Elements of Ocean Engineering

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Lecture - 40
Jacket Pile Selection

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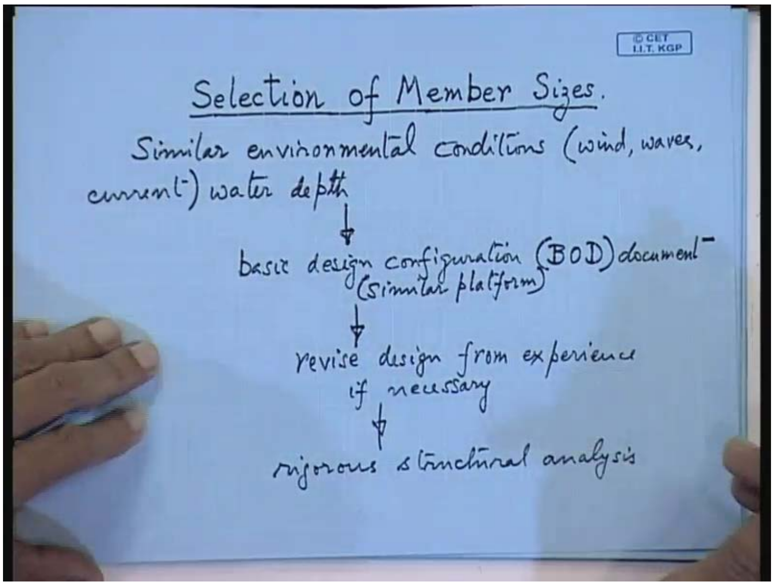

So, today let us continue with the selection of the piles of the jacket platform. Now here last class I have already told you that we will start from basic design of similar environmental conditions and water depth, similar environmental conditions and the other most important, here actually you will have to have data for wind waves and current. So, this you try to gather from the oceanographic or met ocean data. This is called similar data, and the other more important criteria is water depth, because the water depth actually dictates the size of the platform. Now with this you will start and then you come to what is called the basic design configuration.

Now all this information you will find in the BOD document that is the design document. BOD means basis of design document. Now after this, this is more or less coming from the similar platforms that have already been built or past experience. Now after this you can modify this; you revise design from experience, and after this you do rigorous structural analysis. So, this is the procedure that you have to follow. Now here actually you get more or less the rough configuration of the platform is by now it is ready.

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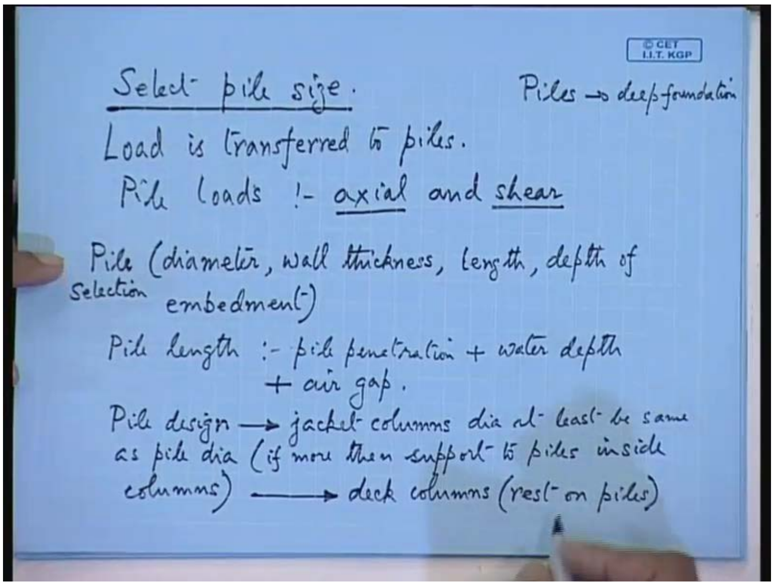

Now if you want to study the detail design the first thing that you have to do is select pile size. This is the most important parameter by which you go about the design; that is most of the load that is coming the load is transferred to piles. So, in case of fixed structures; in ships what is the start of your design in ships? Ships actually normally you start designing by your weight equation; weight has to be equal to buoyancy. If your weight is less than buoyancy then the whole ship will sink. So, here actually you have to find out that the pile has sufficient capacity to take care of. So, basically we will study these two types of pile loads will come; pile loads will be axial and shear.

