Foundation Engineering
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Lecture - 29
Pile Foundation – III

So, last class I have discuss about various types of piles. Now this class I will discuss how to calculate the load carrying capacity of the piles. So, in this course, I will mainly concentrate on this part. That how to calculate the load carrying capacity of the pile then how will design this piles, ok. So, that is the main objective of this course. So, give you these things in detail, that what are the methodology available to determine the load carrying capacity of the piles, and then how will design a Pile Foundation under compressive load only.

So, that is the main objective is the load carrying capacity, settlement capacity, settlement calculation and the design of the pile; that is, the major part of this thing this major that I will cover in this course for the Pile Foundation, ok.

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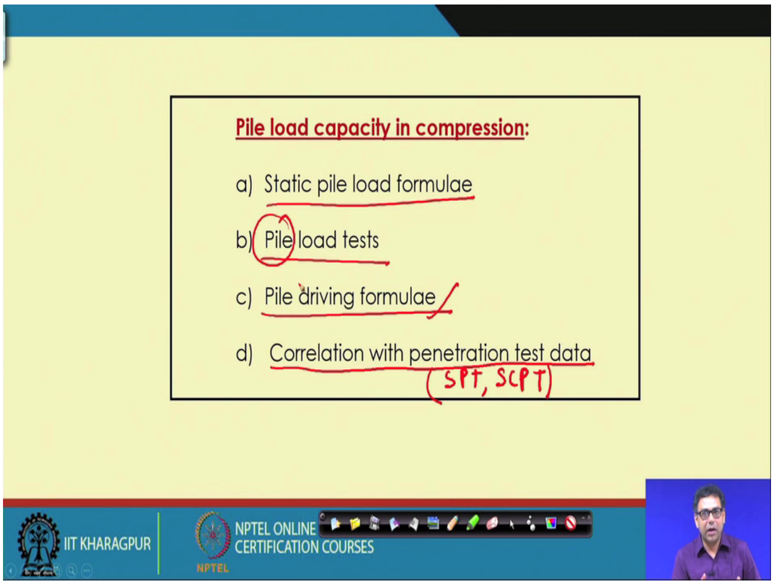

So, the pile load carrying capacity in compression, because why it is compression? Because I will discuss only the pile load capacity in compression as I have discuss that pile can be subjected to tension force, or a plate or pile can be subjected to lateral force.

But I will not discuss those things because that is the part of this course. So, I will discuss only the pile load carrying capacity on the compression, and that is the main objective of this course. So, thus that there are 4 ways we can determine the pile load carrying capacity, one is the static pile load formula, then pile load test data, then pile driven formula, I have the correlation with the penetration data, that mean either SPT or in the pile the SCPT is the main thing, because here I will get friction as well as the cone resistance.

So, either I will get use the SPT data or SCPT data, I will use the pile driven a formulae, if it is driven pile and plate load tests sorry pile load test data also I will use. So, I have discussed about the plate load test during the shallow foundation part. So, similar to that plate load test we can conduct the pile load test also to get the load carrying capacity of the pile or the static pile load formulae.

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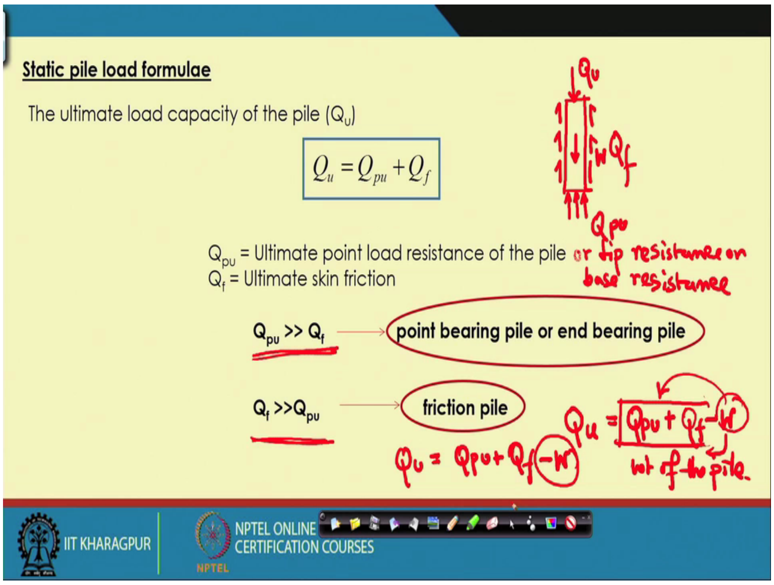

So, first I will use that static pile load formulae so, that ultimate load carrying capacity of the pile can be defined as Q is the ultimate load carrying capacity Qpu plus Q f. Where Qpu is the ultimate point load resistance or sometimes it is called tip resistance or it is called base resistance. So, that means, as I mentioned that when you are applying a load on a piles. So, you will get the resistance from this base or the tip, or you will get the resistance from the friction, ok.

So, this is the friction so, this one is the your Q f and this is Qpu, ok. This is from the point bearing pile or end bearing piles, because end bearing piles, this Qpu is much much greater than the Q f and that is called the end bearing pile, I have discuss. Similarly, for the friction pile so, this is Q f is much much higher than the Qpu.

