Ground Improvement
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Module 6: Drainage and Dewatering
Lecture 30
Design Example

Let us continue from the previous lectures,

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Previous lecture we were described discussing different wells formula and using that how to find out the quantity of flow or finding out the quantity of flow here is important because ultimately initially by some tests you have to find out permeability, but here important thing is to find out quantity of flow because we have to lower the water table and to lowering water how much water to be discharged that will be essential.

So, Q is important here. We have expressed all within terms of Q somehow you have expressed in terms of k but that can be rearranged and it can be expressed with Q and with that actually, how this method whatever we have expressed and we solve a practical problem of dewatering a particular level. Let us take one problem first to illustrate the procedure how we follow and let me go to the problem at the beginning state.

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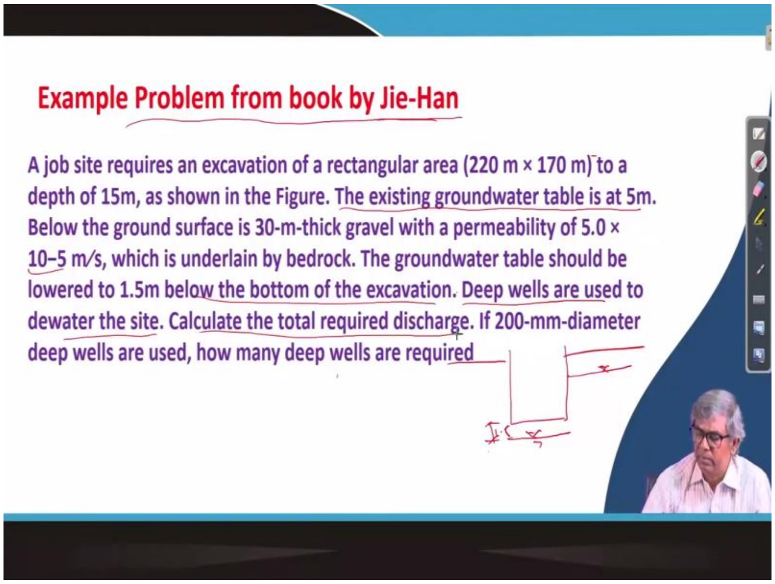

This is a problem actually a particular site requires an excavation of a rectangular area which is having dimension 220meter length and 170 meter in width and to a depth of 15 meter. So, that means the excavation is 15 meter and, and that is the figure I will come later on as shown in the figure the existing groundwater table is at 5meter below the ground surface and is 30meter thick gravel with permeability of the, the existing groundwater table is at 5 meters so this before that I let me explain different difficult to get this type of problem.

Only to explain how do calculation so any problem will do so, I have taken directly the example problem from the book by Jie-Han. And this book actually I am following almost so far everything is from that book because this is the best book, I found presently in the ground improvement a lot of calculations and mathematics calculation and quantification everything is included there.

So, I found that the best one and I am following. I have taken up this problem sometime modifying the problem, but here I have directly taken the problem because only you have to show the calculation. And so, here you can see these that existing groundwater table is at 5meter below the ground surface is 30meter thick ground gravel with a permeability of 5 into this meter per second 10 to the minus 5. This is 10 to the minus 5 which is underlain by a bedrock.

So 30meter thick clay soil and out of that, below that rock and on that soil the groundwater table 5 meter from the top and the groundwater table should be lowered to 1.5 meter below the bottom of the is excavation. That means this is the 15meter excavation and you have to come, you have to bring water table somewhere here, this distance should be 1.5 meter and the actual ground somewhere here water table was originally somewhere here, so like this.

Then how much actually we have to lower that you can calculate from there the final water table location where it is at can be obtained so actually out of 30 meter, this become if you minus 30 this is becoming 25 and from 25 I will come later on to that I better not to get confused here and so on for this work suppose different methods of lower dewatering can be adopted, but suppose we consider a deep wells are used to dewater the submersible pump with deep well that is a method where actually you can draw a quantity of water quite large amount of water can be drawn.

