Elements of Ocean Engineering

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

Lecture - 41
Jacket Pile Selection (Contd.)

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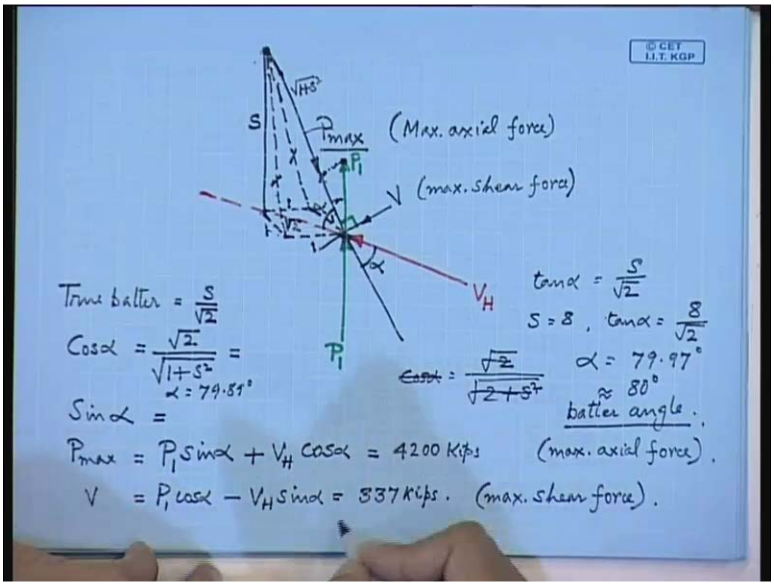

So, let us try to finish this problem that we were working out. So, the pile that is…

Student: ((Refer Time: 01:08))

Square root of 1 plus 1 root over 2. See actually, you take approximately this square root know this 1 square plus 1 square is how much? 2.

Student: ((Refer Time: 01:26))

Cos alpha is root over 2 plus this one, this one you take. So, this is same as this. So, this one you take same as this one. So, then cos alpha is this one is how much root 2. And this one is see this is root over 1 plus 1 plus S square. So, if you take this as similar to this cos alpha is this by this.

Student 1: Sir, then what is tan alpha?

So, better.

Student 2: One side is 2. Sir, 1 side is root 2, so the diagonal is other is root of square that is 2. So, that 2 will not be equal to S square 2 sides.

No this is given some approximate value. So, he has taken this as 1 1, if you take this as 1 1 1. So, you are saying that this one is root 2, this one.

Student: Sir, no sir, the base is root 2.

Diagonal is root 2, if you take this as 1 you take almost, you take this is as a rectangle or a square. So, this will be square root of 1 plus 1 this will be 2 root over 2. And this one he is saying, he is taking this as S square plus 1, square of this. And this all these are similar, his saying; only this is vertical, S is vertical and these are same, but; inclined, this one this one and this one. So, this one you calculate, how much this? This is root over 1 plus S square. So, this is also root over 1 plus S square. So, now you find out cos alpha root over 2 by this.

Student: Alpha is the ((Refer Time: 03:25)).

Alpha is this, angle with the horizontal.

Student: That line, horizontal line is root 2 line?

Horizontal line is root 2 line.

Student: Then, cos alpha will be root 2 by that line ((Refer Time: 03:43)).

Cos alpha is root 2 by this one, this one is 1 plus S square.

Student: ((Refer Time: 03:54)).

So, you are saying that this one and this one, you are taking, even that one also ((Refer Time: 04:05)).

Student: Sir, 1 plus S square is 65 sir. Root 65, root 66 is approximately equal.

This is how much here, 1 plus S square?

Student: Root 65 sir. And actual thing is root 66, approximately equal to.

Approximately, that is why he has made, first of all he has made an approximation here, this 1 1 1 1 even this as better. So, this is more or less same is not it, anyway? So, let us see. So, how much you are saying how much this will be?

Student: Cos alpha equal to root over 2 by 2 plus S square

So, cos alpha is root over 2 by this is 2 plus S square, but; this 2 is coming from where ((Refer Time: 05:15)).

Student: sir that is root 2 by 66.

This is root over 1 plus 1 we are doing. So, 1 plus 1 it is coming root 2 only.