And another thing I want to say that so, when you suppose this is the load Q u is acting so, the weight of pile is also will act in the downward direction, ok. So, that weight of pile will has to be resists by this 2 forces. So, ultimate load then you have to set than the load carrying capacity that when you design the pile. So, you when you design ultimate load carrying capacity of the pile. So, that should be the tip resistance friction plus the weight of the pile.

Because the this pile this has to carry it is own weight, ok. So, that is the weight of the pile, w is the weight of the pile. But here that weight of the pile during the calculation, I will concentrate only this 2 part, now in the design, now to add the weight of the pile, remember that if the pile weight is very significant compared to the your this Q u Qpu plus Q f. If this weight is very significant compared to this total capacity, then you have to add this weight also, that you have to taken as a pile load carrying capacity, ok.

So, that is why sorry you have to subtract this things, because that will be your pile load carrying capacity. Because the this resistance also be taken by the weight, so that means, the Q u will be Qpu plus Q f minus weight, ok. So, there is a correction so, that will be the minus not plus. So, this will be the minus, ok. So, then you have to apply the factor of safety all those things you remember that, but these things in this all the problems in this course that I will solve, I will not consider the weight of the pile, but remember that if these weight of pile is significant compared to the summation of this part then you have to subtract this things, ok.

Because your ultimate load carrying capacity should be the resistance that you are getting from this 2 force, and then minus w because it has to be has to be has to resists the weight of the pile itself. so that you keep in mind, ok.

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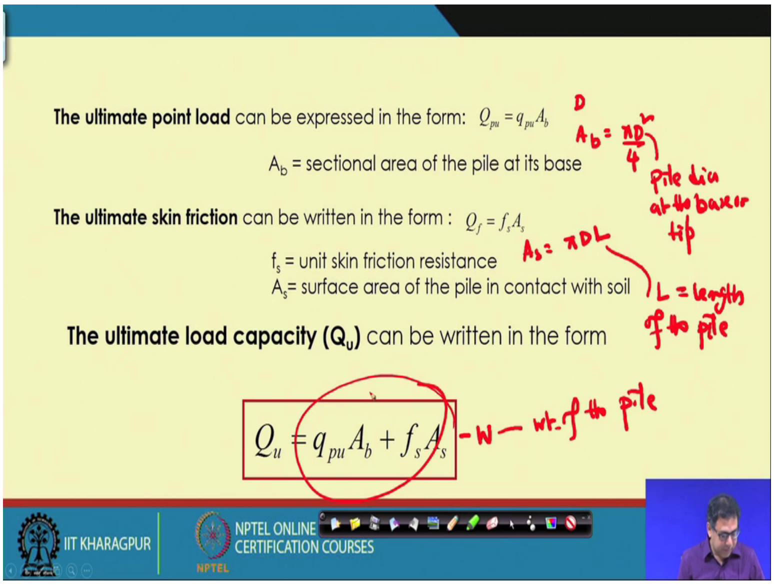

So, the ultimate load resistance is I will calculate in this way that Qpu small qpu, p u into Ab, A b is the base area of the pile and friction; that means, the friction resistance and the total area of the outer surface of the pile. And that is the so, that is mean here if the diameter of the pile is D, then the Ab will be pi D square by 4 ; where D is the pile diameter at the base or tip, ok. And here As will be pi D L, ok, where L is the length of the pi, ok.

So, and then I will calculate the total load, and as I mentioned that if the weight is not small then you have to minus the weight of the pile. So, this is the weight of the pile, but in my all the examples I will not consider this weight of the pile, but you keep in mind when you design this pile, but here the ultimate load carrying capacity means, I will discuss about this part only.

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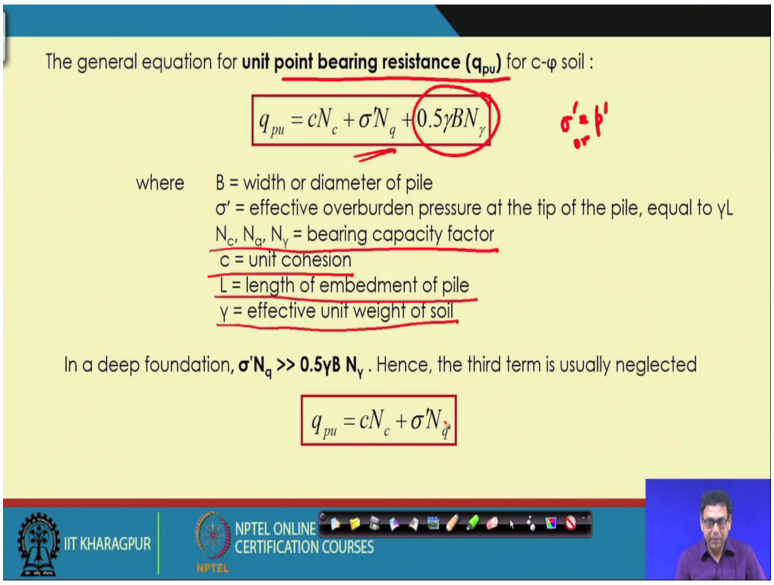

So now how I will calculate the point unit point bearing resistance? Ok, so, how I will calculate that?

