Foundation for Offshore Structure
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Module 1
Lecture No 33
Two Pile Group Effect for Axial Load

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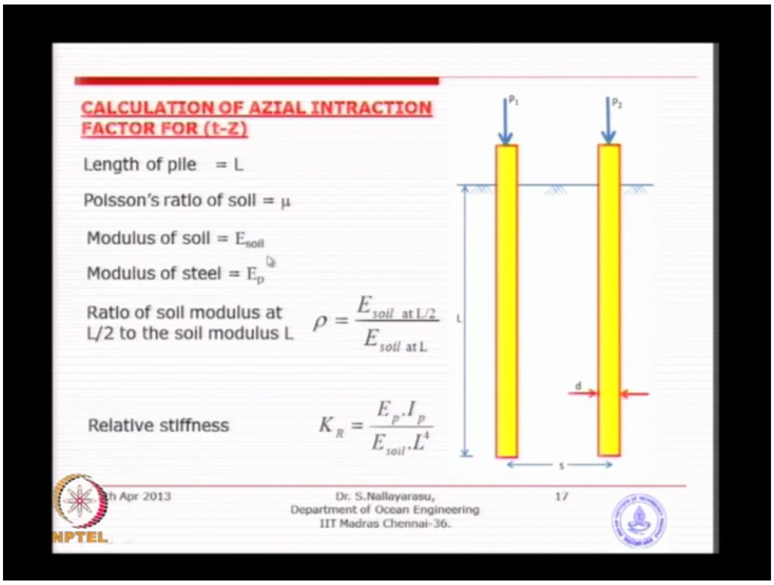

So we will continue with the axial the effects of axial load because of the pile group effect, so the procedure to calculate if you have multi-layered soil what we need to really worry is calculation of average properties for the modulus value that is where the whole issue in fact we were talking about when we are doing the TZ for various soil, if you are developing a TZ at a particular location, what happens to the previous layers is the most important one, so if you look at most of the procedure developed earlier they always will be talk about single layer methodology in fact even the API equations what we have just discussed that actually does not in fact discuss about how you treat with the multi layered soil, so we have to be cautious, so in this principle also the modulus value is playing a major role because you can see the effect of settlement.

So an approximate procedure needs to be developed for computing this (())(1:11) what we normally do in the practice is to carry out a separate analysis at various lower levels and find out what is the displacement of the pile and then calculate back, the back calculate (())(1:23) the value of the soil modulus for the multi-layered soil but in in classroom exercise it will be very difficult hours without a computer you cannot do it.

So what we normally can adapt in our exercise you can take an average value of multi layered soil and use it for the computational purposes and Poisson's ratio length of the pile and value of row which is nothing but the ratio of the modulus at half distance to the full-length that means somewhere here to the 2 of the piles which is going to be one of the parameters and the relative stiffness which we were I think if you remember when we were deriving lateral pile capacity various methods, so K R is actually stiffness factor EI is the pile stiffness whereas the E soil is taken here with L power 4 is very similar to your cantilever problem. So K R will be representative diameter representing the pile and the soil stiffness and this row will tell how the soil modulus varies around the length of the pile and you know typically taken as the ratio of the value of soil modulus are half depth to the pile toe.

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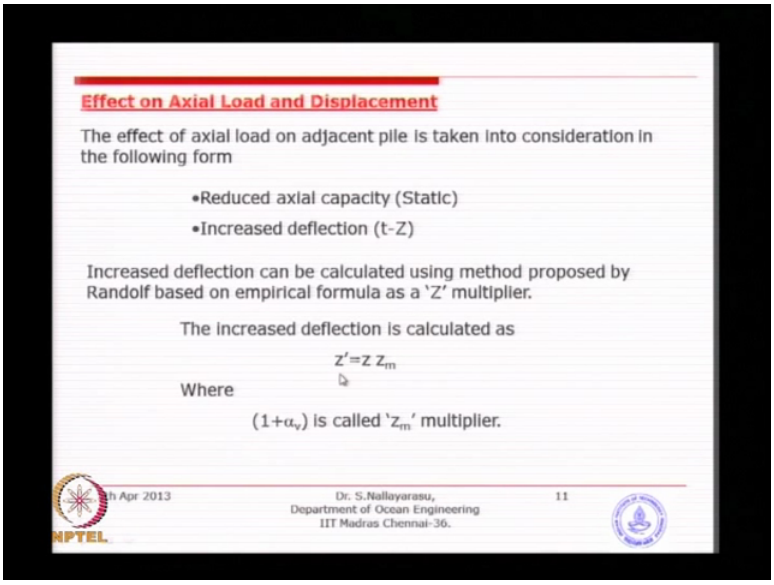

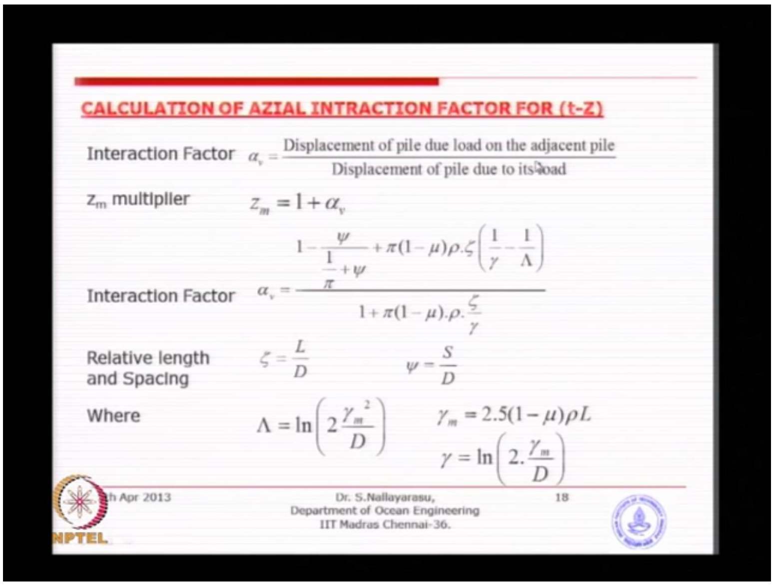

And the procedure to calculate because we were looking at you know jet value something like this the increased deflection is the deflection of single pile for the particular load multiplied by the jet M which is basically a deflection multiplier or jet multiplier and which is taken as one plus alpha v, so we are interested in finding out what is this alpha v? Procedure described here is basically displacement of pile due to load on adjacent pile divide by displacement of pile due to on the pile itself, so research like a unit load problem you apply a load on a pile find out what is a displacement that is the displacement due to that load and that pile and then displacement of the same pile due to the load on the neighbouring pile and this is only we are talking about 2 piles, suppose if you have several piles so you have to cumulatively add the effects all-around.

So we can do or loop computational program just take effect one by one and basically the alpha v is derived as this, is a semi-empirical formula (())(3:47) by Joseph Pauls and basically the parameter zeta and Psi this is length to diameter, this is space into diameter and various parameters involved here is this just to give a notation if you substitute here it will become too big, so that is why I have taken little sub-divisional parameters but what is the involvement is the spacing, diameter, length and then the variation of modulus Poisson's ratio, these are the parameters involved in order to compute this alpha factor which will be added to 1 plus alpha we, so basically as long as you have higher number you will get the effect, so that that much of increased deflection will happen depending on the spacing depending on the spacing to diameter ratio, length to diameter ratio and then the Poisson's ratio increase in these soil modulus value below half depth, so basically if you look at these parameters what else is unknown?

