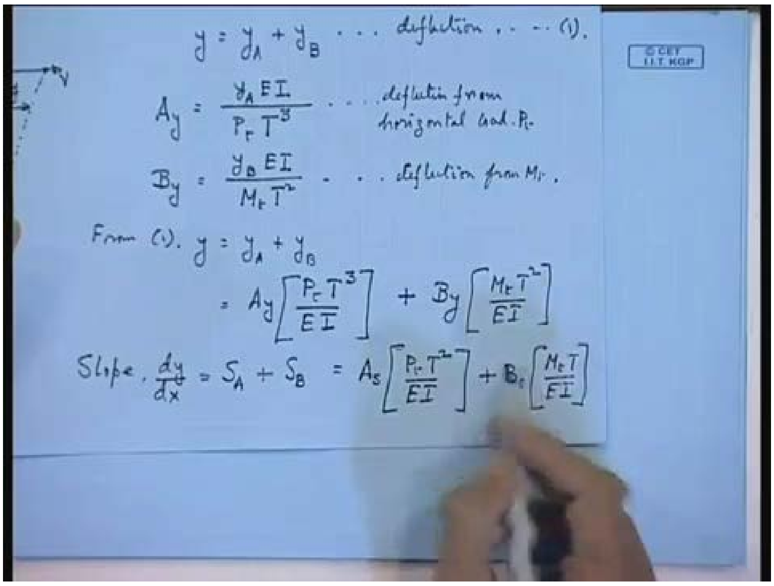
Elements of Ocean Engineering
Prof. Ashoke Bhar
Department of Ocean Engineering and Navel Architecture
Indian Institute of Technology, Kharagpur

Lecture - 42
Jacket Pile Selection (Contd.)

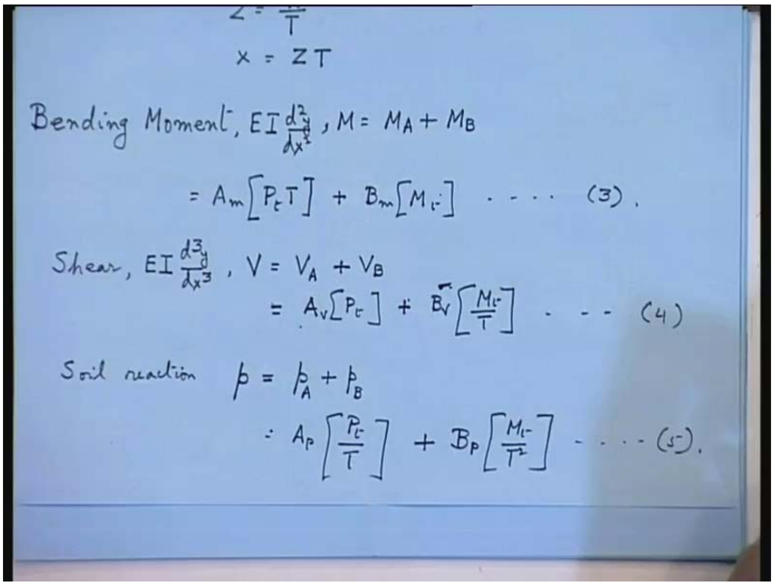
(Refer Slide Time: 00:58)



So, we will continue with jacket pile foundation and the deflection I have told you is composed of two parts; one is caused by the horizontal load P t and the voltening mode. So, this is your y. So, then y is equal to y A plus y B. So, the founders that have I given you still ((Refer Time: 01:20)) that is you write down the equations for deflection. So, deflection, so this is your deflection equation. So, this deflection equation we will start from the deflection coefficient A. So, that is A y as already been given has y A this is y A multiplied by E I and this is P t over T 3. So, mind is these are all non dynamical coefficient. So, this is deflection cos by P t; deflection from horizontal load and the other one is the B y. So, this is coming from the momentum.

