Ground Improvement
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Lecture – 34
Preconsolidation (contd.)

Hi everyone, let me once again continue with preconsolidation topic and in particular, PVD application or NP consolidation. And in the last lecture I have given all calculation procedure, how to design it, design PVD. Design means actually what? You have to find out what is the PVD genre section to be chosen and whatever are available in the market, based on that you have to find out the equivalent diameter.

And equivalent diameter will be obtained by equating the perimeter of circle and perimeter of the stream. And after that, you have to follow certain steps and based on that finally you have to arrive at the spacing required. That means, how frequently you have to, by what pattern you have to use to install the PVD, so that after a certain period which is also fixed, maybe one year or two year we can achieve certain degree of consolidation.

That is also fixed maybe a 90 percent, 95 percent even more or less. So, that is the things we have discussed and while doing that, in PVD application also when you push inside the soil then as we have, I have mentioned that surrounding soil will be disturbed and because of this disturbance, the permeability value will be changed.

If the permeability value get changed, then automatically flow will be reduced, which is actually most important, that radial flow which helps this consolidation to happen faster, and if that get disturbed then automatically the overall consolidation process will be delayed. So, that, that, the disturbance happened that is called smearing effect. And considering the smearing effect, how to modify the calculation that is also shown.

So, now I will try to take a problem, the problem is same, but that problem will be is, will be done twice. One is with smearing effect, without smearing effect and another with, with smearing effect. And you can see, how much or what changes is taking place in the time. So, let me go to the problem.

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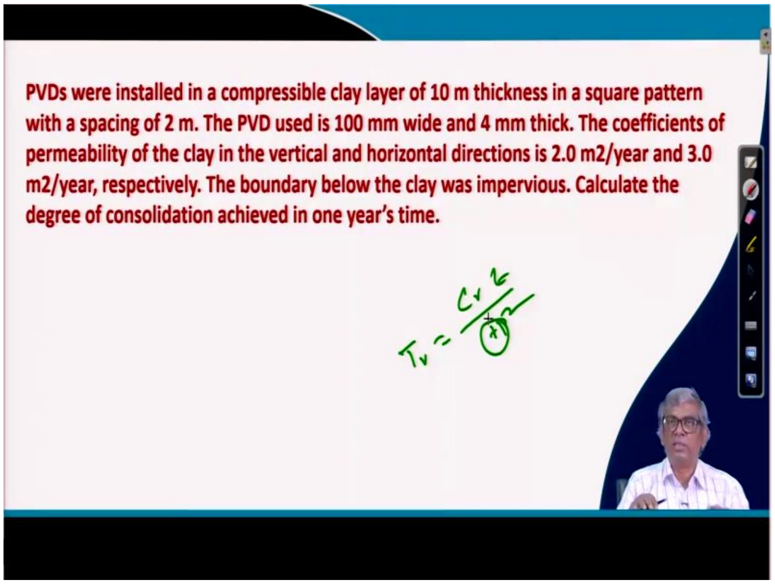

The problem is here, that the PVDs were installed in a compressor, compressible clay layer of 10 meter thickness in a square pattern with a spacing of 2 meter, everything almost said. Everything means, actually what? The thickness of the clay layer is 10 meter, it is mentioned. And spacing is, PVD 2 meter, also what pattern? It is a square pattern, everything is mentioned. And PVD used is 100 millimeter wide and 4 millimeter thick.

$$T_v = \frac{C_v t}{H^2}$$

That is also the standard dimension of PVD available in the market, that is also given. The coefficient of permeability of the clay, the vertical and horizontal direction also given, 2 and 3 meter square per year respectively. And boundary below the clay was impervious, why this information is required? Because when you calculate Tv, when you calculate Tv, Tv equal to Cv T over H square.

And if it is, bottom layer also pervious, then your, this H would have been half. But here actually, this is mentioned impervious, then H will be same as 10 meter. So, that, that way it is required. Boundary below the clay was impervious, calculate the degree of consolidation as achieved in one year's time. So, whatever I have told in the previous module, and that are not a previous lecture, there actually if, if T is unknown, then how to get actually?

You to assume T and then arrive at bison iteration and match the degree to consolidation required. But here, everything is given that design, one suppose, this is a preliminary design. And you have to see how much U is achieved. If the U is achieved is satisfactory, then that is a design. And U achieved, if it is not required, matching with the required then we have to modify.