So, a this is the general expression of bearing capacity cNc plus sigma prime, that is sigma prime is equal to the p prime which is the same or p prime both are same. So, these the width of all here the diameter of the pile, if this is this is rectangular or the square pile then width, or the diameter of the pile. Then sigma bar is the effective overburden pressure as the pile tip pile base. And these are the bearing capacity factor.

And c is the unit cohesion L is the length of the pile, gamma is the unit weight of the soil. Now this part is remember that this part is very small compared to the second part. Because the second part your depth is very high. So, that is why the effective overburden pressure will very high compared to the third part.

So, generally this part is neglected, ok. So, if you a neglect the third part, then we have the expression cNc sigma prime Nq, ok.

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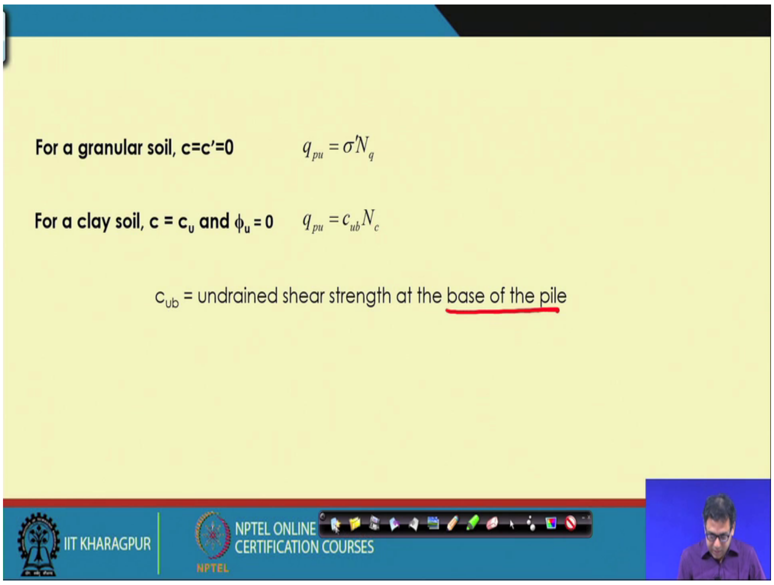

Now, for granular soil if c is equal to 0, then qpu will be sigma n Nq sigma prime Nq, and for the clay soil this qpu will be c u at the base and Nc. So, it is at the base, remember that. So, this will be the at the base of the pile, and then the Nc.

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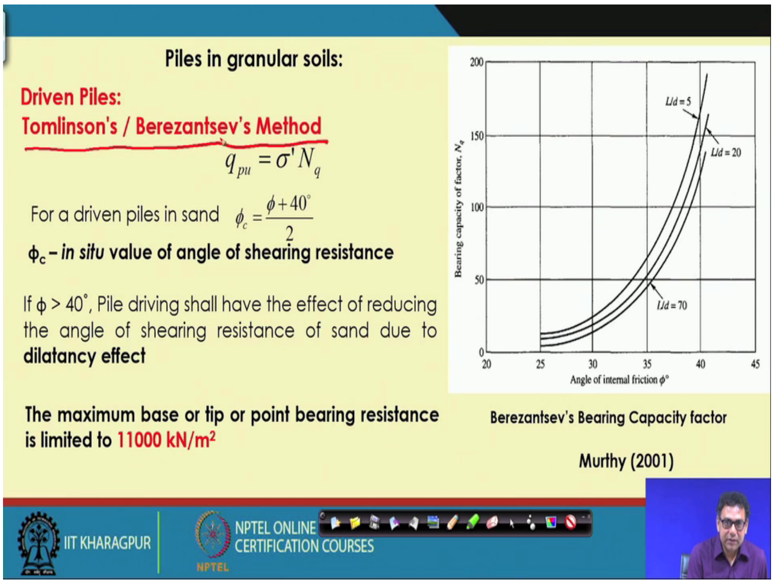

Now, so now, first I will calculate the for the granular piles, how I will calculate the sigma prime Nq? Because for the granular pile now we have 2 2 components, the third term we are neglecting.

So, we have cNc plus sigma prime Nq. Now if it is granular soil c value is 0. So, it will be only Q prime sigma prime or Q prime p prime into Nq. So now, this value I will calculate that.

Now I am doing for the driven piles. So, all the methods there I am talking about is applicable for the driven piles. The first method that I will discuss is called the Tomlinson's in few cases will find this Tomlinson method, or in some books you will find it is this because this graph the Nq value that you are taking which is is proposed by the Berezantsevs safe, ok.

So, this is Berezantsev safe so, that is the first proposed by this a bearing capacity factor that that I will use for this method. So, that is why it is called the Tomlinson's method or it is called the Berezantsevs safe method, ok. So, that is why I am using this expression which is the common expression, but if the pile has a soil has a friction angle greater than 40 degree, then instead of using phi you have to using the phi c.