This is the well supposed to be used because lowering of groundwater quite significant more than 10 meter should calculate the total required discharge that is that means total required discharge, how much quantity of water to be removed from, that the water table will go below the 1.5 meter below the excavation level that is the thing we have to find out. And additionally, what is mentioned if a 200millimeter diameter were deep wells are used, then how many deep wells are required?

200millimeter diameter deep wells that means, quantity of flow can be obtain how much is possible and from there actually is single well, how much quantity can draw that can be estimated at total discharge to be taken. So, from there actually I can find out what is the number of wells can be required and after knowing that number of wells required, then we can plan how to arrange that so, that it will be effectively every from everywhere water will be will come to the well and finally, final groundwater table will be almost uniformly at the same level below the excavation point.

That is the problem by and large. And this problem also schematically shown, which I will be showing in the next page you can see the problem is here.

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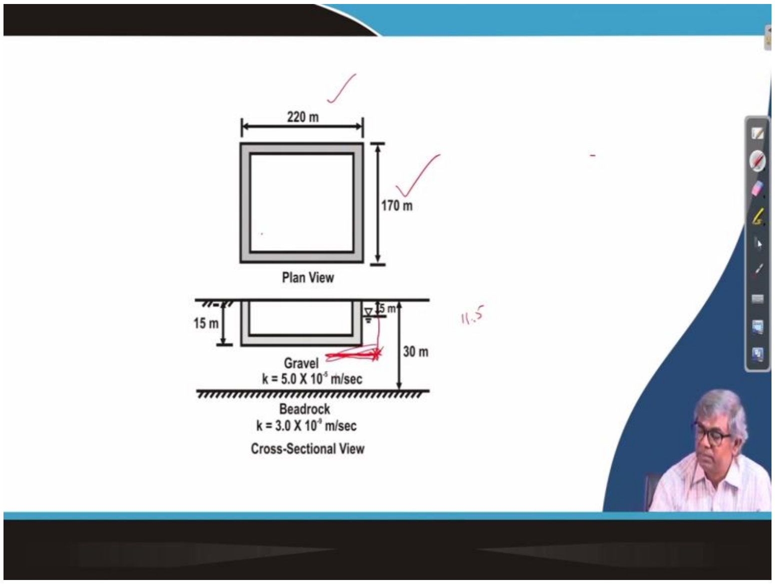

Actually, this is the dimension of the excavation. Site this is a 220 this side 170 this is a plan view and the elevation you can see here; this is a 30meter total soil below the bedrock and out of these 30 meter you have to excavate up to 15meter and water table was here and then water table has to go somewhere here. Somewhere here because the 1.5 meter below the excavation level you have to reach.

That means you have to lower water table from here to here. This actually how much you can estimate. You can see the this is 15 so, 15 to 5 that means here is 10 and so, this is from here to here, it is 10 at 10 and 11.5 meter actually, and ultimately the lowering is required. This is the one so, this problem to be solved. Let us do step by step and for this let me take one page.

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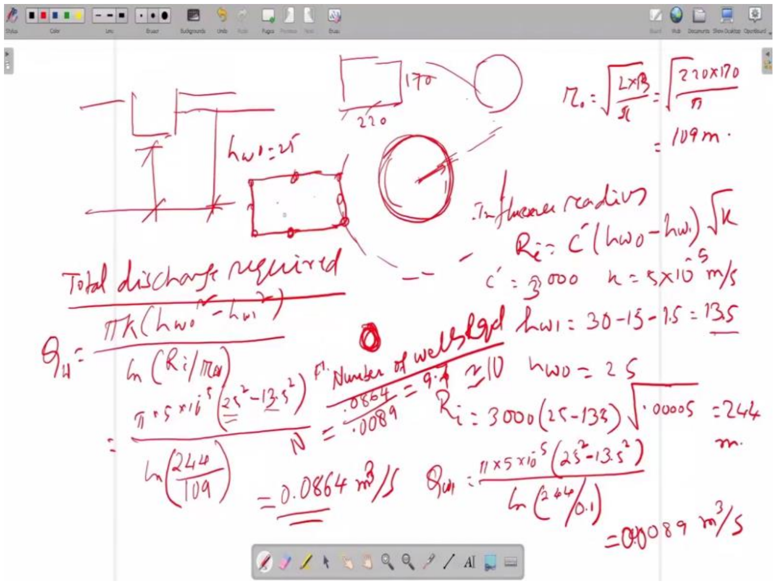

