Foundation Engineering
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Lecture – 37
Pile Foundation – XI

So last class I have discussed about the calculation of load carrying capacity of pile by using a dynamic equation. Now discuss I will explain in the fourth methods by which we can determine the load carrying capacity of the pile and that is based on the penetration or the data penetration means SPT or the CPT data.

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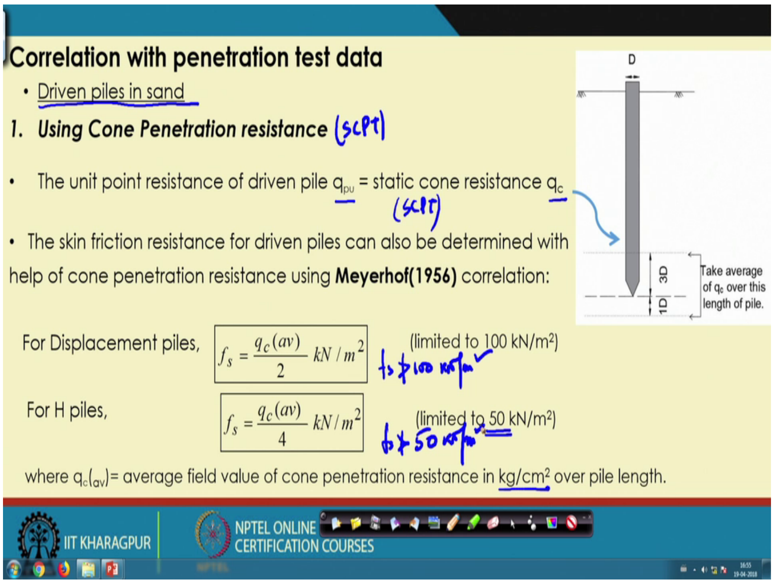

So, the first one that the correlation with the penetration test data and we have discussed the standard cone penetration test and then the static Standard Penetration Test; SPT or the static cone penetration test or the dynamic cone penetration test.

So, as I mentioned in the in the cone penetration test static cone penetration test we can separately determine the tip resistance and the friction resistance. So, in case of pile this SCPT data is very useful to determine the load carrying capacity of the pile. So, first I will discuss about the SCPT data and then we will discuss about the Standard Penetration Test data or SPT data.

The first and all these expressions are again valid for the driven piles in sand. And as I mentioned this is the in situ test are always useful for the granular soil. So, this is also useful for the driven piles in sand. So, this is driven piles in sand. So first the using the cone penetration resistance or the SCPT; so, the this static cone. So, for the pile tip resistance I can determine q pu that is equal to the SCPT resistance; that means, the cone resistance, SCPT this is sc pt this cone resistance qc and; that is equal to the tip resistance of the pile for driven piling sand and sc which qc we will consider? If you look at this figure the qc the average qc below the 1 D and above the 3 D from the pile base, this total 4 D zones SPT average SPT we will consider as these qc ok

So, and this D is the diameter of the pile so; that means, the average cone resistance value a below the 1 D a soil from the base of the pile and above 3 D soil from the base of the pile this total 4 D soil average SPT average cone resistance will be equal to the tip resistance of the pile ok. So, this is for the tip resistance q pu; now for the skin friction also we can use by using the cone penetration resistance data and by using the Meyerhof correlation

So, for the displacement piles displacement piles are nothing by the driven pile because displacement piles when you apply the pile is driven then the soil is displaced. So, this is the displacement piles of the driven piles there the qc average by q will give me the friction resistance fs. And it is limited to a 100 kilo Newton per miter square remember that because this value cannot be greater than 100 kilo Newton per meter square. If it is greater than 100 kilo Newton per meter square you have to take 100 kilo Newton per meter square. And qc average means the average s cone resistance along the length of the pile will be consider here as the qc average.

