Elements of Ocean Engineering
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Lecture - 33
Mooring Systems (Contd.)

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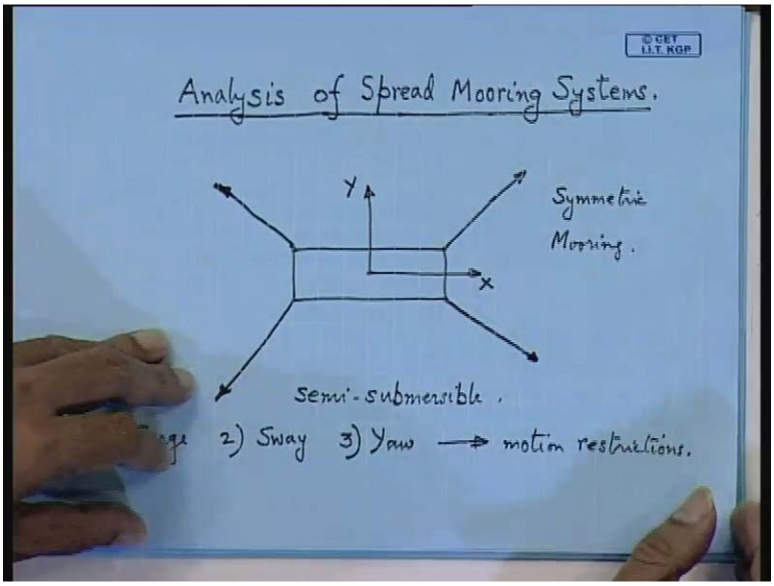

So, today we will just try to finish these mooring systems; so analysis of spread mooring systems. So, this is let us try to study this. Now this spread mooring system is typically employed in offshore platforms, say this is your semisubmersible, yes come in come in. So, in the simplest place let us say that this platform is anchored by four anchors. So, this is a spread mooring system unlike the mooring systems that you will see normally in ships; that is you have one anchor, ships in reverse that you have seen they are normally anchored with one anchor. So, that is called a bow anchor.

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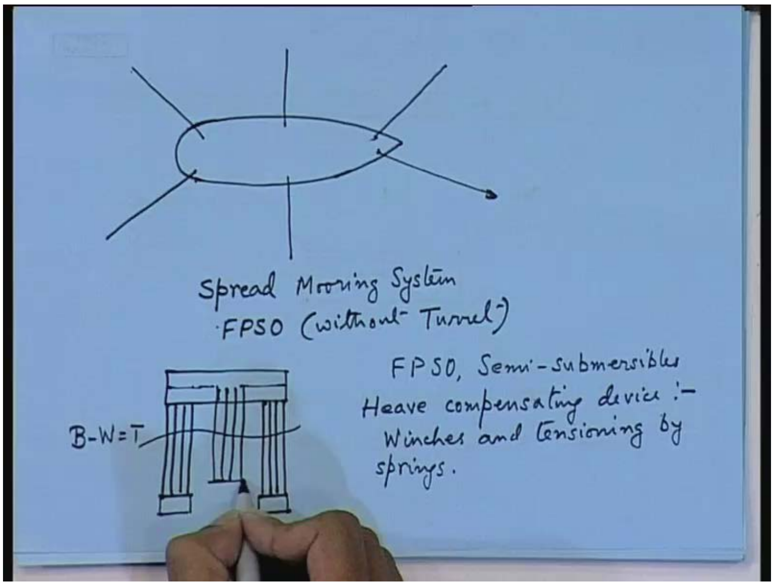

So, I will come back to the mooring systems of ships later on because I am doing this in detail. So, this is your ship. Now later in the class we will see how the anchoring is mooring is done. So, normally you have your anchors coming either from this hosepipe or from here, and the ship is anchored like this. Now if you want to control the motion of the ship normally they drop an anchor, but it is not necessarily done normally; they do it by means of one anchor only. But in this case you will find since you are restricting the motion of the semisubmersible. So, this is your semisubmersible.

So, what are the motions that are going to be restricted? So, it is allowed to have surge sway and. So, these are the motions that are going to take place; heave also we are not at present studying heave motion. So, the motions that we will be studying is this surge. Then you have sway motions. Sway means the thought ship motion that is in this direction, surge is in this. The other one is what? Heave the rotation about this axis, what it is called? Surge is in this direction, sway is in this direction, they yaw this motion; this is called yaw motion. So, these are the three motions let us try to restrict for a semisubmersible by means of anchoring.

