Computer Methods of Analysis of Offshore Structures

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Module - 02
Lecture - 20
Tension Leg platforms

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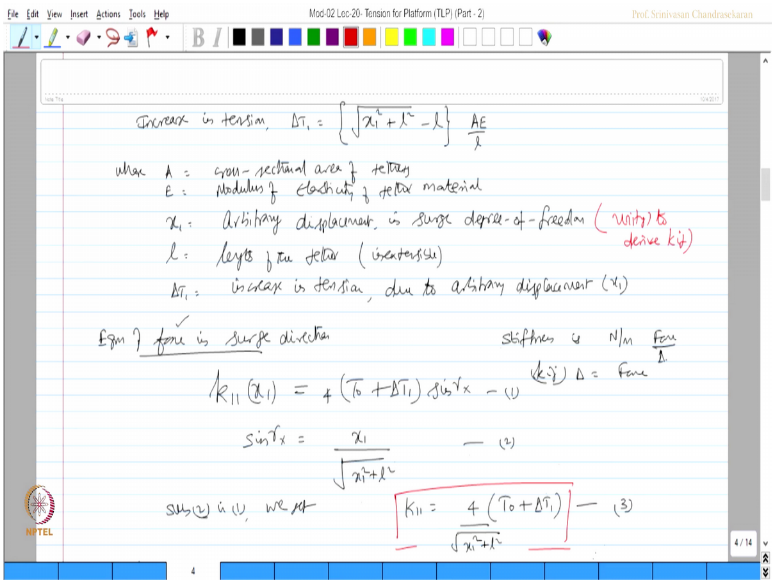

Delta T 1 as x 1 square plus l square the whole root minus l multiplied by AE by l, where A is the cross sectional area of tethers e is modulus of elasticity of tether material if it is T we already know the value of steel x 1 is the arbitrary displacement in surge degree of freedom, l is the length of the tethers, tethers are considered to be inextensible.

So, delta T 1 is increase is tension due to arbitrary displacement x 1 to be very clear this arbitrary displacement is considered as unity to derive the stiffness matrix. Now having said this let us write down the equilibrium of forces in surge direction, I request you to refer to this figure again.

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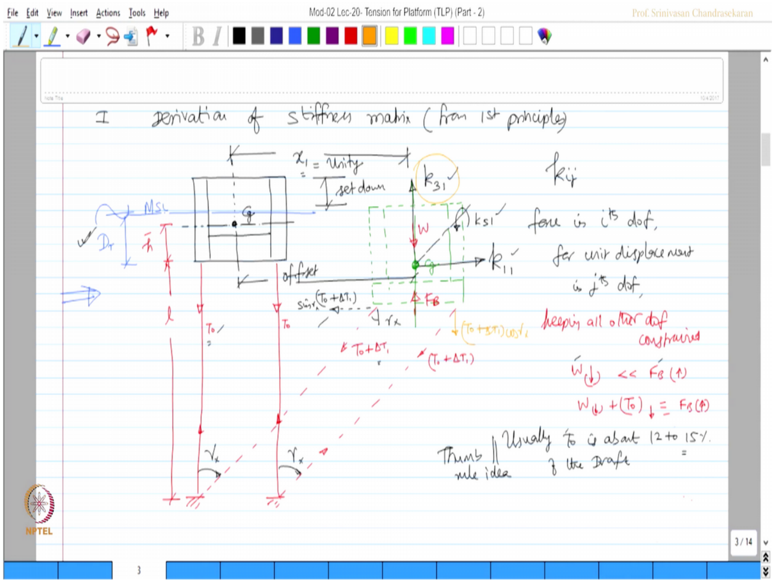

There are forces acting in the surge direction k 11 and there is an component of this in the x axis, if this is gamma x this value is also gamma x.

Obviously, I should say this will be T 0 plus delta T 1 of sin gamma, x because the vertical component will be cos gamma x and this is sin gamma x; so k 1 1 and this. So, our opposites in direction as you see from this figure. So, write the equilibrium of these forces you know stiffness units actually are in newton per meter that is force per by displacement.

So, if you want to find the force I should multiply the stiffness coefficient by the displacement to get the force, I am writing the force equilibrium therefore, I should say k 1 1 into x 1 it should be equal to we can see here this force will compromise, which will be T 0 plus delta T 1 of sin gamma x, but friends please see TLP has got 4 legs or 4 columns each column will have a set of tethers.