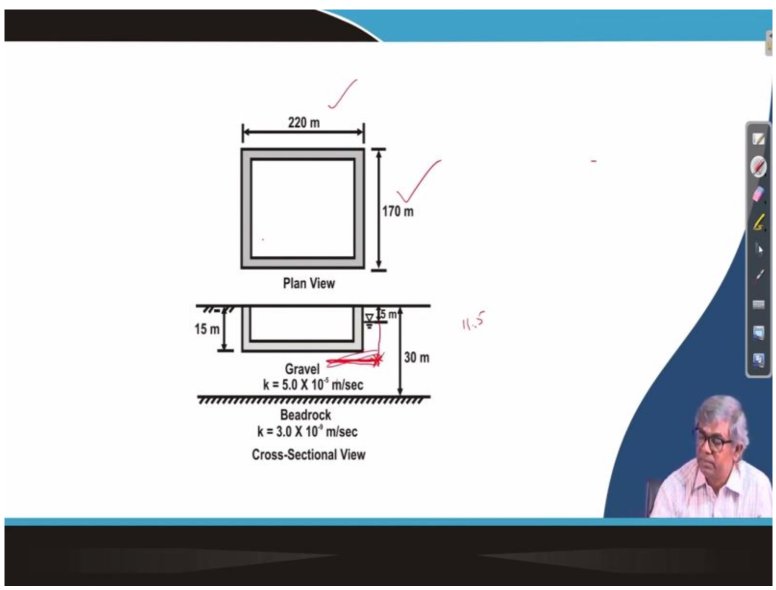

Suppose let me take. So, from here actually when there is a rectangular area, rectangular area of suppose this 170 by 220 then we can imagine this as an equivalent circular area, if I imagine that, then I can find out that equal and radius are not will be equal to under root L multiplied by B divided by pi. That means, it will be under root 220 multiplied by 170 divided by pi so this will be equal to 109meter.

That means, I can imagine instead of a rectangular area, I can imagine a circular area with radius 109 meter and this is the area you have to lower groundwater table by 11.5 meters. This is the problem modified now. Here actually interest radius there was a formula influence radius, influence radius which is R_i is given equal to C dash, hw naught minus hw1 under root k. Then you can see here C dash is 3000 which is given there for well it is 3000 and your k equal to 5 multiplied by 10 to the minus 5 meter per second it is given and hw naught, hw1 which will be equal to 30 minus 15 minus 1.5 so it will be 13.5 h_w.

That means, from the base we are how much lowering I have set, but now, we are trying to find out that is this is the one water table was somewhere here and it has to be lowered here. So, this one this is actually h_{w1} 13.5 and is hw naught which is original water tables somewhere here. So, these two these is hw naught which is nothing but 25 because 30 minus 5. It will be if I know all those things if I put those values then your R_i will be equal to 3000 multiplied by 25 minus 13.5 multiplied by under root 0.0005 and this will give you equal to 244 meters.

So, 109meter actually the radius of these from the center, 244 that means, more than the double distance from the center it will have the affect so like that all around water will be leveled will be unaffected this area will be lowered, but if I but if I go out a distance 244 that distance exactly at that distance, we will not see any effect in the water table, water table will remain at the same place.

This has gone then total discharge required total discharge required, total discharge required this one actually we have formula Q equal to pi multiplied by k and this is an unconfined and this is h_w naught square minus hw1square divided by Ln R_i minus r naught. Actually, this formula originally derived with respect to r_1 r_2, h_1 h_2 and then if I consider r2 as the R_i and r_1 as R_w and R_w well actually you can do and h1 equal to hw1 and h2 equal to original H, h_w, h_w0.

