Water Supply Engineering
Prof. Manoj Kumar Tiwari
School of Water Resources
Indian Institute of Technology, Kharagpur

Lecture-27
Practice Problems on Sedimentation

Welcome back friends. So, last class we have been discussing about the sedimentation and this last lecture for the week 5 we are going to take up some practice problem on the sedimentation.

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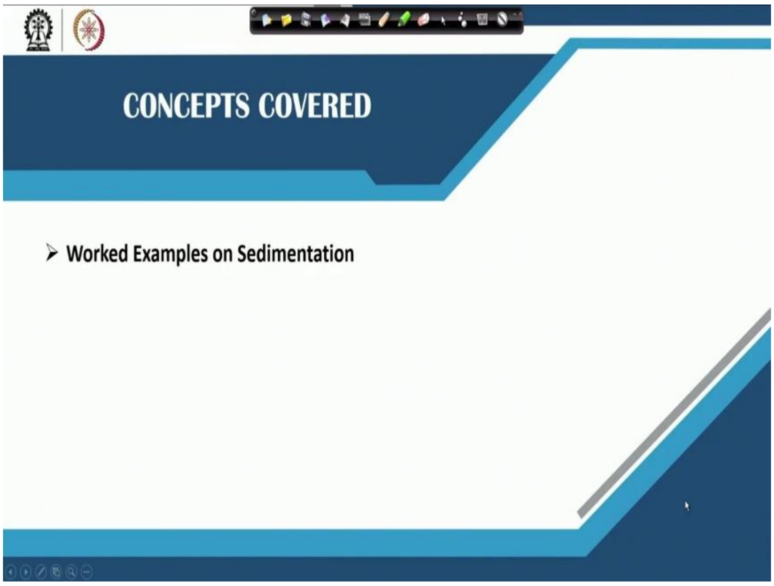

So, we will be basically seeing some worked example on the different aspects of the sedimentation.

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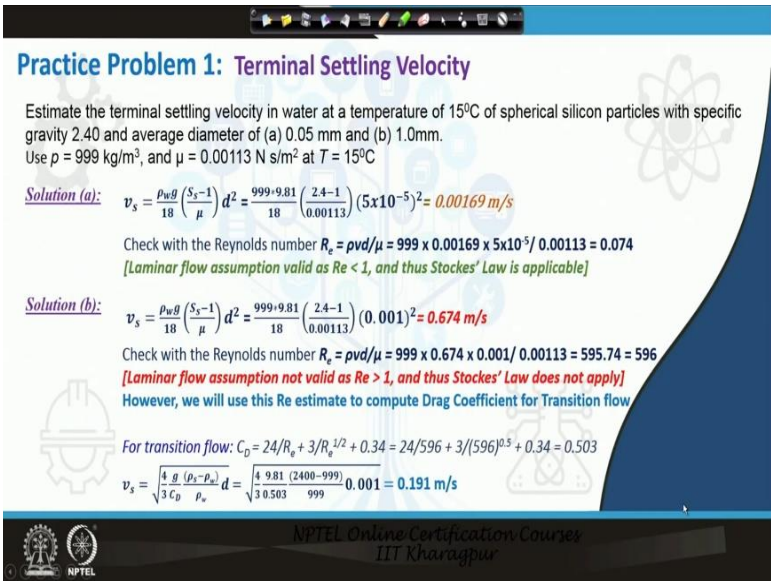

So, the first problem that we are going to take up is for estimation of the terminal settling velocity. So, the problem statement is that estimate the terminal settling velocity in a water at a temperature of 15 degrees Celsius of spherical silicon particles with a specific gravity 2.4 and average diameter of we have been given two conditions here.

The first condition is average diameter is 0.5mm and second one is the 1 mm the density of water is 999 kg per meter cube and the viscosity is also given at the temperature at which basically we need to determine the settling velocity. So, for the two conditions let us take the first case, Case A, settling velocity as per Stokes law. So, we what we usually do in such cases we first apply Stokes Law because that is how we can directly get the settling velocity.

If we go for Newton's equation or say the transition equation or Hazen’s equation will not be able to directly estimate the settling velocity because they need the Reynolds number or they need the drag coefficient which is dependent on the Reynolds number and then Reynolds number is dependent on the velocity of the particle. Because rho v d by mu, so, we have to have the we have to kind of know the velocity of the particle.

So, since we are not aware with the velocity, we cannot use these equations directly. So, we go for the Stokes law to begin with. So, what we will do we will apply Stokes law here in case A, so, the density is given to us g value is given to us and then the specific gravity is 2.4 and the viscosity value is given to us the diameter of the particle 0.5mm, which is basically 5 into 10 to the power -5 meter, we have to use this in meters okay.

So, if we convert that 0.5 mm in meter will be getting thisand square of the diameter. So, this gives us a valueas 0.00169 meter per second which is 0.0017 close to that. Okay now that way we can estimate the velocity. But we do not know whether this velocity is correct or not, because we have taken an assumption that it is laminar flow condition, and we have applied this Stokes law for estimating this velocity.