And another thing you note know if you note here that the fs unit is kilo Newton per meter square. But qc average unit is kg per centimeter square because this way these are the empirical expressions we have to use the proper unit. So, remember that qc average is kg per centimeter square, but fs unit is kilo Newton per meter square. For h pile or h section pile this expression is qc average divided by 4 and it is limited to 50 kilo Newton per meter square.

So; that means, here your qs cannot be greater than 100 kilo Newton per meter square and this case qs cannot be greater than 50 kilo Newton per meter square ok; this is method number 1. So, that is we can get and then the next method is the IS method ok.

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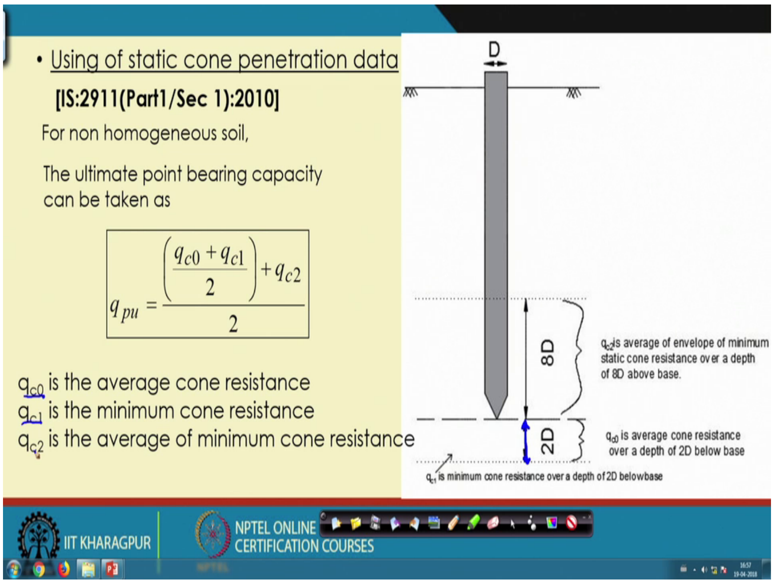

So, our IS code also recommended that how to calculate the tip resistance and frictional resistance based on the SCPT data ok. So, this is the IS code equation q pu which is the average of qc 0 plus qc 1 plus qc 2 divided by 2 these expression we have to use.

Now, let me explain one by one all these 3 cone resistance; what are the meaning of all these 3 cone resistance ok. So, now, qc 0 is the average cone resistance below the twice D soil from the tip of the pile or the base of the pile; that means, we have to consider the a soil below the twice D of the from the pile base and average of the qc value within this twice D zone is qc 0.

So, average cone resistance below the base of the pile is treated as qc 0. Then qc 1 is the minimum cone resistance of this zone; twice the zone below the base of the pile because your qc may not be uniform within this zone. So, we have to take the minimum value of qc within this zone which will be treated as qc 1 for the minimum cone resistance of this zone. And what is qc 2? qc 2 the average of minimum that is a confusing word, but or confusing a sentence this is the average of minimum cone resistance, but let me explain what is that ok.

So, we will take the 8 D zone above the base of the foundation; pile foundation and then that zones minimum average of minimum cone resistance, we have to consider as qc 2 ok. So, these are the 3 meaning; so, I I will solve one problem then I will discuss that what are the mean actual meaning of these 3 three things ok.

