Computer Methods of Analysis of Offshore Structures

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Module - 02
Lecture - 22
New Generation Offshore Structures (Part – 1)

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So, friends welcome to the twenty second lecture in module 2. In this lecture we are going to discuss about derivation of stiffness matrix and mass matrix using fundamental principles which are computer methods essentially for new generation platforms.

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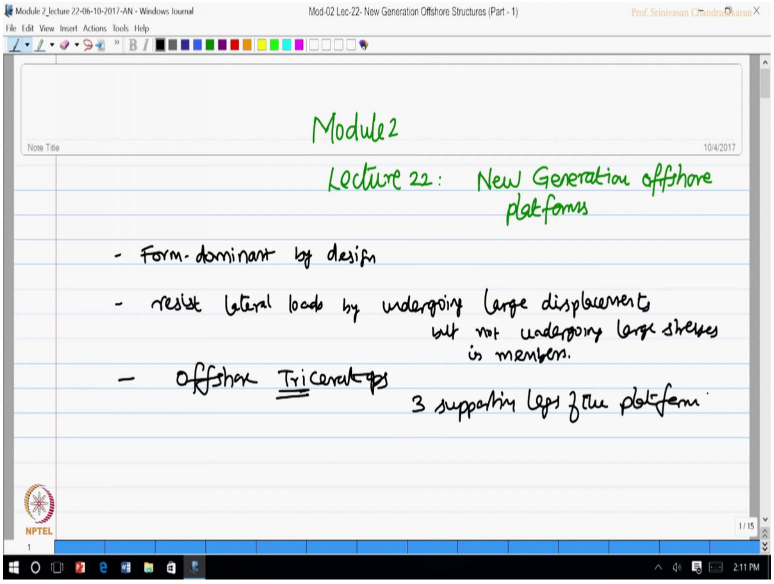

Let us recollect an important task of understanding a new generation platform. The important task of understanding new generation platforms essentially is form dominant by design and they resist lateral loads by undergoing large displacements, but not undergoing large stresses in members.

So, one such example which has commenced in the recent past is offshore triceratops. The word try indicates very clearly there are 3 supporting legs of the platform. Let us quickly understand how a triceratop action looks like.

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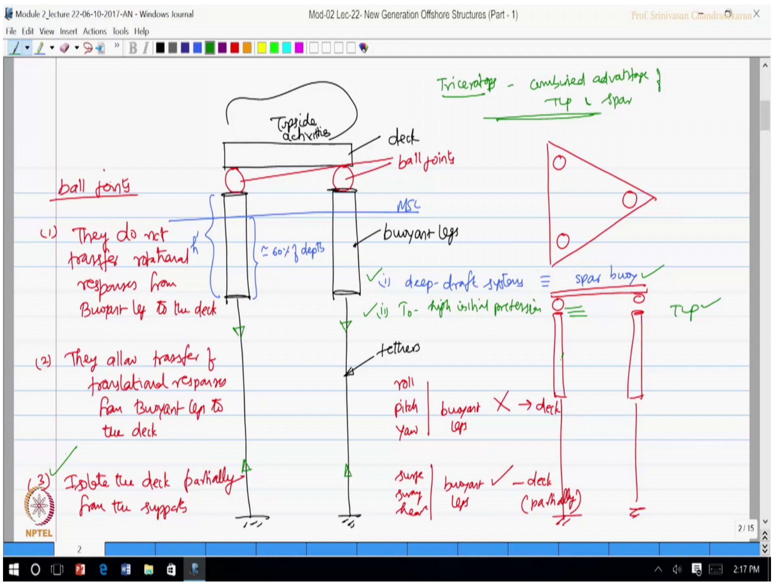

As usual triceratop will be having a deck of some thickness, it be supported by 3 buoyant legs which will further anchored to the sea bed using tethers. These are buoyant legs of course; this is the deck which supports all top side activities.