So, instead of P T you will get M t. So, your non dynamical is deflection. So, this become y B multiplied by E I, M t, t square. So, this is deflection from horizontal load P t derived this is deflection from M t. So, now you can write down the equation for y. So, y terms of to be from this you can get y A. So, coming to this equation this is form 1; we get. So, y equals to y A plus y B; now y A you get from here. Now, this will be equals to the coefficient you keep this has A y. So, this is multiplied by P t, t cube over E I. So, this is the first coefficient; we are getting plus other term will be B y that is coming from the moment. So, this is M t, T square over E I. So, this is coming from the. So, now this is your deflection; now you find out the slope equation? So, slope is given by d y by d x. So, now you differentiate this equation with respect to X.

(Refer Slide Time: 04:25)



Now, X has been non dynamical have non dynamical all this terms; if look into your previous notes what was the definition for X? So, X was given as the Z has been defined as X by T and T is your I think very stiffness factor. So, from this you get X is equal to some coefficient of Z multiplied by T. So, if you want to differentiate X you have to differentiate T. So, you find out the differentiate for T. So, d y by d x; you write this the slope that is coming from the horizontal load plus load coming from B. So, you differentiate this; now, you will get the coefficient that is A S multiplied by this will be T square and you keep all the coefficient outside and correct it in A S. So, that is the way it has been done. So, this become E I.

Similarly, you differentiate this one. So, this will give you B S; now, this coefficient will change because we are taking this out. So, this will be how much M t T over E I. So, this we have got this slope equation. Now, you find out the other terms that is the bending moment. Now, all this coming from the equation; for the bending of the flexure deflection of a beam. So, pile has been taken as a vertical beam and it is been applied as a point load on the pile head. So, bending moment equation how much? So, will you remember all this E I d square d y square y by d x square. So, this you correct the constant terms; now bending moment is also of 2 parts M A plus M B. So, now you write down the equation for bending moment. So, the slop equation you have to differentiate; slope equation we got in terms of T square M t.

So, another constant it will come out; say, this coefficient you can write this has the subsets you know S is denote for slope, y for deflection. So, your constant you write this as A m. So, this will be A m; now, you tell me what is the inside the bracket? So, you see to differentiate this. So, you have differentiation of the slope and that E I you correct in the constant. So, you differentiate how much will comes. So, and this will be P t, T listened the constant are corrected and kept in A M; the other term the differentiate this term with respect to 2. So, this is simply B m t this is you correct in the A M coefficient.

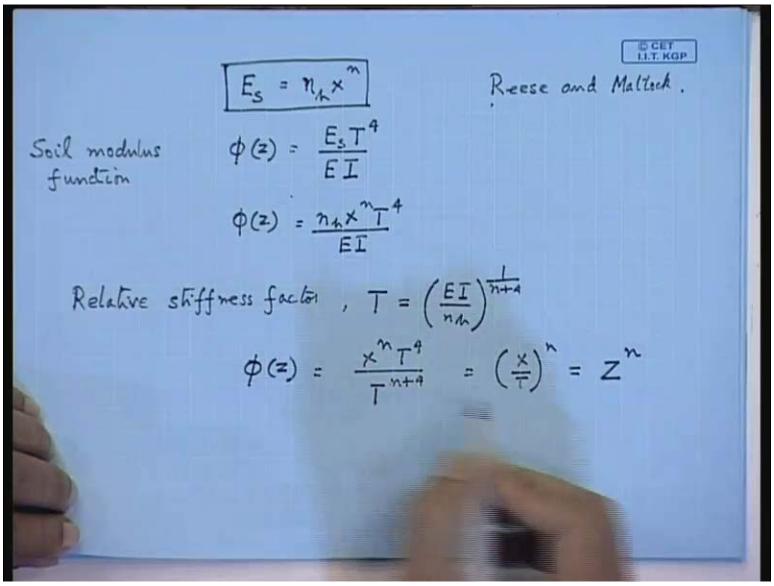
So, this is coming out to be how much we are getting B m multiplied by M t. So, these equations are simple; just we have to remember how their in differentiate. So, this is equation number 1; we are getting the deflection equation, then 2; we are getting this slope equation and 3 you were getting the bending moment equation; what else is left? Here, now share given by this is E I d cube y by d x cube. So, you similarly, should differentiate this equation; you get the share equation. Now, shares is given in terms of V. So, this is equals to V A; share caused by the load and the share caused by bending moment.