Student: ((Refer Time: 05:29))

You are saying that this will be not equal to this, but; this how you are finding out. So, from here, this will be tan alpha you are saying that tan alpha will be S over root 2. So, you can find out from here, tan alpha S over root 2. So, from here, what we are finding out? The better angle anyway. So, you try to find of this, but; then what is this P max? And all these things you have to find out. So, alpha how much you are getting from this? S is given as 8. So, tan alpha is tan alpha according to use your calculation this is 8 over root 2. So, better angle, actually better angle we do not tell it like this. So, alpha is coming as how much?

Student: 79.97.

79.97. So, how much is that this is in degrees also approximately, you are getting this as 80 degrees, I think this 80 degree is more or less right. So, that means; is not much and from here cos alpha if I take this from how much you are getting from this equation. So, better angle is coming out to be 80 degrees, cos alpha is how much?

Student: Sir if you take this formula,

This one

Student: 79.89 this one.

So, from here alpha you are getting 79. 89. So, almost same anyway. So, use this you are able to understand better. So, this is your better angle, better angle is almost 80 degrees.

Now, P max you calculate? Now, if you want to calculate P max. So, you start from P 1. So, this is how much. So, this is P 1, P 1 is going vertically up. So, P 1 cos of 90 degree minus alpha so this is going vertical. So, this is 90 cos of 90 degree minus alpha, this is P 1 sine alpha, this is P 1 sine alpha. And next you take components both from your vertical P 1 and the horizontal V H. So, V H how much you are getting? So, and both will be in the same direction remind you. So, this is plus V H cos alpha is not it, am I right. So, this is your P max see how much it comes?

Student: P max is equal to P 1 by sine alpha.

P 1 by…

Student: Sine alpha, because P max sine alpha is equal to

No, this see you take P 1 is going; you take like this, take component on this axis. So, this will be P 1 cos of this angle. So, this angle is 90 degree minus alpha, P 1 cos 90 degree, sine alpha.

Student: P max cos alpha should be equal to P 1.

No, you do not go from, you calculate P max. You take components from P1.

Student: So, you are taking components along vertical and horizontal?

Yeah or you take component like this, component coming from P 1 and component coming from V H you add those 2. So, P 1 cos alpha from here, and V H is coming here, you add those 2 vectorially, it is added. See how much it comes? And next you calculate V. So, this is your maximum, what, this is maximum axial force. And if you calculate V, you will get maximum shear force. Better angle is 80 degree. Now, P 1 how much we have calculated P 1? P 1 was 4194. So, how much you are getting P 1 was 4194 and V H that we have calculated was how much, 1600 know? No, that is 1600 by 4, 4 piles were there. So, how much it is coming? I have lost that page. Now, shear is how much coming component from V H?

Student: P 1 cos alpha minus V H sine alpha.

P 1 cos alpha minus V H sine alpha so how much we are getting?

Student: 4200.

4200. So, this is ok 4200 kilo pounds. And the other one?

Student: 337 kips.

337 kips, but this is in which direction, this direction or this direction? This direction any way. So, this is a calculation of your maximum axial force, and what else, shear?

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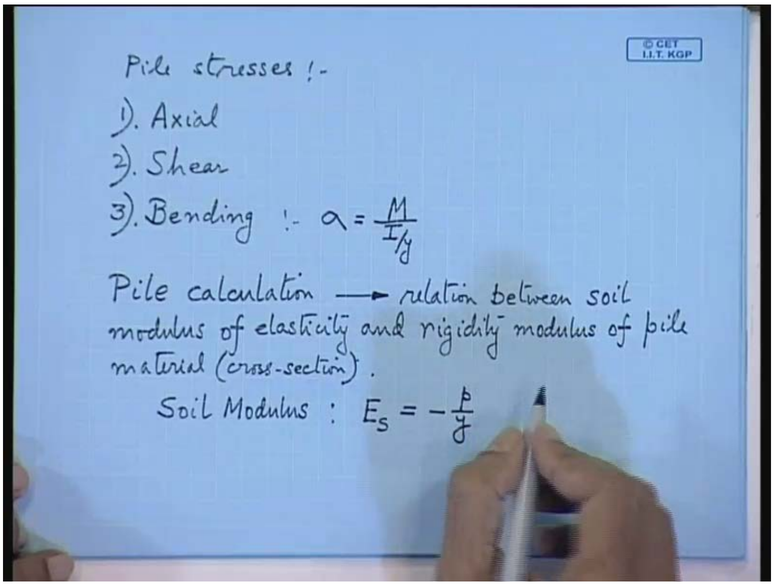

