Computer Methods of Analysis of Offshore Structures
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Module - 02
Lecture – 22
New Generation Offshore Structures (Part – 02)

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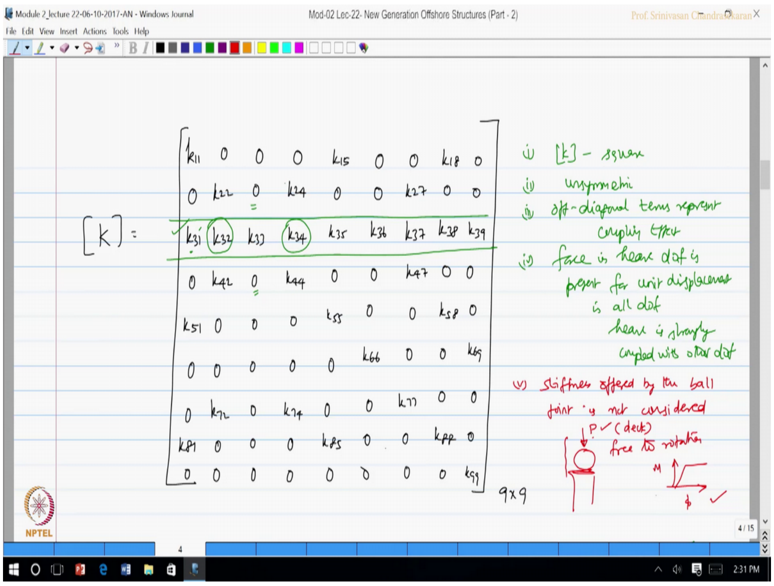

So, that kind of stiffness which is offered or resistance in fact, offered by the ball joints is not considered in the derivation.

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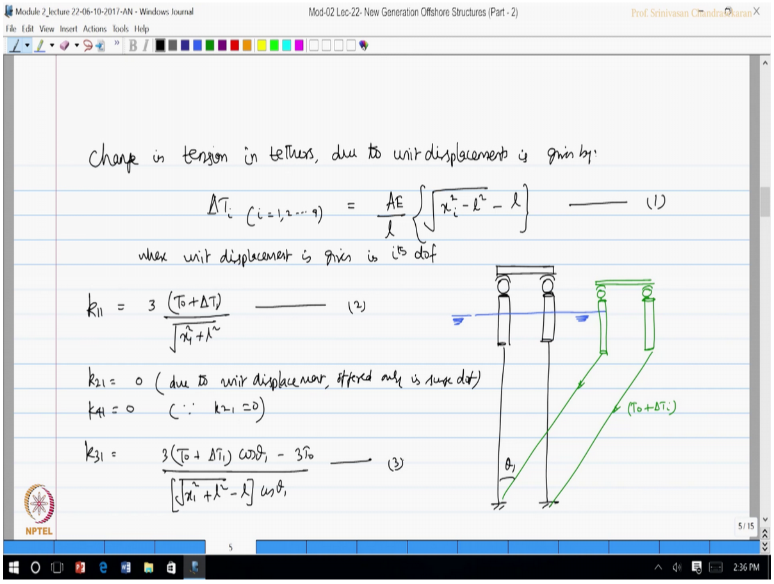

having said this let us now derive the stiffness coefficients; change in tension in tethers due to unit displacements is given by I say delta Ti and i is equal to 1,2 to 9 can be equal to axial stiffness change in length xi square minus l square the whole root minus l, where unit displacement is given in ith degree of freedom.

Now, let say the deck is supported by the ball joints which in turn connects to the buoyant leg, which in turn is connected or anchored to the sea bed and this becomes my mean sea level undergoes a surge displacement which is indicated here, there is going to be a change in tension which is T 0 plus delta Ti.

So, now k 11 will be T0 plus delta Ti or T1 by the new length xi square plus l square root, there will be 3 such legs where triceratops has 3 legs equation number 2. K 2 1 will be 0 due to unit displacement offered only in surge degree of freedom. Since k 2 1 is 0 k 4 1 will also be 0 since k 2 1 is 0.

K 3 1 will be given by T0 plus delta T1 of cos theta 1. So, this is angle theta 1, cos theta 1 minus 3 T0 and 3 divided by root of x 1 square plus l square minus l of cos theta 1.