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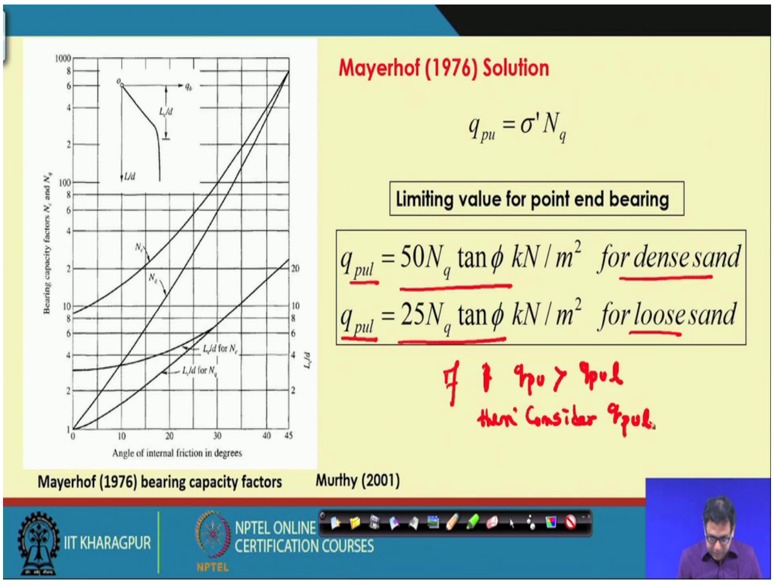

Now, this is the first method that I have discuss in the next method Mayerhof solution, where also Mayerhof also suggested this Nq value.

So, this is a chart if I know the friction angle I will get the Nq value from this chart. But the Mayerhof limited this is the qpul this is a limited Mayerhof also now put a limitation of this tip resistance value, for the dense sand it is 50 Nq tan phi, for the loose sand is 25

Nq tan phi. So, when you calculate the Nq value and then after calculating the effective overburden pressure will check whether these my p u is greater than this one or not. If my p u qpu is greater than qpul, then we have to consider qpul that will be the tip resistance.

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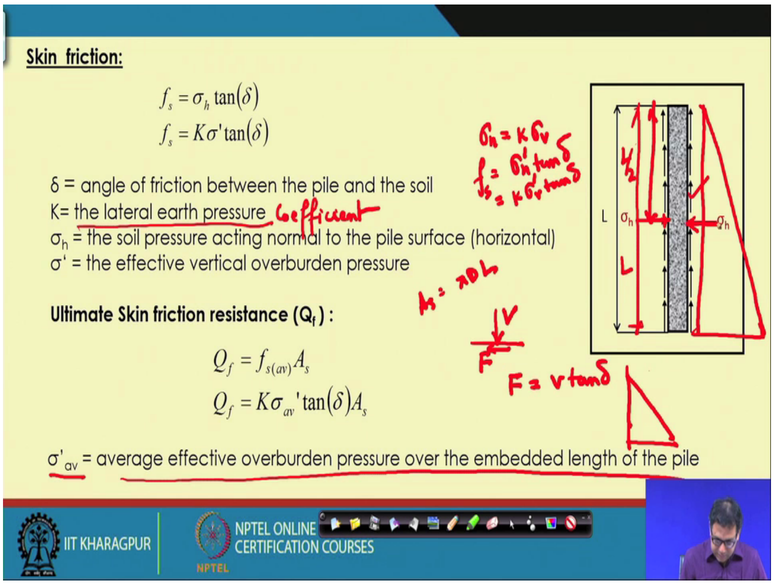

Then the skin fiction so, first part I have discuss about the of the tip resistance make the fiction skin fiction or the friction, and that is also for driven pile,.

So, the skin fiction so, the this is the pile so, the skin fiction means the friction between the pile and the soil. So, if we have a normal stress of any suppose this is the normal stress, and say v and F is the force frictional force. So, my F will be equal to v tan delta or mu into v. Because here mu is the tan delta, delta is a friction angle between soil and the pile. So, here also this your sigma h is acting here. So, sigma h is the horizontal pressure which is equal to K times the vertical stress at that point, and K is the lateral earth pressure coefficients. So, this is the lateral earth pressure coefficient, ok.

So, this K, I will show how will calculate this case. So, that is means sigma h into sigma h is equal to K into sigma v. So, your f will be sigma h into tan delta, ok. This is a the normal force and this is the friction stress.

So, your ultimately f s will be K into sigma v bar into tan delta, this will be also sigma h bar. So, this is the effective overburden stress into the tan delta. And the and then if you multiply it with the area of this pile surface area ; that means, the As is equal to pi D L, then we will get the skin friction resistance, ok.

Now, sigma instead of using sigma dash, will use the sigma dash average, what is sigma dash average then we will take this sigma h at the half of the at the of middle of the pile. So, that means, if this is the length L, then this will be the L by 2, ok. If this is the length this will by the L by 2.

So, we will take this the stress at L by 2 position, and then that is the average effective over burden pressure, because your effective overburden pressure is increasing like this. So, this is the effective overburden pressure that is increasing like this. So, that is why you are taking the average value average at this is L by 2, ok. So, if you take this average this will be at the center.