So, let us check whether our assumptions are right or not. So, for checking purpose, we estimate the Reynold number, which is rho v d by mu, rho is given to us thevelocity we have estimated and Dia of the particle is known to us, viscosity is known to us, so, we get a number 0.074 in case A. Now, as the Reynolds number here is less than 1 that means, it is basically laminar flow condition and Stokes law is valid.

So, whatever theory we have applied is actually correct. So, our correct answer is going to be this for the first case. Now, let us go to the second case. When we haveparticle sizes 1 milli-meter, one milli-meter means 0.001 meter per second. If we keep that in meter, again we do the same thing, we use the Stokes law put all these factors and use the diameter here and then what the velocity that we get is 0.674 meter per second.

Further will check with the Reynolds number, okay, so then Reynolds numbers will be estimated we have the rho we have the velocity, we have the particle diameter and we have the viscosity, the Reynolds number that we get is close to 596. Now this is much, much larger than one, okay, so that means it is not a laminar flow condition and if it is not a laminar flow condition.

So, Stokes law does not apply, but what the velocity that we have estimated is using Stokes law and when Stokes law does not apply, that means the velocity that we have estimated is not correct Okay. So, then we have to discard this velocity okay and have to estimate velocity following other means. So, what we do in this case,we go for the next like formula which is transition state formula, which is V s is 4 by 3 g by CDrho s - rho w by rho w into d.

Okay, so basically this is the density of the particle, this is the density of the water. Now, this requires CD and as we were just earlier saying CD is a function of Reynolds number, particularly in a transition state. Okay, so CD is a function of Reynolds number, and we donot know the number if because our last number is also incorrect.

We have determined this Reynolds number based on the velocity which is incorrect so our Reynolds number is all also not correct, but it is still we take this Reynolds number or the estimated Reynolds number as the first estimate, okay. So, we will consider that Reynolds number as the first estimate and we will use that for computing drag coefficient. So, drag coefficient for transition state which is 24 by R e + three by square root of R e + 0.34. So, this gives us the CD value as 0.503 which is a drag coefficient value.

So, we will use the CD value and get an estimate of the velocity in the transition state. So, we get estimate of the velocity in the transition state, but think that this velocity that you have got has used a CD which is calculated based on a Reynolds number which is incorrect. So, practically this is also not a correct estimate. But okay but this is our one approximation and then we use this for next approximation. So, now we have got another value of v.

Remember for estimation of the Reynolds number we use a velocity which was computed based on the Stokes law, which was incorrect velocity. Now, we have got a new estimate of velocity. So, we will use this velocity to compute the Reynolds number okay. So, now we will be using this velocity 0.91

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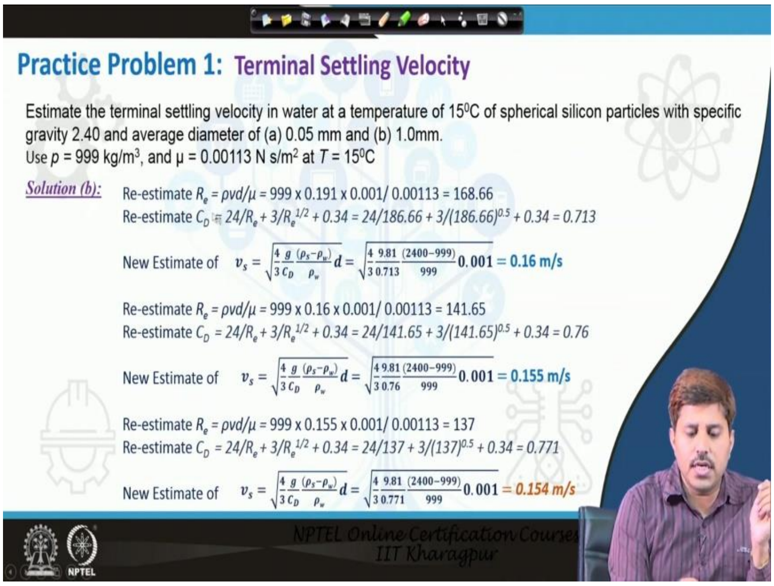

In order for computing the Reynolds number. Our new Reynolds number is 168.66 and based on that our new drag coefficient is 0.713. So, the drag coefficient which was earlier 0.5 has now basically become 0.7 in the new estimate, so we will do another new estimate of the settling velocity okay with new drag coefficient that we have estimated and we will get another estimate of the settling velocity Okay. So, our earlier settling velocity was 0.191.

Now we have got down to 0.16, okay, again, this is a better estimate than the earlier one. So, we will use this settling velocity for our next iteration. So, we basically do it based on the several iterations of what our next, next iteration again, we will compute the Reynolds number. Now we will use this velocity and compute a new estimate of the Reynolds number and using this Reynolds number we will compute a new estimate of the drag coefficient.

Further we will use this drag coefficient here 0.76 and get a new estimate of the settling velocity. Now you see these values are pretty close now. So practically, we are approaching towards the right direction, we are actually approaching towards the true close to true value. Okay, let us do other iterations of for another iteration. Now we use 0.155 meter per second as our velocity and get an estimate of the Reynolds number.