So, these are the two loads which will be coming on to the pile, and the pile should be sufficiently strong to counter your accidental load. So, we will work out an example. So, this is your main starting point of the design. First you find out the basic configuration, then go to your foundation calculation. So, foundation calculation is you start from piles; this is your pile. Now what you have to design? So, pile diameter has to be found out. Then you find out wall thickness. Now what else is required? Pile, say, pile selection; this is your main area of study.

This is somewhat different from your ship design. So, pile selection diameter, wall thickness; another is length, length of pile of course, this has to be decided, and depth of embedment. There are so many things you have to do. So, all this you have to design.

So, here actually the pile length, pile length will depend on basically it will depend on the pile penetration, plus what, plus water depth; that is why I told you water depth is a very important criteria in case of jacket platforms, plus what that? There is another parameter which is plus air gap. Now these three things have to be taken care of; that is the deck of the platform has to be raised above the maximum crest of the wave. So, all these things the engineer has to decide.

So, this is the criteria for going about this. Now once this is done then the other things will fall into place, and load I will just tell you what are the loads? So, after this is over pile design is over. So, pile design is very crucial in case of jacket platforms, and we will work out one problem.

So, our piles are typically laterally loaded piles. Piles you will find they are called deep foundations, the other type of foundations but I think in this class we would not have much time in order to discuss this; they are called deep foundations. And what I was talking about and yeah this is the main structure which will transfer your load. So, pile design from here you come, the next is jacket columns.

So, if it is shallow water jacket your main piles will be driven through the columns. So, they call it jacket column diameter. Now please do not talk, it is disturbing me. Now jacket columns have to the larger than the pile diameter, but how much you will give? So, jacket column diameter at least should be the same as pile diameter.

Now this is the minimum criteria, but obviously, you have to have certain plate inside the column. So, normally you have each mode then support to piles. So, this you have to think about, support to piles inside columns very crucial. Otherwise, there will be vibrated load coming onto the jacket; just like your propeller vibration then for which passage of waves you get a vibratory load, the horizontal vibratory load will come. So, if more than support to piles inside columns has to be thought about. Now this you can do by putting some clips or some concretes leaves or grouting. So, this depends on the local expertise. So, now after this pile design you come to deck column design.

So, deck columns normally they rest on piles. Now remember these piles are not concrete piles. They are all steel piles, and the tip of the pile can be as thick as fifty millimeters; that is five centimeter thick; that is called the pile tip. So, piles have to be graven into the soil by pile hammers. So, these deck columns are going to rest on your piles. So, that means the pile has to be sufficiently strong to take care of the deck load which is coming on the piles. So, this is one aspect which will come.

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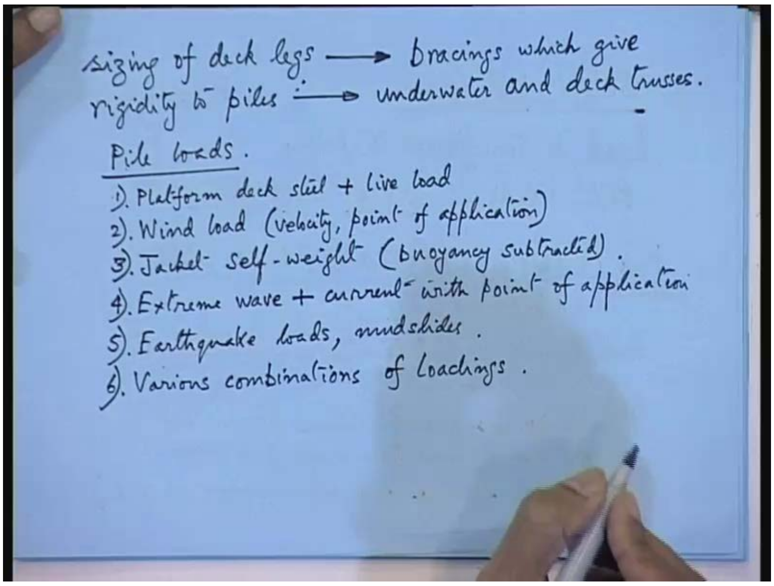

Now after this you formulate deck columns or sometimes these are called deck leg size. Sizing of deck legs, and this you have to configure, but this more or less will be the same as your column diameter. So, the most crucial part of the structural design is your column diameter that is the pile diameter. So, after this you go to your sizing of deck legs. Now after this you come to bracings; bracings which give rigidity to the piles. So, that is your jacket pile is pretty long, say, 100 meters, 200 meters long. So, that means in between supports if you do not have. So, it is going to bend. So, that is the bracings which should give rigidity to piles that has to be thought about. Next is underwater truss, underwater and deck trusses. So, these are to be designed.