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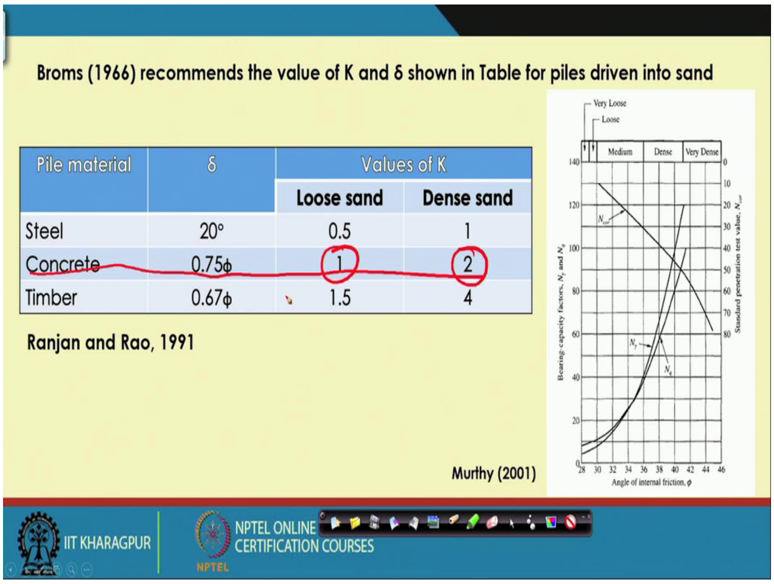

So, then next one is that how I will calculate the delta and the K. So, depending upon the type of the pile pile material, the delta can be 20 degree for the steel pi concrete pile is 75.75 into phi, and timber pile 0.67 into phi. And K value for the loose sand 0.5 dense sand one, and if it is steel and concrete that will use frequently. So, this will be the 1 and 2 1 model loose sand, and dense sand it is 2. And if you have the n value also, or if you if you know the phi value, then you can a from this chart you can judge whether soil is loose dense medium or very dense.

Now, the if your phi value is 40 degree, so, that means, soil is dense if the 5 value is 44 degree, it is very dense. If the soil is your say 30 29 degree, then the soil is loose or in very loose part if it is less than that. So, in that case you will get it take this K value 0.5 for the loose sand, and one for the dense sand.

So, depending upon you can use this chart whether soil is if you know the n value SPT n or if you know phi value, then we can identify the which type of soil it is this is the dense or the loose. So, that is the idea of giving this chart.

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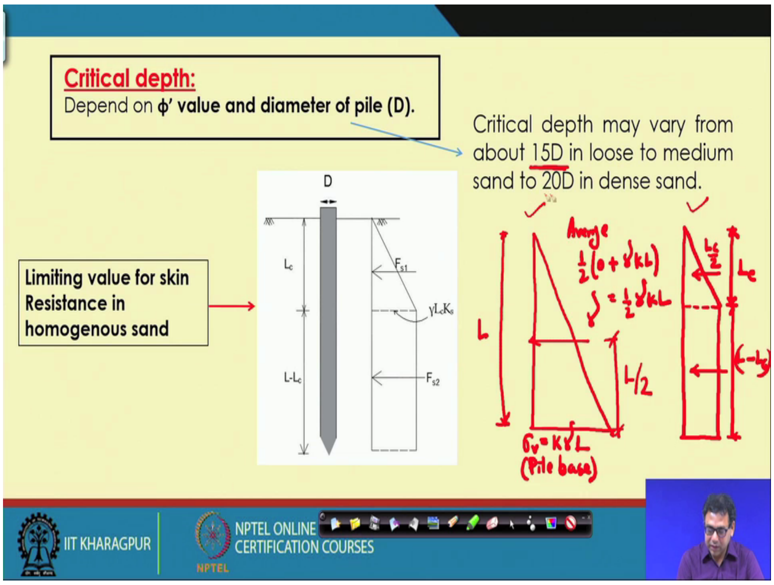

But there is another thing which is very important, that this is a critical depth concept,. So, in the I have mentioned that your that your stress that you are talking about that sigma v nah so; that means, here you are talking about that my this is if this is the length of the pile. And if unit weight is gamma, same then the lateral stress is K into gamma into L. That is the sigma v or sigma v bar at the base or the pile base, ok. So, that is why the average value will be the average value will be half into 0 plus gamma K into L, ok.

So, that will be simple half gamma K L, so that means, the stress which is acting here that will be the L by 2. So, this is the normal way we have discuss about the stress distribution, but the researches researchers have observed that this stress will not distributed linearly up to the up to any depth, ok.

So, because of the soil arching this stress is redistributed. So, what is soil arching in the in the twelfth week I will discuss in detail what is soil arching, because then you will find how the stress is distributed, but now for this part that because of the soil aching this stress is redistributed. And then they are suggested that this is linearly distributed up to a critical depth after that stress does not increases this is uniform,.

So, that length up to which the stress increases or the stress become constant is called the critical depth. So, that means, in that case it will not be at L by 2, we got in that case if I take this part here it will be at L c by 2, ok. We will take this triangular part as L c by 2. So, after that it is uniform so, we take the average will be this one because it is not increasing.

So, it is I mean uniform so, we will take this average will be this one, ok. So, I will I will solve the problem where you will find that is that is means here it will be at the, if this is the L L minus L c, because this is L minus L c. So, this will be at the at the uniform so, the average test is also uniform or this one the same stress.