So, these are the motion restrictions; motion is fixed. Now what you do is you find out the, now all these motions are taking place in the what? So, this is your, so this is the C G of the semisubmersible; you take it out here. So, this is your y direction, this is in the x direction. So, this is x and y, followed. So, T H is out here. So, this is a case of symmetric mooring. Now actually what I have drawn is only four anchor lines, but in actual practice you will find for your FPSOs and etcetera, if you do not have a turret? Actually this diagram I have already shown you last class. You have got to have a mooring like this, and also there may be mooring wires. So, this is also a spread mooring systems FPSO, FPSO without turret.

So, different offshore platforms will have their different mooring systems. So, this is an example of FPSO without turret mooring, turret mooring actually you show that; that means here the motions are again that are going to be restricted as your surge sway and yaw motions. Now heave if you want to restrict the maximum restriction that you can impose normally is in the t and p; t and p has lot of heave restrictions. So, that is because of the tension in their tedders. Now this tension in the tedders how you calculate tension? That is buoyancy minus weight is the tension in the tedders. So, this you have to adjust the tension in the tedders in order to restrict TLP heave.

So, TLP actually the design is of this platform is made in such a way along with the tedders such that they are practically there is no heave motion, but heave in semisubmersibles or in FPSOs will be there; you cannot actually strike down heave motion. Now if you want to do this. So, all the semisubmersibles and FPSOS; so, FPSOS and semisubmersibles they should have what is called a heave compensating mechanism, heave compensating device. So, that consists of winches and tensioning mechanism, you have winches. Now this is also quite complicated; some diagrams I will try to show you winch and a tensioning device. Now this tensioning you can effect by means of huge springs, tensioning by springs.

So, this mechanism also is called a heave compensating device, because normally this you will find in FPSOS and semisubmersibles, and these are situated on the, say, intermediate deck on the twin deck of the platform, somewhere out here you will find. So, this is your marine riser is coming. So, if you are in the offshore field. So, you have to think about the mooring systems, and what else you have to think about? Now mooring systems are efficient; mooring systems will, obviously, restrict motions of the ships, but then also designed on.

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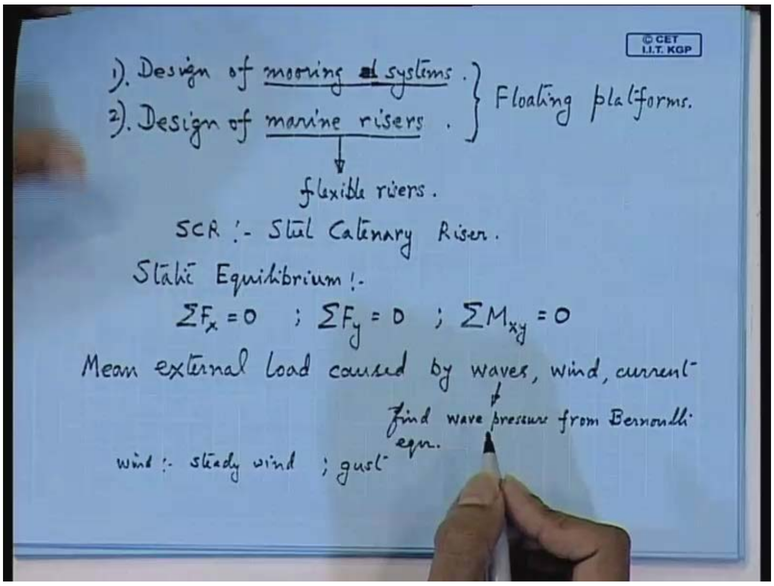

These are the two things which you have to concentrate on design of mooring systems. Now you have to figure out how many mooring lines you are going to give? So, whether here I have given one, two; this is the minimum one, two, three four five six, but again you can have number out here also. So, all these are anchor points. So, I will show you the diagrams or pictures of these types of anchors. They are huge anchors, they are called gravity anchors. So, you have to find out t horizontal for all these cases, and find out the components in this x direction, and find out component in the y direction, okay . So, design of mooring systems, what else we have to sorry. Number two is design of what; very crucial I am telling you.

