Ground Improvement

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Lecture No. 10

Application Problem on Excavation and Replacement

Hello, once again I welcome you to this course ground improvement. The first module was about interaction and second module was shallow densification and first module itself I have mentioned that, overestimation and replacement is one of the method, ground improvement methods and this the simplest method and there is an advantage and disadvantage both for that method.

Generally, it is easiest and it will be good for smaller work, for bigger work and defer work it will not be good and I have also in the during introduction since I will not be able to take cannot devote much time on it. So, I have just mentioned that when you do our exploration and replacement what do you do generally, what are the checks what are the analysis we do some of the points I have mentioned.

And simultaneously, I have mentioned that how much suppose you want to find out a lot you want to construct a foundation on a comparatively weak soil then what we will do excavate the soil and then replace that one by a good soil. Then what should be the dimension of that excavation and what should be the type of soil, what is the category type of soil, what should be the value when different parameters of the soil that of course has to be determined.

And then when you do that or if you have chosen a particular dimension of excavation and a particular depth of excavation and then field with a particular type of soil and below that actually there is a weak soil. And then if I construct a foundation over that, then different ways actually foundation called fail and based on that you have to satisfy that no case actually no way actually the foundation should fail. So, that we have to make sure that every way it is giving you a satisfactory result.

So, that is only I have mentioned, but I thought what type of calculation will do particularly for this type of problem. And for that purpose, I have taken one problem and that problem giving you of course, in this problem which can be very lengthy that means, there are different aspects only one aspect I have taken bearing capacity aspect and also there are 4 different modes have different bearing capacity failure, only I have taken fast mode.

Remaining, if you are interested then you can go through some books, but otherwise, I will just do the first part. So, let me see the problem.

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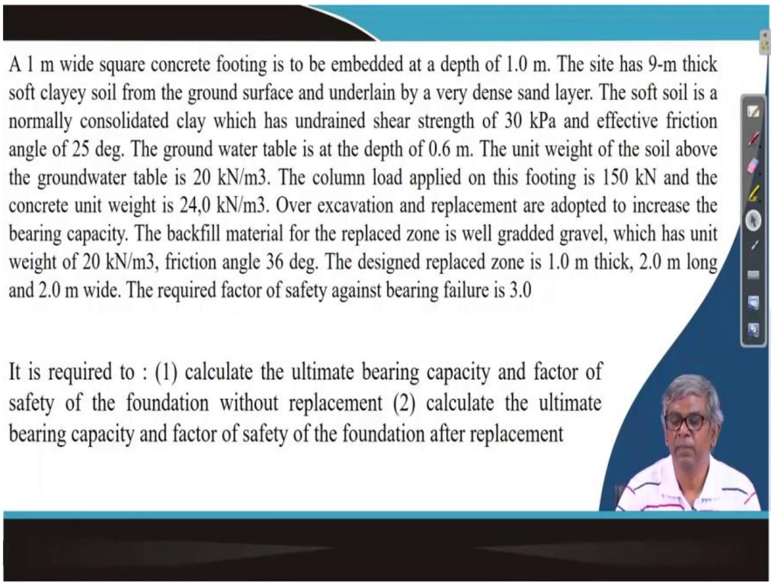

The problem is easy to hear actually here, the 1m wide square concrete footing is to be embedded at a depth of 1m. That means the footing size is 1×1meter and depth of footing also 1m, the site has 9m thick soft clayey soil from the ground surface and under land by a very dense sand layer. That means topsoil 9m is clayey soil and then below that there is a good sand dense sand soil layer.

The soft soil is a normally consolidated clay, which has undrained shear strength of 30kPa that means C_u is 30 and effective friction angle is 25°. So, this is the characteristics of the soil given for the original ground soil. The groundwater table is at the depth of 0.6meters. So, 1m is your depth of the foundation, but the water table is that we have footing level the unit of the soil above the groundwater table is 20 kN/m^3. The column load applied on this footing is 150 kN.

And the concrete unit weight 24 kN/m^3 and under it is seen that or it is some exercise was done and found that under this loading footing will not be suitable on that ground and because of that, over excavation and replacement are adopted to increase the very capacity.

So, over excavation replacement that when that particular soil has to be admitted generally if you want to construct a foundation generally, we do excavation up to foundation depth, but here we are saying over excavation that means, we are excavating some more depth and fill it up to the foundation base.