So, the previous problem; we worked out the maximum, the axis load and maximum share. Now, so this is the will be equals to how much; it differentiate this respect to do this simply get P t and there is another constant will come. So, this will be P t by differentiate M t what will get? Here, there is an M t. So, this is t to the power of 0; actually, this should be 0 but keep it like this in V A and B t terms. So, this if you differentiate it will be sorry, no there is no dot by mistake it has come here.

So, this is M t by T minus 1 this is divided by T; 0 if you there is corrected if the cost and are actually corrected in T this T to the power of 0. So, 0 into B m get 0. But there is since spit up into cos by share the lateral load and the moment you write in this form. So, there is as been T to the power of minus 1 you keep it in below t. So, this is how it as done it; the last one is 0 soil reduction. So, instead of vanishing the constant you keep this in B V; now you can differentiate this.

So, soil reduction is given as p; p is equal to p A plus p B; can you differentiate this same thing know you imagine this 2 T to the power of 0 differentiate this. So, this will be A P P t to the power of 0 if you differentiate; because T to the power of minus 1, you take it outside and corrected in the constant A P and B P. And this one will be M t by T square. So, this is equation number 4, equation number 5. So, this is what we can or this is called lateral loaded because simplest case we are analyzing for single pile. Now, this equation I already given you the formula for this relative stiffness.

(Refer Slide Time: 12:05)



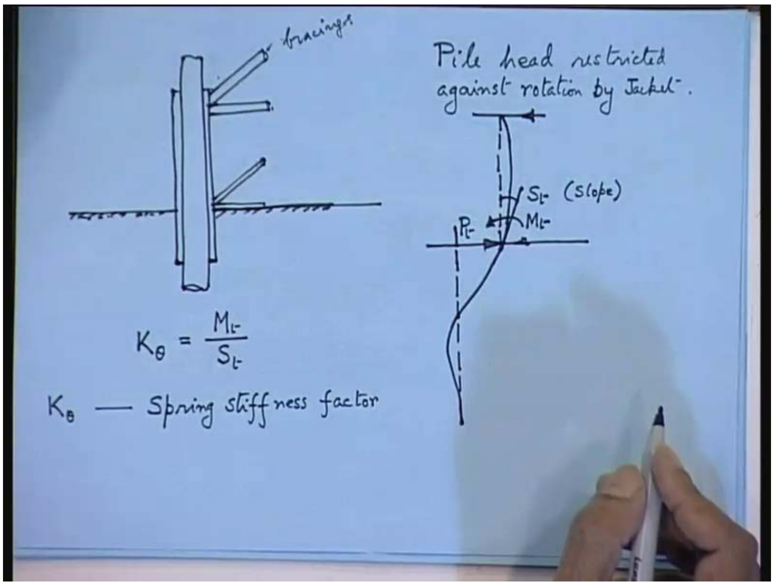
So, other terms are the sub grid model is a E S; we work out to be n h sorry, this is not eta this is n and this is x to the power n and from this you can calculate the phi Z. So, phi Z has been defined as soil modulus function. So, this is E S multiplied by T to the power of 4 over E I. Now, this work was done by 2 gentle men called Reese and Maltsck. So, this is called Reese and Maltsck now this we have to simplify. So, you substitute this E S is n x to power n. So, from here we are getting phi Z; we will substitute this we will get n h, x to the power n, T to the power of n 4 E I. So, it has soil modulus function.