Now, the interesting component is the deck will be supported by the buoyant leg through ball joints. Typically it is got a triangular deck which has 3 legs support at the bottom and then you look at the view, the view typically looks like this which we have just now drawn. Having said this what is the specialty about this particular structural action compared to a tension leg platform. Ball joints have a specific property; one they do not transfer rotational degrees of freedom or rotational responses from buoyant leg to the deck. 2 they allow transfer of translational responses from buoyant legs to the deck. On the other hand roll, pitch and yaw of the buoyant leg will not be transferred to the deck surge sway and heave of the buoyant leg will be transferred to the leg partially I should say.

So, ball joints essentially isolate the deck partially from the supports. So, to protect these ball joints from corrosion as expected, the water level or the mean sea level is much below the ball joints. So, the buoyant legs has got a draft value which is about 60 percent of their depth, which we call as deep draft systems. So, this resembles as spar further the legs are connected to the sea bed using tethers, which has got high initial pretension. So, 1 can now say the characteristic of high initial pretension resembles a tension leg platform, the characteristic of deep draft systems resembles a spar buoy.

So, triceratops has a combined advantage of both TLP and spar. The partial isolation enables them to use for ultra deep waters. So, these structural systems are essentially meant for ultra deep waters. So, let us try to derive the stiffness and mass matrix of this system from the first principles which can be essentially a computer method.

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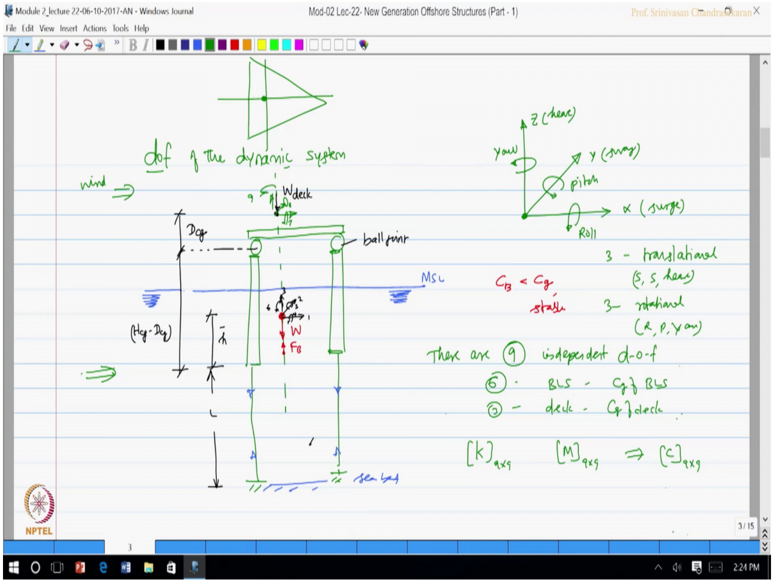

So, let us now mark the degrees of freedom of the system, we all know in general for a point in space for 3 axis being x y and z there are 3 translations along x we call as surge, along y we call as sway and along z we call this as heave and about x we call this as roll and about sway axis we call this as pitch and about z axis we call this as yaw this is for any point in space.

So, 3 translational that is surge sway and heave; 3 rotational that is roll pitch and yaw. But triceratop has got an isolation of the deck from the buoyant leg which is isolated by the ball joints therefore; their degrees of freedom are slightly tricky. So, being a triangular geometry we know that the C g will be located closer to the left side. So, let us say this is my C g line. So, in the C g line let us mark the water level as shown here this is my mean sea level this initial tension this is my sea bed. So, these are my ball joints.

So, this is my deck this becomes my point where weight of the structure is concentrated and this becomes my point where by buoyancy is acting. So, since centre of buoyancy is located lower than centre of gravity, the system is stable. So, now, from the depth of the leg to the C g, let us mark this value as h bar let one be the length of the legs let this distance that is from the bottom of the leg till the centre of the ball joint be marked as h C g minus d C g and let deck has a weight is acting here and that is w of the deck and that distance from here is D c g. So, this is my ball joint now if I try to mark the degrees of freedom at this point, I have 1 2 and 3 translational 4 5 and 6 as rotational.