So, the Reynolds number, which like from 500 to drop down to 168 from 168 drop down to 141 from 141 it is dropping just 137. So, the drop is basically reducing some that means we are getting more and more closer to the true value, So, we will use that we get a Reynolds number, we use this Reynolds number we get a drag coefficient estimates see how close these drag coefficients are now.

Okay, the earlier iteration gave us 0.76 now we have got 0.771. So, further we will get a new estimate of the settling velocity using this drag coefficient which is 0.154 meter per second. Our earlier estimate was 0.155. So, we further before that we got 0.16. So, we are actually like kind of converging to this value we can go for one or two more iterations, but the value again is going to be probably in this range only.

So, we can take this as the settling velocity terminal settling velocity of the particleofdia1.0 mm. So this way we estimate if it is what we will do again we will use Stokes law first then estimate settling velocity using that velocity we will compute there Reynolds number and see if he Stokes law is valid if Stokes law is valid that is fair if it is not valid, then we use that settling.

We use that Reynolds number and estimated drag coefficient and compute a new settling velocity and we do it in three four iterations unless our numbers converge to one value. So, basically, if into three subsequent iterations we are getting very close or almost identical value of the settling velocity, we consider that settling velocity as the answer.

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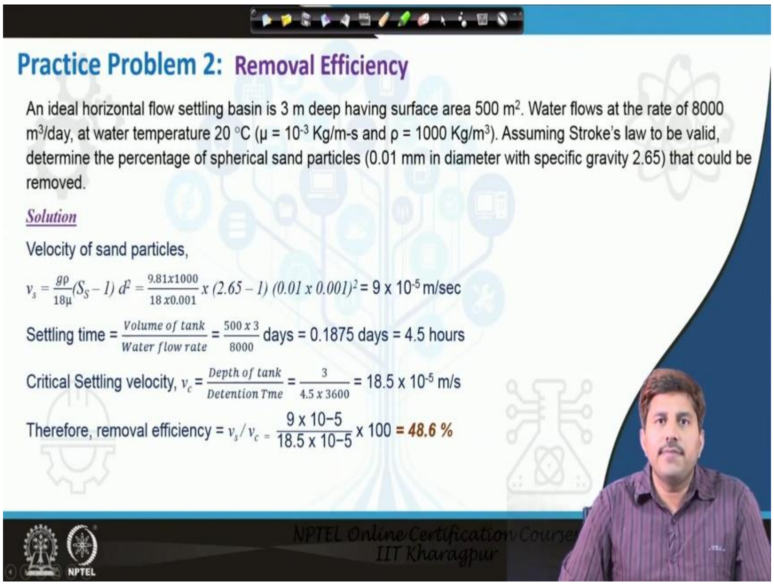

So now we will move to the next problem which is on the removal efficiency, okay. So, say we have an ideal horizontal flow settling basin 3 meter deep having surface area 500 meters square the water flows at a rate of 8000 meter cube per daythe temperature is 20 degrees Celsius and at that temperature we have the value of viscosity and density available.

So, assuming Stokes Law to be valid we need to determine the percentage of thespherical sand particles of 0.1 mm diameter with the specific gravity of 2.65 that could be removed. So, again we know all the parameters and the size of the particle so we will compute the settling velocity okay and this is our settling velocity okay. We have just substituted the given information and we got the settling velocity.

Now, the settling velocity we have got we can test it with the Reynolds number but it already the question already says that we have to assume Stokes is valued. So, let us consider this is our settling velocity. Now, the time which flew dispense in thetank is basically we know the volume of tank, the surface area is 500 meters square and it is a 3 meter deep. So, 500 into 3 becomes our volume of the tank and the flow rate is 8000 metercube per day.

So, that means 0.1875 days or 4.5 hours is the residence time or detention time of the water. So, remember our discussion that within the given time, a particle has to travel the kind of H vertical height and so that it can hit the bottom and then we consider that removed. So, for critical settling velocity, basically, the particle has to travel this G distance in the given time. So, critical settling velocity VC will be actually with the depth of the tank which is 3 in this case and divided with detention time detention time is 4.5 hours or we multiply it with the 3600 to get in the seconds and this gives us a value of 18.5 into 10 to the power -5 meter per second.

So, this is our critical settling velocity and this is our settling velocity of the particle of the size chosen size okay. So, laminar efficiency of that particle, remember as we discussed earlier is going to be the ratio of the settling velocity or ratio of the H tank height versus the basically height that it covers with the critical settling velocity okay. So,it will be ratio of the 2 velocities so 9 into 10 to the power -5 and 18.5 into 10 to the power -5 this will get cancelled and will have eventually 48.6% removal efficiency of these particles.