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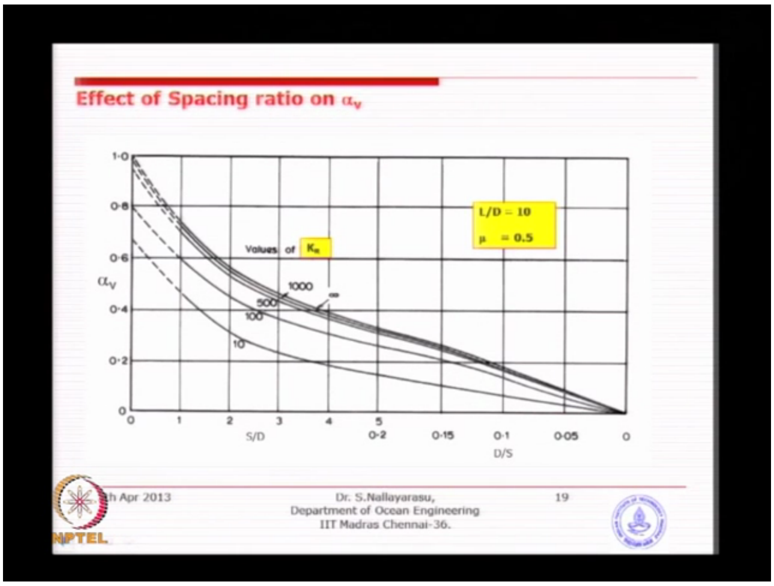

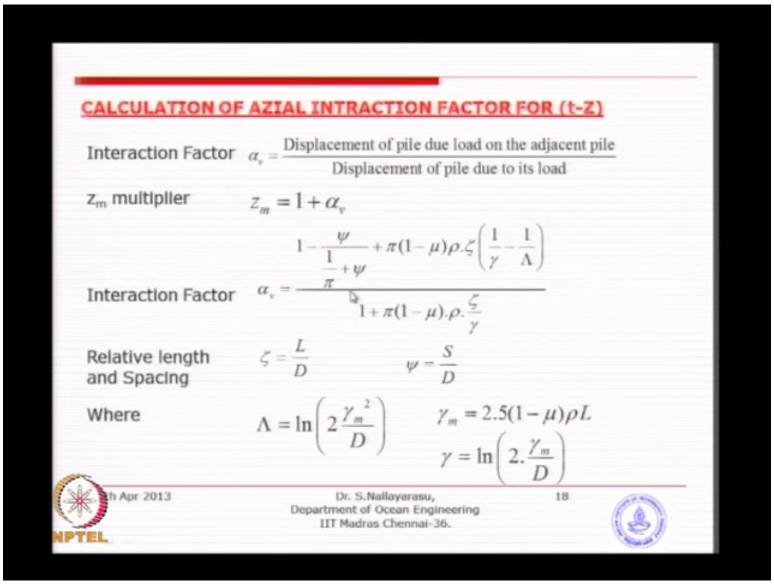

For a given same value whatever you see here instead of computing here he has developed actually several charts for given values of K R length to diameter ratio based on the equation what we have seen and you could have possibly read it from the charts that I have just copied from the book, so you can straightaway use it whenever you have only 2 pile system because typically you cannot use this procedure whatever I have given here is only specifically for 2 pile system and basic… If you have more than 2 piles you have to come up with some additional methodology to take their effect into it.

Various charts I think there are so many charts I think some 10 charts are there just to give you guidance so that in case if you want to use it for practice you can use this, so alpha v is in the vertical axis and s by d ratio and this half the graph on the right hand side is just D by S ratio instead of S by D ratio, so you can up to this you can use either D by S ratio or S by D ratio the alpha v value can be read for a different values of K R, so you have K R values from 10 to 1000 and L by D ratio of 10 and 0.5, so the next graph will show you for different L by D ratio different Poisson's ratio so just repetitive of them I think some 10 charts are available, so basically alpha V can be computed.

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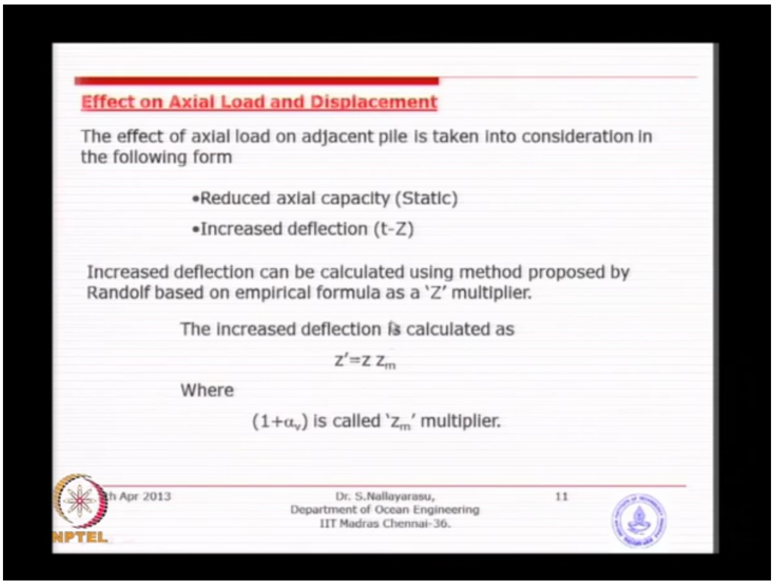
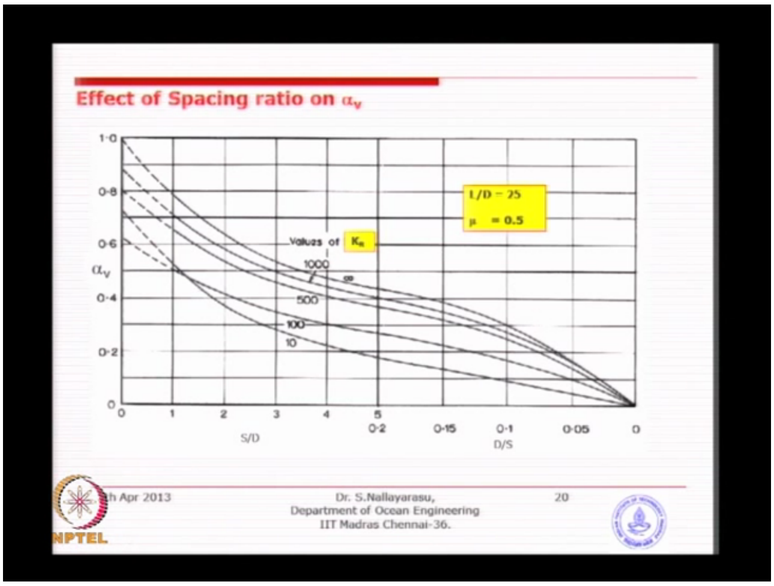
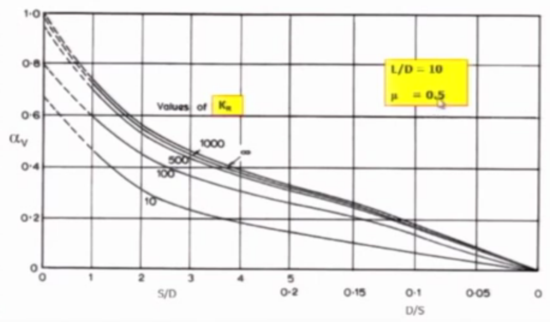
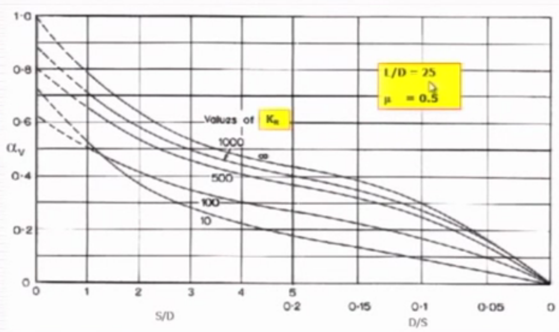