So, this is actually the sequence by which the whole thing is arranged. Now this is coming to this lecture on member sizes, and the other thing that I have already talked about is that you come to this from your. At this stage you should be ready with your deck layout. Now remember this you are giving to the BOD that is the basis of design. So, this has already been conveyed to the client. So, this is very important before you venture out on this underwater truss, and the final thing will be your underwater and deck trusses and the pile size.

Now coming to this pile selection the major pile loads which I have already talked about pile loads, what are the pile loads? Platform deck steel, followed? Then plus the live load. So, this is platform deck steel is called a deck load; in civil engineering term that is this is not moving. Live load is your coming from the drilling operation. Now next wind load. So, wind load is very, very important in case of offshore structures, because that will be raise to your overturning moment. So, wind load I told you that is you have to find out the steady wind and the gust wind and not only that velocity, what else, say point of application. So, this has to be always determined point of application when wind is coming; we find out this centre of pressure or centre of area.

So, this has to be found out, jacket what else is there, jacket self-weight. Now this is your total weight minus the buoyancy. So, buoyancy calculation you have to do. At this stage buoyancy calculation you have to do, buoyancy subtract it, next. So, we have not gone into the wave loading as regime. So, extreme wave plus current; now this you have to configure with point of application. So, I am studying point of application, because you have to calculate; based on this we will work out a problem, and you will find that you have to find out the moments, then what else earthquake. So, this will come from the seabed, then you have these mudslides, then six, you do various combinations of loadings. So, now it is actually you have the computer. So, you create various combinations of loadings; you find out the worst-case scenario.

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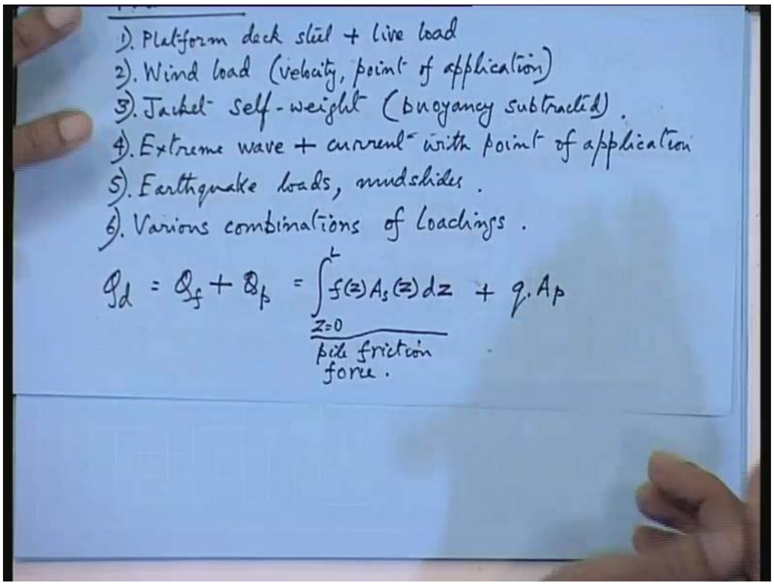

Now pile actually you have to design from what is called the carrying capacity of pile. So, this is your Q f plus Q p. Now this is going to vary according to the depth of the soil. So, f z A s, what else, this varies as z and d z. So, this is actually called pile friction force. Now the other force that will come is your endearing that is q multiplied by A p. So, this is your pile equation, but this is actually for vertical piles.