So, here actually you can say in the design process, one of the steps now actually is given to show how to do the calculation. So, suppose this is the one problem. And the square pattern so, let me take a new page and do it.

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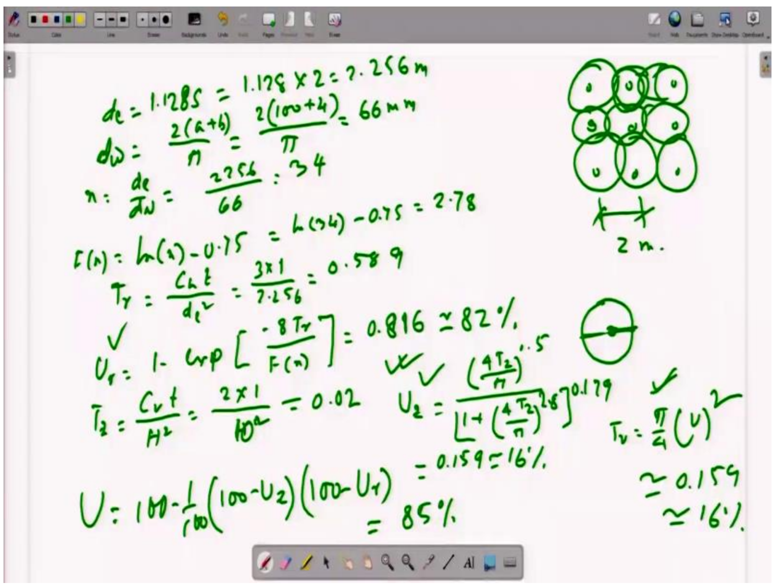

So, square pattern that means, it is something like this. And you will have like this, so like this actually overlapping will be there. Like this, like this it will happen. And the spacing is given 2 meter and all those things. de, equivalent diameter first to be calculated, which will be 1.128 s. So, this will be equal to 1.128 multiplied by, s is 2meter. So, 2.256 meter. And dw, diameter of well will be the by 2 a plus b divided by pi.

So, twice 100 plus 4 divided by pi. So, this gives you, something 66millimeter. So, n will be equal to de by dw, and that is actually 2256 divided by 66, which will be equal to 34. Then Fn, Ln n minus 0.75. That gives you Ln 34 minus 0.75, which will be equal to 2178. And Tr equal to, Tr equal to Cv, Cr T Ch T divided by de square. Because when a particular value is there, so, longest distance is this.

So, this one, so, so, this one if you do, so, value is 3 multiplied by one year. And de is 2.256, 2.256 meter square. So, this gives you a value tr is equal to 0.589. And then Ur will be called to 1 minus exponential, 1 minus exponential minus 8 Tr divided by Fn. So, this is the equation already I have shown. And if I substitute all those values here, then you will get 0.816, sorry, 0.816. So, that means, it will be equal to 82 percent, Ur.

$$d_c = 1.128s = 1.128 \times 2 = 2.256m$$

$$d_w = \frac{2\left(a+b\right)}{\pi} = \frac{2(100+4)}{\pi} = 66m$$

$$n = \frac{de}{dw} = \frac{2256}{66} = 34$$

$$F\left(n\right) = \ln\left(34\right) - 0.75 = 2.78$$

$$T_r = \frac{C_h t}{{d_e}^2} = \frac{3 \times 1}{2.256} = 0.589$$

$$U_r = 1 - Exp\left[\frac{-8T_r}{F\left(n\right)}\right] = 0.816 \approx 82\%$$

$$T_v = \frac{C_v t}{H^2} = \frac{2 \times 1}{10^2} = 0.02$$

$$U = 100 - \frac{1}{100}\left(100 - U_Z\right)\left(100 - U_r\right) = 85\%$$

$$U_z = \frac{\left(\frac{4T_z}{\pi}\right)^{0.5}}{\left[1 + \left(\frac{4T_z}{\pi}\right)^{2.8}\right]^{0.179}} = 0.159 \approx 16\%$$

$$T_v = \frac{\pi}{4}\left(U^2\right) \approx 0.159 \approx 16\%$$

And Tz will be equal to Cv T over H square. So, this will be again, Cv equal to 2 1 year and H square. Here actually, 10, 10 square, here actually one has to remember that most of the time that you have to check what unit is given in the Cv and what is unit in the time is used. So, both, if it is not given in the appropriate unit, you have to convert. Otherwise, finally here Tz has to be dimensionless. But if you use different unit, then you will not be able to make dimensionless.