Now, piles actually you will find. There are other important pile stresses; first you calculate axial then, what we have calculated? Shear, and last one you need to calculate is bending. These are the 3 important stresses coming on the off shored pile. Now, this bending stress how you are going to calculate. So, this you have to calculate from sigma is equals to M divided by, what I by y. M is your bending movement at a particular section and this is your section modulus. Now, this we have to calculate, but; before we go in to this or this, this is quite complicated stuff.

So, this is now, the function of the pile you write pile calculation. Now, in the formula for this bending, you to have a relation between what, relation between soil modulus of elasticity. Now, actually this type of calculation you are not familiar with, because; most of you are familiar with the ((Refer Time: 17: 27)) calculations. Now, pile the scantlings if you want to calculate, you have to formulate a relation between soil modulus of elasticity, and what?

And rigidity modulus of pile material or rather you can write pile cross section. Now, if you want to do this then, you have to have a definition of soil modulus. Soil modulus is defined as E S is equals to minus p over y. Now, this y is not the axial deflection this is the horizontal deflection. Now, this we will try to found out. Now, before we go into this there are certain assumptions that are required.

Now, in our case off shore piles; now, what I am teaching is a very simple calculation, if you go in off shore you will find all combinations of loading that I have told you. So, off shore pile foundation, we have calculated the axial this thing was we find out the check from this. And here actually the maximum load is coming from the waves. So, you have to find a solution for laterally loaded piles. These types of piles are called laterally loaded piles. Now, we are studying single piles only; that means, we are not calculating pile groups, but; you will find those towers the platforms which are very large, they are called off shore towers. The towers actually they are going to say 600, 500 meters of water, you cannot drive piles to the corner columns will be too long. Now, what is normally done is you drive piles on the peripheral columns.

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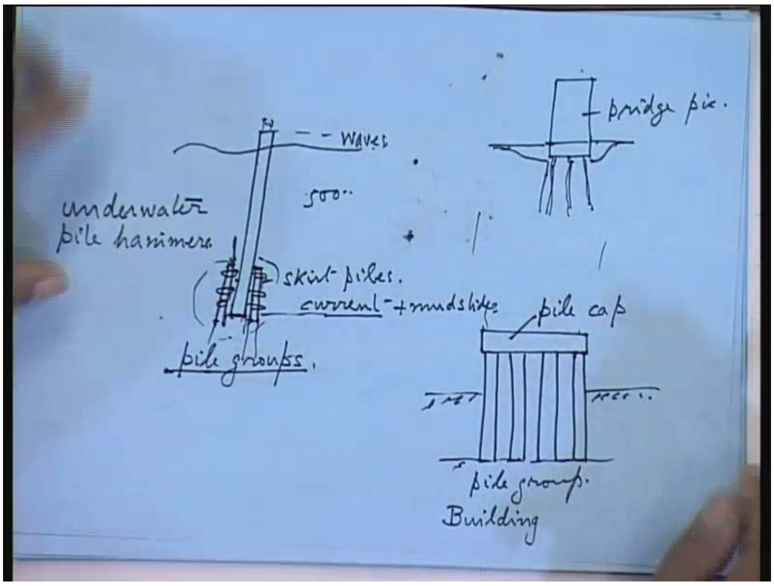

So, this is your say better pile, better angle you have calculated as 80 degree. Now, there will be pile sleeves like this. Now, through this you insert piles, you cannot insert main column piles through this, because; this will be the of the order of say 500 600 meters. So, normally this is the case and this called skirt piles. Now, this type of piles we want to study and this whole thing is a pile group. And these piles are given below the water surface. So, this is your water surface, you have to drive piles in this mode, this is called underwater pile hammers. So, you can see that this type of civil engineering job or structural engineering job is dangerous.