The two most important things which you should know, design of mooring systems, design of marine risers. Now these are very crucial for floating platforms. Now this marine riser I have already talked about that here actually you can have flexible risers. This is a separate area of study altogether. So, this we can discuss when we discuss about offshore pipelines and risers. Offshore pipelines of course, they do not have flexible joints, but marine risers you have flexible joints. And nowadays they are doing away with the steel risers at. They are called sometimes you have SCRs. SCR is called a steel catenary riser. So, this is actually a separate area of study, steel catenary riser. So, these are the two things; anyway we will come back to this riser if we have time. So, these are two focal points of your floating platforms.

So, here actually you do not bother too much about the resistance and proportion part of the ship, because you are not transporting cargo from one location to another, but these are the area of concerns. Now, what you do? Say, let us take this simplest case. Now here you have this t horizontal will come here; so, your angle is making an angle of psi with the horizontal. Now you take a component up in this direction and also a component in the y direction. So, actually in the static analysis what you are doing, for static equilibrium what are the forces? So, you have to calculate sigma F x equal to 0, then sigma F y equal to 0, and you find out this; sigma moment of x y will be equal to zero. So, this you find out from the environmental forces, followed.

So, this is your origin. Now you just take, say, let us take one force, say, T H. Now here you find out mean external loads on vessel or rather you write mean external load caused by waves, wind and current. So, wave force how are we going to calculate? So, you have to calculate all these three forces, mind you. Now waves actually I have already talked about how to calculate the wave force. So, wave force calculation is done by what? Find wave pressure; this has to be integrated from what, from Bernoulli equation. So, here actually you have to find out what type of waves you are getting out here at this region? And ultimately you have to calculate the pressure wave pressure which is coming from wave velocity and acceleration velocity potential.

So, this has to be calculated. Now current, the other one is wind. Wind actually I have told you they are of two types. One is called steady wind, and the other is called gust. So, these actually there are explicit formulas with the wind velocity wind velocity square for the ted surface to wind, shape and shield factor; gust how are you going to calculate? Now remember in the ocean engineering environment all these load calculations are very important. So, these are actually load calculation. Now wind actually velocity you will find.

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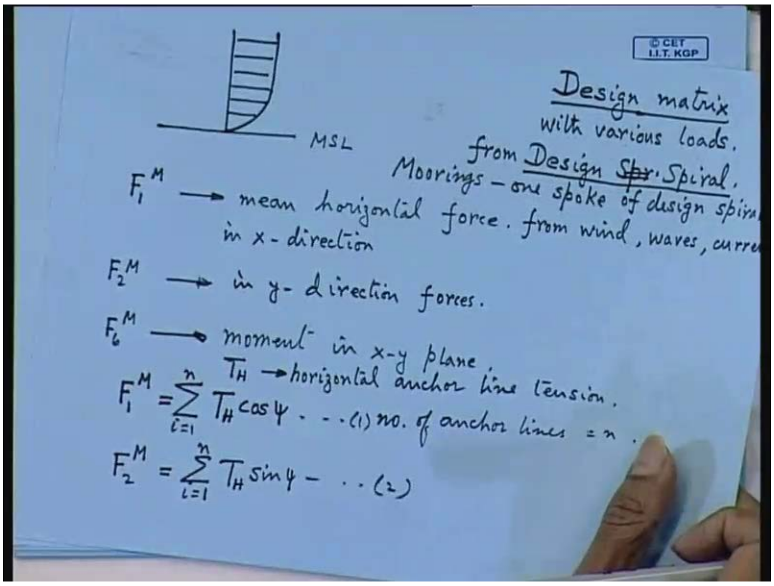

So, this is your mean sea level, MSL. Now wind velocity has a profile which is uniform above ten meters from the mean sea level, and then it goes like this. So, this I have already talked about. So, now you find out the velocity from here. So, this is your wind velocity profile. Current also has more or less the same profile, or it may be different actually according to the intensity of the current. So, this is actually either you have to do or you find from oceanography; oceanography calculations you have to make. So, after doing all this you calculate this T H.