So, each tether value is T 0 there will be 4 such legs, further from the figure sin gamma x is actually equal to x 1 by root of x 1 square plus l square you can see from this geometry sin gamma x will be x 1 by root of this value this value . So, now, substituting this let us say call this equation 1 and equation 2 substituting 2 in 1, we get k 1 1 as 4 times of T 0 plus delta T 1 by root of x 1 square plus l square equation 3.

So, this is my coefficient which obtained from the surge displacement, naturally no force in sway direction.

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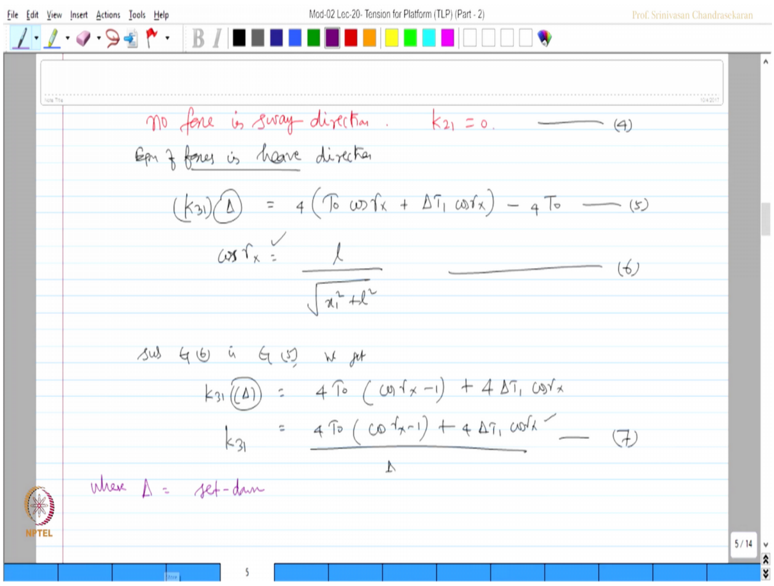

And therefore, k 2 1 will be 0, let us talk about equilibrium of forces in heave direction. So, I am talking about equilibrium in the vertical axis now heave direction. So, you see k 3 1 will be 1 component k 3 1 will be 1 component in the heave direction and the vertical component of this will be T 0 plus delta T 1 of cos gamma x.

So, now I want to write the equilibrium for this which will be k 3 1 into delta will be equal to T 0 cos gamma x plus delta T 1 cos gamma x there are 4 such legs minus initial tension of 4 because I am looking only for the difference right. Also from the geometry cos gamma x is actually l by root of x 1 square plus l square. So, substituting back this is equation number let us say 4.

This equation number 5 this become 6. So, substituting equation 6 in equation 5 we get k 3 1 into delta will be 4 T 0 cos gamma x minus 1 plus 4 delta T 1 cos gamma x again substituting for cos gamma x, we say 4 T 0 cos gamma x minus 1 plus 4 delta T 1 cos gamma x by delta this becomes my k 3 1 which is going to be a 7.

Now, you know the value of cos gamma x and substitute them and write in terms of l by x 1 square plus l square now what is this delta? This delta is nothing, but the set down. So, delta is the set down effect. So, naturally when we apply a force along x axis the rotation about x axis will be 0.

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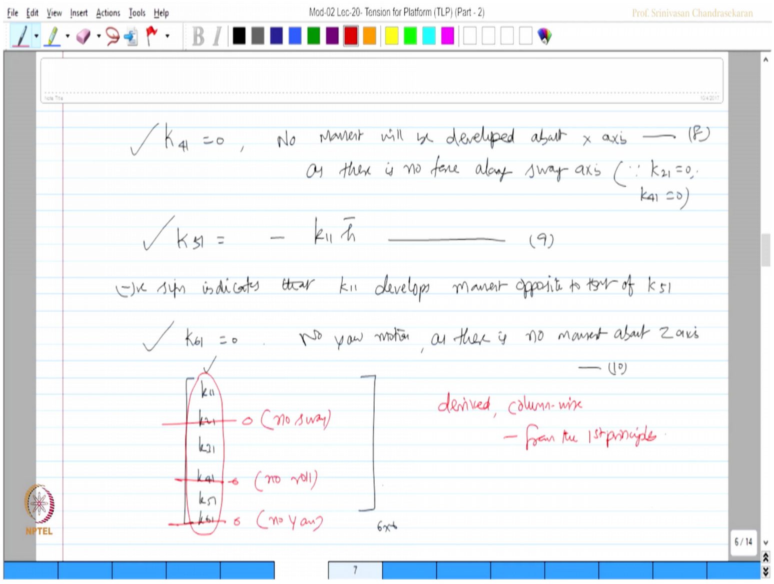

So, k 4 1 will be 0 because no moment will be developed about x axis as there is no force along sway axis that is since k 2 1 is 0 k 4 1 will be 0 ok.