So, I have 6 degrees of freedom for the buoyant legs now the rotations are not transferred to the deck therefore, I will have additionally 3 more degrees of freedom which will be 7 8 and 9 for the deck now 1 may ask me a question how the deck will undergo rotational responses when there is no transfer of the rotation from the buoyant leg to the deck that is true under the wave action there is no transfer of rotation from the legs to the deck, but under the wind action there can be rotation caused which will not get transferred to the buoyant legs.

It means there are now 9 independent degrees of freedom which are marked. So, 6 is for the buoyant legs, marked at the C g of the buoyant legs and 3 for the deck which are marked at the C g of the deck. So, the stiffness matrix should now become 9 by 9 mass matrix should now become 9 by 9 and obviously, the damping matrix will also be 9 by 9.

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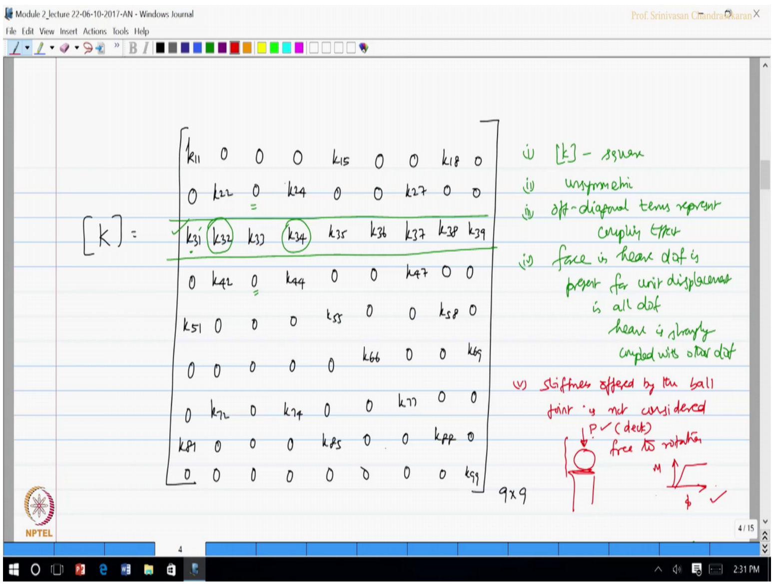

So, let us quickly get the overview of this stiffness matrix.

So, we will have k 1 1 and k 3 1, k 5 1, k 8 1 and 0 similarly k 2 2, k 3 2, k 4 2 ,k 7 2 and 0 then the third column will have k 3 3 and all other elements are coefficients in this column will be 0 then the fourth column will be k 2 4, k 3 4 and k 4 4 remaining except k 7 4 are 0 then the fifth column k 1 5, k 3 5, k 5 5, k 8 5 0 then the sixth column k 3 6, k 6 6 then the seventh column k 2 7, k 3 7, k 4 7, k 7 7 0 eighth column k 1 8, k 3 8, k 5 8, k 8 8 0 and the last column is ninth column is this elements sets of full 9 by 9 matrix where you can see that there are off diagonal elements present which imposes a non-linearity plus look at this k 3 2 is present, but k 2 3 is absent k 3 4 is present, but k 4 3 is absent and so on. So, the stiffness matrix is square 2 it is unsymmetric. The off diagonal terms represent coupling effect further we can see that the heave is present through and through.

So, this coefficient exactly means that force in the heave direction by giving unit displacement in the surge direction that is the meaning of k 3 1, similarly meaning of k 3 2 3 3 and so on can be established which shows that force in heave degree is present for unit displacement in all degrees of freedom. So, by this logic we can also say that heave is strongly coupled with other degrees of freedom. One important issue here the stiffness offered by the ball joint is not considered, now one may ask me a question how ball joint will offer us stiffness.

You have a ball joint connected to a member and let the ball joint be free to rotate, it will have some moment rotation characteristics. When you apply an axial force of a very high magnitude you will see that the ball joint will rotate under some constraint. So, the resistance offered by the ball joint under the presence of axial force which is nothing, but the deck weight and the rotation offered by the ball joint to that of the buoyant leg will be actually disturbed and it not be similar to an ideal characteristic of a ball joint.