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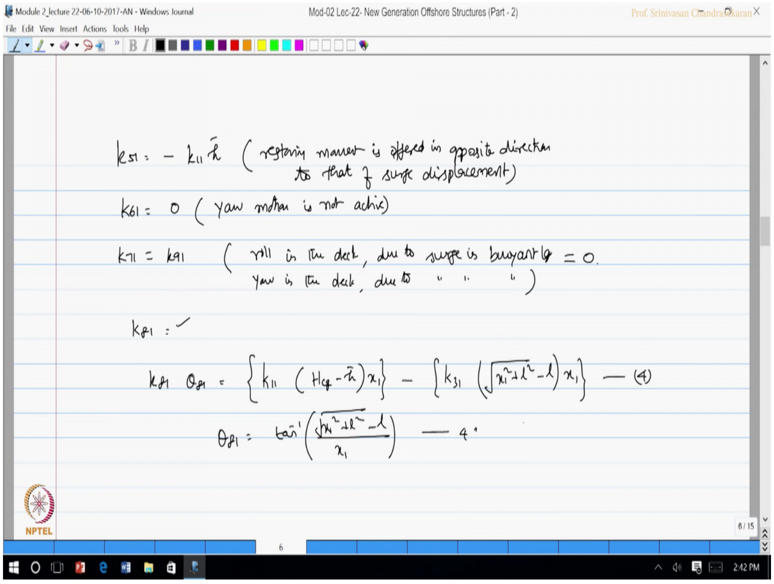

Let say equation 3; k 5 1 will be k 1 1 into h bar a negative sign, negative sign indicates the restoring moment is offered in opposite direction to that of surge displacement. So, that the re centering moment, k 6 1 will be 0 because yaw motion is not activated.

Now, interestingly k 7 1 and k 9 1 that is roll in the deck due to surge in buoyant leg or yaw in the deck due to surge in the buoyant leg will be 0. K 8 1 will be present which can be computed as k 81 into theta 8 1 will be equal to k 1 1 of H cg minus h bar into x 1 minus k 3 1 of root of x 1 square plus l square minus l of x 1, this equation is 4 . So, now, we have the first column derived of the stiffness matrix.

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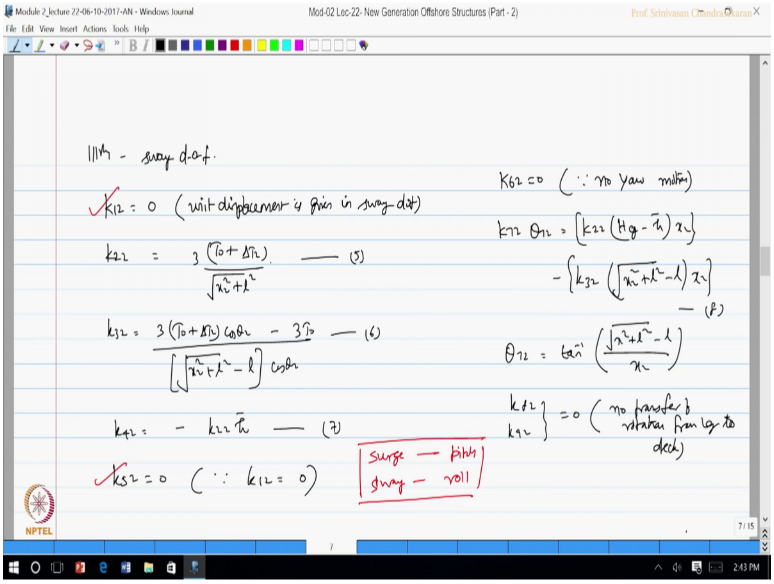

Similarly, we can also do for the sway degree of freedom, k 1 2 will be 0 because unit displacement is given in sway degree of freedom, k 2 2 similar to 1 1 will be T0 plus delta t 2 divided by root of x 2 square plus l square into 3 times say this is equation 5. K 3 2 will be T0 plus delta t 2, of cos theta 2 3 times minus 3 T0 by root of x 2 square plus l square minus l of cos theta 2.

K 4 2 will be minus k 2 2 into h bar, k 5 2 will be 0 because 1 2 is 0. Friends please note surge invokes roll sway invokes roll. So, this is when surge is absent pitch is also absent similarly, when sway is absent roll is also absent. So, k 5 2 is 0, k 6 2 is 0 since no yaw motion, k 7 2 into theta 7 2 will be given by k 2 2 H cg minus h bar of x 2, minus k 3 2 root of z 2 square plus l square minus l of x 2 equation number this is 7 this is 8.