So, Cv actually is given actually meter square per meter, year actually. And T is also one year, so it get cancelled. So, since year is given there is no conversion. If suppose, Cv is given meter square per day or month and you have to calculate in one year then that one year has to be converted to what unit is given. So, many times you do not see and blindly you use these and as a result you will get, end result is erroneous.

So, that to be checked. And so here actually I am getting correctly, so because of that, these value will not have any problem. So, here this if you do this calculation, it comes around 0.02. And 0.02, and I have given new equation Uz equal to 4 Tz divided by pi to the power 0.5 divided by 1 plus 4 Tz by pi to the power 2.8 and whole to the power 0.179. So, if I use this equation, then I get from here 0.159 equivalent to 16 percent.

And if I use that equation up to 60 percent, that is equation T, Tv equal to pi by 4 U square, that is equation. So, up to 60 percent, if I use this equation there also I am getting same, 0.159 that means 16 percent. So, whatever I have said that either you can use this equation or this equation, both gives almost same results. Particularly this it, when it is close to 40, 60 percent this may give little different result but otherwise this can be whatever way you like, you can use it either this or this.

So, this is the equation, little longer equation. But, but a single equation so, this can be used. So, once you get this, then we know that, you know you have got now Ur, you have got now Uz. So, if I go get two independently, then U combined U equal to 100 minus 1 by 100 and 100 minus Uz multiplied by 100 minus Ur. And these values Ur Uz if you put and if you calculate here, this gives you value equal to 85 percent.

So, this is actually most of the time, this problem as I have told you that this may be a intermediate step, that U as I have told you that you have to find out, generally requirement is that I have to complete the project in one year. So, that means that within one year I have to achieve 95 percent or 98 percent or 90 percent degree of consolidation. So, that is target, and you have to find out the time.

So, here actually whatever problem is given, you can assume that it is the intermediate step because when time is given ne year and in one year how much you are getting? 85 percent, if your requirement is 85 percent then this, this is actually solution. But your requirement is 90 percent, 95 percent and you got 85 percent, then what you have to do? You have to change the time, the time actually you have to change.

Or, or the time may not be changed, you can time maybe kept fixed, you can change the spacing, spacing was two meter. You can make 1.75 meter and accordingly everything will change and finally you can, maybe time a targeted time is one year targeted, degree of consolidation also 95 percent. What way we can achieve or approve or improve this result? By changing the spacing, so, that can be done.

So, so I hope this is by a large is a step in calculus, steps of calculation in using PVD. So, the I will do some other methods, the generalized method later on. That I will, I will show you, I will how to do it. But now I subsequently I will take same problem and maybe with, with your smearing effect, let me go to that. So, here what I have done?

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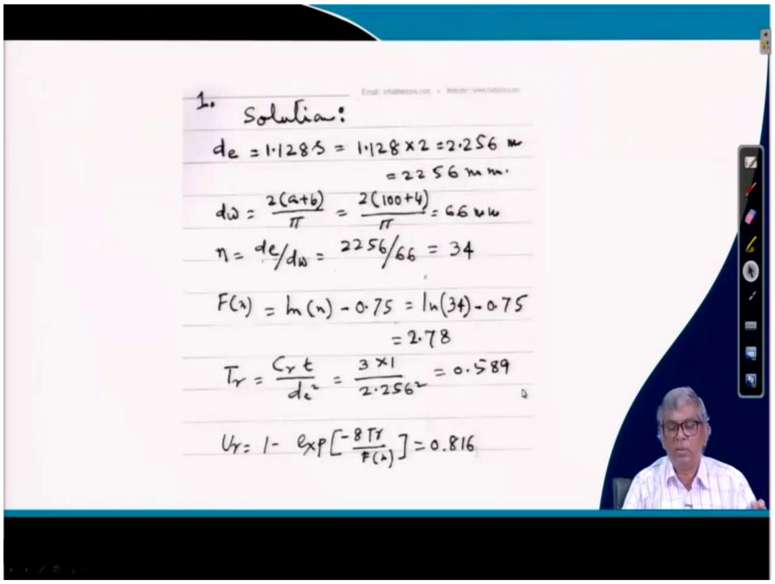