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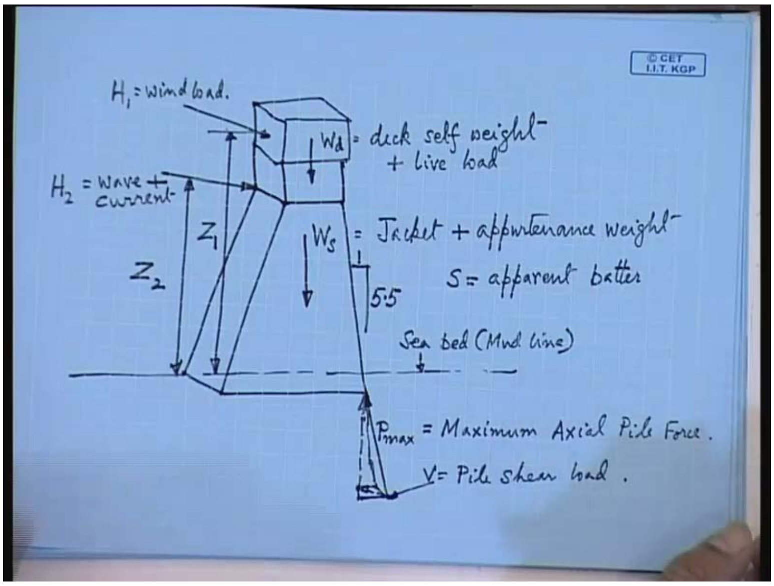

Now coming to the problem that we have to solve; so here if you have a pile, so this is your Q d. So, this is Q f plus Q p, and Q p is going to come here. So, this is your Q into a p, and this is Q f. Now Q f is an integral, because it varies according to the depth of soil. So, this is your equation. You find out from 0 to L. So, this force you come from and this. Now here are the problems; let us try to this things will be made clear. Suppose I give you a jacket structure like this. So, let us say this is idealized. Now your wind load is coming in this direction. So, this is let us say H 1. H 1 is your wind load, and here you will find that you are acted upon by wave and current. Of course, here the current has been added along with the wave, but current point of application may be different. So, wave plus current.

Now this you calculate, and this is your mud line. So, your jacket is on a seabed. Now seabed is called a mud line. Now you take moments about the seabed, and your lever arm that we have getting you will say that this is your z 2, and this one you try to find out this one. So, now this centre of application you have to find out from the centre of pressure.

Normally for a rough base you can find out the centre of the area along the bed. So, z 2 is there and what else is required? You find out this W d. So, W d is equals to deck self weight; deck self weight has to be calculated plus live load. So, this you have to find out. Sorry, you write this as W d, the deck weight.

Now there are two types of load; can you add? Self weight is now your static load and the live load is a dynamic load. So, that means you have to transform live load into your static load. So, that is normally done by where some time you have to divide by that acceleration or you multiply, say, your live load will be five times or four times your static load. So, those things you have to find out here. Now the other portion that is here you will get the underwater truss. So, that is called W s. So, this is jacket plus appurtenances weight. So, this is the appurtenance is the add-on to your jacket. So, jacket is normally this is what I have drawn is a bare jacket, but here you will find barge bumpers, then boat landings.

So, those are called appurtenances weight; that is something like that is on the hull they are the objects that are welded. Now here actually the main problem is piles are not vertical. So, you have to find out this ratio. In the problem this is given as 1 is to 5.5. And this s we will discuss; this is called apparent batter pile. So, this is not a vertical pile. So, this is a battered pile or pile which is having a certain slant order rate. Now you calculate the axial load that is coming on to the pile. So, axial load will be somewhere in this direction. So, this you derive this by P max. So, P max is maximum. So, what we have to find out? From this we have to find out the sectional area of the piles, pile sectional area and the pile diameter.

Pile diameter is more crucial, and pile length how you need to calculate? Pile length have to come from this situation. Now this you have already found out, and from this you try to find out the maximum pile cross-sectional area and the pile thickness. So, this is maximum axial pile force. Now remember your pile is having a batter, but what you calculated is a vertical load, is it not. So, you have to transform this. So, you will get at this junction you try to make a force diagram. So, this is your vertical load, and there will be another load which is coming in this direction. So, that is called the horizontal load.

Now at the base you create a. So, this is not going to, this is going to a parallelogram. You construct a force parallelogram. And remember your pile, this is your pile axial force, and your piles shear will come along in this direction. So, this is the direction of v or pile shear load. Now you calculate this maximum pile axial force and pile shear load from where? What is your data? Anyway you try to find this out, and the other thing that is going to be of importance is platform footprint.