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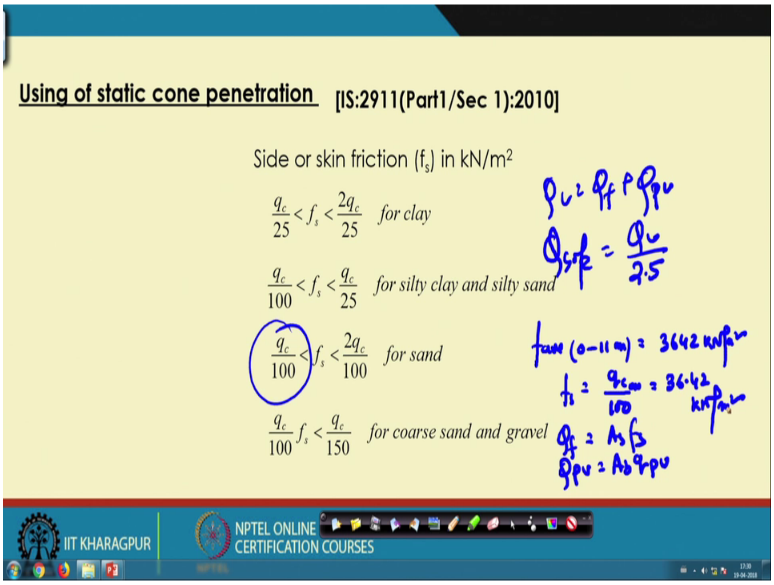

So, first and then this is the that was the tip resistance or q pu and the friction resistance IS code recommended that from this different soil; you your friction resistance should be for from this zone to the this the limit to that limit; that means, if it is k clay then qc average this qc average is the average penetration along the your length of the pile.

So, if you have the qc value then this will be qc divided by 25, this will be qc within 2 qc divided by 12.5. So, this range this is for the silty clay to silty and silty sand, this is for the sand and this is for the coarse sand to gravel ok. So, this is these qc is the along the length of the pile; this will give you the range of the frictional resistance ok.

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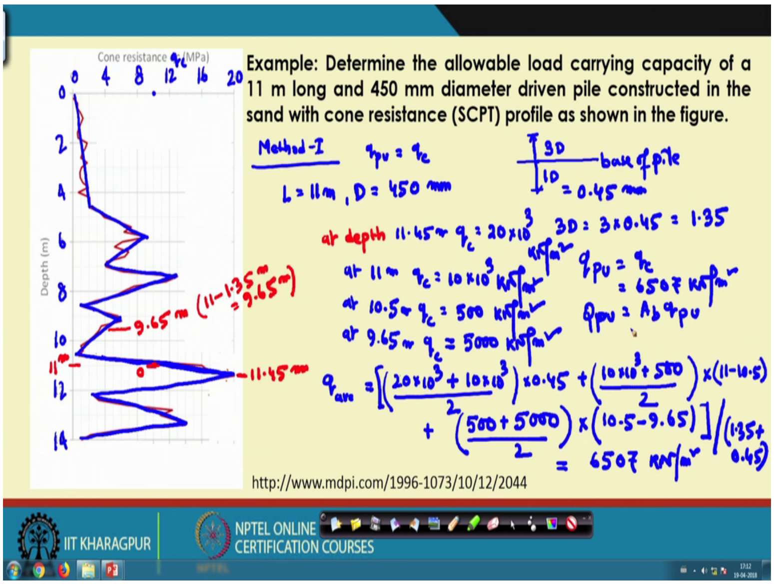

So, let us solve one problem by using 2 methods that I have discussed; one is first one then the next one is the IS code recommendation. So, first one this is the one this is one field data of your qc value along with the depth x axis is cone resistance qc it is in Mega Pascal ok. So, this is 0 this one is 4, this one is 8, 12, 16, 20 ok; this is in Mega Pascal and this is 0, this is 2, 4, 6, 8, 10, 12 and 14 ok; so, this is the total cone resistance.

So, this is the variation; so what I am doing? I am getting I am plotting them in a straight line where the variation is very less ok. And if the variation is more then I will take the separate straight line part. So, that is why from this zone to this zone this variation is not that much. So, what I am doing? I am taking them as a straight line ok. Then from this zone to this zone again there is a small variation; so, I am taking like this; then from this zone to this zone this is the variation. So, I am taking if you want to calculate it more accurately you can take more variation ok.