So, under water pile hammers very easy to drive piles from the above the sea surfaces mean sea level is, but; here actually problem will be there. So, this is called pile group. Now, pile group; when you want to study the mechanics, the mechanics will be slightly different, because; 1 pile will be interacting with another, because here, soil is getting compacted. Some soil will be pushed out and all these things will happen. So, this is called your pile groups. Normally, if you in civil engineering, all these foundation piles if you see there also have pile groups, but; they are not arranged in this fashion, they are more or less arranged vertically. In your case; this is going to have a slant or a better and at the top you find. So, this is the pile group.

So, this is driven inside the soil, this is your soil. So, this is you can say soil, this is a pile group. And at the head this is called pile cap. Now, you build the structure on the pile cap. Now, this is the normal case for a building; a building pile foundation will have something like around this the structure will come. So, you make a pile cap, this is similarly, in bridge pears that you go in the bridges, you will find the bridge pear is also on a pile cap like this. Bridge pear, why? A bridge is also you will find your pile cap normally you cannot see which is under the river bed. So, this is greatly loaded that is why you make a foundation like this on pile cap.

The pear is always built on piles, you will never find the pear on just sitting on the sea data, you cannot see the river bed you cannot see with your open naked eyes, there below the river bed you will find huge piles.So, you have to make the foundation strong. Now, here actually in the sea open Ocean the problem is much more, because; the surface would have waves then, you have large current. So, Gujarat coast is having current of 7 kilo 7 knots huge current will be there, you have mud slides. So, all these has to be catered so; that means, this cut piles are also quite long and to drive number of piles. So, anyway this is the scenario.

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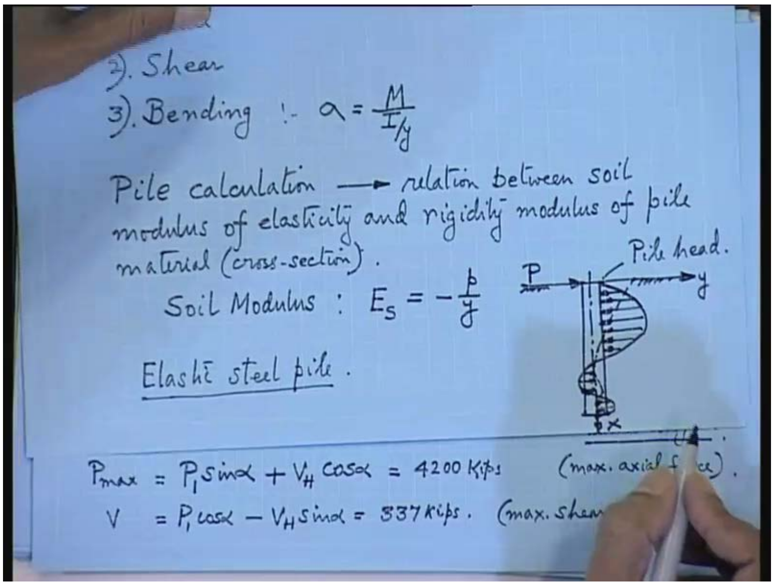

And, now the in the simplest analysis, let us study for a single laterally loaded pile. That is when you come to this section modulus calculation that I just now talked. That E S, where was that E S? Here this. So, if this was your case; that means, you find a pile will get deflected. So, this is your seabed. So, this is the pile now, why this negative sign is coming. So, in my calculation I have given a negative sign, section modulus calculation your pile is going to bend like this. So, let us say that this is your center line here, 2 things you have to study. One is the force that is coming from the soil. Now, you take say you apply your force see this is your y direction, and this is the direction of x.

This is the direction of x and you are giving lateral load. So, that means; P is horizontal and this is your seabed so; obviously, if you push the pile in this direction your soil is going to be exert an opposite force in the reverse direction. Now, as you go deeper down, you will find that this force is decreasing, because; at this is normally called a pile head. Now, if you push the pile in the right hand side, you may push in more soil at the surface where you go deeper down you will find lesser soil will be shifted. So, that means; at this you find the maximum force.