Though I have solved but again if you want to, sometime in the PDF or in the document form if you want to find out, because of that my handmade solution also it is kept here, same thing.

$$d_c = 1.128s = 1.128 \times 2 = 2.256mm$$

$$d_w = \frac{2(a+b)}{\pi} = \frac{2(100+4)}{\pi} = 66mm$$

$$n = \frac{de}{dw} = \frac{2256}{66} = 34$$

$$F(n) = \ln(34) - 0.75 = 2.78$$

$$T_r = \frac{C_h t}{d_e^{\,2}} = \frac{3 \times 1}{2.256} = 0.589$$

$$U_r = 1 - Exp\left[\frac{-8T_r}{F(n)}\right] = 0.816$$

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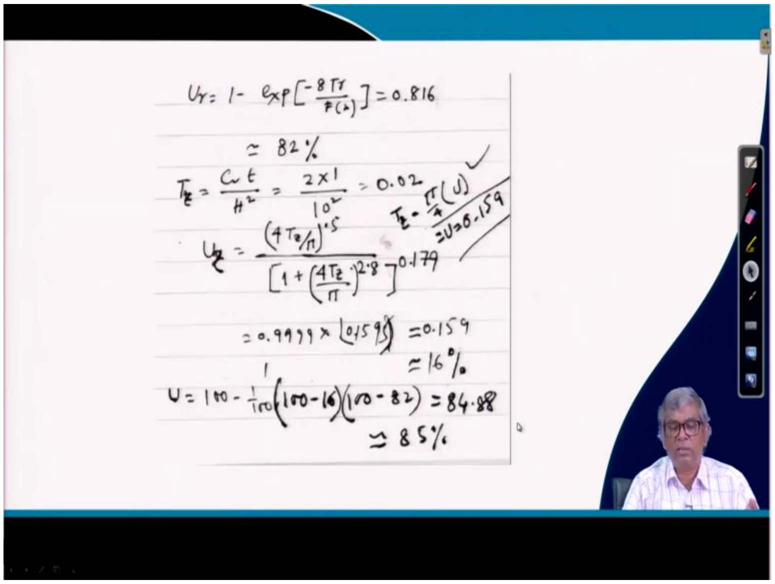

You can go through if you wish.

$$U_r = 1 - Exp\left[\frac{-8T_r}{F(n)}\right] = 0.816$$

$$U_r = 1 - Exp\left[\frac{-8T_r}{F(n)}\right] = 0.816 \approx 82\%$$

$$T_v = \frac{C_v t}{H^2} = \frac{2\times1}{10^2} = 0.02$$

$$U_z = \frac{\left(\frac{4T_z}{\pi}\right)^{0.5}}{\left[1+\left(\frac{4T_z}{\pi}\right)^{2.8}\right]^{0.179}} = 0.9999\times0.1595 = 0.159 \approx 16\%$$

$$\mathrm{T}_z = \frac{\pi}{4}\left(U_z^{\,2}\right) = 0.159$$

$$U = 100 - \frac{1}{100}\left(100 - U_Z\right)\left(100 - U_r\right) = 84.88 \approx 85\%$$

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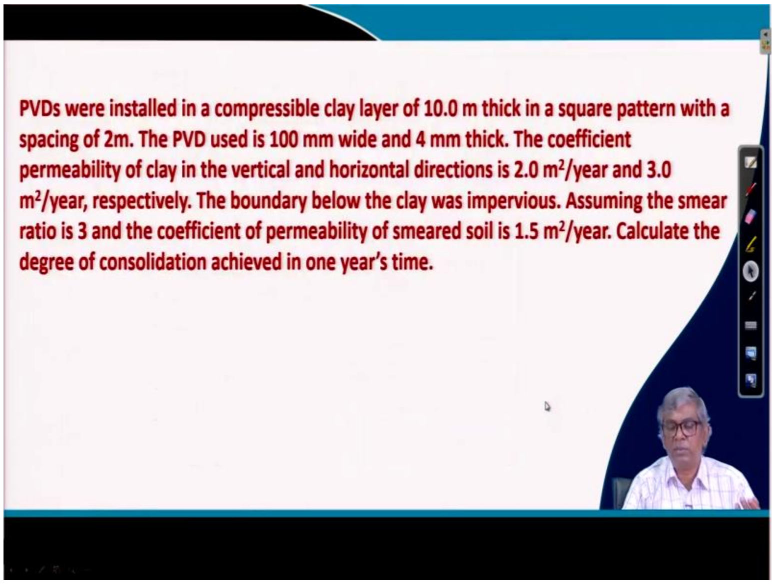

Now second problem is given, same thing PVDs were installed in a compressible clay layer of 10 meter thick in a square pattern with a spacing of 2 meter. The PVD used is 100 millimeter wide and 4 millimeter thick, everything same so, far. The coefficient of permeability of clay, the vertical or horizontal is a 2 and 3 meters per year, respectively that is also seen.