Now, so phi Z comes out to be and the relative stiffness factor has been defined has what? Now, T has been define by E I over n h to the power 1 divided by n plus 4. So, these are all actually empirical formulas; which is come from your that soil mechanics.

So, these are all carried out by Reese and Maltsck. So, now you can write down what is the equation for phi z. So, you signify this equation phi Z you substitute this. So, this becomes how much n h over E I, T is 2 bar. So, this will become X to the power of n T to the power 4 is divided by T rest to the power n plus 4. So, we had the T, x by T to the power n.

Now, what is this is X by T? X by T nothing but the Z that is your depth coefficient. So, phi Z works out to be that depth coefficient to the power n. So, this is the number. So, this is the formula for soil reaction is important and the equation for phi. Now, come back let us come back to the partially restrained pile head which we are analyzing.

(Refer Slide Time: 16:41)



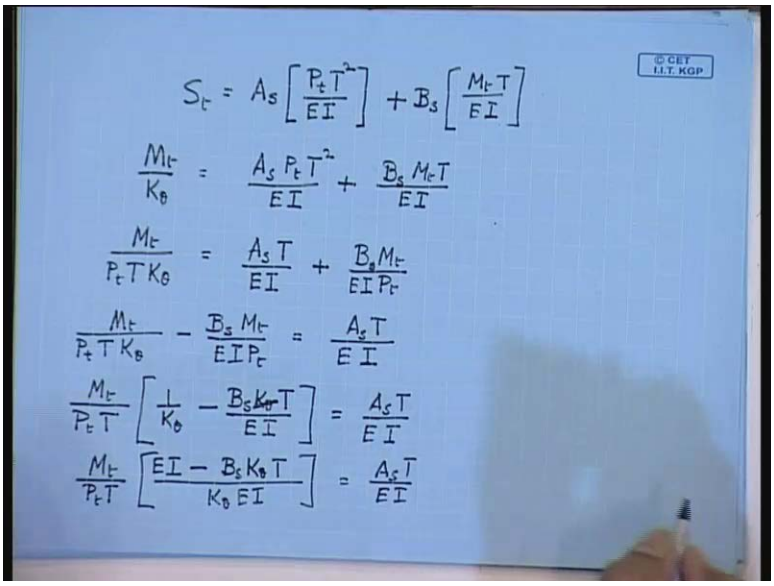
Now, if you look at the jacket pile form. So, this is the pile. So, pile has gone inside the jacket; actually, we should draw on dash line. So, this you are offshore pile; now your jacket actually this is a cover for this pile. So, it is go like this than mind you this is offering the sea bed; say portion of the jacket is gone down the sea bed. Now, this junction you have only basic number. Now, here you get your that plate that is called the mat that is come somewhere here, which I have not drawn. So, these are your grazing. So, we are just looking at the jacket part which has gone down below this sea bed; the other portion this is extended. So, this is sea bed. Now, the jacket I told you here analyzing this as a what was the type of pile this is called pile head restricted against rotation of partially I have define as s this is partially restaurant pile it that type of pile that we are analyzing.

Now, this has special partially restaurant pile head. So, this is pile head restricted against the rotation; this is rotation by what? By jacket; jacket is the restraint. So, there is a offshore column pile. So, now if you applied say that is supplied and load the pile is going to bend but it is not free to bend. So, there will be restricting coming on the pile and it will go like this the deflection curve or the pile; of course this is the very enlarged case it will try to go like this. So, this is a pile head restrict restraint by the jacket now at this point you will get a slope. So, there is deflection as well as rotation.

So, this slope you mark this as S t. So, I am that it I am writing this has slope. Now, we will employ this since slope equation; the slope equation that we are derived is this one. So, we will try to use this in our analysis. Now, what we are getting at this junction suppose your wave load is coming at this point. So, you will be getting actually 1 moment at the sea bed. So, this is your M t will come and obviously, the load will come here. So, this is called your pile head load P t; you take this at the sea bed there will be a couple as were as a horizontal force. So, this is the situation.