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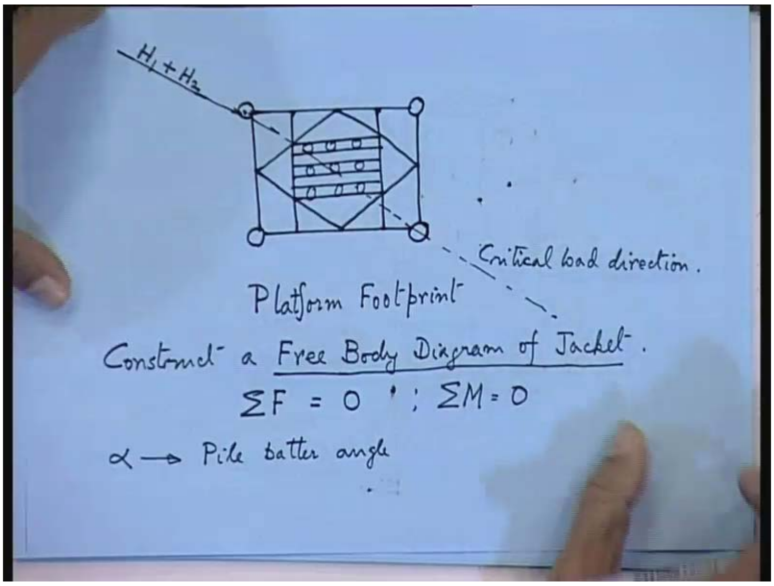

Now I told you, you select the pile orientation and the force orientation in such a way such that you get the worst loading condition. So, this is your corner piles, anyway. So, my diagram is. Now this is called a platform footprint. So, remember in your platform design you should not stop at the truss level, but you have also to design the base, because the platform that your designing should have certain base area or supporting area, okay. So, now this has to be configured at this stage, and you will find that the conductor pipes that will come into the platform, you have to make certain arrangement for fixity to the platform at this level. So, these are your conductor pipes. So, I am just giving in some idea. So, this is called a platform footprint.

Now you have to find out from this evidencing will be larger in size than at the deck level, is it not. The base area has to be greater than, I just now drew the platform on the other side. So, you can see from this diagram that means the base size is very very large compared with the deck level. So, how you configure this? So, this will be influenced by pile batter. So, pile batter how you select. So, that means what you have to do is you construct a basic free body diagram. So, in static analysis first thing what you have to do is construct a free body diagram; that is what I have actually.

This is actually your free body diagram. Construct a free body diagram of jacket. Now after this, what you do? Suppose you are doing static analysis in any structural engineering problem; basic structure problem is going to start with a formulation of a free diagram, where we have to find out the forces where the forces and the moments and the lever arms will be there. Now next thing you find out sigma f. This should be equal to zero in all the directions and sigma m it should be taken care of. So, basic free body diagram has to the constructed, okay; that is why this footprint will come, and from this you will find out this pile batter. So, pile batter, this alpha you have to find out, pile batter angle. Actually they do not say angle in the sense simply mention they tell you the batter.

So, this you have to find out from the force equations that will be coming from the free body diagram. Now here what you do is the footprint that you have constructed, you can see that the worst-case scenario is going to come in this direction; that is your worst loading condition. So, this will be the direction it should come from here. So, this is the direction of h 1 plus h 2, followed. So, this you write as. So, this has to be critical load direction. So, that means all the piles are not going to have the same load.

So, pile design, pile design how you are going to do the pile design? So, suppose your load is coming from one corner in the worst-case scenario. So, that means the worst loading you will come in this pile, say, if you take your jacket. So, your load is coming from this direction. So, that means the main overturning moment is being registered by this corner pile. Now what happens to this pile?

Now those of you are not interest you please go; you give your attendance, I think that sheet has come here and quit. I do not like any disturbance in the class.

Now the minimum pile force is going to come in this direction. So, that means you have to decide the directions of the forces that are coming onto each corner pile. So, this is the worst-case scenario, and you find out this critical pile direction. Now the footprint that you have drawn, so pile batter angle has to be designed; this is the jacket footprint or platform footprint. Well, now what is going to happen to this? Suppose your load is coming from this direction, what is going to happen to the jacket? So, that means this jacket is going to rotate like this. So, it is trying to topple over.