The same boundary below the clay was impervious that is also seen, assume the smear, smear ratio is 3. Smearing ratio means, kh by ks, that is 3. And the coefficient of permeability of the smeared soil is 1.5 meter square per year. That ks is 1.5 meter square per year. And calculate the degree of consolidation achieved in one year's time, same thing. Again, time is given and how much degree of consolidation is achieved, if this much smearing happened in this design.

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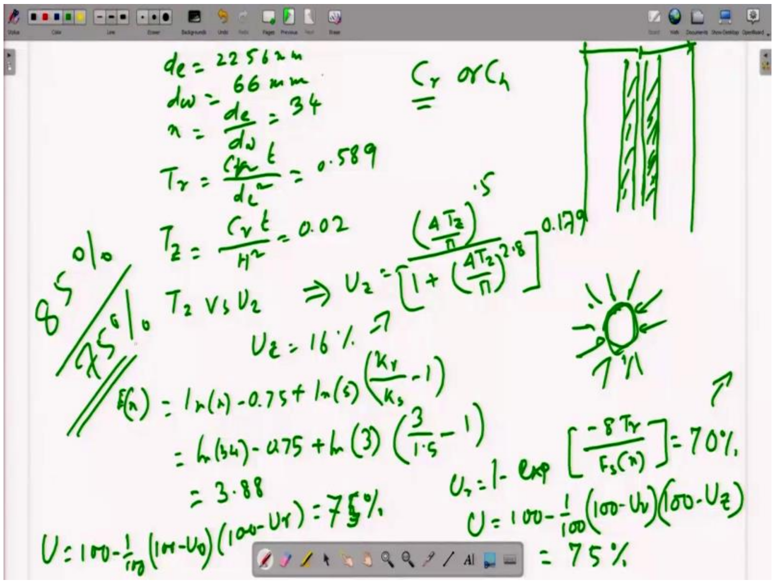

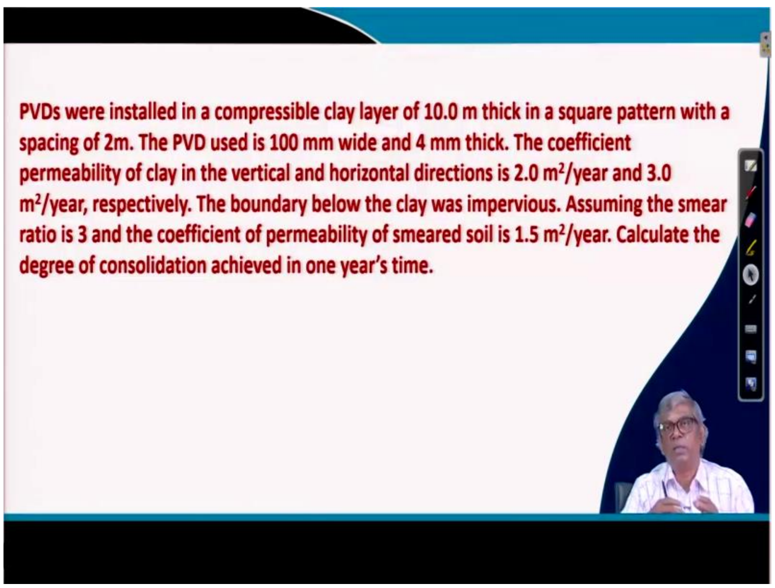

So, let us see that, and taking, making a new page, new page that means, you have something drain and then we have smeared zone, which is this. And we have actual area of influence of this drain is this, upto this. So, that effect that with, earlier problem we have not taken effect of this, now we have to take. So, same one actually step by step I will repeat once again.