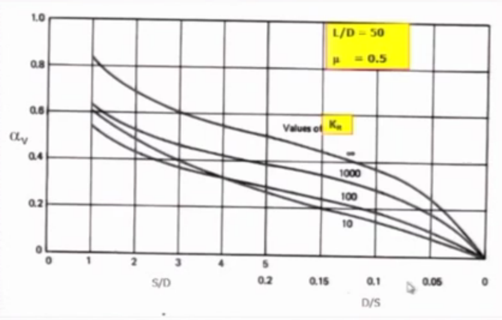
Effect of Spacing ratio on α_v

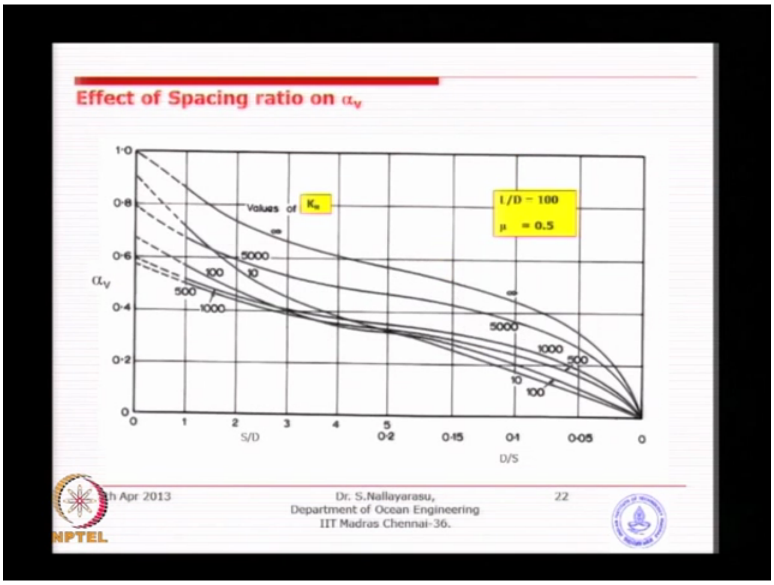


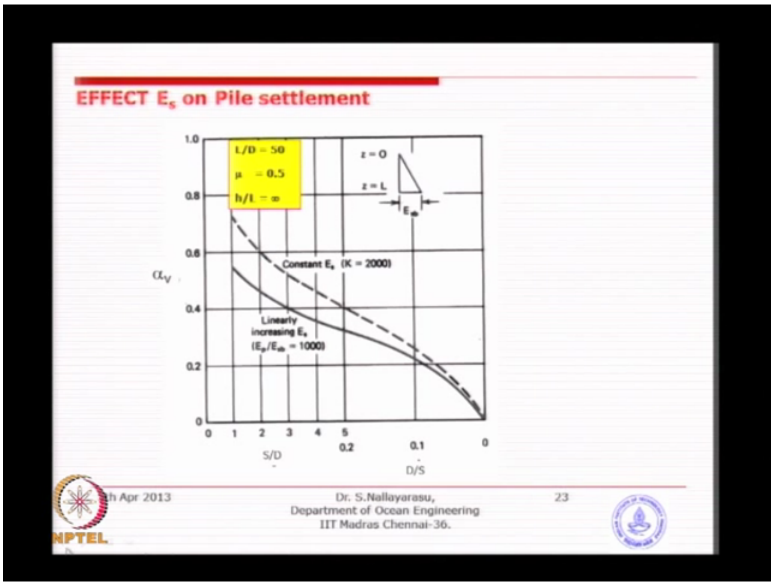
Effect of Spacing ratio on α_v



Effect of Spacing ratio on α_v







So ultimately once you have the alpha v value then you calculate your increased deflection, you just start plotting your graph, so if you look at several graph 0.5 you see here this 0.5, 10 this is 25 and then 50, so if you look for different Poisson's ratio you have to look at the original application, I have only taken some few samples 100 and then effect of E S on pile settlement basically for L by D ratio of 50.5 and H by L is very large so this is the last graph you can find from that book.

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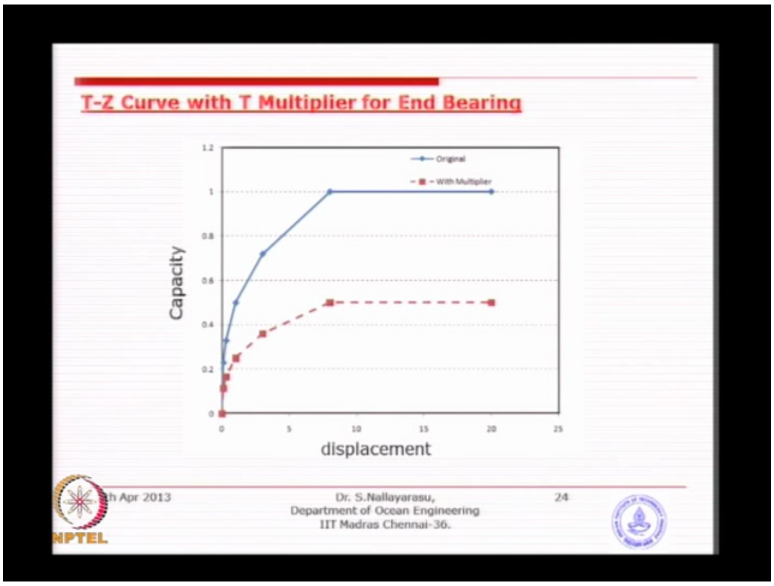

So typically how TZ the effect of TZ on the pile group effect, you can see here the original is in blue color basically the TZ graph drawn for I think this is typically for a clay type of soil, so you can see here several coordinates were given in API, so you can draw that and then after multiplying this is basically T multiplier not Z multiplier, so for a given displacement the modified the TZ curve has got lower capacity than the original capacity say one, so reduce capacity is about 50 percent, so this is basically a multiplier on the capacity.

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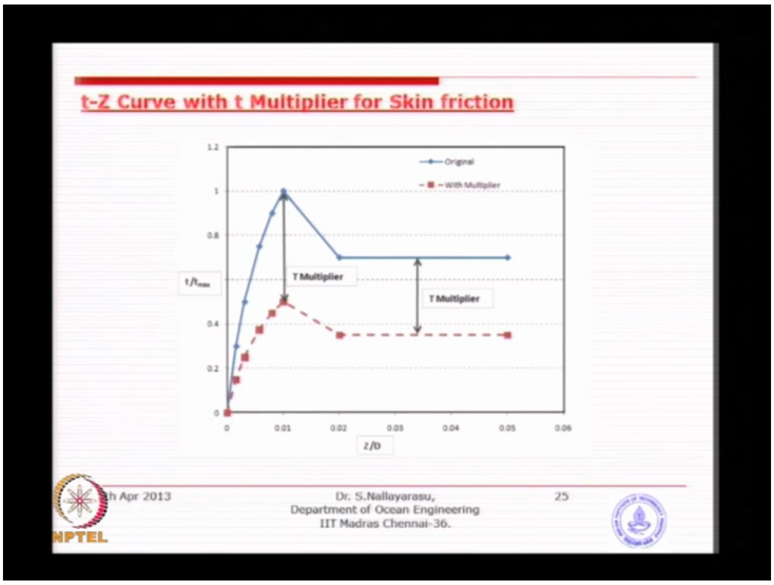

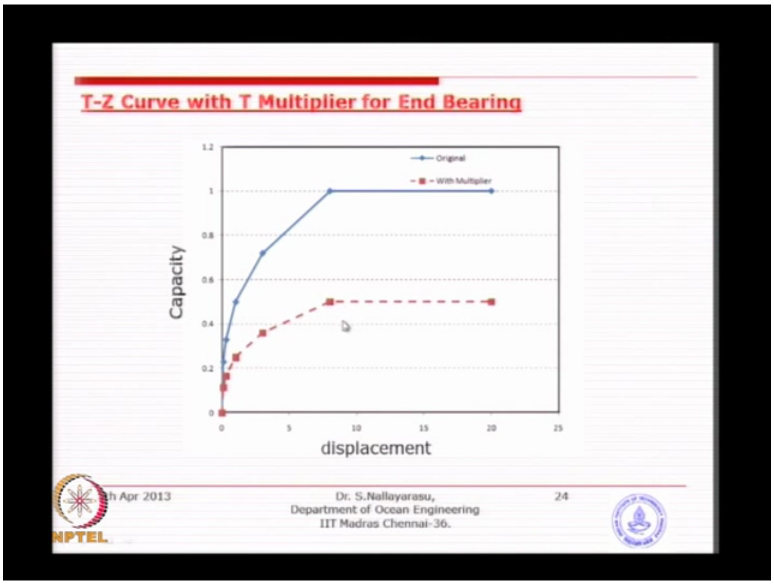

Suppose if you do this is also T multiplier, if you do a Y multiplier Z multiplier it will not look like this because the deflection will be more for the same, so this point will be you know you have deflection of 10 or maybe 8 mm for full capacity, so what will happen this if you multiply Y multiplier the defection will be more but the capacity is the same, so either way you can deal with it. Most of the time in practice we use a T multiplier.