Now F 1 M here what is done, find out the mean, say, F 1 M is mean horizontal force. Now I told you in this book actually what they have said you precede with the mean, but normally in the design scenario you do not do calculation with one load, is it not; that is very dangerous. Here what you normally do is I told you, you take the hundred year storm criteria. Then you take some mean or median values, say, go to fifty year storm or twenty five year period, like this you calculate. So, always you have to remember whenever you are doing calculations you perform what is called the design matrix. You never give 1 value to your client in offshore any design; they do not go like that, is it not, because he is not going to get convinced, and offshore is very tricky business.

First of all it is very costly, and the other thing is safety requirements are very stringent. So, perform design matrix with various loads. Now remember your loads are also not one offloads. So, you have to calculate loads from all these waves, wind and current. And then you have to combine all this and find. Here of course, the calculation has been done with only one value. So, here you see that mean horizontal force from this wind, waves and current, but when you go to any of these offshore engineering firms they have sophisticated programs. Here of course, this is only 1-line solution, wind, waves, current. So, that is normally not the case. So, you have complex programs to take care of that.

So, at the end you produce a design matrix from what is called, you have to formulate your design spiral. And in ship design I think you are standing ship design. So, any design you will find that this, sorry this is spiral; you will formulate this. So, here actually moorings are just one spoke; moorings actually you find one spoke of the design spiral, but mooring itself is a very complex calculation like most of you are doing in orthoflex. So, anyway; so, here actually this is a mean horizontal force in x, say, let us call this in x direction. So, when you study your design your marine design or ship design the professor or teacher will talk about this design spiral concept.

Now F 2 M you will find out the same thing. So, this is in y direction, and the last one is what you have, what is this F x y, or you can call this as F 6. So, this is the y direction forces. Now what is F 6? That is the moment, moment in x y plane. Now F 1 M if you want to do this you find in the x direction I have said. So, if this is T H; T H you write horizontal anchor line tension. So, what is F 1 M? So, this is T H cos psi, okay. Now here you have to do it for, say, if there are number of anchor lines, you have to do for all the anchor lines. So, you take i equals to 1 to n.

So, you write anchor lines number of anchor lines, the semisubmersible may have other anchor lines. So, one anchor line might come out here; another anchor line we have here. So, you find out all the force components in the x direction. So, this you write number of anchor lines. So, this is denoted by n. So, the same thing you do for the y component. So, y component will be how much? So, you do it for anchor line i equals to 1 to n. Now this will be T H cos phi or sin phi? So, the last one is the momentum. So, you find out what is the moment.

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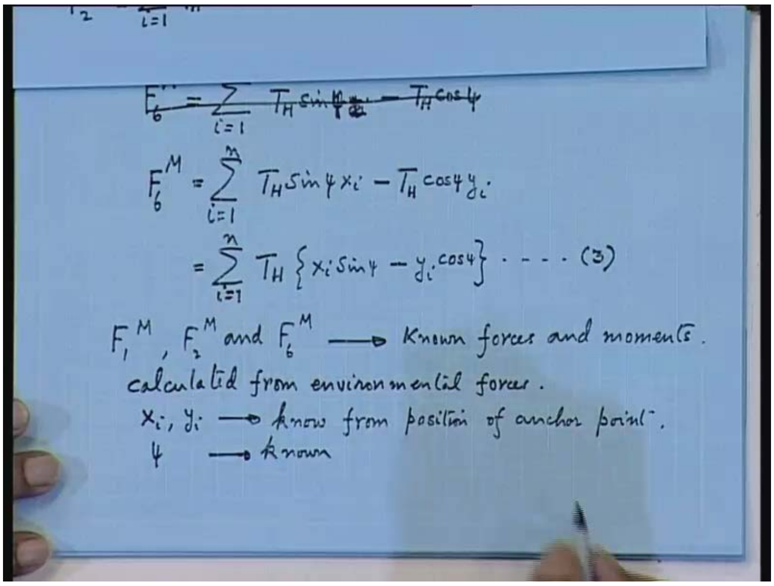

So, moment, what is the moment? So, this is, say, T H cos phi. So, what moment you are getting? So, this giving a clockwise moment about of T H cos phi multiplied by this one. So, that is how much? So, your x coordinate is let me write down. So, this point x and y let us say this you define this as, say, x i y i point. So, x is this horizontal direction, so T H cos phi minus y and the other one is going to be how much? So, the other one is going to be. So, this direction it is T H cos psi, and this direction this is T H sin phi. So, which one, you take one positive and the other negative. So, this one will give you if take anticlockwise as positive.