$$d_e = 2256mm$$
$$d_w = 66mm$$
$$n = \frac{de}{dw} = \frac{2256}{66} = 34$$
$$T_r = \frac{C_h t}{{d_e}^2} = \frac{3\times 1}{2.256} = 0.589$$
$$T_z = \frac{C_v t}{H^2} = 0.02$$
$$T_z \text{ vs } \mathrm{U}_Z \Rightarrow U_z = \frac{\left(\frac{4T_z}{\pi}\right)^{0.5}}{\left[1+\left(\frac{4T_z}{\pi}\right)^{2.8}\right]^{0.179}} = 16\%$$
$$F(n) = \ln(34) - 0.75 + \ln(s)\left(\frac{k_r}{k_s} - 1\right)$$
$$F(n) = \ln(34) - 0.75 + \ln(3)\left(\frac{3}{1.5} - 1\right) = 3.88$$
$$U = 100 - \frac{1}{100}(100 - U_Z)(100 - U_r) = 75\%$$
$$U_r = 1 - Exp\left[\frac{-8T_r}{F(n)}\right] = 70\%$$

De equal to 2.2256 millimeter, 2256 millimeter already we have done in the previous problem. Dw also we have done in the previous problem that is 66 millimeter. And n equal to de by dw, which is again 34, we have done previously. And Tr equal to, Tr equal to Cv, or no Cr or Ch, Ch into T. Actually Cr or Ch both, because when we do PVD calculation, generally if this is the PVD then water enters all direction.

So, so, this is actually, with respect to this circle it is radial. And also same thing, water is moving in horizontal direction. So, because of that, either you can use coefficient of consolidation in radial direction or coefficient of consolidation in horizontal, both is applicable. So, sometimes if I by mistake if I write Cr, this Ch or if I by mistake, if I write Ch, it will also can be treated as Cr.

So, Ch T divided by de square, that will be equal to your 0.5, 0.589 which I have shown before. And your Tz equal to Cv T divided by H square, that is also calculated before that is 0.02. And now, Tz versus Uz, that equation is there. So, that is whatever we did that is Uz equal to 4Tz divided by pi to the power 0.5 divided by 1 plus 4Tz divided by pi to the power 2.8 and whole to the power 0.179.

So, this is there. So, this calculation from here actually will get Uz will be equal to 16 percent. Now, Fn, when there is a means, smear effect then Fn equation will be equal to Ln n minus 0.7 pi plus Ln is multiplied by kr by ks minus 1. So, that is s actually as given 3, already given. So, if I put this one, Ln 34 minus 0.75 plus Ln s is given 3, smearing ratio. And kr by ks, this is actually one is 1.5 and another is 3.

So, k is actually 3 and this is 1.5 and minus 1. So, ultimately 2 minus 1 to 1, and so if this calculation if you do it gives you 3.88. And 3.88 so, Ur equal to 1 minus exponential minus 8 Tr divided by Fs n. And if we put all those, values then we will get ultimately 70 percent. So, this value we are getting 70 percent. So, now combined U, your U equal to 100 minus 1 by 100 100 minus Uv multiplied by 100 minus Ur.

This is Uv and this Ur. So, if I put this one, then you are getting a value equal to 75 percent. So, what is the difference actually? You can see that, without smearing effect whatever value the degree of consolidate or degree of consolidation achieved in one year time was 85 percent and when there is a smearing effect is considered, it is to 75 percent. That means, it consolidation becomes slower.

So, that is why this is the one is shown, when there is a particular thing is used that means, PVD is used. And that PVD while installing, I will show that figure also how they generally install, only photograph I can show you. And while installing of course, there will be disturbance around the periphery. And the way we calculate the equivalent diameter of the well, similarly equivalent surrounding that actually up to some distance.

And that smearing happened, that is actually based on research only they have quantified how much it can go. And that is actually incorporated and in this problem depending upon the type of material etc, they have assessed the value is 3, that is given. So, that value is taken and consider and calculated and finally, what we got? We got a value of combined degree of consolidation is 75 percent.

That 10 percent difference is seen because of this. That means if you do not consider if a particular site, if you use PVD and do not consider smear, smearing effect, obviously it will be affecting the result. And you expect that 90 percent consolidation is happened, but really it happened 80 percent or 75 percent. As a result if you construct the, the embankment or whatever infrastructure you wanted, and then you will be expect more settlement.

So, that is the danger. Because of that one has to consider seriously this smearing effect. These are the two problem I wanted to show to illustrate whatever lecture I have given in the previous part, that PVD how to calculate? And then the smearing effect actually, what is the effect on the final results that I have shown here. This one, whatever, I have step by step calculation I have shown.