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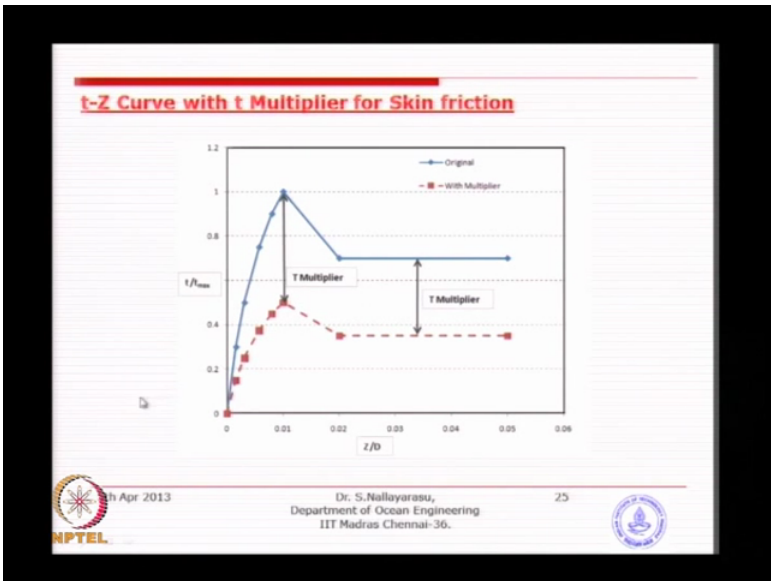

Similarly for TZ curve for T multiplier is basically you see here the original graph is the blue one whereas the reduced capacity for the same deflection is this much, so we are just having the same capacity scaled deflection to a same level and only the capacity is reduced.

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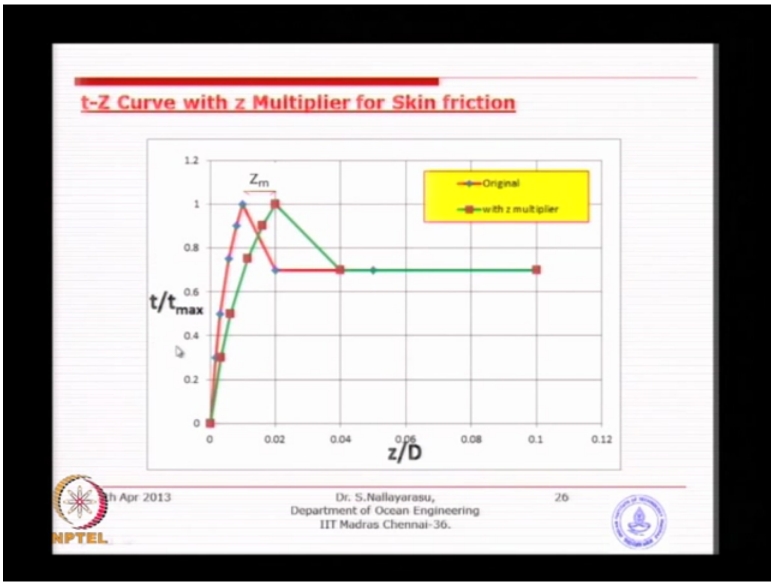

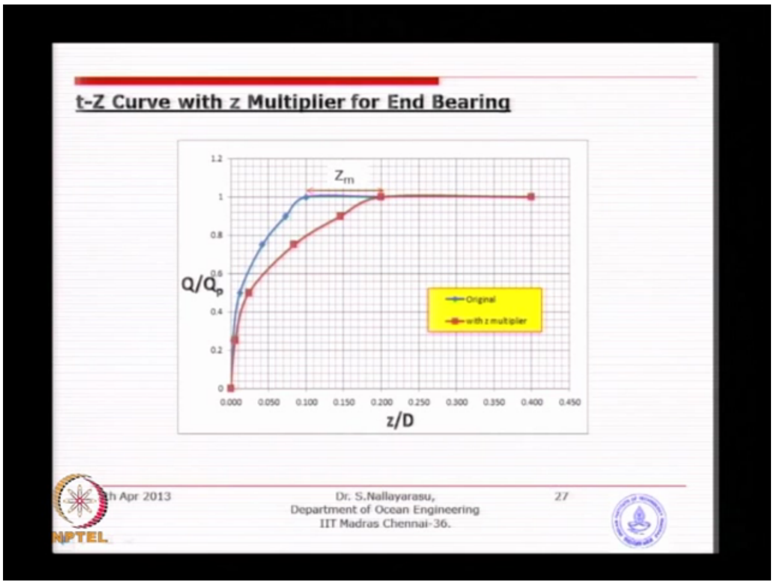

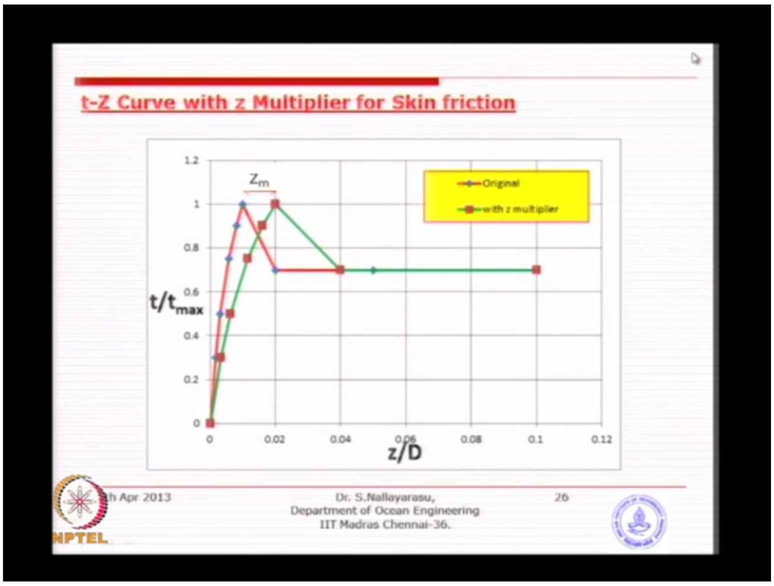

If you want to use Z multiplier this is what will happen just I was trying to explain for the capacity of the same capacity, see the red color one is the original and the green color one is the after multiplying with…so always that multiplier is going to be greater than 1, so you see that more reflection will happen, so the shape of the graph is same except that it is getting shifted by that much amount whatever be the if it is a Z multiplier of 2 you know 1 mm becomes 2 mm or 10 mm becomes 20 mm for the full capacity to achieve. So what it means is you will take more deflection you know basically that is the idea. For sand I think this is for clay and this is for sand just to give you an idea how and what happens when you apply the multiplication factors.

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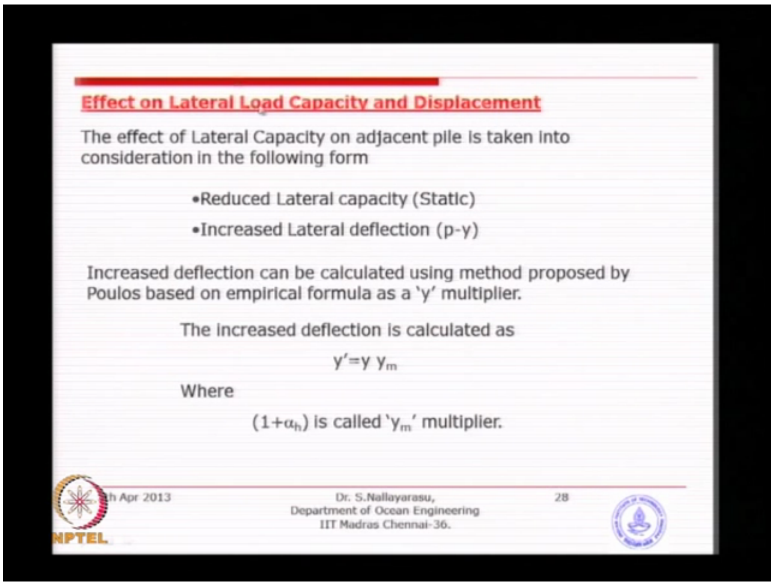

The next one is basically the effect of these groups or the spacing of piles on lateral capacity similar to the actual capacity will also have a Y multiplier instead of Z multiplier because that was vertical and this is going to be lateral, so Y multiplied by Y m and again instead of alpha vertical you calculate the alpha horizontal, so it is a similar procedure and basically one of the problem is the modulus value what we were taking average here may be very difficult to do average because the effect of the pile of displacement on the soil is varying along the length because you can see less effect on the pile below and more effect on the soil near the you know the seabed and just little bit down.