Now, interestingly theta 7 2 simply is tan inverse of root of x 2 square plus l square minus l by x 2, by that logic theta 8 1 can also be said as tan inverse of x 1 square plus l square root minus l by x 1, 4 a k 8 2 and k 9 2 will be 0 because there is no transfer of rotation from the leg to the deck.

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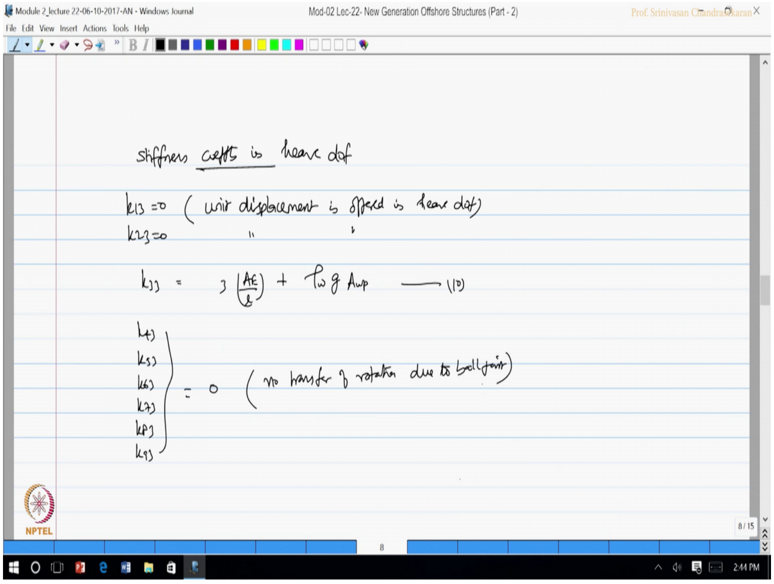

Let us talk about stiffness coefficients in heave degree of freedom. K 1 3 will be 0 because unit displacement is offered in heave degree by that logic k 2 3 will also be 0, k 3 3 will be actually equal to the axial stiffness of all the legs plus rho wg of Awp, which is now equation 10. K 4 3, k 5 3, k 6 3, k 7 3, k 8 3 and k 9 3 will be all 0 because no transfer of rotation due to ball joints.

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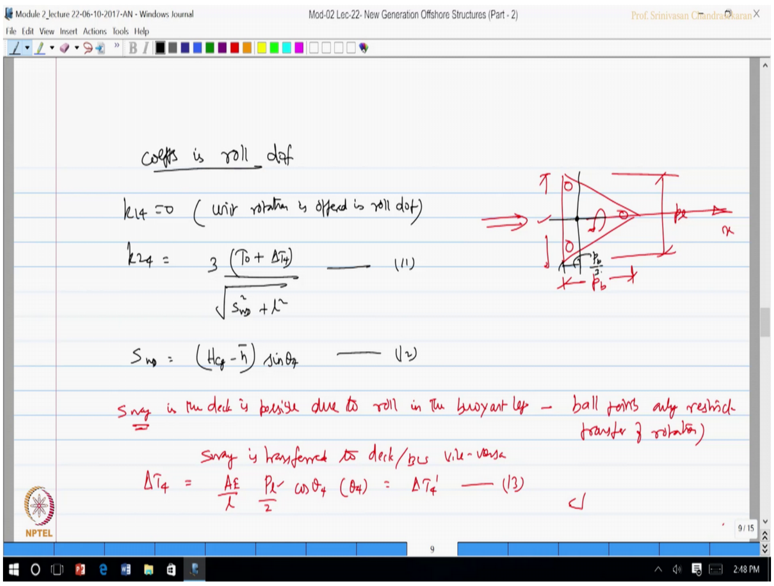

Let us talk about coefficients in roll degree of freedom k 1 4 will be 0, because unit rotation is offered in roll degree. K 2 4 will be T0 plus delta t 4 divided by square root of

SwD square plus l square of 3 times we call this equation number 11, where SwD is Hcg minus h bar of sin theta 4 equation 12; interestingly please note sway in the deck is possible due to roll in the buoyant leg.