So, I will solve the problem, then will find that if I consider the uniform or linear variation, and if I consider this type of variation where after the critical depth the stress is constant. But different I mean later on the researchers have observed that there is no I mean guarantee that whether this soil arching will happen, and this type of distribution will occur. So, that is why in few researchers they recommend that we use the full stress, that mean the first distribution during the our fiction resistance calculation.

But few they have suggested that we should use this critical depth constant concept. So, that means, here the critical depth constant concept is also recommended, on the a few researchers are also recommending that you use the full stress.

So, I will solve that is that way that I will consider the critical stress or critical depth critical depth constant concept. And I will use the normal full stress concept also, and then we will see how we can determine the pile load capacity. Now this critical length it is observed that for loose to medium sand, this critical depth is 15 D, and for the dense sand it is 20 D.

So, this is the value which is recommended, and this all the discussion as that I am talking about is for granular soil. So, this friction as the bearing, these are applicable only for the granular soil where c value is 0.

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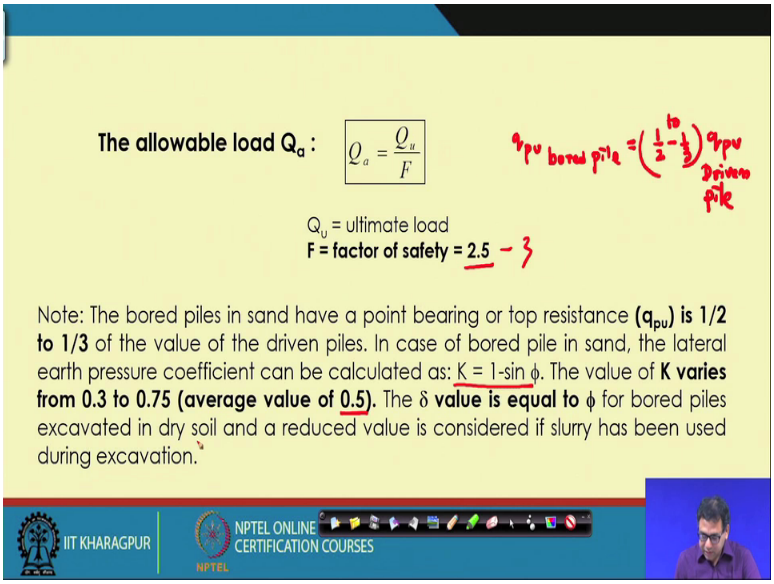

So, then allowable bearing capacity will be the ultimate load carrying capacity of the pile divided a factor of safety factor of safety is recommended as factor of safety is recommended as 2.5. So, you can take factor of safety 2.5 to 3 like the shallow foundation. So, here I will use the 2.5, ok. So, as I mention these things are develop for the bored pile,, sorry driven pile

Now, if the all are thing is that I have discussed is applicable for driven piles and for sandy soil. Now if the pile is the bored piles in sand have a point bearing resistance is half to one third of the value of the driven piles. So, that is mean for the for the bored piles you cannot use this value that you are getting, because that is applicable for the driven pile for the bored piles, you have to reduce it by half to one third. So, that means, the bored piles tip resistance or the base resistance is equal to 1 third or half to one third of the tip resistance or driven piles.

So, that means, the qpu for the bored pile is equal to half 2 1 third or half to one third of qpu of driven pile. So, first you calculate the pile load capacity of the driven piles expression, then you we reduced it by half to one third. And in case of bored pile in sand the lateral earth pressure coefficient can be calculated by using these expressions, and in case of bored piles the K varies from point 3 to 0.75 average value 0.5 you can take. And delta value is equal to 5 for bored pile is excavated in dry soil, and you have to consider reduce value, if the that slurry or is used during the excavation, or the that I am talking about this slurry is used for the during the excavation.

So, later on you will find that people researchers they have recommended, when you are talking about the load carrying capacity based on the penetration value, they recommended you take one third of the that mean the bored pile tip resistance is one third of the driven pile tip resistance. But here in between recommended in between one third to half,.

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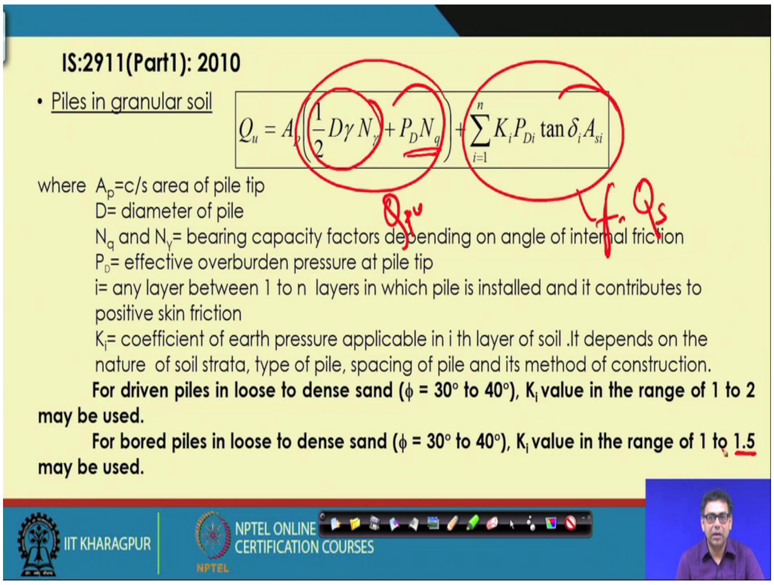

So, and the next one that I am talking about the IS code. So, these 2 methods I have discuss one is that Tomlinson’s solution and the next one is the is the Mayerhof solutions.