Now it is the toppling thing will be done by means of the overturning moment. So, that means pile footprint is going to rotate, but once you have to decide on which is the rotation. So, that means it is going to rotate about this arm. So, let us say that you have footprint that you have seen let us for our case here it is given as we are having a square footprint, say, this is your dimension is, say, a . So, then what is the going to the dimension of the diagonal? So, you will make another diagram like this for footprint.

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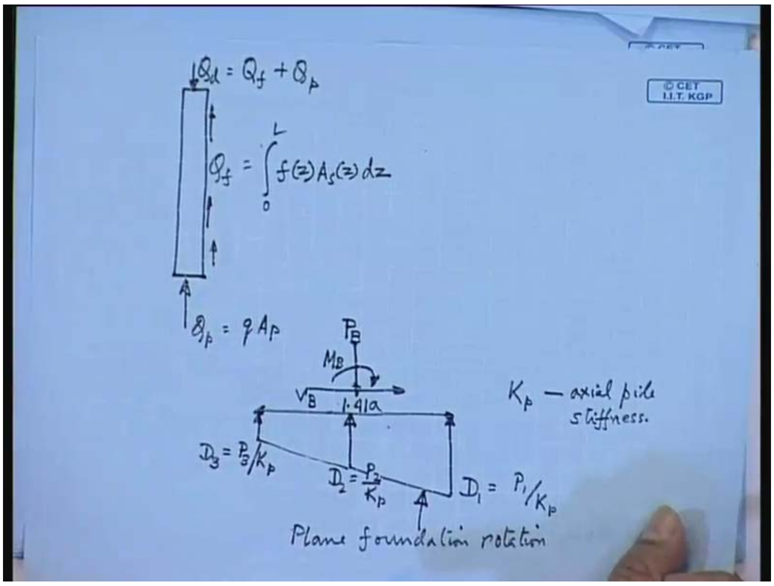

So, this is your foundation rotation is going to take place. So, you tell me the diagonal length. So, if you take the footprint size. So, this will be square root of a square plus a square. So, there square root of 2 a square. So, that is going to come as 1.41 a. So, that means the whole thing is going to rotate about this your moment arm. So, that means pile rotation is being caused by a force which is having a moment arm of 1.41. So, all these calculations all this you are. So, the maximum vertical force that is coming will come at the corner right-hand bottom most corner pile. So, that is the critical load that is coming out here.

So, how will you calculate the displacement of pile displacement is d 1 is equals to p 1 divided by k p. K p is your pile stiffness; that p is equal to k x formula. So, these are all simple equations. Now at the middle, so that means, if this we have taken you are looking from this end, okay. So, here this is your corner piles and this centre pile is coming somewhere from here. So, this you say this is your d 2. So, d 2 is the displacement coming at the centre pile. So, d 2 is equals to, but your pile load is different. So, this will be p 2 over k p. Now the piles of course, you have design with the same diameter.

So, all the piles will have the same diameter, but you have to design them from the worst loading condition; that is the worst loading which is coming on the corner pile. So, the corner pile is the most critical pile which has to be examined, but all the other piles which you have driving through the other columns; obviously, you are not going to shorten the diameter, is it not. You have to do with the same diameter, because at one time the load is coming from this direction; again it may come from this direction, this direction, etcetera. So, you do not know. So, this is the thing that is coming out here and because you are having the base rotation of footprint rotation; so this you do this as if you join all these vectors you get this line.

So, this is called plane foundation rotation. So, here actually you have to be very careful, because the ultimate load is being transferred to the pile foundation. So, pile foundation rotation has to be very thorough, and k p you write this k p as axial pile stiffness. Now we have not examined the bending stiffness. So, this is your axial pile stiffness. Now here since the pile is rotating there will be two forces. One, you will find because of these h 1 and plus h 2 which is coming in this direction; the whole platform is going to shift these. So, piles will have a shear; shear force will be coming here and a toppling moment.

So, your shear force you write this as v b, and you have a rotating moment and also a vertical force which is coming will be at centre of this 1.41 a. So, this will have a moment which is going to be m b. So, these are what is called the free body diagram of your platform footprint; platform footprint has to be carefully configured. So, now you calculate how much is going to be your angles.