So, that the below the foundation will have a good soil. So, that is why it is called war escalation. Over excavation and replacement is adopted to increase the bearing capacity not only bearing capacity reduced settlement many other things that there will not discuss that only we are in capacity aspect are discussing this.

The backfill material for replaced soil is well graded gravel. That means, after excavation soil will be that one will be filled with a soil which is gravel, which has unit weight also 20 kN/m^3, friction angle 36° that designed replaced zone is 1 meter thick and 2 meter long and 2 meter wide that when sidewise 2 meters 1 meter is fully footing size.

The filling, side of the field actually is considered double that double of that size. So, 2meter by 2meter. So, that means, we are considering 1meter thick and 2meter by 2meter size replace soil and, on that footing, will be placed and we have to make sure that this arrangement will be good for supporting that 150kN load. So, this is the description of the problem and the required factor of safety as bearing capacity of failure these three are given.

Now, it is required to calculate the ultimate bearing capacity and factor of safety or the foundation without replacement. That means, we have recommended over excavation replacement. So, we have to first check that really, if you do not do this is not the solution because backdrops empty you have to see if you see the factor of safety becoming more than three that will require excavation and replacement is not required. So, because of that first exercise you have to do that, without over excavation and replacement, what is the factor of safety that we see?

And that you may find that it will be less and then second part will be that after taking dimension of replacement that went 2×2×1 meter, gravel soil and then on that, if I put this footing, and then what is the bearing capacity and you got to make sure that we are given is more than a factor of safety is more than 3, then all of these arrangements will be acceptable otherwise, you have to modify the dimensions or thickness or other things or type of soil, then only the design will be acceptable. With this, I will try to take a solution step by step. Let me go to the next slide.

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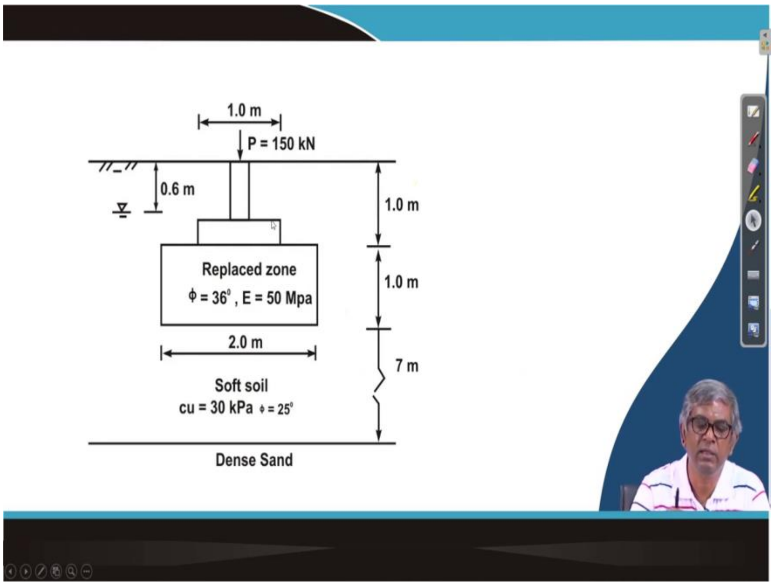

The actual arrangement you can show here whatever is explained through the through your description, you can see here that your water table is 0.6 meter is mentioned putting depth as 1 meter and this is a replace zone and actually 1 meter is the depth of footing and then from 1 meter, actually 1 meter will be the replace soil and then beyond that seven meter still there will be poor soil and beyond that then with the dense soil.

So, this is actually whatever problem we have described in the previous page, this is the schematically the same problem is given. So, with respect to these now, we have to see 2 things one is actually factor of safety before or a special replacement and factor of safety after replacement. So, these 2 things we have to do.