But I think that is fine as per as per my understanding for this problem. So, then this one I am taking like this and then like this again; this one like this and then this is and then the bigger one and then this one ; this one and finally, this one. So, this is the variation of the qc; this is your qc along the along the depth, depth is in meter and remember that qc is MPa. Now the example is determine the allowable load carrying capacity of a 12 meter long pile with a 450 millimeter diameter; it is a driven pile constructed in the sand this is a sandy soil with cone resistance profile as shown in the figure.

So, this is the cone resistance profile. So, that I have taken as a straight line wise now I will take the all the values based on the recommendation ok. So, now the first case that I will discuss is that. So, yeah; so, for the method I; that I have discuss method I your equation was that q pu is equal to qc, but qc is 1 D from the base and that is 3 D from the base above the base 1 D below the base of pile and 3 D above the base of pile that is the average ok.

So, pile length is 12 11 meter and diameter is 450 millimeter so; that means, the 1 D means 1 D means it is 0.45 millimeter below the base of the pile and 3 D means 3 D 0.45 is that this is 1.35; 35 from the above the base of the pile. So, 11 meter is this is the 11 meter; so, where this is the your 10; so, this is the 11 meter now it is cutting. So, this is the point; so where the pile base is here because this is the pile base 11 meter this is 11 meter this is 11 meter; so, this is the pile base.

So, the qc from up to the 0.45 meter; 0.45 meter is here this is 11.45 meter ok; this is 11.45 meter. And 1.35 meter means 9.65; this is 9 this is 9.65 is somewhere here ok. This is 9.65 meter because 3 D means 1.35 above the pile base; so, 1 D means it the soil 11 plus 1 D; that means, 0.45; 11.45 meter and then the 11 minus 1.35; so that is 9.6. So, 9.65 we are getting 11 minus 1.35 meter. So, that is actually 9.65 meter because that that is the 3 D.

. So, this 9.65 meter to 11.45 meter zone that qc this zones qc average will be the q pu ok. So, now, let me let me write this way that if this is the 0 the tip and if this is the q b 11.45. So, at your depth I am writing in depth. So, at depth 11.45 meter your qc value is 20 into 10 to the power 3 kilo Newton per meter square ok. So, you can see qc value is 20 because 20 is this point 20 is the qc value and it is 10 to the power 3 because qc is Mega Pascal.

So, I am writing them in kilo Pascal that is kilo Newton per meter square. So, at 11 11 meter the qc value is 10 into 10 to the power 3 kilo Newton per meter square. So, this is at 10 at 10 meter this is the 11 meter your qc value is 10 Mega Pascal; so; that means, 10 into 10 to the power 3 kilo Newton per meter square. So, from here to here there is a variation then from here to here that is a another variation. So, this value is at 10.5 this is at 10.5.

So, at 10.5 meter qc value is 500 kilo Newton per meter square; that means, this is this is your 0.5 mega Newton at this point. So, you can remove this point; so, this is 0.5 Mega Newton. So, this is 500 kilo Newton meter square and so, this is the from here to here one zone then from here to here another zone and from here to here at 9.65 meter; qc value is equal to coming out to be your 5000 kilo Newton per meter square or 5 mega Newton per meter square this is the 5; so, this corresponding to 5.

So, this way you will get the qc value now you take the weighted average. So, the weighted average of qc or qc average is equal to; so, what I am taking? First I am taking this zone this is below the a base. So, average value is your sorry 10 into 10 to the power. So, average value I am taking the here it is 20; so, 20 into 10 to the power 3 plus here it is 10; 10 into 10 to the power 3 divided by 2 is the average and that length is 0.45; so, it is 0.45 ok.

Then from here then this length is here it is 20 into 10 to the power 3, here it is 10 into 10 to the power 3 I am taking the average of this zone below the base of the footing and that thickness of that zone is 0.45. So, I multiply it by 0.45 then from here to here that average is you can see from 11 to 10.5; the it is 10 into 10 to the power 3 plus 500, take the average then multiply that thickness that thickness is 11 minus 10.5 and then the next one.