If I know that hw naught so, because of that if I use that that way actually the equation can be modified and you can put those values like that when this is equal to pi multiplied by 5multiple by 10 to the power minus 5 and then at this height actually 25 square this one hw naught and hw1 actually 13.5 this one Ln divided by Ln 244 is R_i by R_w is 100millimeter. That will be your, Now, this is r naught that is r naught that means area of influence how much area you have to do. So, this is one point. It will be 109 this problem we are doing.

So, so, I am assuming these as well and that we everywhere water table should be because we are cutting so, that is like it well only circular well, that was at that level actually water table is how much and at a distance Ri what is the water table and correspondingly their height 25 and 13.5

and permeability and other things have given. If I put this, this gives you the calculated value equal to equal to 0.0, 0.0864meter cube per second.

This is the total quantity of flow required. Now, yes, and now, in a if I use a 200millimeter dia well, so that means, I will do not know I will be using in 200millimeter diameter wells. So, in that well, again if I apply same equation that a distance Ri and at a radial distance equal to the radial distance of the radius of the well, that formula if I use that means Q_1 or q_{w1}, Q_w, this is Q_w suppose and Q_{w1} discharge in a particular well will be again similar pi multiplied by 5 multiplied by 10 to the power minus 5 25square minus 13.5 square divided by Ln R_i will be the R_i.

This will be 244 divided by that now, individual well become the observation well so that become 100 200millimeter, it will be 100millimeter, 100 millimeter if you are expressed in meter, it will be 0.1. So, these one if I calculate then it will give you a value equal to 0.0 0.089meter cube per second. So, that means when a particular well in a single well this was quantity of water can be taken and but total required is this much 0.0089, 0.0089. you, number of wells required number of wells required, number of wells required will be equal to n will be equal 0.0864 divided by 0.0089 so this gives you something 9 point some 6 or so or 9.7 and which will be equal to 10. So, 10 well finally, one can design.

$$r_0 = \sqrt{\frac{L \times B}{\pi}} = \sqrt{\frac{220 \times 170}{\pi}} = 109m$$

$$Inference\ radius\ R_i = c'\left(h_{w0} - h_{w1}\right)\sqrt{k}$$

$$c' = 3000 \text{ k} = 5 \times 10^{-5} m/s$$

$$h_{w1} = 30 - 15 - 1.5 = 13.5$$

$$h_{w0} = 25$$

$$R_i = 3000\left(25 - 13.5\right)\sqrt{0.00005} = 244m$$

$$Total \text{ discharge required } Q_w = \frac{\pi k\left({h_{wo}}^2 - {h_{w1}}^2\right)}{\ln\left(\frac{R_i}{r_0}\right)} = \frac{\pi \times 5 \times 10^{-5}\left(25^2 - 13.5^2\right)}{\ln\left(\frac{244}{109}\right)} = 0.0864m^3/s$$

$$Q_{w1} = \frac{\pi \times 5 \times 10^{-5}\left(25^2 - 13.5^2\right)}{\ln\left(\frac{244}{0.1}\right)} = 0.0089m^3/s$$

$$Number\ of\ wells\ required = \frac{0.864}{0.0089} = 9.7 \cong 10$$

Finally, though for the calculation purpose I assume the equivalent circular area, but if I now, go back to the actual plot and 10 well to be used, for corner there can be 4 then the midpoint can be there. So, 3368 and there can be two or in between somewhere two more wells can be used here to find out the total 10 numbers of wells in this way. And then if I pump then the lowering of groundwater to that whatever desired depth is possible.

This is the calculation and similar to these some more problem could have been taken that is actually using multiples, whether the circular arrange or in between arbitrary arrangement. So, that maybe I will try to show in some along with some other lecture, but in this topic, there are two points actually I want to discuss in addition to these, they are actually let me go to that page first.