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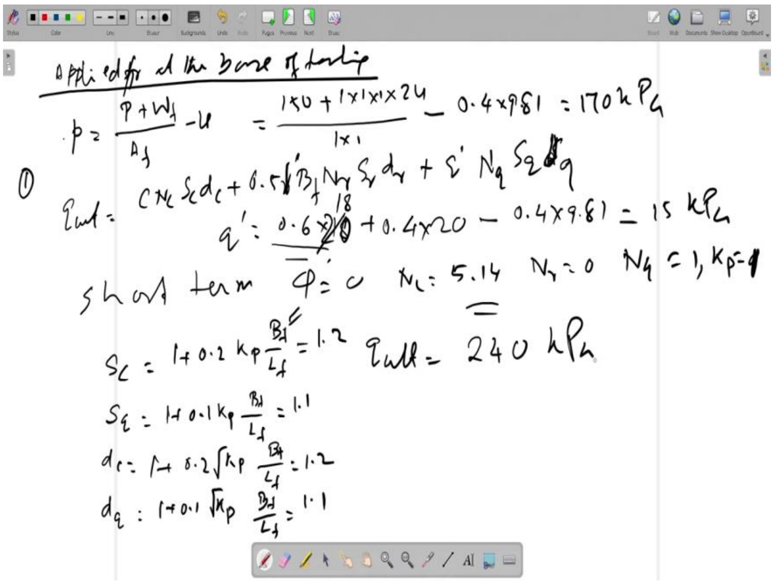

So, let me take a page, new page and you can see the applied pressure at the base of the footing. So, applied pressure at the base of the footing that will be equal to if I say p then it will be equal to p multiple plus w divided by divided by area minus u and you can see p is a what is 150 kilo newton and w is the weight of the foundation w f. So, that will be 1 meter by 1 meter and by 1 and multiplied by 24 and these divided by again putting size is 1 meter by 1 meter and you become actually 0.4, 0.4 meter actually underwater.

So, they are actually putting bass what is the pore pressure is going to give so, 9.81. So, if I do this calculation, you will get a pressure actually 170 kPa. So, this is the pressure we are getting. So, we have to do now first part and while doing the first part, so, I have to do q ultimate equation you know the generalized equation actually C Nc then Sc dc plus 0.5 gamma dash Bf n gamma and then S gamma d gamma plus your q dash Nq Sq dq, Sq dq.

So, this is the formula and you know and here actually q dash that means, short charge at the foundation level how much it is? It will be 0.6 multiplied by 18 plus 0.4 multiplied by 20. So, above water to these also can be taken 20 let us take 20 and I said this is actually generally our water table it will be less so, it will be so let us take 18 and 0.14 into 20.

So, this is becoming while you are taking total weight, but because of the water weight actually 0.4 multiplied by 9.81 this will be subtracted, then it becomes effective pressure at this level. So, this he will do he will find out 15 kPa. Now, this bearing capacity failure can be done for 2 different ways short term and long term.

If I do short term then your phi dash to be taken 0 and if you take phi dash 0, then Nc become 5.14 and N gamma become 0 and Nq become 1 and then corresponding I can find out this thing I think I have shown in the theory part that Sc will be equal to 1 plus 0.2 Kp and then Bf by Lf, Bf by Lf. Bf is width of the footing and length of the footing. So, if I put these and here also Kp also 1, so under phi equal to 0, Kp also 1 so, if you do these then it is coming Sc coming 1.2 and then a Sq coming Sq is 1 plus 0.1 Kp multiplied by Bf by Lf and if I put all values then it is coming 1.1.

Similarly, dc equal to 1 plus 0.2 under root Kp and Bf by Lf and if I put all values then it is coming 1.2. Similarly dq it is, it is the equation is 1 plus 1 plus 0.1 root Kp and Bf by Lf and if you put all values which is known, then it is coming 1.1 and now if I use this in this equation q ultimate. If I substitute Nc values and all q dash and everything, then I will be getting a q ultimate value equal to 240. And then I will be doing long term so let me better take a new page.