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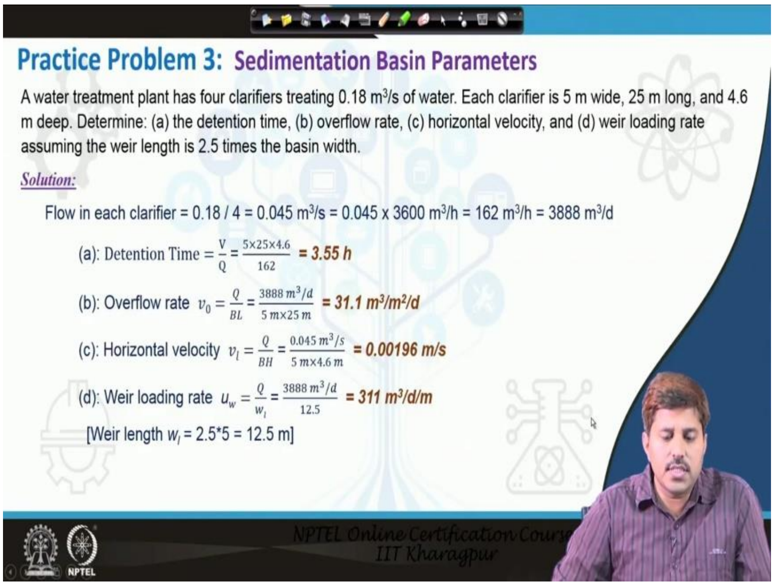

Let us move to the next problem which is basically how we determine the parameters of a sedimentation basin. So, the question is a water treatment plant has for clarifiers treating 0.18 meter cube per second of water, each clarifier is 5 meter wide, 25 meter long and 4.6 meter deep. So, the sizes are given to us, okay? It is basically 5 meter width into 25 meter length and depth is 4.6 meter. Okay? It is basically 4.6 meter deep.

Now we need to determine the detention time okay again detention time. So, flow rate is given to like, 0.18 meter cube per second, okay. And it is divided into four clarifiers we have 4 units of clarifier not one right. So total flow rate is 0.18. And since we have four clarifiers, so flowing each clarifier is ¼th of the 0.18 that is 0.045 metercube per second. Or we can say that 162 metercube per hour or 3888 meter cube per day. So, this is basically our flow rates, okay, all these are flow rates now for detention time.

Okay, the volume of the tank is 5 into 25 into 4.6 length into width into the effective depth and the discharge is 162 metercube per hour, we want to determine in hour so let us use meter cube per hour and this gives us 3.55 hours as the detention time Okay. The next is the overflow rate we have to estimate the overflow rate as well. So, overflow rate is Q by A, as we know, okay and Ais basically L into B, so basically Q by Linto B, so Q by BL or Q by L into B.

If you want to present in hour we can use this Q, if you want to present in the day we can use this discharge value. So, 3888 meter cube per day and 5 meter into 25 meters. So, this gives us 31.1 metercube per meter square per day as the overflow rate in the tank.The next one we need to determine the horizontal velocity as well okay. So, horizontal velocity component is basically how the water is flowing horizontally and that is going to be the discharge per unitlike we get the overflow rate per unit plan area of the tank if say this is our tank.

So, if this is our time for that matter, so, the overflow rate we take this area discharge per unit this area okay, but for horizontal velocity, so, horizontal velocity is basically flow has to take on this. So, we know velocity will be Q by A and because we are talking about horizontal area so, cross-sectional area here is going to this cross-sectional area okay and this cross-sectional area is the width of the tank into height of the tank okay.

So, basically Q by BH the velocity in the horizontal direction or basically velocity in length wise direction is going to be equal to Q by Binto H. So, we take this the Q value is if you want to determine again in meter per second so, we can take the velocity in discharging meter per second so, 0.45 metercube per second and B is 5 meters depth is 4.6 meters. So, this gives us 0.00196 meter per second.

Then we have the weir loading rate Okay, weir loading rate is the if say this is our tank and we have installed weir somewhere here in the tank for collecting the discharge over there and the length of the weir is given to us, the weir length is 2.5 times the basin width and basin width is the 5. So, basically, we are length is 2.5 times of the 5, which is basically 12.5 meter Okay.

Now 12.5 meter is the weir length okay and this weir has to carry the discharge from the tank and the discharge from the tank is basically this much meter cube per day if you are taking a meter cube per day you can use other units also okay. So, 3888 meter cube per day is basically getting collected by 12.5 meter long we are so, what is the loading rate on the weirs discharge divided by the length of the weir.

So, discharge is 3888 and length of the weir is 12.5 we divide it we get 311 metercube per day, per meter weir length as the weir loading rate.