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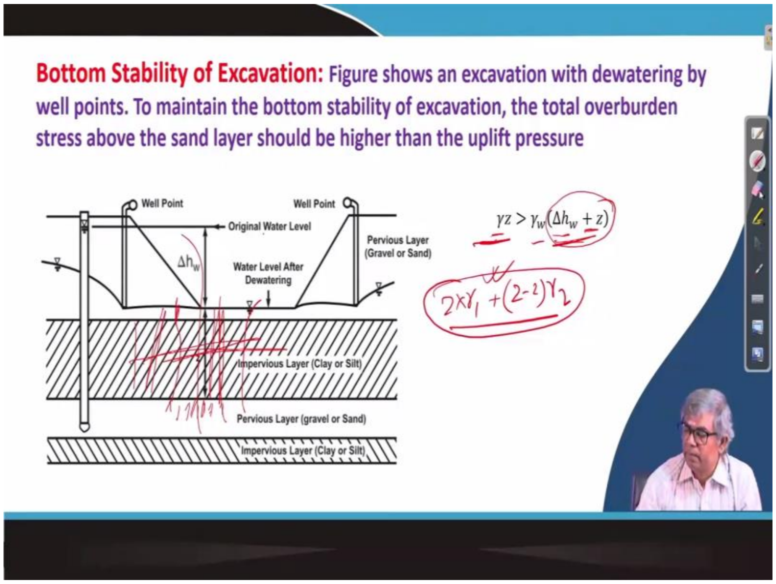

This is the one actually that when you excavate sometime if there is a hydrostatic pressure will be there an uplift blood pressure is becoming too much then sometimes there can be a bursting of bottom and then entire thing full of water will can be filled up. you can see that when you are processing suppose this is about this is a pervious layer and this is the impervious layer and this impervious layer actually helps to prevent water movement from here in this layer actually if you punch and see an observation well, you may see the water is coming here that means actual pressure is this much as at this point.

$$\gamma z > \gamma_w \left(\Delta h_w + z\right)$$
$$z \times r_1 + \left(z - 2\right) r_2$$

Now, at this point at this point, actually, there are pressure uplift pressure equal to the water head multiplied by this height that much water pressure is there and if that must pressure is there if there is no sufficient pressure here, then it can bust. That is why when you are calculating or you are doing this excavation from this side, always you have to see that the total weight after removal, what is the remaining weight and then what is the pressure is creating at that point and what is the uplift pressure from here because of the water.

These two that are uplift pressures should be smaller than the pressure coming from this top then only equilibrium will be maintained a bottom will not bust an excavation can be done safely.

This one suppose this is the situation on a particular case actually, this is a situation and then how to handle this one you can see here you can see here, the water table, you will punch here above this point actually would swing the water level here that means, this is the total this z.

This is actually your del hw plus z these two together is the total water head that means total water head this is acting here. That would total hydrostatic pressure uplift pressure is del hw plus h z these two together actually is the total head multiplied by gamma w that is the hydrostatic pressure giving uplift pressure here and what is the pressure coming from the downward from the top actually at this point to keep the in equilibrium. Only this much this was soil.

So, this much soil actually what is the pressure it can create it can create only z multiplied by gamma you can of course, here actually I have shown z multiply by gamma assuming both the soil is having same unit weight if you have supposed, it is a 2meter depth, this soil will be different unit weight may be different. This soil again maybe another z minus 2meter. So, it may have different unit weight in that case, this could have been 2 minus gamma 1 2 multiple gamma plus suppose z minus 2 multiply gamma 2.

This gamma z can be substituted by this is if I know individual thickness and unit weight then I could have written this way also. So, these must be greater than this then only equilibrium will be maintained. So, otherwise during excavation and sometime it will crack will form, crack will form and then water will be coming out to the entire layer entire layer will bust. This is the one this is the stability against bottom excavation.