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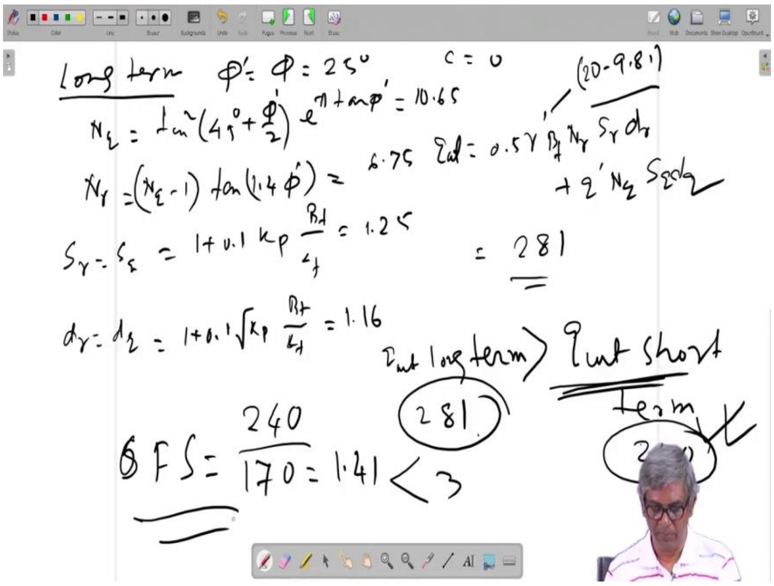

And now I will do long term, long term then phi dash will be equal to phi given that is 25 degrees and for that you can say your Nq become 10 square 45 degrees plus phi by 2 e to the power phi then phi dash. So, so, if I put those values phi dash actually is equal to 25, then I will get here at 10.65 and N gamma will be, N gamma will be Nq minus 1 multiplied by 10 1.45 phi dash.

So, if I do this becomes 6.75 and of course, when phi equal to c equal to 0, no c for this. So, Nq and N gamma is required and under these your S gamma equal to Sq will be equal to 1 plus 0.1 Kp Bf by Lf and if you put all those values then it gives you 1.25 and if I then similarly, d gamma equal to d q that will be good equal to 1 plus 0.1 0.1 under root Kp and then Lf, Bf by Lf by Bf or Bf by Lf, I think. So, if I do all calculation, you will get a value 1.16.

So, now, your equation we are in q ultimate q ultimately will be equal to 0.5 gamma dash Bf in gamma and S gamma d gamma plus q dash Nq Sq dq. So all, everything is known. So, if I now substitute here so here this gamma dash will be nothing but 20 minus 9.81 and rest of the things I have shown here. If you substitute, then you will get a value equal to 281. So, then you are getting 281 and there it was 240, so, q ultimate long term is better than to ultimate short term.

So, q ultimate long term is greater than q ultimate short term that means, the short term actually will be governing things. So, that you have to consider that one. So, 240 which we have got here you got 240 and here you are getting 281. So, that means the real factor of safety under bearing capacity failure will be factor of safety that means factor of safety will be equal to you are getting 240, we are getting we are because either of out of these two the smaller one to be considered because we long term.

So, if I use this 1, it will fail by this short 240 feet again and you know the base of the footing pressure is 170 it is giving you a value equal to 1.41, but your requirement is 3. So, that means, if I use the foundation on the original ground, then your factor safety is insufficient. As a result, that over excavation and replacement is essential. So, now we will try to see the calculation that how over excavation replacement giving you a better result that we will try to see.

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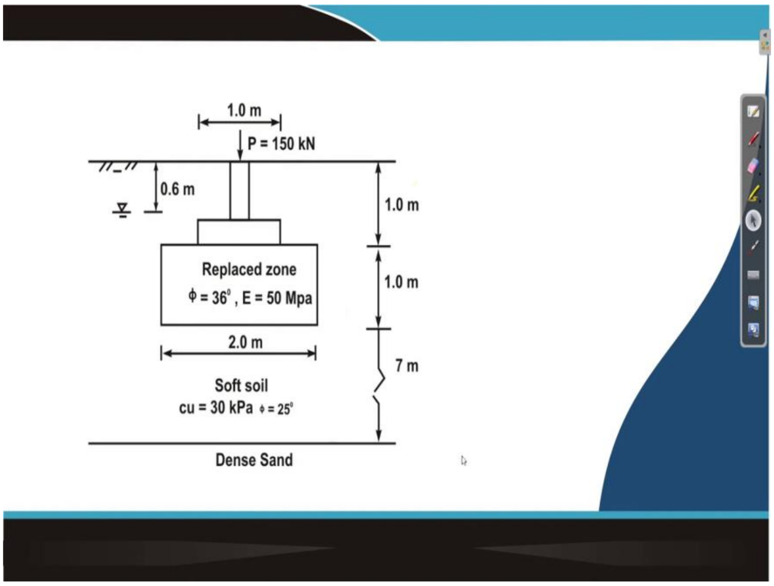