Now, if you want to analyze this kind of pile you there is another factor which is should know it is called the relative stiffness factor. So, this is defined as the moment divided by slope S t. So, K theta called springs stiffness factors. Now, you write down this slop equation; in terms of this K theta. So, what was the slope equation? So, this was the equation for this slope; now you will substitute k theta. So, we are getting both n T and P t out in the slope equation.

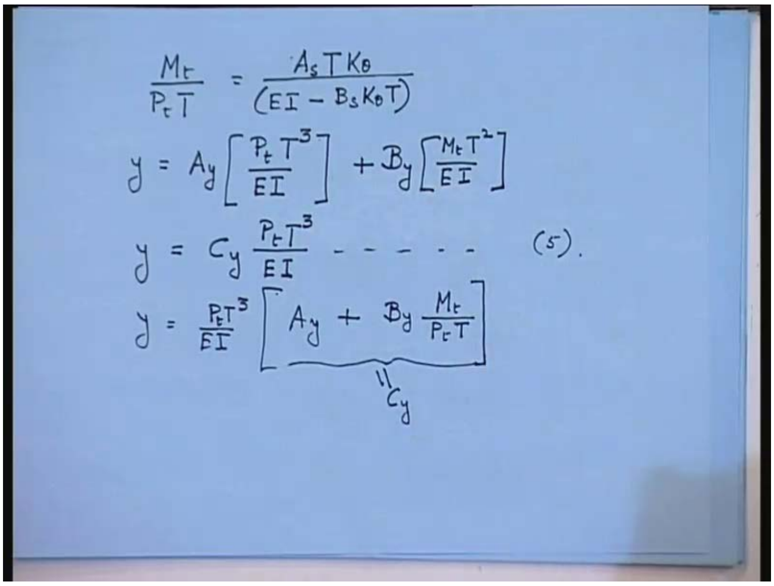
(Refer Slide Time: 23:00)



And, you correct the all the terms in the moment that is your M t and P t to one side and see what will get. So, our slope equation is; now, you try to bring this k theta term inside. So, S t is how much S t given as K theta by this is M t by K theta. So, you take this outside. So, sometimes you get and divide by P t this single fourth S t equals to n T by K theta now in correct all this terms. So, this side we will get M t this P t, T K theta. So, now this comes to how much? Now, you have the signification we do. Now, we are left with this term this is 1 by K theta it try to been this outside we need to multiplied by this thing; by this we minus B S K theta and T will come out here.

So, this will be b I am right and multiplied this 2. So, you are getting M t your T will cancel this is K theta will come, K theta will kept here. So, K theta M t P t, T K theta M t; I mean, here on this is K theta should be there. Now, it is M t and P t; we are kept it outside, K theta will not be there now it is. So, this will be a S t over E I; now, any for the simplification we can do. Now, it is ultimately we have got this. So, what is the equation for M t this one.

(Refer Slide Time: 29:51)



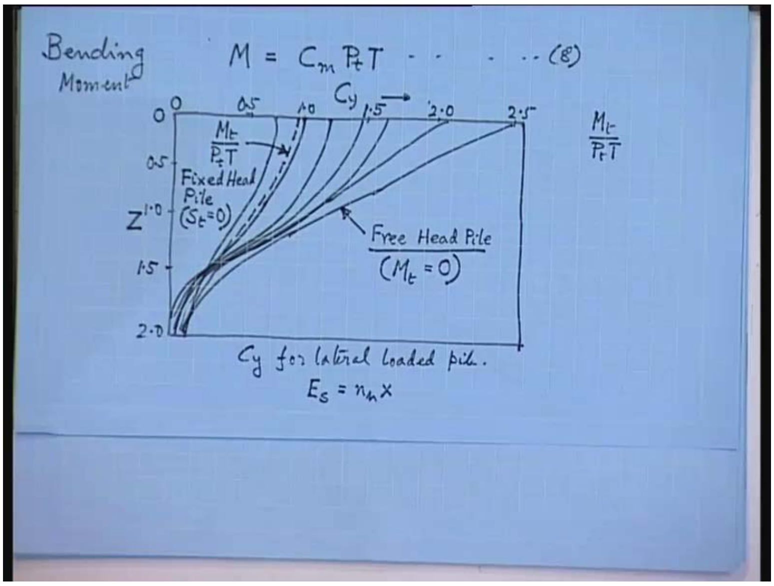
So, your E I is going to cancel in both sides. So, this will go; on the right-hand side we will be getting this is S t we are getting and K theta will come S t K theta will come; and the denominator will get E I minus B S K theta this is B S K theta T. So, we have finally, succeeded in isolating this term. Now, you write down deflection equation; what was your deflection equation? You will see at the equations that have given you what was the equation for y? y we written has y A plus y B. So, that same equation you can write in terms of this term.