Please understand ball joints only restrict transfer of rotations, but sway is a displacement. So, sway is transferred to the deck and buoyant leg vice versa. So, delta T 4 which is change in tension because of roll degree of freedom is given by AE by l, Pl by 2 cos theta 4 of theta 4 which also same as T 4 theta. So, let us call this as equation number 13.

Where in a triceratops with a triangular deck these being 3 legs this being the wave direction this dimension is pb and this dimension is pl and this is my x axis. So, I am talking about rotation about this axis. So, Pl will be involved here and we also know that cg lies at pl by 2 and this distance is pb by 3.

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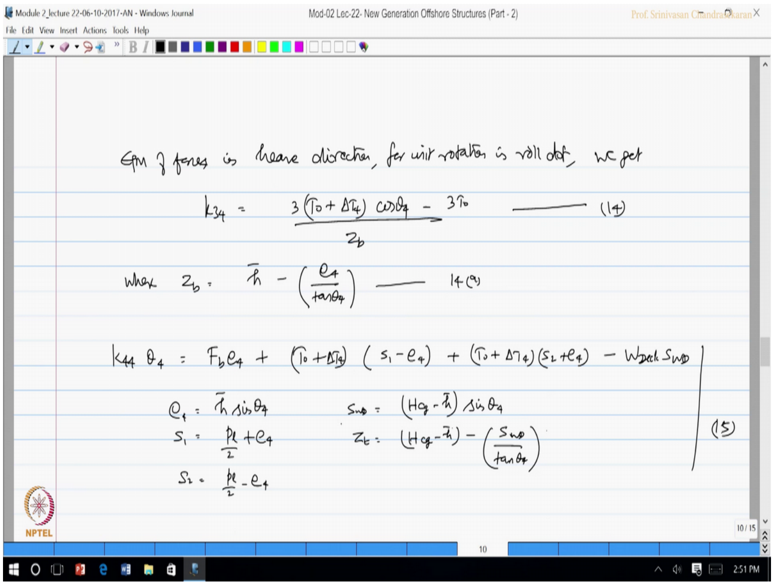

So, now trying equilibrium of forces in heave direction for unit displacement or rotation in role degree, we get k 3 4 as T0 plus delta t 4 of cos theta 4, minus 3 T0 by Zb where equation number 14 can be assigned to this, where Zb where equation number 14 can be assigned to this where Zb is h bar minus e 4 by tan theta 4, equation number 14 a.

Now, k 4 4 theta 4 can be said as buoyancy of e 4 plus T0 plus delta T 4 of s 1 minus e 4 plus T0 plus delta T 4 of s 2 plus e 4 minus w deck into SwD, e 4 is h bar sin theta, 4 s 1 is pl by 2 plus e 4 and s 2 is pl by 2 minus e 4, SwD is anyway we said it is H cg minus h bar of sin theta 4.

Let us also insert 1 more expression Zt, which is Hcg minus h bar minus SwD by tan theta 4 call all these equations as 15.

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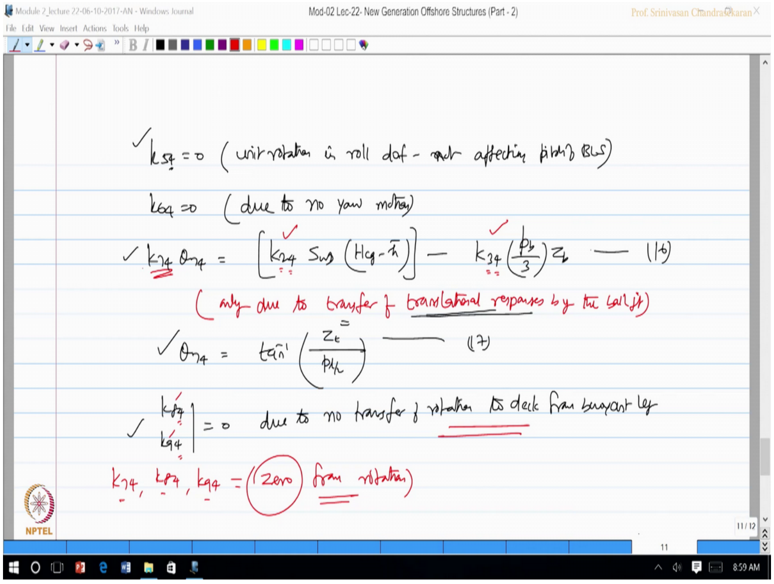

K 5 4 will be 0, because unit rotation in role is not affecting of buoyant leg; k 6 4 is 0 due to non-sway sorry due to no yaw motion.