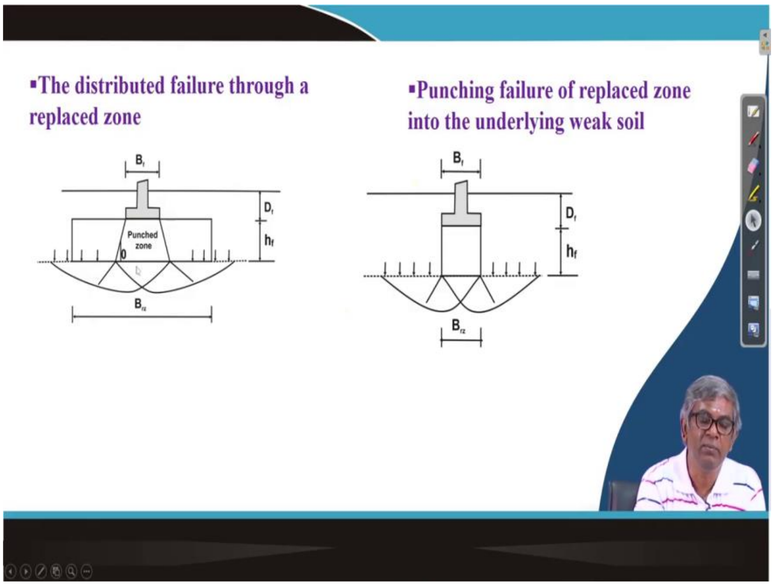

And here actually, you can see that before going to that, I will just show you that that I have power I have shown you a different types of folly failure actually, this is general shear failure routine replace zone. This is the one, this is the replace zone and we assume that it will fail within this zone and this is the punching shear pillar within the replace that means inter soil with along with the putting like one thing and you will punch and foundation will be task bar at this zone. That is another type of failure.

And then this is the distributed file that means, when you use a better soil, the footing will be transferred the soil in the wider area and these become finally like a footing and failure really very variability failure will take place here or punching failure of the replace zone into the underlying soil.

So, that means, this entire soil and footing will punch here that is also a possibility, there are 4 different types of possibilities are there, but out of these 4, I will be considering only first that means bearing coverage in general getting coverage the failure within the replace zone. So, if I do that the how will be the calculation. So, that is not sufficient obviously, when you want to do actual design, you have to check for all but I am checking only showing only one.

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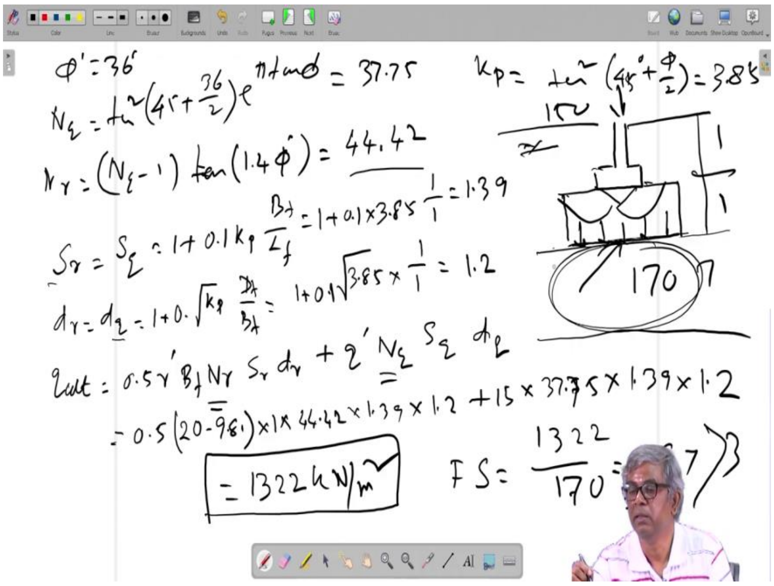

So, let me create a new page. So, here actually phi dash is 36 degrees now. So, Nq dash will be, Nq will be tan square 45 plus 36 by 2 e to the power pi tan phi dash that were which is nothing but 36 degree. So, if I put all those things, you will get a value equal to 37.75 and then N gamma will we call to Nq minus 1 so it will be, Nq minus 1 multiplied by tan 1.4 phi dash. So, if I do this one we are getting a value equal to 44.42 and your k_P, k_P under this equal to tan square 45 degrees plus phi by 2 and that gives you a value equal to 3.85. So, you have got Nq N gamma and we have got Kp now here to calculate different safe factors.