So, and then what our IS code is saying. So, IS code remember that, IS code is not neglecting this part, because in other 2 cases we are neglecting this part, because it is not significant as compared to the, to this part, was IS code is also considering this part remember that. And these are the all this is summation mean this is for the layer’s soil, different layer soil; you have to use the different friction resistance. So, this is friction resistance, this is the, if is part or the Q s part and this is the Qpu part, ok.

So, this is the friction part this the Q u part, and for the driven piles loose to dense sand, the K value is ranging for one to 2 as we have used in the similar table. And for the bored piles lose to dense sand these values 1 to 1.5. So, bored pile it is let us so, here we cannot use the one third tip resistance is half to 1.3 half to one third of tip resistance or driven pile no.

Because here we are using different K values for different condition bored pile is and the driven piles. So, that value you have using here. So, you will get the driven piles and bored piles capacitive directly from this equation.

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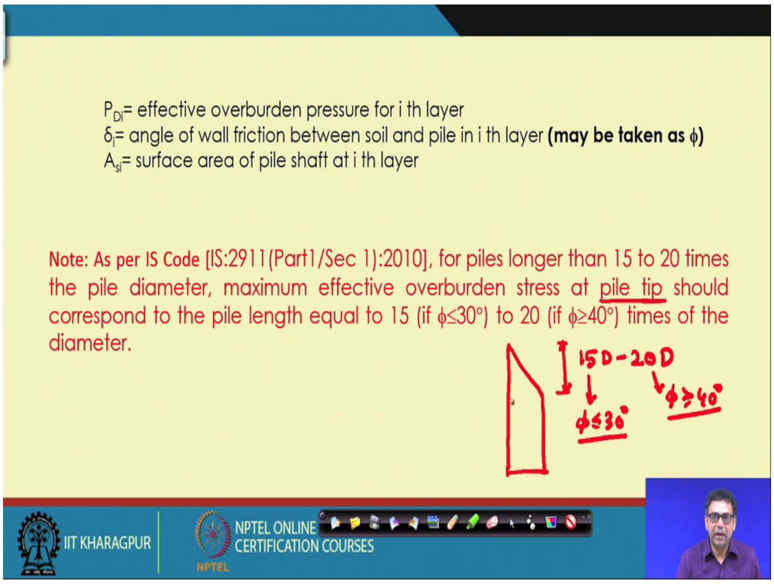

And the, this is the and delta is the fictional angle here it is IS code has recommended, that it can be taken as a equal to phi, ok. And other things are are so, this is that your this is the diameter of the pile this is a bearing capacity factor Nq n gamma.

So, how I will get Nq n gamma will discuss and this is the average pressure this PD Q PD Q is the effective overburden pressure as the PD is the effective overburden pressure that pile tip this is the effective overburden pressure as pile tip, but PD i PD i is the effective overburden pressure as the center of the ith layer, ok.

So, I will I will solve one problem, and then you will find how I will use this theories. And remember that that as per IS code for piles longer than 15 to 20 times of pile diameter, maximum effective overburden stress a pile tip should correspond to the pile length equal 15 to 20 times of diameter.

So, that is mean it is the same as equal I mean critical length concept,. Because IS code also recommending that if if your overburden stress at pile tip is greater than 15 to 20 times of diameter, then you should consider that value.

But it is mentioned for the pile tip, then it is what will happen for the friction part it is not mention, but it is as per my understanding that if the pile tip overburden stress is restricted up to the 15 to 20 diameter of pile, then definitely it should be informed, ok.

So, that is why in the IS code also you will use this type of stress distribution ok. So, this value is 15 D to 20 D depending on the type of the soil, this is to your if the phi value less than equal to 30 degree, and this is valid for phi value greater than equal to 40 degree, ok. Is if it is within that you have to take the value in between that 15 20 degree. So, that means, it is for the dense soil it is for the loose soil. So, loose soil 15 D loose to and this is dense soil it is 20D. So, I will also consider this is the critical depth concept as recommended by the IS code.