Factor of safety when it will work 1.2, 1.25 at least has to be maintained otherwise it will be risky. Now, next slide let me take

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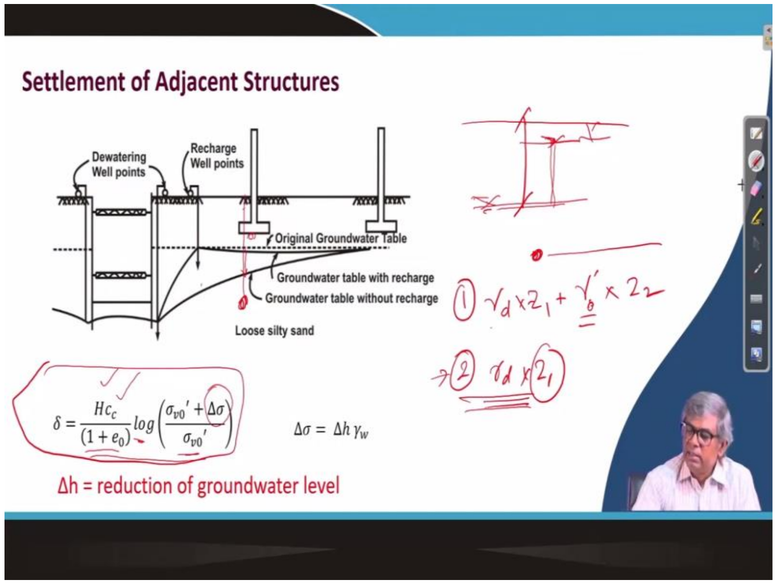

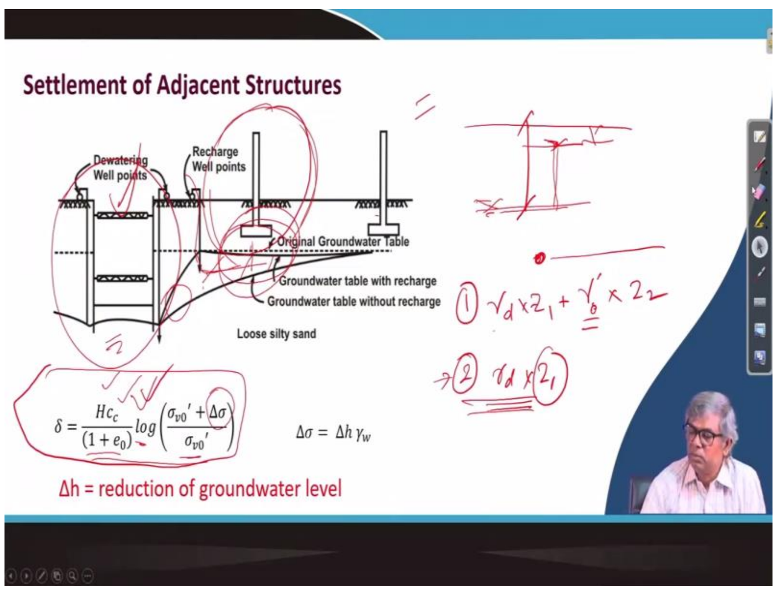

Then another thing is sometime that I have also mentioned before that recharge well point our topic main topic here actually in this module is the dewatering that means, by pumping water you had to lower the water table from a particular level to particular level for the ease of construction. So, here suppose we this is the construction point and you have to lower the water table because of that suppose you have done well point some arrangement you have done and based on that water table.

$$\delta = \frac{HC_c}{(1+e_0)}\log\left(\frac{\sigma_{v0}' + \Delta\sigma}{\sigma_{v0}'}\right)$$

$$\Delta\sigma = \Delta h\gamma_w$$

$$\Delta h = reduction\ of\ \ groundwater\ \ level$$

$$\gamma_d \times Z_1 + \gamma_0' \times Z_2$$

$$\gamma_d \times Z_1$$

So, this is that this one is applied here and then water table is came down here and when water table came down here then automatically the here all-around whatever water table was here, they also came down it will be coming down like. So, this water table also will have it this is a, this is the curve and this one will be actual. Now, what will happen you can see if there is a building here like this foundation, then water table from here now water table gone down here for these actually might have not gone.

When this foundation water table is lowered then the water table is lower than automatically effective stress will be increasing and because of this increase of effective stress what will happen actually you have the, the that consolidation equation, this is the consolidation equation you can see that the, the effect of this is del sigma will be increasing. Particular site at a particular site, if suppose this is the one and water table is somewhere here and if water table lowered here.