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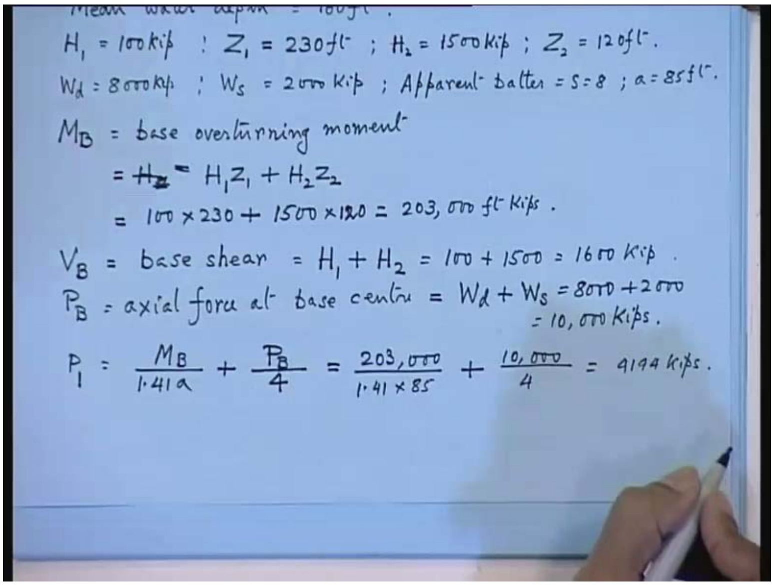

Now in this problem that has been given we do for mean water depth. Now mean water depth has been taken; I am sorry, this is fps units. So, I have not transferred this. So, this is 160 feet, and h 1 has been taken as 100 kilo pounds. Now the height z 1, z 1 is height of the deck, centre of pressure for wind. So, wind is giving a lever arm of 230 feet, and the wave and current is at, say, h 1 has h 2; h 2 is 1500 kilo pounds. So, remember the wave force is more than ten times your wind force. So, here we are getting z 2 that is the centre of action of the waves is 120 feet from mud line. Now w d is your deck weight that is 8000 kilo pounds, and the structure weight that is the jacket weight is only 2000. So, you remember how important is the deck?

Now apparent batter is given as s. So, this is 8, and the a that is the platform footprint is 85 feet. So, we have taken a square footprint. Now the first thing that you do is calculate M B. Now M B is denoted as base overturning moment. So, what is the overturning moment? Overturning moment is simple, h 1 z 1 plus h 2 z 2. So, this is simply h 1 multiplied by z 1. Sorry, this is h 1 z 1 plus h 2 z 2. So, how much is this? So, h 1 is 100, and your z 1 is 230 plus h 2 is 1500 multiplied by z 2 is 120. So, this works out to be 203, 000 feet kilo pounds. So, that is the first thing that you calculate is the base overturning moment.

Now next is base shear. Now all of you, you have done your free body diagram, is it not. So, how will you find out base shear, shear force? So, shear force is h 1 plus h 2. So, this will be 100 plus 1500. So, this is only 1600 kilo pounds. Now you calculate P B. P B is the force that I have told that is coming from the vertical load. So, that is an axial P B is denoted as axial force at base centre. So, this is simply your vertical load. What is that? Your deck load that is your w d plus jacket load w d plus w s. So, this comes as 8000 plus 2000. I think this has been given in the problem, yeah. So, this is only 10000.

Now you find out the maximum axial force that is coming onto the pile. Now we will be examining what pile. So, you see this diagram. So, this is your maximum pile force. Now this maximum pile force is coming because of p 1, okay. Now you try to find out p 1 and at the corner piles; that means the piles which are at the diagonally opposite corner. So, this piles; so if your maximum pile is critical in those direction. So, here you will find p 1. So, that is your maximum pile force. Now diagonally this diagram if you look from this direction you will find the maximum is coming here, the minimum is coming at this region at the opposite corner, and the summary in between you are getting this d 2.

Now if you want to calculate the load on these two piles if you calculate this as p 1, this should be of much, p 2 or p 2? This should be p 3, and these two will be p 2 and p 2, followed. Your load is coming from the corner h 1 plus h 2 direction. So, now, you find out p 1. So, you footprint rotation is being caused; you look into the moment. So, you find out the force that is causing this moment. So, p 1 is vertically it will take care of p b and the moment that is causing m b. So, you find p 1 is m b divided by what? Lever arm is 1.41 a, footprint rotation is suppose a force is here and you are taking moment, here you can find out that there is a couple.