So, y equation becomes A y this is P t, T cube. Now, all this coefficient there is your S, A y, B y; if getting form of a table it reason mat lock otherwise you cannot find out the y is slop deflection moment you cannot find out. Now, in this equation you try to bring this factor. So, this factor if you want to bring then you have to make some correction. So, this will become how much? M t, P t by T. So, you will write y in terms of a coefficient C y multiplied by P t, T cube divided by E i. So, then what is C y? So, y if you put in terms of a coefficient C y; then you have you have brought this out. So, y become equals to now inside we have getting A y plus how much? What will be this?

So, B y; you will remind as it is given here. Now, since you are this is P t; so the divide by P t. So, this is divided by P t and P t, T and numerator. So, now this coming P t cancel this will come T square M t and your getting E I. So, now we have some of brought this term; inside of deflection term. So, then what is this? So, this is your C y you bring this in terms of coefficient and keep this factor out. Now, similarly you write down the moment equation. So, this is what we are getting this is equation number 5; writing. Now, you write down this is 6 as on write down moment equation.

So, moment equation you try to bring another coefficient. So, moment equations there are formula that have written; what I have left yeah that bending moment equation. So, you were moment equation you write bending moment M is are other it is written as a M t whatever it is. So, this is A m P t, T plus B n multiplied by M t. Now, you try to bring out this factor again M t, P t over T. So, there was this one is symbol. So, bending moment comes out to be M if you take this P t over T out; we will inside you will get A m plus simply in this B m multiplied by this M t over P t, T. So, in both cases we have subsidiary in being this term out because this is the C m coefficient.

(Refer Slide Time: 36:18)



So, we are getting that two important parameters; one is the deflection we are getting in terms of a coefficient which is called C y multiplied by P t, T cube over E I. So, this is the one important relation we have brought; in another important relation that we have got is the bending moment term. So, this is simply C m multiplied by P t, T. Now, this 2 equation we will use to find out the. So, this is a question number 7, this equation number 8. So, these 2 equations are given number get deflection in bending moment equations and the coefficient of C y and C n. Now, you plotted a graph; we will find will plot C y around this axis and you plotted Z and you will get a series of graphs.