At this point water table is here at this point if I want to find out the effective stress, then what will happen what I will do effective stress actually will be at this point for case one will be this is, this way can gamma d multiplied by suppose z_1 plus gamma minus gamma submerged minus gamma submerged multiplied by your gamma submerged multiplied by suppose, here actually z2 but when water table is here you can see that gamma d multiplied by z_1, this z_1 is increasing and this gamma d also compared to gamma submerged is more as a result.

This second case actually where water table when here and here because of this change of this water table, if I consider a point below that second case actually will have more effective stress and if this effective stress is more that will cause actually consolidation settlement how it will cause consolidation settlement we know that the formula actually H multiplied by C_c divided by 1 plus e naught by considering the compression index C_c formula log sigma v naught plus del sigma by sigma v naught, sigma v naught is what that meant at that point condition when water table is like this under this condition what is the sigma naught here at this point.

And because of this lowering what is the change of stress suppose del sigma, because of that, it will give you some amount of settlement. Generally, design is design is done based on certain amount of settlement and then if during service that is satisfied with that requirement and if suppose during service period.

If I modify the situation, then automatically it is also performance also get modified and how what way it is modified actually, you can see that it is a settlement of this foundation is increasing and that settlement actually if it is more than that, particularly if these buildings are these are the two foundation and over that there is a building and this foundation is a settling and this found that this, this foundation is settling more and this is not the differential settlement and that also will cause a lot many other problems.

Because of these problems actually, what do you have to do some time there is a one type of problem, but because of this lowering the particular founder area water table is lowered by this much then what would be the expected settlement because of these lowering activities dewatering activity, then I can use this formula and find out this is one type of problem for exam can be practiced. So, I may take some problem later on.

But actually, this is not only the solving problem, here actually you have to solve the problem in the practice. What is the problem the practice now, settlement up on foot foundation is increased, but that should not be allowed? How to solve that though by pumping here get lowered here water table and is satisfied for this zone, but this is regarding unsatisfactory then we can install another recharge well and water can be pumped here.

That this area again water table remain unchanged, that means it goes to the original groundwater table, without making much change in this area. That is the way actually some time problem will be solved. Two things actually, to be learned from here that when you do the dewatering activities, then the surrounding foundation or soil or buildings, what is the effect?

Effect is generally because of this lowering of the water table effective stress is increased and because of this increase of effective stress that because of this increase of effective stress generally the foundation is expected to settle particularly if it is a reformed fine grain soil is there by consolidation process. And this is actually one outcome we can find out if we know this outcome and if we estimate the value, if it comes within some limits small limit, then we can ignore, but when you I find that it is a significant amount of 30millimeter, 40millimeter, 50millimeter, which is not allowed in that case, you have to arrange one in addition to dewatering you to arrange recharge well somewhere to recharge and maintain the water table locally.

This is a problem relevant problem in dewatering and how to solve, with this perhaps, I will be closing dewatering, but I could have taken one or two problems, like one problem from multi wells and one problem from this, but somehow, I am not no time today. I will be taking somewhere in the next module, while solving the problem, I may take that part also together and that it will be complete.

Of course, whatever information I have given to you now, if I give a problem, you will be able to solve but to show once again I may take some problems.

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With this dewatering aspect of Ground Improvement, the purpose of Ground Improvement dewatering already I have mentioned that whenever we want to do some construction activities, if you inquired our water table, then it will be difficult to do the construction activity. Temporarily or permanently sometimes we generally temporarily, we lowered the water table to for ease of construction and that lowering actually there are different methods, different procedures, some of the methods, we have discussed, some of the relevant topics also have discussed.

And finally, I have shown the how to find out that well, how many wells to be required. Of course, you have to choose here actually in the problem it is mentioned 200diameter well. But instead of saying that, then if you have to really you have to design, then you could have pick up some other diameter and we could have checked if you are taking very small diameter becoming very large number, then you can increase the diameter to bring it to reasonable number.

Like that the design process will be there. So that I hope it is clear enough with this. And I will close here and maybe I will be in the subsequent lecture. I may start with some other topic like maybe Grouting or something else. With this I will stop here. Thank you.