So, I have gone from here to here; here to here and then this one then the last one average is 500 plus 5000 divided by 2 into the lay that thickness is 10.5 minus 9.65 ok. And then that total one we have to divide by the total length total length is 4 D and this is 1.35; 1.35 plus 0.45 ok. So, that is the total length total length is 1.35 plus 0.45. So, we will get the final value of qc average or this is weighted average is 6507 kilo Newton per meter square ok.

So, this is the qc average of that zone using the first method. So, if I use this first method; so, this will be the qc average that I am getting ok. So, now, I can write that my p or q pu is equal to qc and I have taken the average. So, that will be equal to also 6507 kilo Newton per meter square ok. And then if I multiply it with the um area; then I will get that qu q pu is equal to ab into q pu ok; so, finally, if I multiply it this value.

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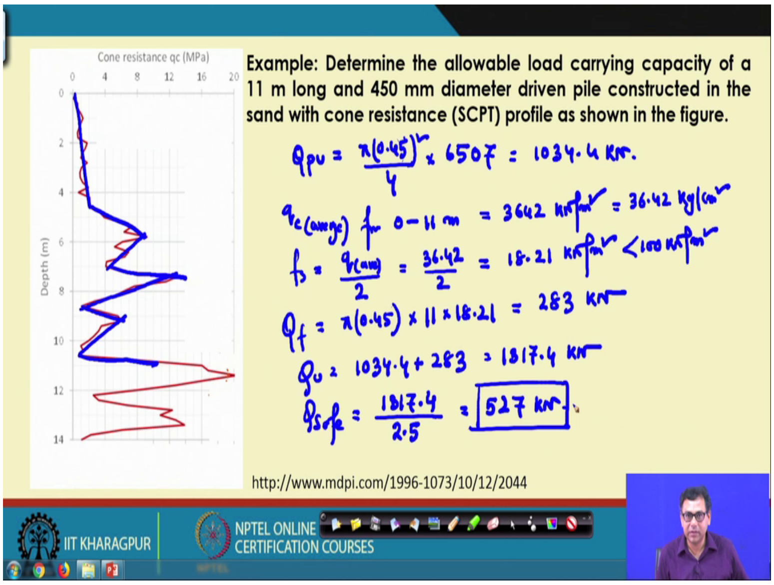

So, I will get that q pu is equal to pi d square pi d square by 4 into 6507; so, that is equal to 1034.4 kilo Newton ok.

So, this is the q pu or the tip resistance I am getting. Now similarly you can if you have again you draw the same straight line; now from 0 to 11 meter you take the weighted average. So, I have taken these zone weighted average for qp and if you take the weighted average for entire length of the pile that will give you the frictional resistance. So, that weighted average of q c average from 0 to 11 meter; so, you take from 0 to 11 meter is here.

So, from here you take this value. So, from here you take the weighted average the same way that I have done if there is a change in the direction of the or the change in the slope of this straight line because then you take this is the one line from 0 to this one zone, then this is another zone this is one this is one this is one and then up to this 11. So, you take this is average into the thickness this qc average into the thickness, this qc average into the thickness then this one qc average into the thickness of this zone like this you take the average.

So, I am not doing this average you can calculate this for your problem take the average. So, average value if I do it is coming out to be 3642 kilo Newton per meter square. So, now, I will use that fs is equal to q average divided by 2 for driven pile and remember that these q average is kg per centimeter square; if you now convert it divided by a 100, it will be 36.42 kg per centimeter square.

So, now if I put this value 36.42 divided by 2. So, this will give you 18.21 kilo Newton per meter square that I mentioned that your qc average is kg per centimeter square, but fs is kilo Newton per meter square and that is less than 100 kilo Newton per meter square because that is the limits ok; so, we can use this value. So, my Q f is coming out to be pi d 0.45 into 11 is the length of the pile into 18.21 ok; so, that is equal to 283 kilo Newton.