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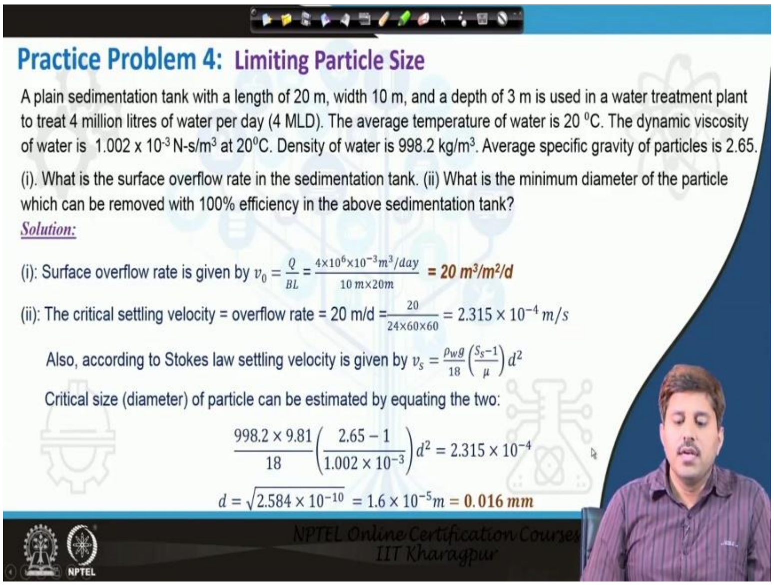

So, this is how we can estimate some of the parameters of the tank. What size of particles could be removed or limiting by particle size can also be estimated. So, we have another example on that.A plain sedimentation tank with a length of 20 meter width the 10 meter and depth 3 meter. So, here also we have all those information of length, width and height, all the three dimensions is given to us.

Is treating 4 million liters water per day 4MLD the average temperature of water is 20 degrees Celsius the dynamic viscosity is given the density is given and specific gravity of the particles is given to us. We need to determine the surface overflow rate in the sedimentation tank and what is the minimum diameter of the particle which can be removed with 100% efficiency in the above sedimentation tank.

So, surface overflow rate like we just did in a previous example, Q by LB and we have the 4MLD. 4 million liters that means 4 into 10 to the power 6liters or we can further multiply by 10 to the power -3 to get meter cube per day. So, this is basically discharge and 10 meter into 20 meter is the width into length of the tank.

So, this gives 20 metercube per meter square per day as the surface overloading rate Okay. Now, the next part of the questions is what is the minimum diameter of the particle which can be removed with 100% efficiency okay. So, if you recall for 100% efficiency the critical velocity that particle requires to get 100% removed is equal to the overflow rate right. So, we will estimate the critical settling velocity of a particle and have to put that as equal to the overflow rate.

So, the overflow rate we have just estimated which is 20 metercube per day or 20 meter cube per meter square per day which will come 2.315 into 10 to the power -4 meter per second. Okay, now this has to be equal to the like, for, for a given diameter of the particle, the settling velocity, the terminal settling velocity of that diameter of the particle should be equal to this and we get the terminal settling velocity following Stokes law, let us say.

Let us use Stokes law and get the terminal settling velocity of the particle and we have to equate these two. So, these two actually has to be kind of put equal in order to get the diameter of the particle. So, for Stokes law, we know here the density, the specific gravity, the viscosity, g value, what we donot know is D. So, when we equate these two, so this filling all this value into D is equal to basically we keep that equal to the over flow rate or critical settling velocity and this will basically give us, we can compute diameter from here.

So, this is the effective Dia thatbasically is going to remove with 100% efficiency. Okay. So, particle of this dia or larger dia will be removed with 100% efficiency particles of smaller Dia will not be removed because they are settling velocity will be lower than this okay. So, that is how basically we can estimate this.

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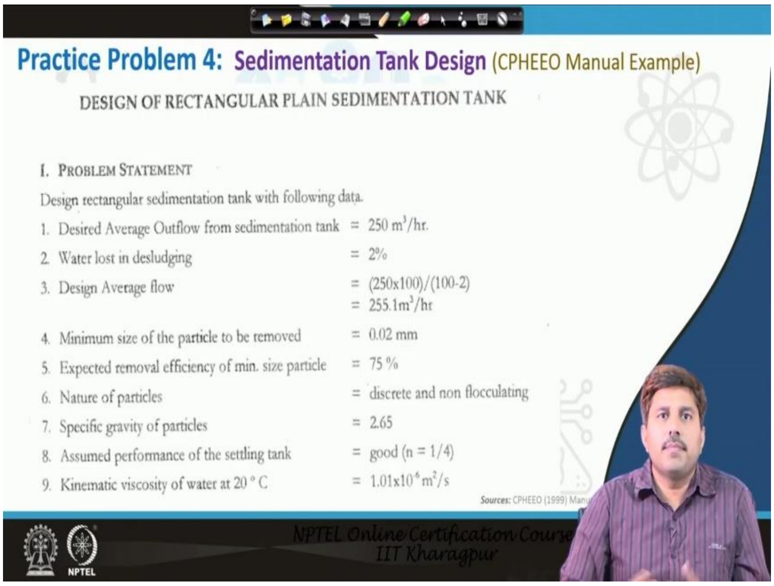

Now,the last problem what we are going to take is the sedimentation tank design and we have taken the example from the CPHEEO manual. So, whatever the example is given in the CPHEEO manual that is what we are going to take. So, this is the problem statement like we have say the average outflow from the sedimentation tank water lost in desludging is 2%

Okay, the average design flow is basically because what we need out from the sedimentation tank is 250 meter cubeper Hour,it is 250 meter two per hour, but 2% water is lost in desludging means in sludge removal. Okay, so let us say if this is my sedimentation basin say.So while removing the sludge, I am actually getting 2% water loss. So, I for an outflow my desired outflow is 250 meter cube per hour.