So, anticlockwise moment is becoming T H sin phi multiplied by y i, and the other one if you take as negative. So, this is your clockwise moment coming from T H cos phi. So, this is T H cos phi, and how much is your lever arm; sorry this is psi not phi. I am making a mistake. So, this is y i, isn't it. So, the other term is T H sin phi. So, this has to be multiplied by x I, sorry. Anyway let me write this again. So, the F 6 M this is equal to sigma i equals to 1 n. So, from here which one we are taking as positive? Anticlockwise is positive. So, that is T H sin phi multiplied by x i. So, this is T H sin psi multiplied by x i. The other one is negative. So, this is becoming as T H cos psi.

Now what is your lever arm? Lever arm is only y i. So, here then we can take this T H thing out. So, F 6 and the yaw moment we are getting this as i equals to 1 to n multiplied by T H multiplied by, this is x i sin psi, and this is minus y i cos psi. So, like this you have to calculate. So, here you can see these three formulas that I have written. So, this F 1, F 2 and F 6, this you get from the environmental forces. So, that has to balance your this T H cos phi T H sin phi and this is moment. So, from these equations you find out T H. So, this is your one, this is second equation, and this is the third equation.

So, you write this F 1, F 1 M, F 2 M and F 6 M. These are known forces and moment, known forces and moments calculated from environmental forces, followed. Now what are the other known values x i y i. Let us find out; these are also known from position of anchoring or right position of anchor point. So, these are also known values. So, only unknown is. Now this psi; psi is also known, or you can find out because you will be suspending all these cables. So, you can measure with respect to psi; obviously, it will be some average value, because at any point of time your semisubmersible will always be acted upon by environmental forces. So, you go on board this semisubmersible you will find that this platform is having this kind of motion. So, psi will also be an average value.

So, the average only you are calculating. So, psi is also known. So, T H you can find out. So, once you know T H, then obviously, you can calculate anchor line tension. So, anchor line tension is that t phi cos phi w is going to be this anchor line tension T H. So, this is the gist of the problem what you have to calculate from the environmental forces. Now what happens if F increases? Now suppose suddenly you will find a storm has come; so, then what you are going to do? Now next there is a problem out here which we will solve later on; you will find this semisubmersible is acted on by a storm. The captain of the ship is not aware of this. So, he finds the whole semisubmersible to be going forward. The surge is taking place.

So, now, how you are going to limit; so, that means his aim is to bring the platform to the original position of this, is it not. Suppose the cable lines there is no stiffness, 0 stiffness. Now if there is 0 stiffness in any structure then what is the result of that, say, complaint structure; this anchored vessel is also a complaint structure. It is not having any stiffness; that means with the environmental forces this will go like this. So, there is a swept. So, it will be swept away. Now, to prevent this sweeping away, so what you must do? So, there is a surge motion is going, and this whole semisubmersible is going in this direction.

So, what is the captain of the ship has to do? So, these are some of the problems. So, the thing is the ship is moored; the storm has come down. Immediately you cannot lift up the anchors; it will take time, is it not. Now at any cost so there are 2 options that he can do is you stop the production of oil, abandon it. So, that means that is called in the offshore they have a special term for this.

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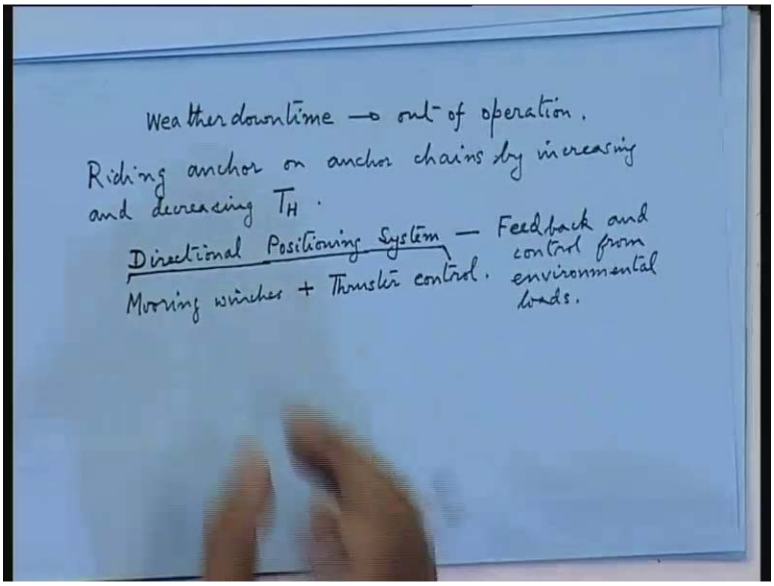