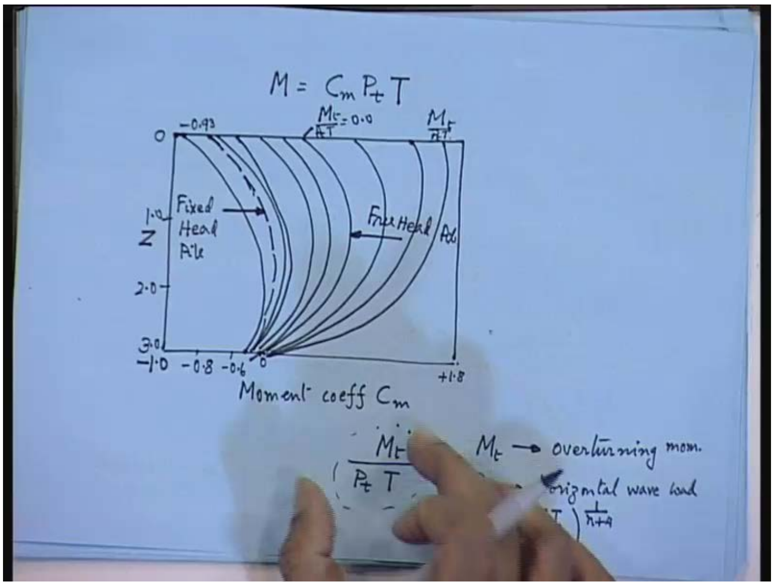
So, this starts from. So, let you take the axis starting from 0, 0; and these will go up to of course say half. So, this is 0.5 this one somewhere you will get, 1 you will get 1.5here you come here. So, ground with 1.0. So, this is the value of your Z coefficient. Now, you plots C y you get 0.5, this will get 1.0, this is 1.5, this is 2.0, this 2.5. Now, you get a serious of graphs like this the start from around here. Now, you plot this for various series of values of this M t that is why we have brought this thing out; in both the coefficient C y and C n you will find M t, P t over T this is the actually numeration of coefficient. So, this will plot M t values of this.

Now, for a fixed head case what it should be the value of S t? You will get varies of graph like this let actually comes over here whenever in the book and this and the end you will get; this will become like this. Now, your outermost one is here free head pile and then another line somewhere here. Now, this set of cross of various values of this ratio. So, these are values of M t over P t, T. Now, if you want to use this graph and find out this C y coefficient; so that means your range of values should lie between there free head pile and the fixed head pile.

Now, this free head pile; your definition free head means in this case the value of M t should be equal to 0. So, that means there is no bending moment; fixed head means S t is equal to 0. So, these are the 2 limits. Now, in between you have to find out for these values are M t by P t at the pile depth you see y value. Now, once you know C y that means you deflection is known. So, this C y value; if you know P t, T value all this other T is know listened; you immediately you can calculate y at a particular values of Z. There is Z is equal to X t; this is actually not giving in terms of X this is giving in terms of Z that is your non dimensions coefficient. So, this we can find out the pile deflections.

So, this is actually this is given in Reese Matlock 1961. C y; but in this case E S to the power n, C y for lateral loaded pile so. But in this case the E S formula that has been used is n h X the this one has been taken as 0. Now, 0 is for what type of soil? Types of soil I have told you this coefficient this I think see n equals to 0; did not mention I think now sorry, n is equal to 0 you write first it clay. So, here is taken this for n equals to 0; so that means stiff clay as been taken. So, this set of graph you will find you Reese Matlock. Now, another set of calls can be withdrawn which of course is not shown here for n equals 1. So, n equals 1 is granular; granular means Sandier. So, this is how you calculate deflection. Now, how you calculate the bending moment? bending moment equation now let you know the value of C m.

(Refer Slide Time: 45:40)



So, bending moment equation we have derived has M equals to C m, P t, T. Now, in set of curves actually drawn for C n the moment coefficient. So, again we will find. So, once you move C m; we can calculate the bending moment M t. But C m again depends on M t, P t over T. So, here you will get now this stretches from minus 1.0 this is minus 0.8 minus 0.6 like this goes to plus 1.8. Now, your 0 will comes over here; actually, you might set of curves and this is your Z value and another side of curve like this. Now, you have fixed that 2 boundaries; one is your fixed pile, fixed head and free head case. So, depth coefficient Z you start 0 from the top here it is 3.0.

So, like this you go somewhere here this will be one. So, this is 2.0 and this is 3.0. And here you get various values of this one M t, p t over T followed. So, this will be from minus 0.93. So, this is what this is your fixed head case, fixed head pile. So, most of your calculations will lie between this line and your free head pile. So, this is fixed head and free head values you get free head will be coming 2 0. Now, in all case what we define the same thing I think we have given this as 0. The other set curves that we have drawn here free head is M t is equal to 0. So, obviously this is going to 0 listened. So, free head is coming somewhere here; this is value of said M t, Pt T equal to 0.