So, S gamma equal to Sq which will be equal to 1 plus 0.1 Kp Bf by Lf. So, that means if I put the values 1 plus 0.1 multiplied by 3.85 and Bf by Lf so, that is 1 1. So, if I do this I will be getting a value equal to 1.39 and then d gamma equal to d q that will be equal to 1 plus 0.1 under root Kp and B f by Lf actually this is Df by Bf. So, that means it will be 1 plus 0.1 and then under root 3.85, 3.85 multiplied by again 1 by 1. So, this gives you a value equal to 1.2.

So, now, q ultimate will be equal to your q ultimate will be equal to 0.5 and gamma dash then Bf then N gamma then S gamma, d gamma plus q dash Nq then Sq dq. So, here actually 0.5 and gamma dash is nothing but 20 minus 9.81 and Bf is nothing but 1 and N gamma is already obtained here 44.42 and S gamma d gamma multiplied by S gamma, S gamma is 1.39 multiplied by d gamma is 1.2 plus, now q dash is 15 and N q is how much N q is p 37.75 multiplied by I can say Sq dq.

So, Sq is 1.39 and your dq is here a dq is 1.2. So, this one, I can calculate and see how much it comes it is 0.5 or no before I will do 20 minus 9.81. This gives you these multiplied by 0.5 multiplied by 44.42 multiplied by 1.39 multiplied by 1.2. So, this gives you this much plus 15 multiplied by 37.75 multiplied by 1.39 multiplied by 1.2. So, this gives you a value equal to 13.1322 kilo newton per meter square, this much Kp.

So, you can see now, the after doing the replacement that means, what our footing is somewhere here and I have given a replace zone equal to this match and then remaining soil will be as it is then the sand layer is here and water table is somewhere here and ground level is somewhere here. So, this is one we did and this is this is 1 meter and this is also 1 meter 1 1 and this is 7.

So, under these we have done that when bearing capacity failure takes place when it happens like this. So, we are assuming that the failure is within this zone and based on that we are given the failure the of bearing up theories applied and based on that we could get the ultimate bearing capacity is this and we have applied when the, 150 kN load is applied to this footing and what is the pressure here we have got at this pressure is applied 1.70.

So, now, you can see, so, with respect to that you can calculate factor of safety equal to 1322 divided by 170. So, that gives you a factor 50 equal to 7.87 or something like that, 1322 divided by 1322 divided by 170 that gives you 7.76 or something. So, anyway whatever 7 point more than 7 actually good. So, it is greater than 3 that is important.

So, that means, this is the arrangement is acceptable with respect to a bearing capacity failure, but there are other problems like because of this load, this is a comprehensible layer. So, this comprehensible layer also can have a certain amount of settlement etcetera and that settlement again to be checked, then only to settle for settlement aspect we have not consider of course, here all the bearing capacity aspect only I have considered here.

So, that is the thing I have told again and again. Even during the discussion in the in the theory part that I have already discussed up to this and I have told that quickly I will show what are the calculation we will do to make sure that after putting the replace soil you are going you are achieving the desired factor of safety.

So, so, this is an out of four arrangement out of four arrangement actually, that first arrangement only I have considered and I have shown you that that factor of safety is much bigger than 3 that means what about arrangement I have suggested or the problem it is suggested that is satisfactory with respect to your bearing capacity failure.

So, this is one sort of application I have tried to show how what excavation and replacement work in a particular area. So, suppose in a in a building project, there are 10 or 12 foundation is there, even it is a soft soil, I can make a bigger excavation and then I can put certain depth by a good soil and then I if I construct the building it will be sometime satisfactory, but if it is a very large area and very deep soil at a great depth soil is very soft or unsuitable for construction.

In that case, you have to use different ground improvement technique, which we will cover in the subsequent modules which I will discuss later on that do this they are dynamic densification we have done shallow densification only just before but now onwards again we will do different methods where actually deep densification can be achieved. So, those things will be coming in the subsequent lecture with this I will just close here. Thank you.