They call it weathered downtime. Usually the platform is down and out of operation. So, this is also not a very desirable features because of the fact is during this period you will not be able to lift oil from the oil well. So, that means the platform is no more producing oil; it is having a weather downtime. So, weather down time is a very crucial aspect; you come across this when you have studied this. Now suppose the captain of the ship wants to prevent weather downtime. So, he is under pressure no he have to deliver so much of oil to your tanker, because that is the economic output that you are getting from the platform; you are selling so much of oil.

So, in any business normally the quicker you take out the oil so much is the profit. I mean you are able to sell off now. So, what he has to do? He has to bring the platform to the original position. So, that he can only do by changing tension. So, you ride the vessel on anchor. So, that is called riding anchor, riding anchor on anchor chains.

So, this we will try to calculate. Suppose how much anchor riding you have to do in order to bring the ship again back to the original position? So, this is by actual the equilibrium or static position where I can take out the maximum quantity of oil as this is only the surge motion. So, there also we sway, there will be yaw motions, etcetera, but those have to be controlled.

So, normally you try to ship. So, that is this is normally done, riding anchor on anchor chains by increasing and decreasing T H. So, normally you will find nowadays most of these ships they are equipped with what is called a DP system, directional positioning systems. So, this is actually a feedback and control mechanism inside the ship and the captain of the ship; that is he looks into the terminal, and he can see what is the ride of the vessel, and how much tension he has to increase on all the winches? So, remember all these are winched.

So, here you have an anchor winch; at this end also you have an anchor winch. So, normally you increase the tension or decrease. So, either you have to pay out anchor line here or you have to retrieve anchor line here in order to bring the ship back to your original position. Suppose you are having this sway motion then you have to do it for alternate either this one or this cable. So, you have to have a control on the winch, mooring winch.

So, all mooring winches are now centralized along with. So, this is mooring winches plus you may have thruster control. So, all these are now centralized into a DP system that is called a directional positioning system of the ship; essentially a feedback and control mechanism which is a feedback and control from environmental loads. So, nowadays the master of the ship he does not have to do all the hand calculations.

So, all these are programmed inside the computer and only he has to increase or decrease the winch. And on the nice computer screen you can see the position of the vessel, and he has it brought back. So, this is a DP system. Now this normally the equations I have given you. So, those are equations that are fed to make this feedback and control, now coming to your problem. So, let us take a problem since some of you are interested in this.

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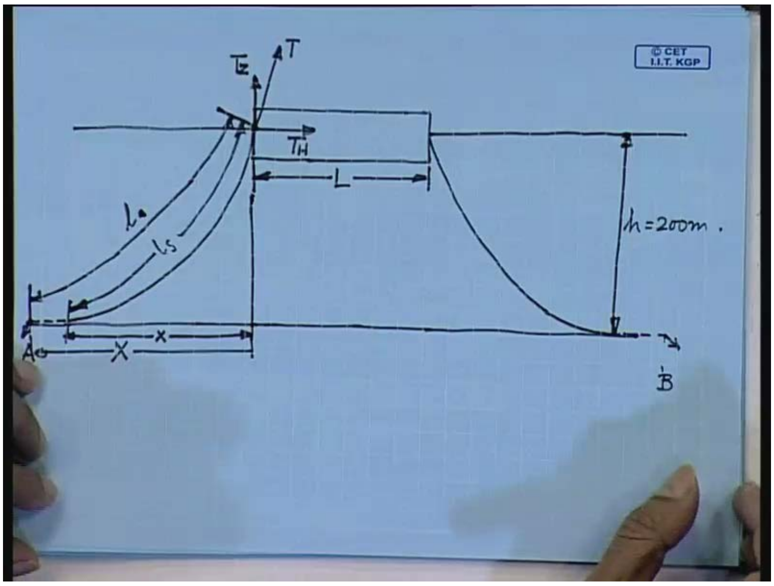

So, here is the semisubmersible or a platform. Now semisubmersibles they hardly have a single anchor line. You will find semisubmersibles normally having four, six, eight anchor lines. So, this is a case of a semisubmersible, let us take an idealistic view. There are two anchor lines, say, one forward and one after. Now anchor lines usually have a portion of the cable lying flat on the seabed; you will never find anchor lines which are completely taut. So, these are steel catenary anchor lines. So, another anchor line is coming out here. So, that is also lying flat on the sea bed. So, this is the point of anchor line, say, this is at a, and this is point b anchor b.