So, this is your the distribution of the force from the soil it is coming in this direction. And then again it is going to be reversed anyway. Now, your pile deflection also will come somewhere like this, it is your pile deflection. So, ours is a elastic steal pile, there are other types of piles also which we are not studying. So, this is the case of a elastic steal pile, in the present scenario. Now, offshore structures; when, they are first constructed there in shallow water then we had wooden piles, but; now of course, we have gone to hundreds of meters. So, that is no point in having that is wooden pile.

So, in this diagram you can see if the direction of force is in this direction then the deflection is in the opposite direction. So, that is why you give a negative sign. So, E S is minus P by y which is coming from the P is equal to k x formula straight, from that you can calculate now this is called the soil modulus.

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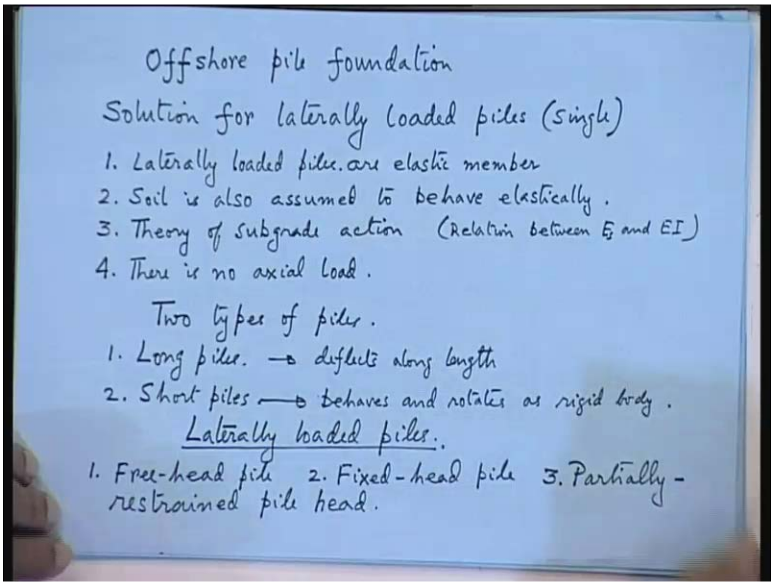

So, we will come back to this again, but; before we make the analysis there are certain assumptions, we should be careful about that. One of the assumptions is; so this is solution for lateral loaded piles. And number 1 is be laterally loaded piles now, in off shore actually, we find that most of the piles will have a better what we will study is without better in the simplest case. So, laterally loaded piles are elastic members. So, we are not making analysis in the plastic zone. Normally, failure of offshore structures you make it what is called a elastioplastic analysis, I do not know whether you have come across this term. In failure when you go in the failure mode actually. Anyway, you forget about that. So, we assume these 2 elastic.

So, the other assumption is soil is also assumed as elastic. Otherwise that E S is equals to minus P by y you want get. Theory of sub grade action; what is this theory of sub grade action? So, I told you; that means, we have to strike a deviation between E S basically, you have to strike a deviation between E S and E I. So, deviation between E S and E I you will find of this. So, that is called sub grade action. We are not taking any, there is no axial load so; that means, that the analyses that we are going to do right now is very simple. Simply you take a lateral load.

Now, 2 types of piles are there; 1 you write long piles, and the other one is called short piles. Now, these are short pile category is it behaves as a rigid body, behaves and rotates as rigid body. And this one is deflects along length. So, there is pile, this actually I do not know why the short pile we are not considering, we are considering the long pile. Now, long pile you find that after a certain length of pile it becomes so; that means, there is no pile load. All pile loads is taken up by a particular length of pile as I have given in that equation. That fiction and bearing equation that we have started out quickly.

So, once all the load is taken over. Now, laterally loaded piles; there are 3 types, one is called a free head pile, the other one is called fixed head pile, the pile head that I have already defined that is where it is entering the soil. The last category is called a partially restrained pile head. Now, off shored pile is belonged to the third category.