So, now qu is equal to 1034.4 plus 283; so, that is equal to 1317.4 kilo Newton. So, q safe is equal to 1317.4 divided by 2.5; so, this is 527 kilo Newton. So, this is the total load carrying capacity of the of the pile and the qu is a safe load carrying capacity is 527 kilo Newton ok; so, this is the first method ok.

Now, let me explain the next method that is the IS code method ok. So, I will do the same thing, but here the, that is slightly different ok.

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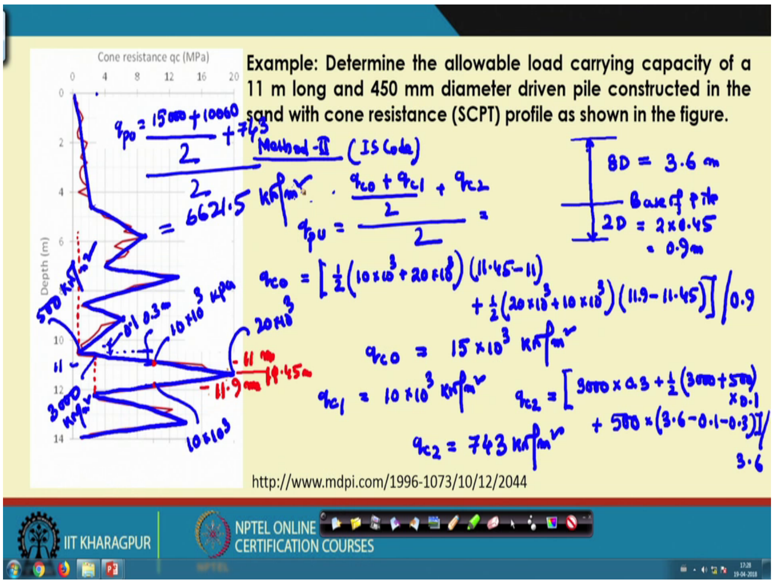

So, I am doing the same one I am just taking this straight line; this is the straight line then again this portion straight line, then this is straight line straight line ok. So, the method II; that is IS code. The expression is that that q pu is equal to q c 0 plus qc 1 divided by 2 plus qc 2 divided by 2.

Now, here as I mentioned that my qc 0 qc 0 is the average of the zone which is that below the 2 D zone. So, 2 D zone means your so; that means, the one this is the base; base of pile. So, these zone above we are taking 8 D and this zone we are taking 2 D for the this IS code method. And 2 D means 2 into 0.45 that is 0.9 meter below the base of the pile and 3.6 meter above the base of the pile 8 D means 3.6 meter here because your D is 0.45 meter.

So, now here 0.9 meter; so, this is the 11 meter. So, 0.9 meter will be somewhere here 11.9 meter. So, this is 0.9 meter is here; so this one is 11 point; 11 0.9 meter and this is the 11 meter. So, this is the here 11 meter; so, you have to take the average value qc 0 means average value of this zone ok. So, you can take the same way average here it is 10000 kilo Newton per meter square, here it is 20000 kilo Newton per meter square, here also it is 10000 kilo Newton per meter square.

So, and this zone is a 4.45 thickness of 11.45 this zone. So, from here to here it is 0.45 is the thickness. So, the average value will be; so, the average value will be I am just doing one that is 10000 into 3 plus 20 into 3 and thickness of this zone is 11.45 minus 11, then plus again from here to here also half into 20 into 10 to the power 3 plus 10 into 10 to the power 3 because here it is 10000 here it is 10 into 10 to the power 3 KPa.

Here also it is 10 into 10 to the power 3; here it is 20 into 10 to the power 3 ok. So, from 10; 20 average the thickness here also the average and thickness will be it is 11.9 minus 11.45. So, and the total one will be divided by 0.9 because that is the 0.9. So, qc 0 is coming out to be here 1500; 15 into 10 to the power 3 kilo Newton per meter square ok. Then qc 1 qc one that I have mentioned it is the minimum value below the base of the pile up to twice D.