Now the length of the vessel is there are suppose this is L, followed. Now here what is the total length? Total length of anchor line that you have paid out is from point of anchor to point of suspension on the cable. So, that is L s; I am not good on drawing. So, anyways this is the L s value, sorry this is L, do not write L s. So, this one is this diagram I have already drawn in your earlier class. Now this is your L s. Now you tell me how you are going to heave anchor? Now when you have to heave anchor, so this distance is L minus L s. Now you make it zero. So, when you make it 0 you will just pull in the anchor line out here.

So, this is your anchoring point, and your chain cable is going to go like this. So, this is your T H, and this is the vertical direction. So, heaving you can never lift anchor in this situation. So, you have to bring in the anchor line and then make L into L M and then it will go up. Now see this is the situation. Now we have calculated this value of. So, this was small x or capital x? So, this you have calculated this as small x and capital x is from this end. Now this is the situation; your depth of the water depth is given as 200 meters.

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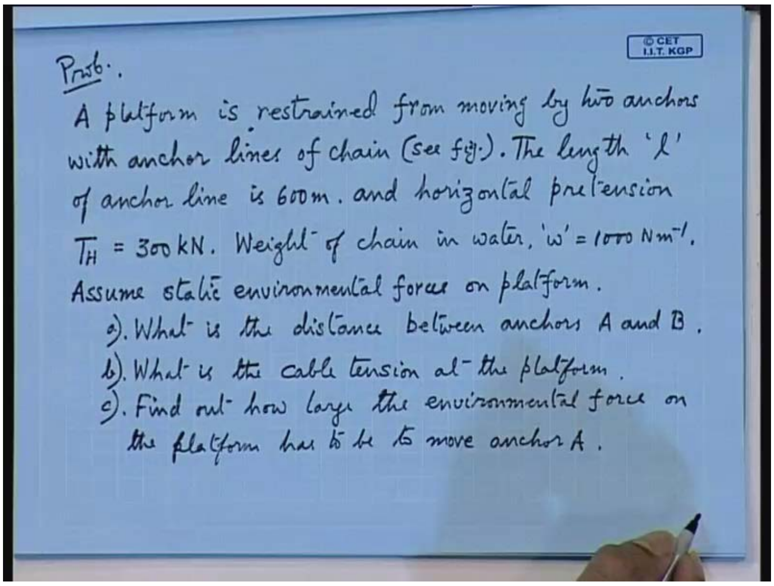

Now you write down the problem. Say, a platform, you just follow this figure you know; say, a platform is restrained from moving by two anchors with anchor lines of chain, and in bracket I am writing see figure, okay. Now the length l of anchor line l is out here; this l means total length, the length l of anchor line. You write this is given in the figure is 600 meters and the horizontal pretension; horizontal pretension you write T H. So, this is equal to 300 kilo Newton's, followed. Now weight of chain in water; weight of chain in water means the absolute weight corrected for buoyancy. So, that is called weight of chain in water. Now this is given as weight of chain in water.

So, this is what small w is it not; small w is given as 1000 Newton per meter. Now you assume static environmental forces on platform. Now you have to find these three. a, you find distance between anchors A and B. Number 2 that is b, you write what is the tension at the platform. And number three is little bit difficult the c is, find out how large the environmental force on the platform to move, say, anchor A. Now anchor A has to be moved to original environmental force. So, these are the three items you have to calculate. So, without environmental force you calculate distance between A and B. So, what is the distance between A and B?

So, this is the condition of what symmetric anchor line, is it not? So, you have made the problem simple. So, these are the symmetric anchor line. So, this also will be if this you have taken capital X. So, same thing will come out here. So, this is 2 X. So, A B distance is how much? See if you want to calculate A B you find out. So, this distance is L. So, this is 2 x plus L. Now you just employ your formulas to find the X.