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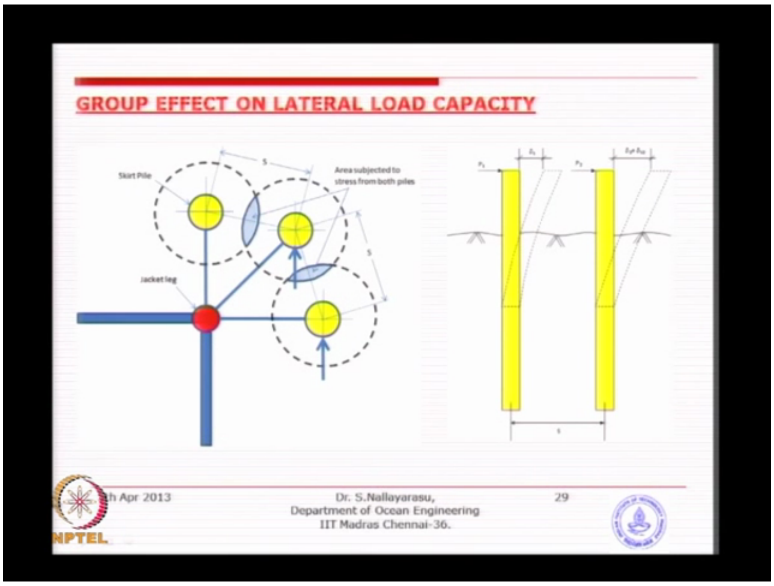

So in that case we have to find a methodology to find out the values of modulus along the depth of the file, so typically if you look at this picture you know 3 piles arranged in the corner of the jacket leg and basically you have an overlap here, overlap here and this is the one that we were thinking of taking into account, so you see here if the loading is like this, so some amount of shadowing effect on this pile because of this pile and of course there will be a very little depending on what is the load. Suppose if the load is in this direction there will be full shadowing, so now horizontal loads it is going to be dependent on the direction of loading and what we need to do is generally in practice we take the most you know the (()) (11:09) case in which the group effect is going to be higher.

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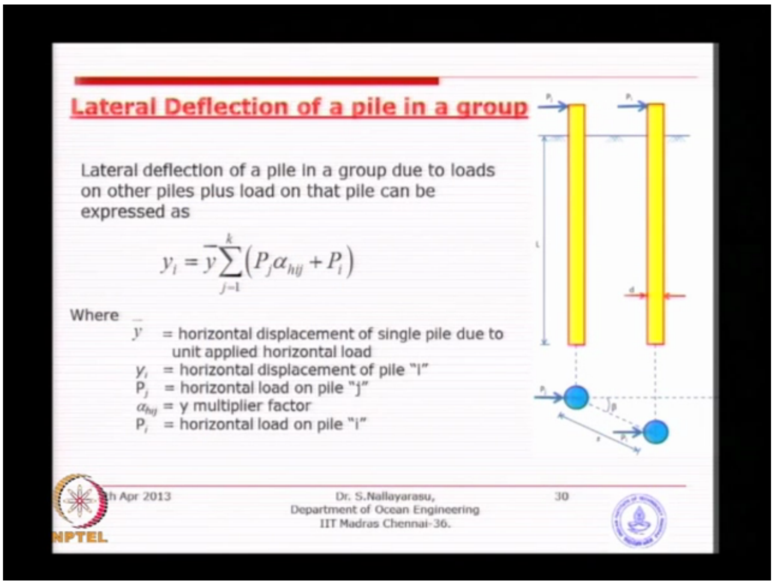

So as I mentioned for vertical piles, so you can see here is a cumulative effect of a particular pile displacement because of this the loads on the neighbouring piles, so you could add from 1 to end number of piles is a generalized procedure given in a text book which generally we use it in practise basically Joseph Pauls book is based on simple matrix methodology in fact we might have studied in your structural analysis program matrix method of solution by dividing the section the pile into several sub segments and solve for the displacement along the length and all along the full length once you find then you just iterate for all other groups, so basically Y is the multiplication factor, alpha is the multiplication factor for the displacement of the Z pile due to (())(12:08) load that is the notation and just keep doing for all the piles and beta is the angle between the 2 piles which is going to form the group and the load on this pile is P i and load on this pile is P j. So just you will have a…so K number of files in the group the spacing is yes.

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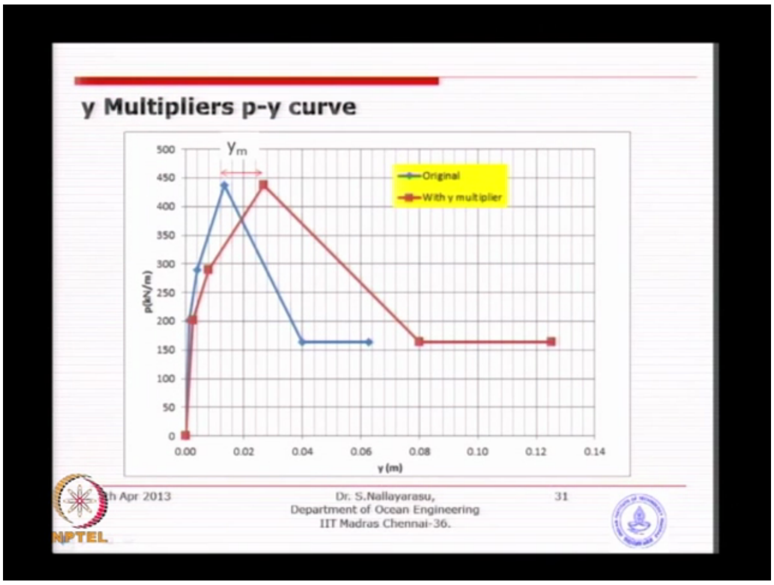

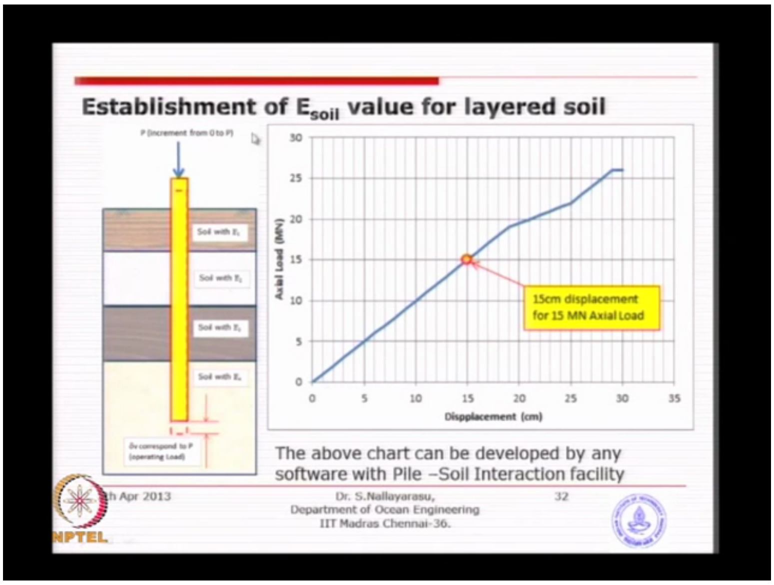

Typically again similar idea, once you find out y multiplier you can just increase something like this, this is the original this is the increase deflection for the same because this much increase is due to the load from the neighbouring pile, it is not because of the load on that pile itself. So in order to find the combined soil modulus normally what we do this, we construct this type of diagram, so you have to do a computer analysis, apply various loading and try to derive the displacement of the pile head or pile at any location and derive the relationship between load versus displacement, so this slope of the graph will give you an idea about you know what is the kind of modulus, the combined modulus of the total soil.