Let us say like this. So, if I call this as equation number 8 let us talk about k 5 1 the rotation this is going to be this is anti-clockwise about C g let us take the moment about the keel right . So, this distance is h bar. So, I should say k 5 1 should be actually equal to minus of k 1 1 into h bar. So, this is equation number 9 the negative sin indicates that k 1 1 develops moment opposite to that of k 5 1 and k 6 1 will be 0.

No yaw motion because as there is no moment about z axis. So, that is equation number 10. So, now, if you look at friends we have k 1 1 we have k 2 1, we have k 3 1, we have k 4 1 we have k 5 1, k 6 1. So, now, in the k matrix of 6 by 6 the first column k 1 one k 2

1 k 3 1, k 4 1, k 5 1, k 6 1 are now ready please understand stiffness matrix is always derived column wise.

So, the first column of the stiffness matrix is now derived from the first principles similarly we can do for the sway direction.

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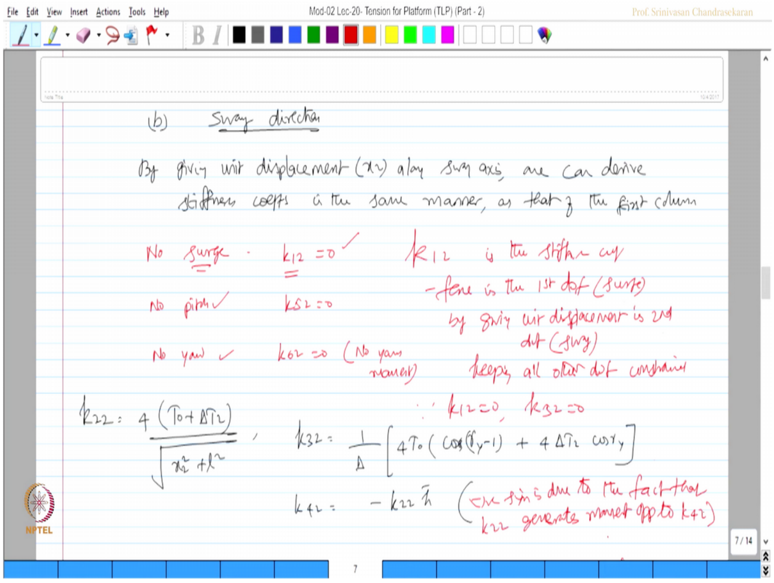

So, look at this figure if you look at this figure we have given displacement x 1 along surge. So, now, I should give displacement x 2 along sway where sway is along the y axis. So, having said this by giving unit displacement x 2 along sway axis, one can derive stiffness coefficients in the same manner as that of the first column.

But let us keep a very important I on the non-zero elements or let us say 0 elements if you look at the first column we already said that k 2 1 is 0, k 4 1 is 0, and k 6 1 is 0, k 2 1 is 0, k 4 1 is 0 and k 6 1 is 0 it means no sway no roll and no yaw on the same basis I should say no surge, no pitch and no yaw no surge that is k 1 2 will be 0 please understand how I explained k 1 2 k 1 2 is the stiffness coefficient that is force in the first degree of freedom, that is surge by giving unit displacement in second degree of freedom that is sway keeping all other degrees of freedom constrained.

So, k 1 2 since there is no surge this will be 0. So, I should say k 1 2 0 since k 1 2 is 0 I can expect that k 5 2 will also be 0 it means no pitch. So, k 5 2 will also be 0 and of course, k 6 2 will be 0 because no yaw moment. Now I am interested in finding out k 2 2 which is similar to that of k 1 1 see a k 1 1 T 0 delta T 1 by this similarly I can write k 2 2 as T 0 plus delta T 2 divided by square root of x 2 square plus l square 4 times you can see here.

