, I will move on to the relevant aspect. Until now, what did we look at? We looked at removing most of the suspended matter and we settled them down.

Even after that, we are still going to have some suspended matter that we still want to remove, even some of the bacteria . So, how do we do that? For that, we are going to use a filter, different filters. Earlier, we used to use cloth and have the water pass through it. So, the principle is same ports of lesser size and the water will pass through.

And depending upon the size and the type of removal, different types of particles will be removed. It is not only the part port size, the mechanisms are going to be different. So, in the next session, we will look at filtration. So, with that, thank you for your patience. I will end today's session.