So this cannot be found by simple means of hand calculation that is one of the you know the problem associated with this methodology, somehow you have to find out an average behaviour of the total soil layers when you have more than one layers, so that is something that you have to find out to establish because this is very similar to load displacement characteristics in your pile load test. Suppose if you are able to establish this graph in pile load test that will give you good average behaviour of the total soil layers, if you are not having pile load test then you have to do something similar like a Numerical method to solve you know the representative E parameters and you can use that value for your hand calculations.

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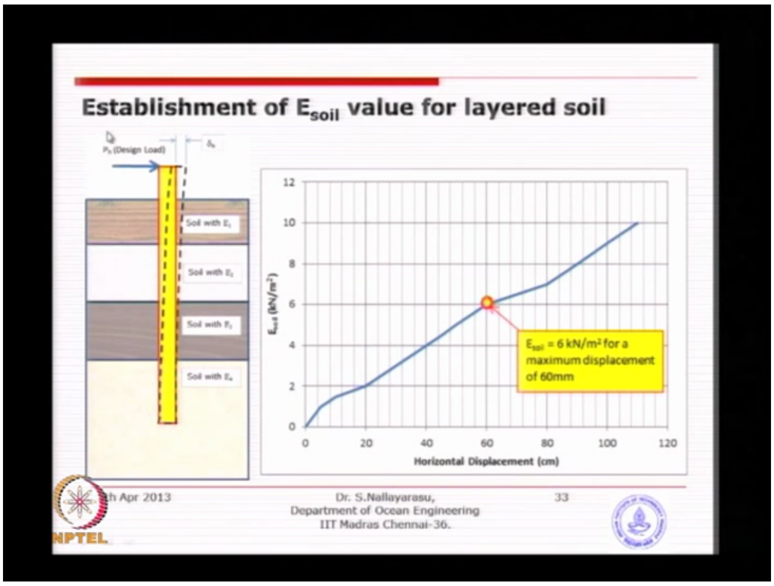

Similarly when you are applying horizontal load you could also need to find out apply the loads and incremented whichever steps and then plot with respect to this will give you horizontal soil modulus for use in your modification work and mostly if you see something similar what we are looking at piles soil interaction soft base you can apply load in various steps, obtain the displacements and plot this type of relationship to get the E value.

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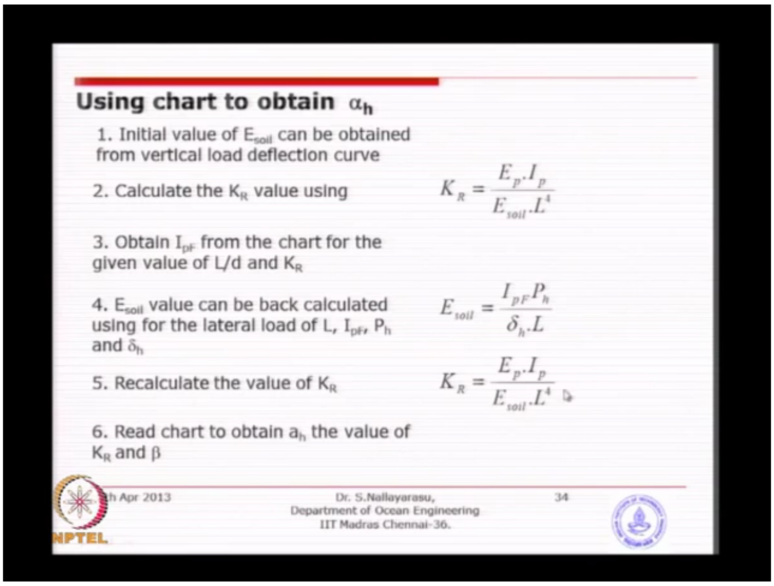

So the simple procedure to use the chart given by Pauls book is the procedure given here, initial values of soil modulus can be obtained from vertical load deflection curve which I think we just have an calculate the K R value which is the relative soil to pile stiffness obtain I value, the interaction factor from the chart using the K R value and L by D we are going to see the chart little bit later and E value can also be back calculate it after obtaining Delta h and I value you have read from the short and recalculate the K R value which is because E soil is going to affect your K R value, so as long as you are e-soil value is correct then you are K R because you are going to read you know i value from the chart, so as long as K R is incorrect you going to have a wrong value of (())(15:27), so just do a recalculate few times when read the chart for alpha h this is not a h alpha h for different values of K R and beta, beta is the angle of loading, so just few procedures would just…so if you look at the whole idea the representative soil parameters is going to be very important parameter in deciding what will be the alpha value.

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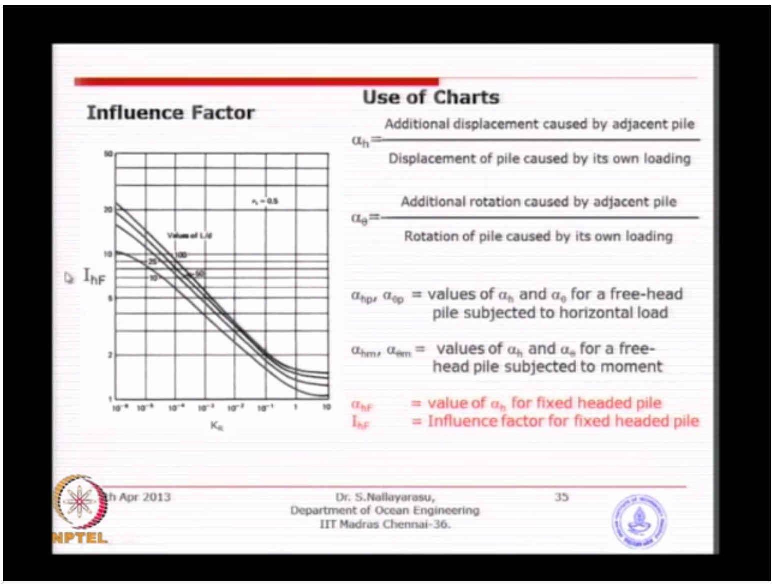

So there is a chart for I which is influence factor depending on the soil to pile stiffness which is given for various…so this d is the diameter because the other one was capital D, so this I did not modify just because it is given the textbook and given (())(16:09) ratio is 0.5. (())(16:12) value of L by D is given here and influence factors for different values of K R, so alpha h is the additional displacement caused by adjacent pile divided by displacement of pile caused by its own loading, so neighbouring pile…so it could be as big as the original displacement if the load is so much or if it is smaller load you will have fraction of displacement increased on the…so normally you will you will not have very big alpha h value but when you add with one may have 1.2, 1.3, 1.5 and as the effect increases and the spacing is closer you will see that alpha h value can reach as much as 2. Some cases you will find that you will have to use deflection increases of 2 times of the original deflection.