I have only replaced this and this the second suffixes 2 done this. Once I know k 2 2 I can now find k 3 2 also. So, that is going to be 1 by delta of 4 T 0 cos gamma y minus 1 plus 4 delta T 2 of cos gamma y and k 4 2 will be minus k 2 2 of h bar now one can write negative sign is due to moment due to the fact that k 2 2 generates moment opposite to k 4 2 ok.

Now, I have got the second column you know k 1 2, k 2 2, k 3 2, k 4 2, k 5 2 and 6 2 I got the second column.

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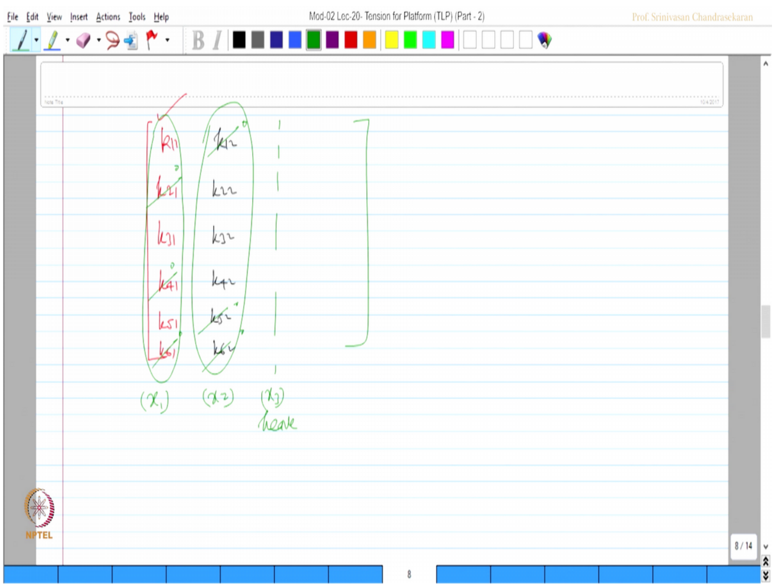

So, I can now say I have got the second column k 1 1, k 2 1, k 3 1, k 4 1, k 5 1 and k 6 1 I already have now I have k 1 2, 2 2, 3 2, 4 2, 5 2 and 6 2 out of which let us mark the zeros this is 0 this was 0 and this was 0.

Similarly, this is 0, this was 0, and this is 0. So, first column is completed second column is completed by giving unit displacement along surge you know displacement along sway let us go for the third column. So, what should I do? I should give unit displacement along heave that is good. So, let us do this we will continue with the discussion in the next lecture.

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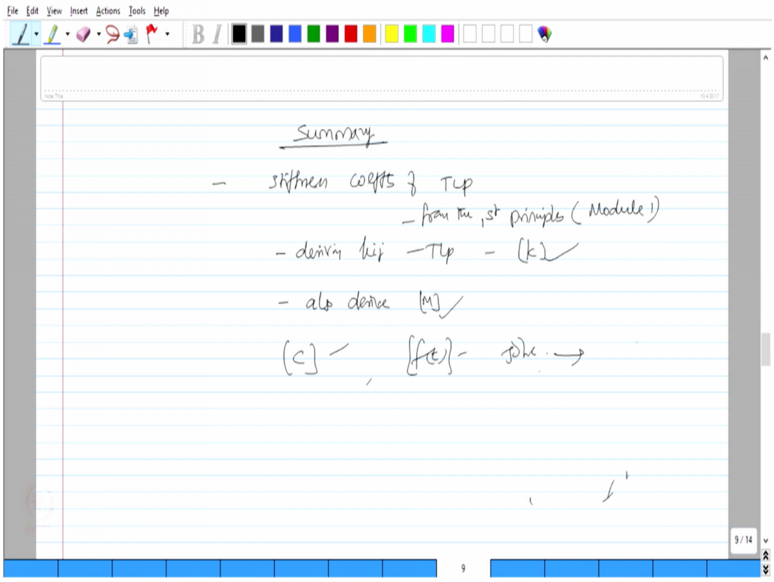

So, the summary friends we are attempting to derive the stiffness coefficients of a tension leg platform from the first principles, which we learn from module 1 we are deriving the stiffness coefficients of a TLP to get the stiffness matrix. We will also derive the mass matrix. Once I have the mass and stiffness matrix I can find the damping matrix I can find f of t. And then I can solve this problem which I will explain in the subsequent lectures.