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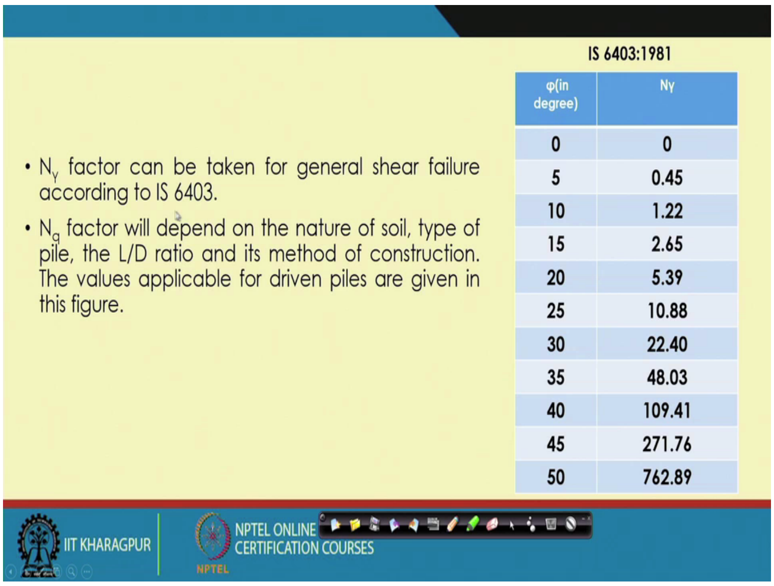

Then the Nq factor it is suggested that the that the same a shallow foundation Nq factor we can use, and that is the IS code 6 4 0 3 so, this is the Nq value, that you have to use for the IS code and this table is given for different phi values,.

Sorry n gamma this is for the n gamma value n gamma value we have to use from this this table. And Nq value that Nq value IS code has recommended chart by which I can take Nq value.

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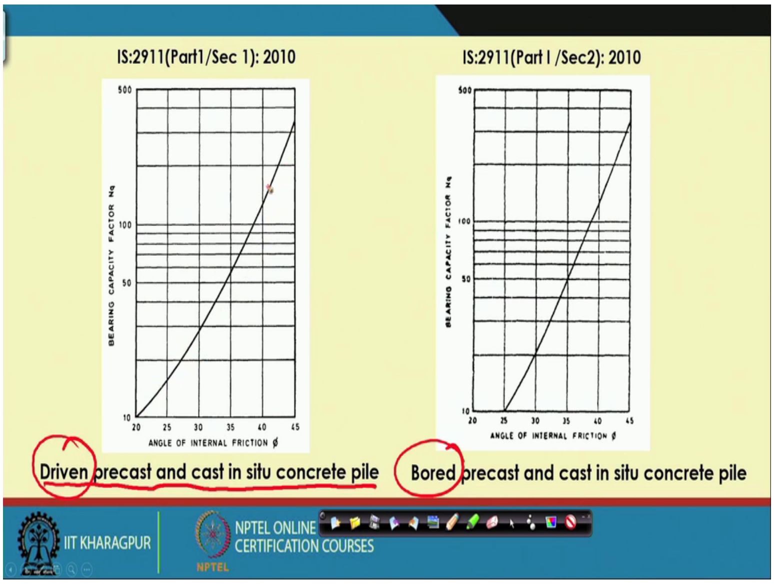

So, this chart first chart is for the driven piles, driven precast and cast in situ concrete piles if the pile is driven pile. Basically driven piles and driven piles in both can be the cast in situ and the precast. So, for the driven pile we use this chart and for the bored pile we use this charts. So, again here we are separately we can calculate the driven pile and the bored pile.

So, this chart is slightly there is difference, but you have to use this 2 chart if you are using for the driven piles, then you have to use this chart, if you are designing a bored pile you may have to use this chart.

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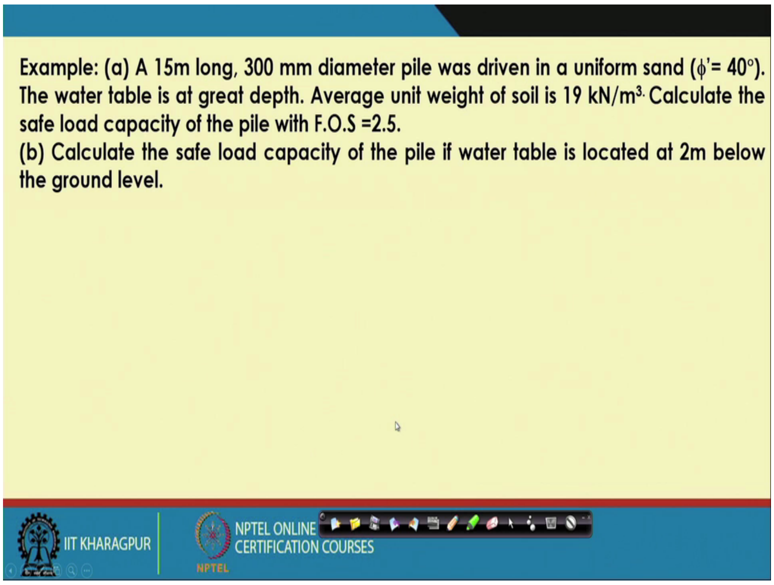

So, then so, in the next class, I will solve a problem by using different methodology that a discuss about the 2 methods basically 3 methods, ok. Including the IS method how to calculate the tip resistance of the pile and then the friction resistance of the pile.

Then we have to add them and get the ultimate load carrying capacity, remember that if your loading cell point of the pile also you have to subtract from that equation so that that much of load you can actually applied form the superstructure. So, so, today I am finishing this class and then in the next class, I will solve different types of problem that is pile in homogenous soil pile in layer soil. And I have discussed only the pile load capacity for the granular soil first the problems on the granular soil, then I will discuss the piles on cohesive soil.

Thank you.