K 7 4 into theta 7 4 will be k 2 4 into SwD, Hcg minus h bar minus k 3 4 of pb by 3 of Zb call this equation number 16 this is only due to. So, friends k 5 4 will be 0 this is because of the reason that unit rotation given in roll degree of freedom does not affect pitch of the buoyant leg, unit rotation given in roll degree of freedom does not affect pitch degree of freedom of the buoyant leg.

Similarly, k 6 4 0 because there is no yaw motion in the buoyant leg, now 1 can estimate k 7 4 which can be given by equation 16, which is k 7 4 is given by the equation as you see here. It arises from 2 components one is because of k 2 4 and other is because of k 3 4. Please note that these components are only due to transfer of translational responses; you know 2 and 3 are the translational responses 4 of course, is the rotation given to estimate the stiffness coefficient because of unit rotation in the roll degree in the buoyant leg.

So, by simplifying equation 16 we can get k 7 4, provided theta 7 4 is given by this expression shown in equation 17. K 8 4 and k 9 4 will be 0 because there is no transfer of rotation to the deck from the buoyant leg; friends, please note that 8 and 9 are degrees of freedom of the deck now the buoyant legs are 6 degrees of freedom 1 to 6 and 7 8 9 are degrees of freedom of the deck.

So, 8 and 9 has no responses on the deck due to rotation given in the buoyant leg, because the ball joints do not transfer this. So, k 7 4, k 8 4 and k 9 4 which arise because of rotation from the buoyant leg is kept as 0, then 1 may ask me a question how do we get k 7 4 when there is no transfer of rotation. Please note k 2 4 and k 3 4 are translational responses of the buoyant leg due to invert rotation given in the buoyant leg and translational responses are transferred therefore, k 7 4 is active.

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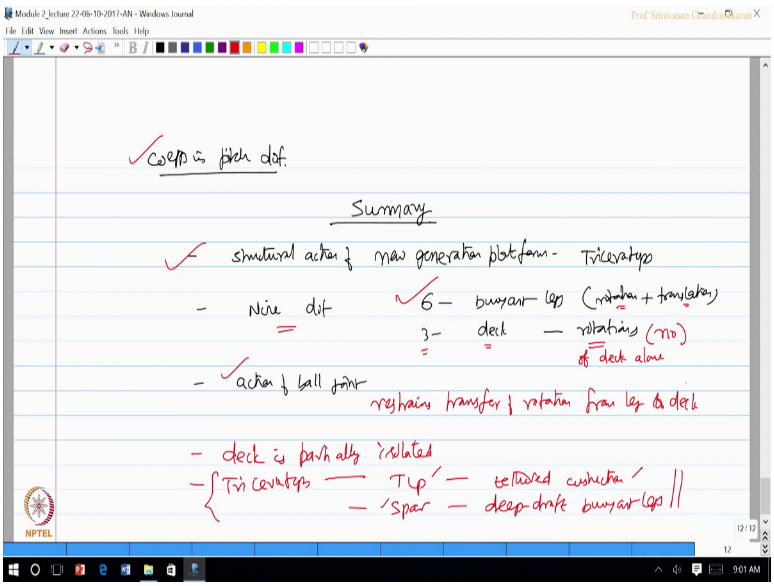

So, friends, we will derive the coefficient of pitch degree of freedom and further in the next lecture let us look at the summary; we have learnt that the structural action of a new generation platform by name triceratops is highly innovative triceratops has 9 degrees of freedom, 6 degrees of the freedom for the buoyant leg 3 rotations and 3 translations about the respective axes x y and z.

And of course, the deck has an additional 3 degrees of freedom which are all the translations and no rotations are transferred to the deck. So, I should say no rotations are transferred therefore; they are ideally rotations of the deck alone. So, I should write here rotations of the deck alone which will be independent of the rotation of the buoyant leg, we have learnt also that action of ball joints restrain transfer of rotations from the buoyant legs to the deck and therefore, deck is partially isolated.

So, triceratops derives advantages of tethered construction from that of a TLP and a deep draft construction of the buoyant legs from that of a spar. So, it is an hybrid new innovative, new generation platform for which we are trying to derive the stiffness coefficients to form the stiffness matrix from the first principles which can be aided by computer methods.

Thank you.