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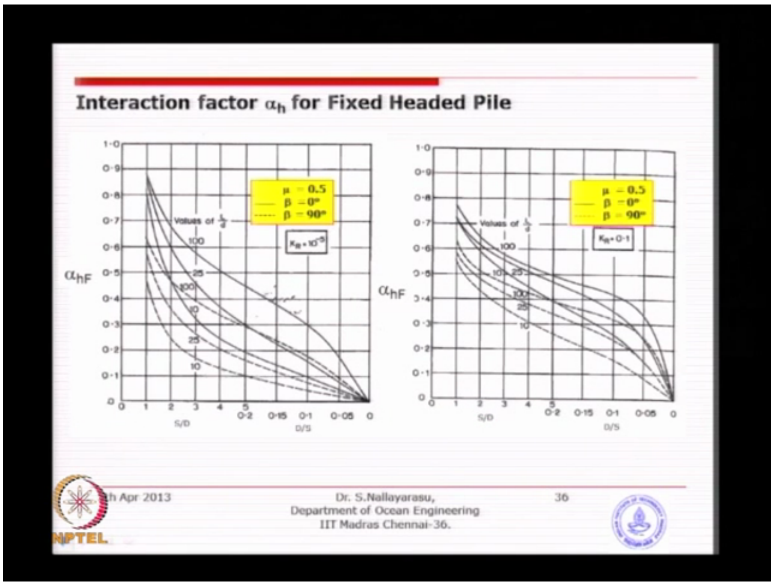

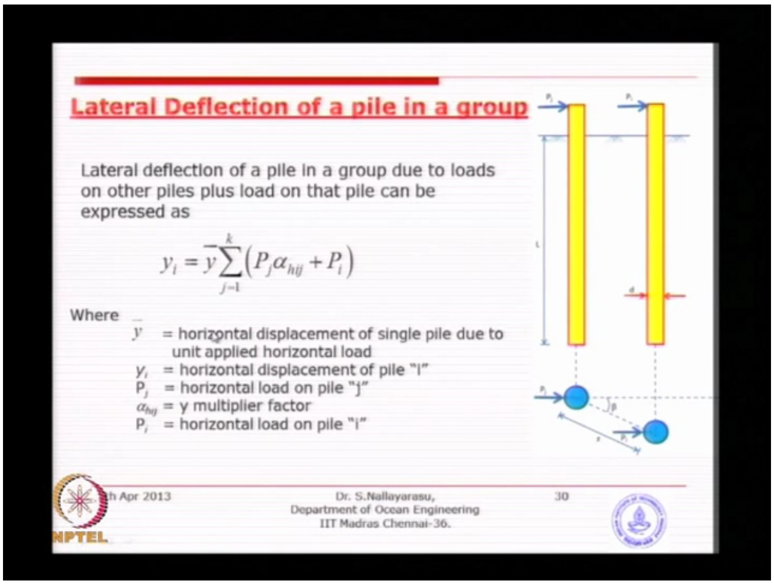

And then the various charts for reading the alpha h value is given here for similar idea beta 0 degree 90 degree and Mu is 0.5 here what is the difference, so here is S by D alpha H for K R value of 0.1 K R value of 10 to the power minus 5, so you have 2 different K R values and this is typically for 2 pile system so basically that is so when you go back to this picture based on this Numerical scheme he has developed this and solve the equation in computer and plotted these graphs for 2 piles, so suppose if you are interested in solving for more than 2 piles you have to go back to the matrix equation and then solve for your particular.

So some of the programs commercially available can do this exercise instead of you go and use this chart, you can actually buy the program and used for your 2 pile system, 3 pile system but for most of the practical applications I think 2 pile system is okay instead of buying a software you can use these charts and then slightly approximate because you are reading this charts because you can see here the values can jump very big to small unless you are careful in calculate in the K R value correct and reading the chart carefully because then it may influence reasonably higher, so this is for 2 different values of K R and for the solid line is for 0 degree and dotted line is for 90 degree, so that means perpendicular loading and Mu value is 0.5. 0.5 only difference is 10 power minus 3 from minus 0.5 minus 3 here it is 10

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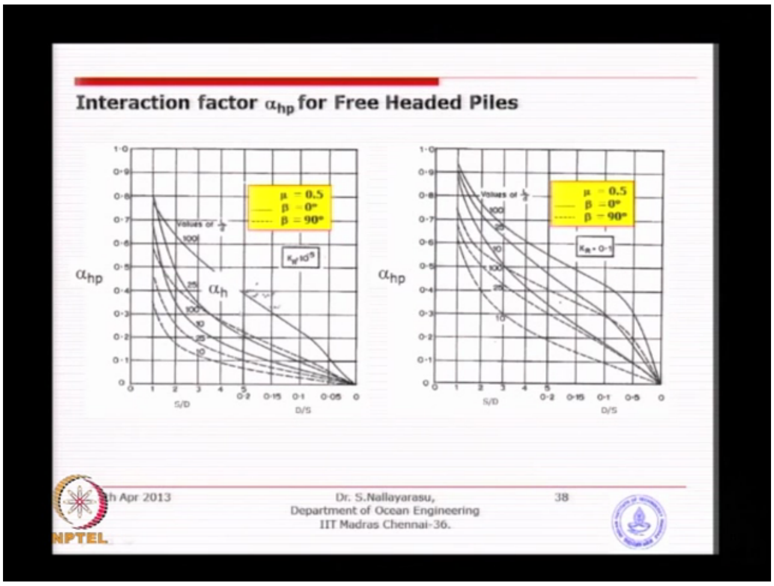

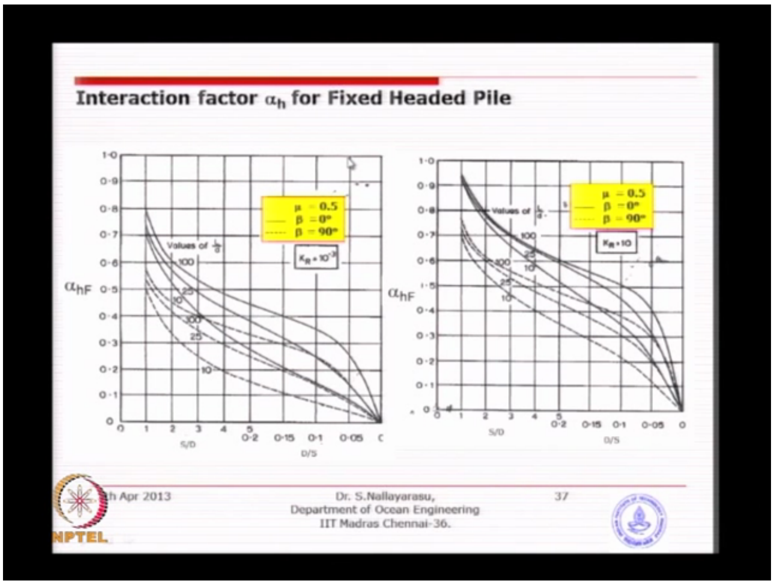

And then seems to be same or different seems to be same this is free headed piles, this is fixed headed piles so there will be another repetition of 3 more graphs. Mostly you will need to read the fixed headed piles because for offshore steel type jackets were the pile head is connected to the jacket leg you will not be able to treat it as a free headed pile unless you have onshore or may be near shore structure where the pile head is free to move because most of the cases you will be having fixed headed pile or our jacket type of structures.

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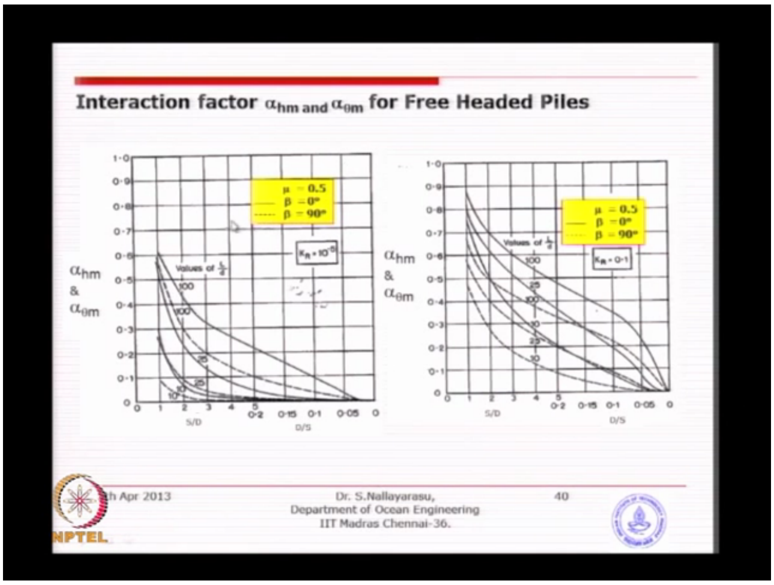