So, here you can see twice D means up to 11.9. So, this 11.9 the minimum value of qc is 10000 kilo Newton per meter square for 10 Mega Pascal because that is the minimum value; here all it is 10000; here also it is 10000, in this case in other case its may be different, but in this case this is the 10000. So, qc value will be 10 into 10 to the power 3 kilo Newton per meter square.

Now, the next one which is the average of minimum penetration ok; so, that is very important ok. So, for that purpose let me do something that it is up to 3.6. So, that is up to that distance is 3.6. So, that is 11 minus 3.6; so, up to that you have to consider. So, here minimum means that; so, here first you draw this is the minimum value ok. So, you draw this line and there is a another minimum value here this is the minimum here you draw this line also ok.

So, now here average things will be calculated like this that your qc 2; the average of minimum value. So, here from 11 to this zone this is the average and that average value is 300 or that is 1 2 3 yeah 3 Mega Pascal. So, 3000; so, this is the average value from this point to this point. So, I am taking 3000 into that distance is up to 0.3 ok; you can measure this distance from here to here I have measure that that is 0.3 point 3 is this one ok; this is 0.3 meter fine; this one.

Then from here to here it is increasing. So, you will take the average value of that. So, take the average value that is 3000 plus here the value is 5 or 500. So, we will take this is 500; so, this is 500 and this thickness from here to here is 0.1 meter this is 0.1 meter ok. So, I am multiplying it 0.1 meter then plus now rest of the things this 500 is the lowest value ok; so, I have to take 500 rest of the thickness.

Now, if there is any lowest value within that 500 then you have to again go go like this because as the way I have proceed here. But here the next lowest value is the 500; so, what I will do? 500 and then the 0.3 and 0.1; I have already taken. So, that will be multiply by 3.6 minus 0.1 minus 0.3 ok. So, that will be 3.2 and then the total one I have to multiply divide that is divided by 3.6 ok; so, that is divided by 3.6.

So, qc 2 will be equal to in this case is 743 kilo Newton per meter square. So, now, if I put these values here that my q p 2 will be; so that means, if I put these values here because now this point this value is this is 500 kilo Newton per meter square ok. This value is 3000 kilo Newton per meter square and this is 10000 this one 20 this is the 10000. So, this way you have to do this analysis. So, this is 7.3 kilo Newton per meter square.

So, now if I put these values here my q pu will be equal to 15000 divided by qc 1 is 10000 divided by 2 plus 743; 743 divided by 2 ok. So, that is equal to 6621.5 kilo Newton per meter square ok. So, that is; so you I can write 6621.5 kilo Newton per meter square which is the similar or the similar kind of value that we got on the first method.

Now, once you get q pu then you multiply it with the area base area you will get the force; that is the tip resistance in terms of the force or the load and then you have the average value for these things. So, now, the last thing that I want to explain that now the average a qc you will get like the previous method ok. So, you take the average of the throughout the length of the pile average qc value.

Now, it is sand; so that average qc value was coming out to be that for the first method it was calculated that that your q average for a 0 to 11 meter was 3642; 3642 kilo Newton per meter square now if you are taking this is in sand or. So, you can take this is the range; so, qc your fs you can write that qc divided by 100 average.

So, this will be 36.42 kilo Newton per meter square then you multiply it Qf will be the As fs and Q pu will be Ab by p qpu; then finally, you will get Qu is Qf plus Q pu and then this is Q safe will be Qu divided by 2.5 is the factor of safety. So, this is the IS code method. Because you take the average and then you take this limit I am taking qc divided by 100; it is mentioned only sand.

So, this is the limit I am taking this 100 ok; so, I will get this is the resistance 36.42. So, this is the way by which we can determine the load carrying capacity of the pile based on the sc pt value ok. So, next class I will discuss about the SPT value; how about the load carrying capacity of the pile based on the SPT value and then I will discuss about the group load carrying capacity of pile.

Thank you.