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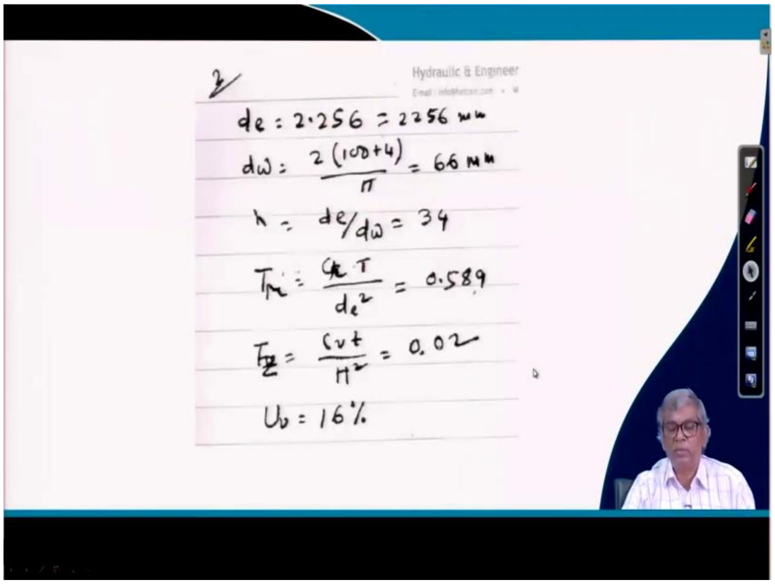

But still, I have kept my handwritten solution also in this.

$$d_e = 2256mm$$
$$d_w = 66mm$$
$$n = \frac{d_e}{d_w} = \frac{2256}{66} = 34$$
$$T_r = \frac{C_h t}{{d_e}^2} = \frac{3\times1}{2.256} = 0.589$$
$$T_v = \frac{C_v t}{H^2} = \frac{2\times1}{10^2} = 0.02$$
$$U_z = 16\%$$

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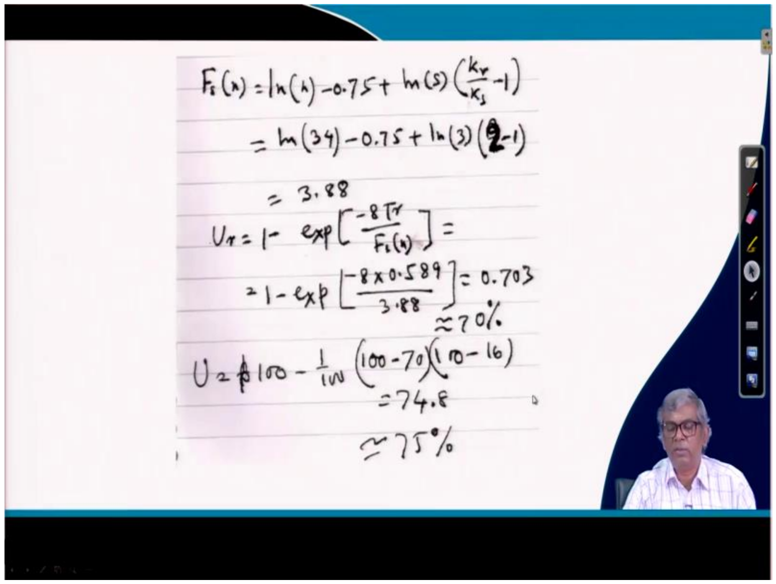

$$F\left(n\right) = \ln\left(34\right) - 0.75 + \ln(3)\left(\frac{3}{1.5} - 1\right) = 3.88$$

$$U_r = 1 - Exp\left[\frac{-8T_r}{F\left(n\right)}\right] = 1 - Exp\left[\frac{-8 \times 0.589}{3.88}\right] = 0.703 \approx 70\%$$

$$U = 100 - \frac{1}{100}\left(100 - 70\right)\left(100 - 16\right) = 74.8 \approx 75\%$$

So, that if you sometimes without listening me also, from the document, you can get also this problem. With this, I will just close here with the PVD application. And maybe I will take some concluding part of the preconsolidation that means PVD. Then what is the DN state? What is the quality control, quality etc, and all those things in the last module. Thank you.