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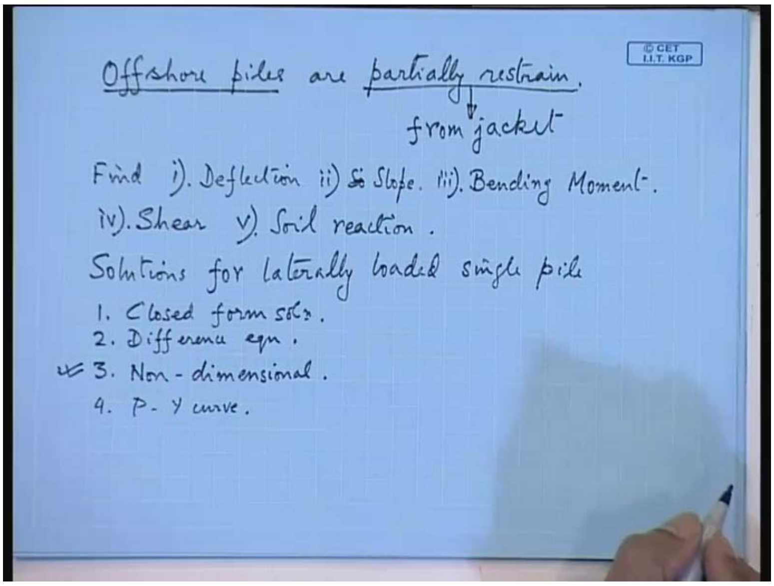

So, your off shored piles are partially restrain. Now, what is a restrain? When you are talking about free and fixed head then; obviously, there is a question of restrain is coming. So, that means; it is not free to rotator getting displaced. So, that is called a partial your, under partial restrain, this is coming from where? This is from jacket. Now, jacket is giving you the restrain that is limiting the horizontal displacement and rotation that is your restrained is coming. So, this is coming from off shore piles. Now, we have to find out this, find deflection. Now, this we have already same thing we have done for bending. Slope sorry, movement, bending movement then, calculate sheer, soil reaction.

Now, this method has been devised by a person called Vee Metalok. And there are number of solutions to the equation now, the one that we are going to study is the non-dimensional method. Now, that corner pile calculation that you have made is only for a single pile. So, solutions are numbered 1; you will get closed form solution. Number 2 is difference equation, the third one is non-dimensional method, there are other methods are there. This is called the P y curve etcetera, and all these things. So, we will study this one only non-dimensional method. Now, if you want to study this you first assume the pile to be beam.

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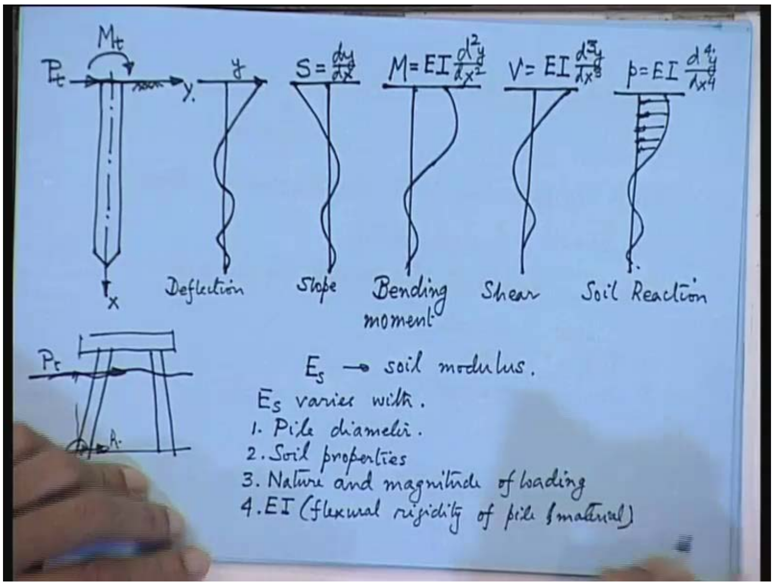

See, this is our pile we are considering only a single vertical pile say this is single vertical pile and this is your pile tip. Now, you take the X direction to go vertically down and the Y direction to be on the soil. So, pile force is coming here, on the sea bed. So, this you mark this as P or rather you write P t. Now, you are going to get another moment out here, this is M t and this is your ocean bed. So, you try to analyze like this now, this I have told you, your jacket is jacket column coming like this. Now, this is your sea bed and this is your wave. So, you transfer this force to here, you find an equivalent force and moment, if you replace this. So, there will be a forces acting under water line say this is P t. So, you; obviously, you make an equal force if you want to find a force.