Now, in order to get this outflow, I have to compensate this losses, so, that is why 215 to basically 100 divided by 100-2. So, I have to design the flow sedimentation basin for this flow. So, that after 2% loss I will be still be able to get 250 meter cube of 250 meter cube per hour flow out from the sedimentation tank.

It says minimum size of the particles to be removed is 0.02 mm, the expected efficiency 75% it is basically discrete and non-flocculating particles,the specific gravity is this, the performance we can take good which is which gives n value as 1.4 and the dynamic viscosity is also given okay. So, this is basically example from the manual we can quickly see how,

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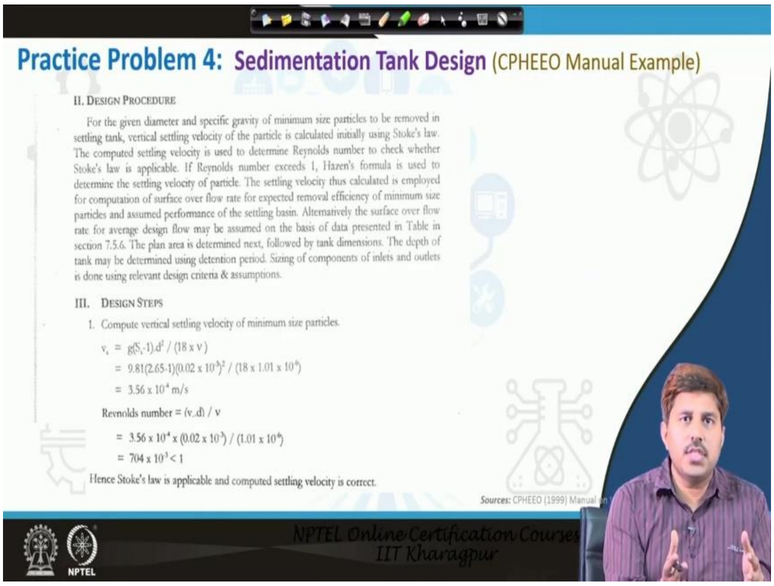

This is solved. So, they described the design procedure day which we have discussed anyway. For starting, first we will compute the terminal settling velocity of the particle for which we have to design the tank. So, the dia is given to us okay.As just we have computed earlier so, far the given diameter of the particle okay for given diameter of the particle will come to the terminal settling velocity will check with the Reynolds number which is coming less than one.

So, we say that Stokes law is applied. If that is not applied, we like in earlier example, we calculated the settling velocity will have to follow the same step here, but here Stokes law is applied so it is fine. So, we get the settling velocity of the particle.

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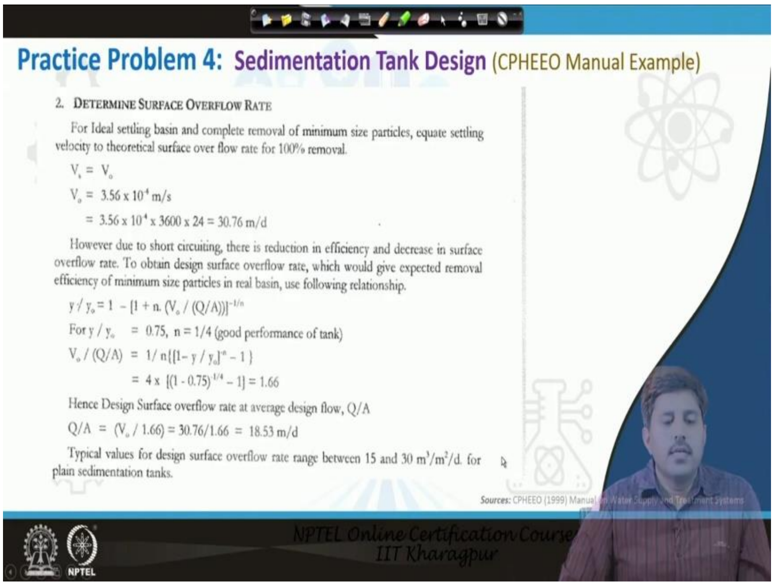

Now, the next step is to basically estimate the overflow rate okay and for an ideal settling basin the settling velocity will be equal to the overflow rate as we know for an ideal settling basin the terminal settling or critical settling velocity is equal to the overflow rate. So, from there we can get the overflow rate.

However, for real tanks were basically in order to counter the effect of the short circuiting any kind of possible flocculation or other things, we use this formula as we discussed earlier, which is the efficiency of the tanks the efficiency of the tank is given to us 75% Okay.That means 0.75,the end value is given as 1.4 So, we know all othersoverflow rate we know So, from here we can get the value of Q by A putting in here. So, we know that value of Q by A we know the discharge. So, from here we can compute the area of the tank needed, okay.