So, obviously this is your free head, fixed head pile. So, most of your value is write between this the other value is not bother. So, once M is know that means are you can calculate bending moment. So, bending moment and deflection you can get. So, after you are got the bending moment than what is can you do?

Student: ((Refer Time: 50:14))

Z is equal to that Z by T; X is equal to Z b y T.

Student: ((Refer Time: 50:30))

Is it; how I what we have definition has Z we have get Z is the X by T.

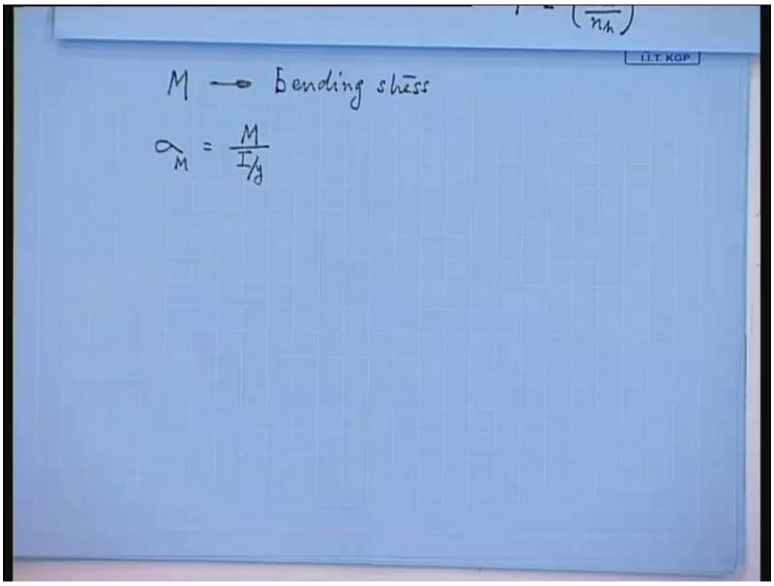
Student: ((Refer Time: 50:41))

No, T is not that T. T is coming from of course that will be there. Now, what is problem actually? T is very stiffness factor yeah, T is the yeah; you see remember this has been done with respect to Z; see this value this M t, P t, T. So, this is the most crucial factor. And M t is what? This we have to calculate, this is coming from your wave load; P t is horizontal wave load. So, what is M t? M t is P t multiplied by ((Refer Time: 52:01)). Now, this T is actually wearing with respect to these this the E I is you are the this is called the pile viscidity and the other value that is your n h term.

The n h term; if you want to get you have to derived it from the E S value or modulus of soil. So, the T is actually dinking your soil with the pile in this term. So, here now all this know values M t you know ,we have a getting from the horizontal wave load moment, P t is you are the horizontal load T is know. So, in both the equation of M, n, y this value is known. And you know in the set of drops actually what is used is this A y, by B y, Am and B m that is. Now, this actually is given in tabular form in the reason Matlock you can use that table sorry if we do not want use the table you concern this graphs.

So, this part is know and also the coefficient and known. So, now you can calculate your y and M spitted. Now, the reason that we have calculated y is the sometime is you know they limit on deflection for pile; pile deflection there is cannot keep on deflecting the pile according to load it will break. So, most of the clay clock association society they have a limit on y.

(Refer Slide Time: 53:56)



And, from this Am you can calculate; once, you know the bending moment you can calculate bending stress how you calculate bending stress? Sigma bending is bending moment divided by I y by pile this is right or wrong same thing in shift you can calculate. So, same thing will come out here. So, here we have calculate their limiting stress which is coming from bending once you know the I by y value; your pile is actually behaving like a this thing column or beam with a point load. The load is coming and the head actually this it is all somewhere. The only problem is the action is taken place below this soil; that is why the soil action coming because this n h. And we will stop here and the all after this we will we have some knowledge of this thing.