So, this will be the moment like this and a force in this direction, transfer this force at pile head. You transfer this force at pile heads; you will get P T and M T. Now, you study your deflection. So, deflected nature of the pile will be, I am just drawing one vertical line. Now, what we have to find out your pile is going to bend like this. So, this is your y. now, in off shore actually, there are 2 things; one we are interested is I told you that our calculation was bending stress. We have found out the axial and axial at shear.

So, that is important and you have to find out bending stress from this and pile deflection. Now, sometimes most of the regulatory bodies they put a limit on this y. Now, that means; we have to find out this value of y from your slope. So, you write down the slope equation, in that ship guard problem how we started out remember, the same procedure we adopt here, your slope is around this line. So, this is your S equals to d y by d x.

Student: This is only vertical plain?

This is vertical pile.

Student: Slanting?

Slanting, we are not considering right now, slanting we have to take the projection and do this. So, better piles those are called better piles. So, let us study the simplest vertically loaded pile. There is no, I have not given any axial load also; this is just your say the movement that is coming from the waves. So, we have taken this at the sea bed; obviously, at the seabed you get one force and movement, if you take equivalent force. You put equal to P this side this side. So, you get a force in this side and this couple will be turning is not it. So, that is how you get an equivalent force and movement.

So, you calculate y from this is the deflection, this is slope. So, you integrate the slope curve; you will get your deflection. And how you will get this slope curve? So, this is the beam bending formula if you remember. So, we worked out an equation where you calculated the slope. So, bending movement equation; now, here you find this rigidity modulus coming in to your calculation. So, this E I what is the formula? You remember this. Next so this is your moment, bending movement rather. So, you have to calculate shear. So, shear also you will get E I. So, E I is your modulus of rigidity d cube y divided by d x cube.

Last one is the P 1, the load so this is going to vary like this. So, integration of the soil reaction will give you shear integrate sheer you get bending moment, integrate bending moment gets slope, integration of slope will give you deflection. The same procedure that we have followed for the ((Refer Time: 47:00)) bending. But here actually, you find that this problem is with E S, E S is called the soil modulus. Now, E S varies with pile diameter then, your soil properties, with this actually you have to find out from your lab experiment. Nature of loading; see all this you have to control. Now, working with soil is different from working with water. And the other one is E I, E I is called flexural stiffness or flexural rigidity of pile material. So, these are some of the values which you have to find out. So, it is not an easy job you think that you can do this.

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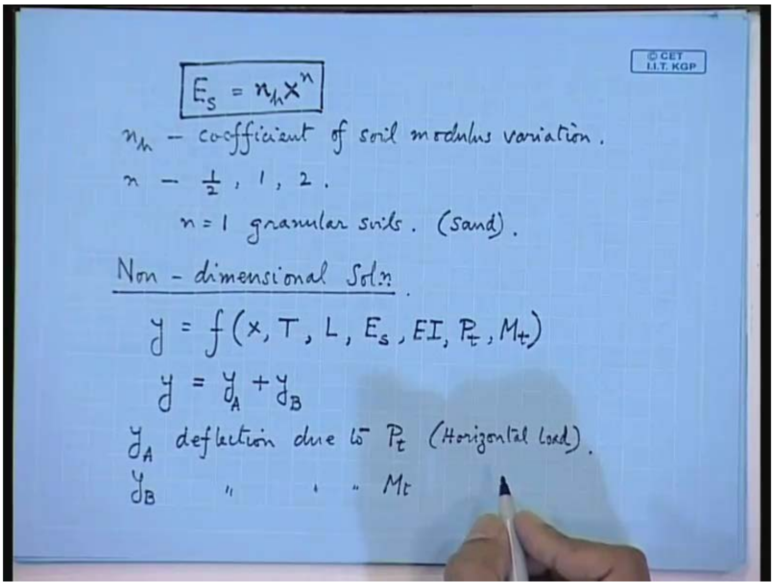

You strike a equation, when E S is normally given in this form. This is n h into X to the power n. now, n h is called coefficient of soil modulus variation. So, this you can say and the other is the n, this power x is already, what X? X is your pile depth that is you have taken X along this axis, this is your X. Now, this n the power you take as either half or 2, half, 1, 2. So, this is your power. Now, n equal to 1 is for granular soils. Now, in general case you take n equal to, granular soil means; sand. Now, in our general case you take this equation. So, any problem with pile foundation this n h and n has to be specified, n is this will be given in the table. So, you need not to worry about this.