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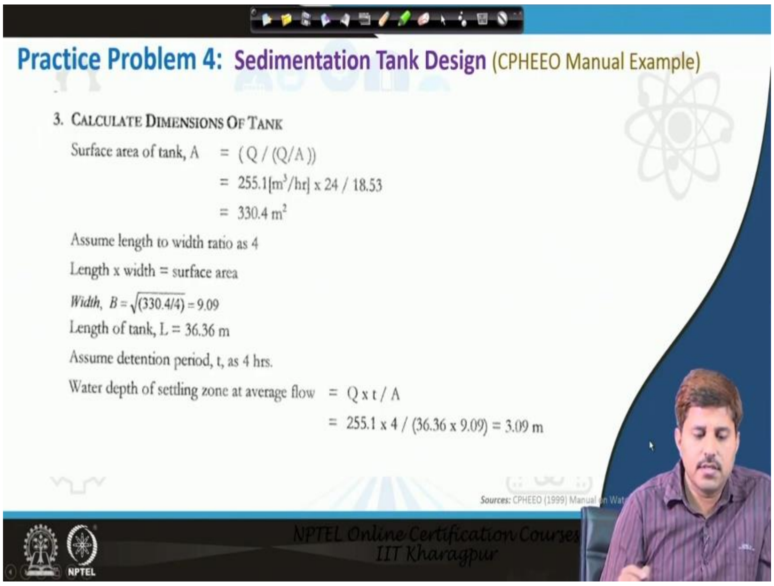

So, that is the next step with known Q by A and Q value we get the area of the tank, okay. Now, we can assume suitable length to width ratio, there are criteria as given as discussed in the previous class. So, let us like this particular example, it takes a ratio of 4. So, if length to width ratio is 4, so, basically, width is ¼th of the length and eventually we will get the tank length and tank width by solving this and we can assume a detention period and that will give us the depth of the water we can cross check whether depth is adequate or not.

It has to be from 2.5 to 5 meter also generally, so, if it is 3 meter, we can say that okay this depth is adequate. So, we got the tank dimensions, we got the length we got the width we got the depth and when we assume the detention time.

Contrary to this we can assume the depth also we can assume the depth and then compute the detention time and detention period and see if that detention period is within the adequate range.

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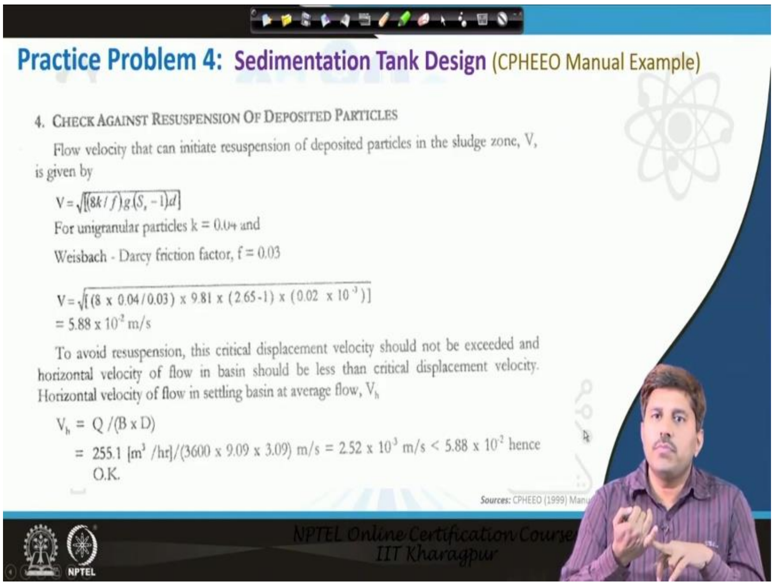

So, either of the 2, either we have to assume death and check for the detention period or we assume the detention period and check for the tank depth. So, that way we can size the tank and then rest is basically some checks like checks for the resuspension of the deposited particles whether the particles are coming back in the resuspension or not.

So, for that, we use this expression okay and basically, we can compute the V value and see if it is less than that, so, we can confirm this. So, this is not of that like we are not too much focusing on these checks here, okay.

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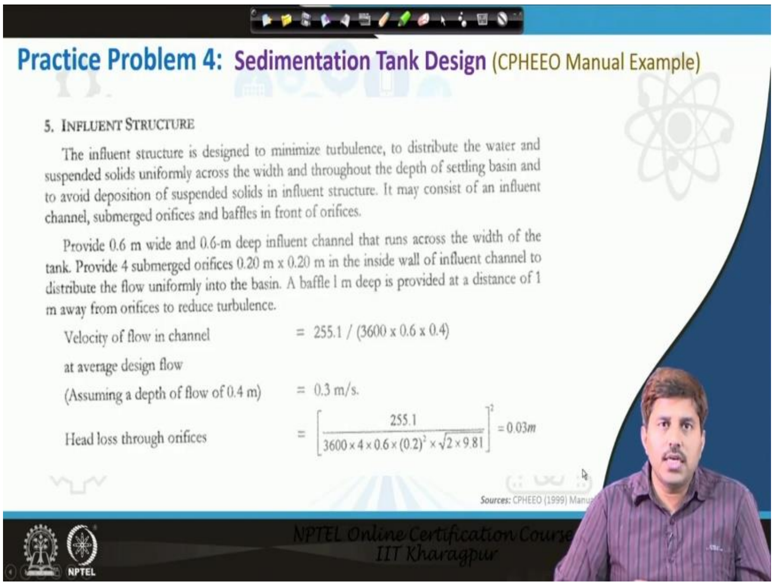