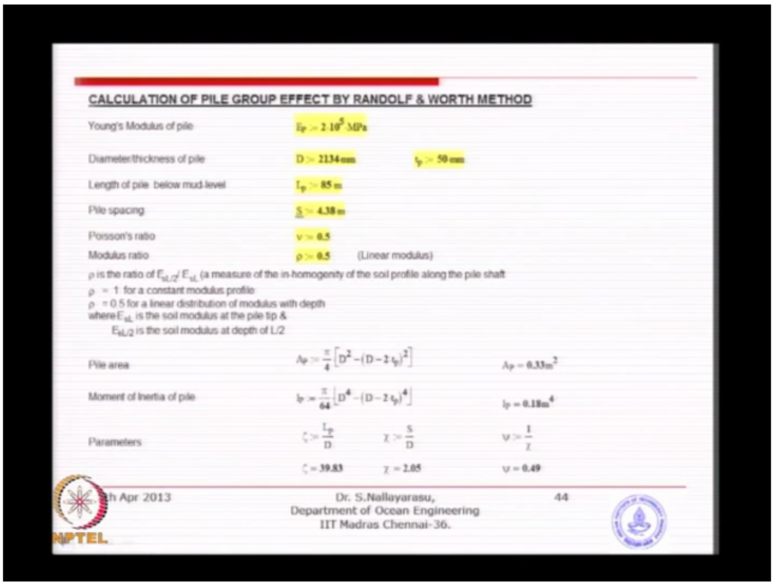

This is for rotation anyway which is not going to be very much useful, a typical example is given here basically the Randolf and Worth for axial and the lateral capacity. Similar whatever we have explained I have given an example, so basically the modulus of the pile is this much diameter and thickness length of the pile is 85 meter spacing is 4.38 metres, so basically it will you can look at it is 2 times of almost 4.38 metres is coming nearly to 2 meters 2 diameter spacing Poisson's ratio and modulus ratio of the soil nearly increasing from half to full depth and you have the properties calculated here.

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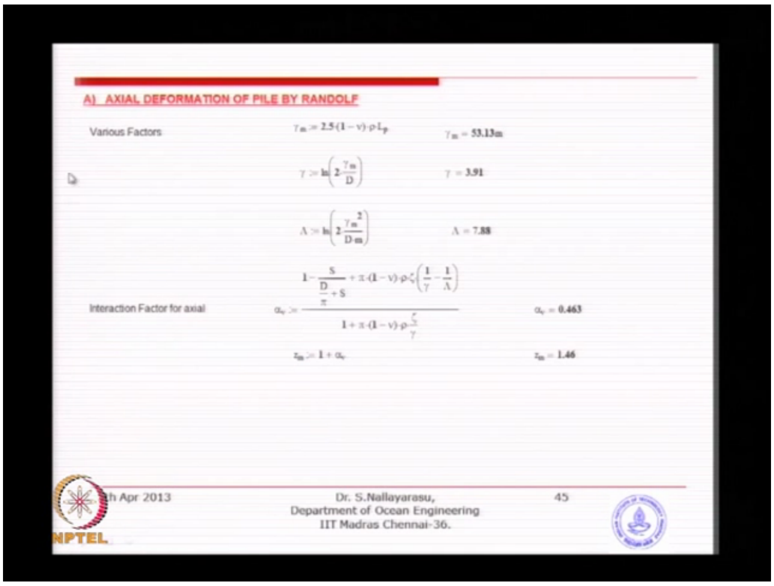

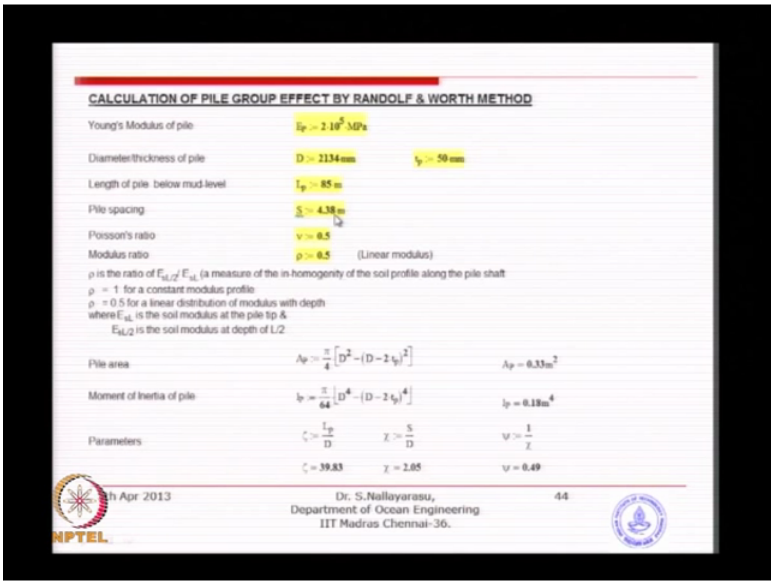

And the various factors involved in the calculation of alpha b, so you see here the alpha b comes out to be 1.46 about 1 and half, so there is a 50 percent increase in the axial deflection because we have the spacing is just only 2 diameter, so if you go to 3 diameter you may find that this may come down to 1.1. Normally we adapt in practice minimum 3 diameter I think I body mentioned in initial classes we should maintain at least minimum 3 diameter at any cost because most of the codes whether it is local codes or other codes, they ask for minimum 3 diameter because the axial capacity reduction, you do not want to see that it is substantially bigger like this 46 percent is very big but 5 to 10 percent is reasonably acceptable, so that is why this this are just wanted to demonstrate that you can actually go back and calculate or 3 diameter you will find maybe 10 percent, if it is for diameter probably you will not find any effect at all on the deflection it will diminish.

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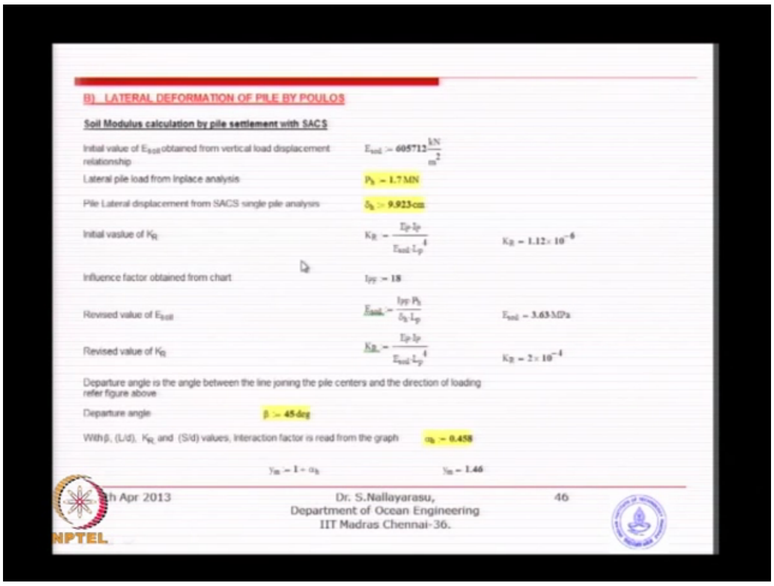

Whereas if you look at the lateral deformation this will be even bigger effect or depending on the type of soil, so you see here the initial value of soil modulus for a multi-layered soil is given to you in case of examination or in case of your practice this value is given basically based on computer analysis because it is a multi-layered soil, so analysis has been separately and then you have got the initial value (())(21:48) low displacement graph otherwise you have to establish this, so to establish this you apply unit load and just keep increasing the load versus displacement and try to get this the slope of the graph will give you the modulus value and total load applied on the pile itself is so much maximum load and maximum displacement is this much, so this gives you a total ultimate behaviour and initial value of K R can be calculating because you already have been given this number.

So you calculate the K R. Influence factor read from the chart which we were seeing and revised value of soil based on the new value of IP and then revised value of K R and then again you can go and do a few iterations if you write company programs you can do iteration to make sure that starting value and the next value the Delta is smaller, so that your error in accuracy this smaller and then the departure angle of your loading is given to you 45 degrees because you can go and read it and then for value of beta L by D and K R you read the value of alpha h 0.48, so 1 plus so you can surprisingly see that this also comes to 1.46 does not mean that it will be 1.46 for your problem, it so happened that depending on the values of your know the soil parameters this can change. So I think that gives you an idea of a typical pile group effect what we have looked at is only the deflection and capacities.