And, other coming to the calculation that is your non-dimensional solution, you write pile deflection in this form. Say function of X, T, T I will tell you what is this T? L is now, all these are non-dimensional. Now, E S; E S is the sub grade modulus from soil, E I is your rigidity modulus. P t is what? The horizontal force coming at the pile head, M t is the venturing movement at pile head. So, this is your non-dimensional equation and deflection you write y equals to y A plus y B. y A is deflection due to P t that is horizontal load. So, there will be actually 2 type, 2 deflections, one coming from the horizontal load and y B is coming from the moment. So, these are the things which you have to find out.

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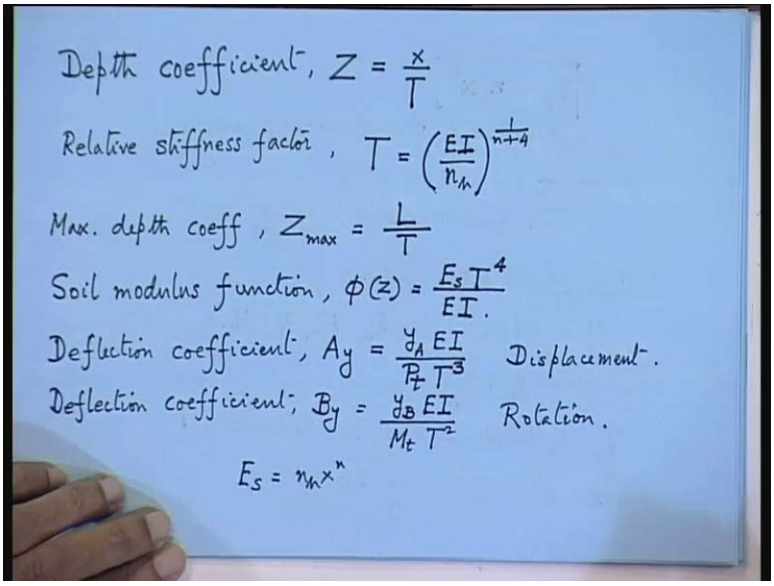

So, we are doing non-dimensional so; that means, in non-dimensional is depth. Then, what is T? T is called the relative stiffness factor. Here, that n h term will come, this is to the power 1 divided by n plus 4, this n and n h is different. So, that is called a relative stiffness factor. So, here actually this T is a term which links your pile modulus of rigidity with the soil that E S is coming. So, this is one then, the other is depth coefficient we have already defined. So, maximum depth coefficient, so what is the value of this Z max? If this is your definition for Z where, X is the depth of pile so; obviously, Z max will be the total length of pile that is given by L divided by T. So, that is called the maximum depth coefficient.

Then, you have soil modulus function. So, you can see that with a simple single pile we are having so much of equations. So, that is termed as phi of Z, this is given by your soil modulus E S multiplied by the rigidity modulus that is T to the power 4 divided by E I. Then, you have deflection coefficient. Now, remember there are 2 types of deflection we are considering that is one caused by the horizontal load that is your y A. So, this is called deflection coefficient A y. So, this is y A into E I over now, this is what type of deflection that is coming from P T so; obviously, this will be a displacement.

Now, there will be another type of deflection, this is given as y B. So, instead of P t this will be M t and T square will come. So, all these are non-dimensional terms is just because we are doing non-dimensional analysis. Now, this will give what. So, pile head is having both lateral displacement as well as a rotation. Now, you have to find out these 2. So, that is the main job now, E S equation that I have already given you, you use that. So, this is your n h X to the power n, the main exercise will be you calculate these values, this y S M V and p from these non-dimensional parameters and your job is complete. We will work out next class since, you want to go. So, Thursday afternoon all of you are free.