Then we can put the inlet structure and outlet structure. So, a suitable inlet structure as of the we earlier discussed certain suggestions about the inlet and outlet structures, there are variety of options available. So, we can choose a suitable option for inlet structure and

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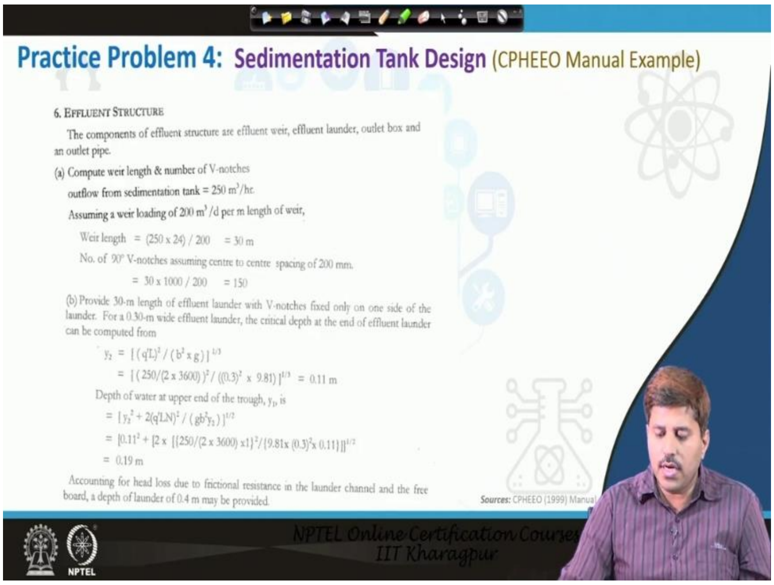

Similarly, one suitable option for outlet structure on influent is structure and will do the appropriate calculations accordingly.

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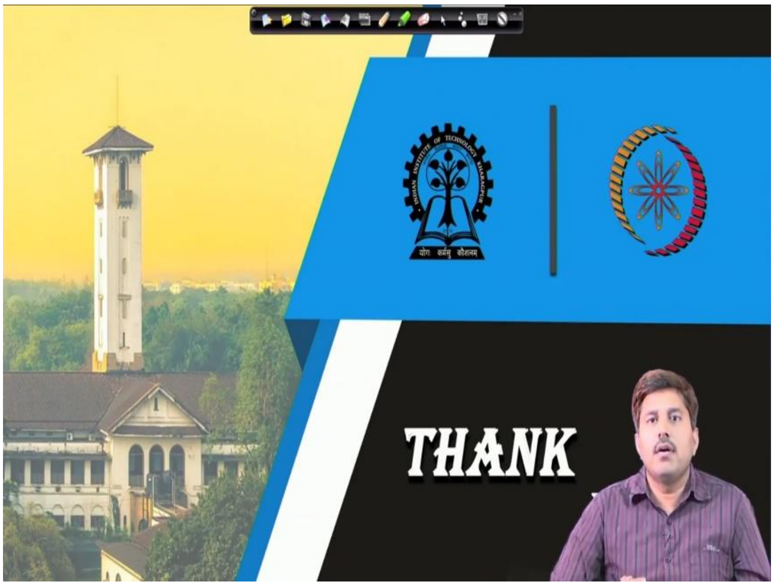

So, with this we conclude the discussion for this week. In this week we discussed about the basic quality aspects of water, what are the water quality parameters which we need to know for say assigning or understanding the quality of water whether it is adequate for certain designated uses or not. And then we discussed about the basics of the water treatment, why it is essential and when it should be provided. And then what are the various types of approaches for treatment including the treatment systems which depend on the source of the water.

So, for groundwater sources or for surface water sources, and then we have started discussing the unit wise we discussed the very preliminary units like Screening and Aeration and even Sedimentation. Plains sedimentation is also not quite often used in the system. Sedimentation is one of the most important unit and it is almost there in every treatment facility. But it is not the primary sedimentation it is basically sedimentation is provided after coagulation flocculation in most cases, but in some cases if water is too turbid, we can go for primary sedimentation as well.

So, we discussed about the sedimentation as well. In the next week, we will take up the other units like Aeration and Aeration, we already have discussed will take up the other units like Coagulation, Flocculation, Filtration and those kinds of units which are again quite important for the treatment of the water arrived specifically from the surface water sources. So, we conclude the discussion here. Thank you for joining and see you in the next week.