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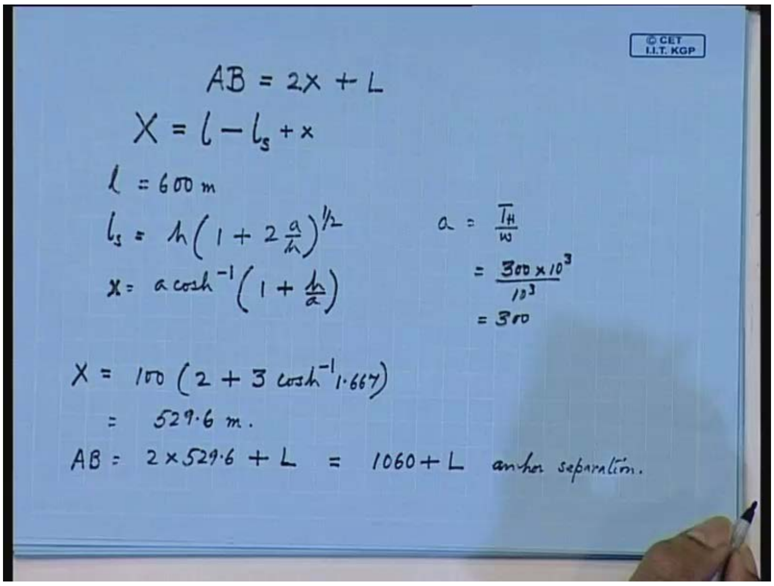

So, calculation we start A B is equals to twice x plus L, but what is the capital X? Now capital X if you remember. So, we have already worked out as total length of chain minus L s; L s is the suspended length; L s actually the substance stands for suspended length. So, L s is the suspended length. So, L minus L s plus what, plus this small x, followed. Now this capital L you know or it has been given. So, now the problem that we are coming is about this small x. So, capital L is equals to 600; that has already been given in the problem. Now what is this L s we have to find out? Ls formula you have got suspended length of chain cable.

So, we have derived the expression in last class; you just look into your notes. Now one thing you do not know is the value of A. So, if you want to calculate this, so 600. So, this is minus h 1 plus 2 h. So, what is the formula for L s? So, I have given you that no, but how I have not worked out. So, small x is having the hyperbolic term, means small x is. So, this is h into

Student: 1 plus 2 a over h.

1 plus 2 a over h. So, this is to the power half, and small x is coming to the hyperbolic term it will come out. So, you find out the values. So, this is a cos hyperbolic inverse; this is the troublesome part. You have got your calculator? 1 plus, so find these two values. Now what is this a?

Student: a is T H by w sir.

A is T H by w. Now this you can immediately calculate because T H is known. T H you just substitute as 300 kilo Newton's, and small w is given as 1000 Newton per meter. T H is 300 kilo Newton's.

Student: Sir, a is 300 kilo Newton's.

Oh, a is given. So, this is coming as, yeah. Now 300 kilo Newton's means 300 into 1000 divided by 10 k. So, this is a you are getting as 300, h is known. So, you find out this small x, and you can find out L s also straightaway, found out. You find out L s and small x. And using this formula the value of a is known means small x is known.

Student: Sir, capital X is 529. 58.

Or I do not have a calculator; you have to find out the value of cos hyperbolic inverse.

Student: Sir, capital X is 529. 6.

529 you are getting?

Student: 529. 6.

So, this capital X will come out in my expression; you work this out. So, this is 100; this is 2 plus 3. I am getting you check whether you are getting this value or not 1.667.

Student: Yes sir.

But how you have found out cos hyperbolic inverse? It is there in this calculator. So, this expression is okay, this one. So, this is coming as 529?

Student: 58.

529.6. So, here this is your answer 529.6. So, that means A B is coming as A B is 2 multiplied by 529.6 plus what? The value of L has not been given, the length of the ship. So, therefore how much this is? Now you remember this capital X value, because later on we will find that we have to increase T H. So, A B is coming out 529.6 multiplied by is how much. So, it is close to 1060, is it not? So, this is 1060 let me write plus L, right or wrong? You take as 530.

Student: Sir 1059.16

1060 no, 1059 point something. So, this is your separation. So, this is anchor separation. Now the second part you find out line tension, what, break. No, he has shown two.