So, the couple divided by this 1.41 a. So, that is the part of p 1, and the other part; this we will assume equally distributed on all the four piles. So, your p 1 consists of two parts. One is coming from the moment m b, and the other is coming from the axial force p b. So, now you calculate this, how much is the m b? A has been given as 85. So, this you just check with your calculator. So, this will be 203,000 divided by 1.41, and a has been given in the problem as 85, and p b we have calculated as 10000, is it not. So, this is 10000 and divided by 4.

So, this should give as 4194. You just check with your calculator whether this calculation is right or wrong, but p 1 is not the axial force. Now you try to make a larger diagram at the corner pile; so corner pile configuration along with batter. So, you try to make a blowup here force diagram.

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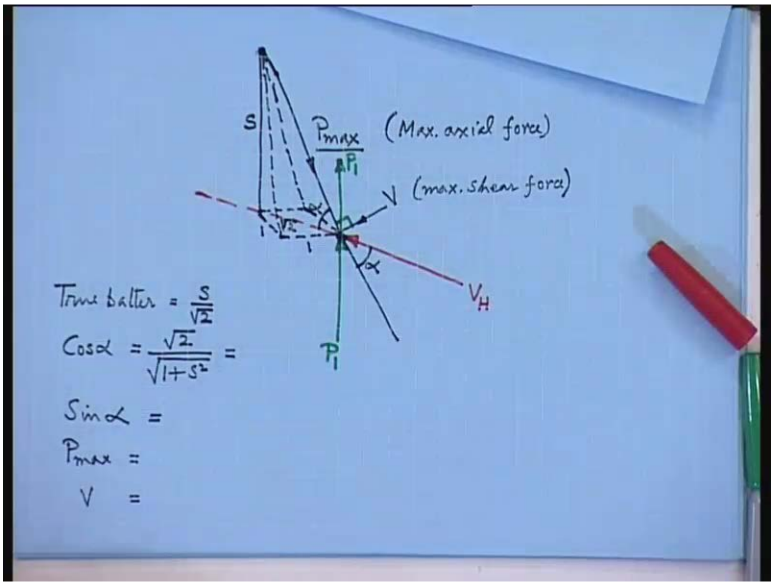

Now if you draw the force diagram that is coming out here you will find that the downward force that is going to come from the pile is coming in this direction. So, this is your p max, and this is what you have to calculate, okay. Now you have to calculate another force which is coming at right angles to the pile. Now this is what force? This is your pile shear. So, this is your maximum axial force and this is what maximum shear. So, these are the two forces which are going to tell me about your cross-sectional area of the pile. Now what you have calculated from the problem is this one, but from the problem we have not found out p max; rather we have found out this force that is your p 1 force.

P 1 force we have calculated as how much? 4 1 something, and what you have calculated? Now the critical direction is along this; that is along the diagonal. So, that means you have calculated the horizontal force but not the pile shear. So, this is coming as this is what; this is v h. So, this we have found out only p 1 and v h, but you have not calculated the axial force neither the shear. So, this angle you take this as 90 degrees. This is your 90 degree angle. So, now you find out from geometry. So, what are the things that have given parameters? So, pile geometry and footprint geometry will be required now. So, you drop a perpendicular.

Now this is denoted as s. This is calledtter. You draw a parallelogram of forces. So, you draw a force like this. Now this is the thing that you have to find out. This angle is alpha; this is called the batter angle. Now you make this diagram. Now how much of p 1 is coming onto the column? This is the line of action of p 1. Now this angle is how much? So, this is alpha know. So, this angle is alpha. So, now you find out. So, this p max will have a contribution both from p1 and v h. Now if you take this as 1, and this length will be root over 2, square rout of 1 plus 1 square, the diagonal of the parallelogram. Now this is your diagram. So, 10 alpha is s over root 2.

Now you find out cos alpha 1 plus s square p max p max. So, this length; so this length you take same as all these sides of the triangle. So, this diagram is how much? Square root of 1 plus s square; this is the diagram. So, cos alpha will be root 2 over this one, followed? So, now this is how much? You calculate, now next you find out sin alpha. So, this you do in your hull, and from this you find out p max and v. So, once we have found out p max and v our problems is solved, but this you remember you have to make two force diagram; one for the platform footprint, and the other is for the corner pile. So, this is simple equations. So, next class we will finish this, and then go to lateral loading piles.