Computer Methods of Analysis of Offshore Structures

Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 02
Lecture - 20
Tension Leg platforms

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Friends, welcome to the 20th lecture in module 2. Where, we are going to discuss about details of analysis of tension leg platforms briefly known as TLPs. Tension leg platforms are form dominated offshore structures meant for deep water oil exploration.

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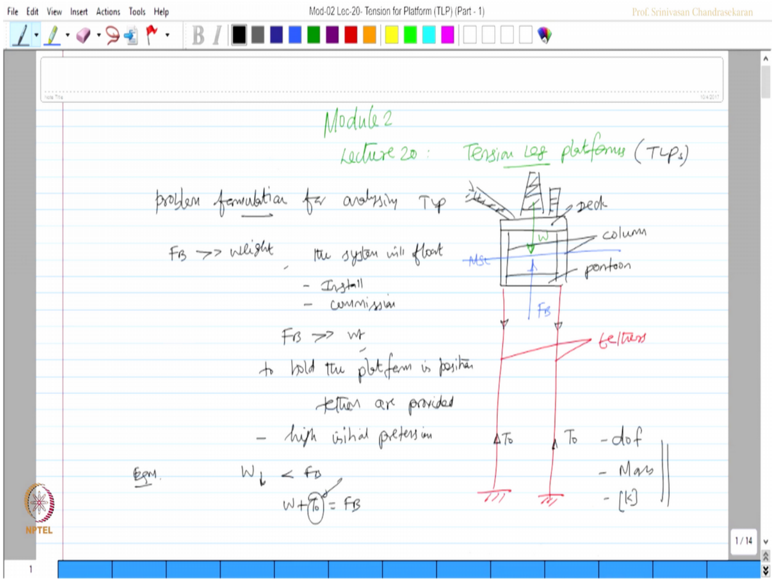

If you look at the problem formulation for analyzing a TLP, essentially TLP consists of a deck which will have all tops I details as drilling derrick, living quarters, flare boom etcetera which will be supported by the column members and pontoon members.

These are column members, this is the pontoon member which rests on the sea bed and anchored by tethers. So, these are called tethers. The basis design concept of a tension leg platform is the buoyancy force exceeds the weights, we know buoyancy is proportional to the submerged volume. So, if this is my water level which is my mean sea level the buoyancy force will act on the upward direction and weight of the platform will act in the downward direction. If buoyancy exceeds the weight it will make the system the float, ok.

When the system floats it is easy to install, to commission, but since the buoyancy is larger than the weight to hold the platform in position, tethers are provided these tethers will be of high initial pre tension. So, these tethers will have high initial pre tension, we call this value now the basic equation of equilibrium will be w is acting downward which is lower than F B. So, w and F B need to be balanced I should say w plus T 0 should be F B.

So, the difference between the weight and the buoyancy is will be by T 0. So, now, to analyze the system, we need to know the degrees of freedom of the system we need also know the mass these degrees of freedom we also need to know the stiffness matrix of the system to do the primary or preliminary dynamic analysis.

Let us talk about degrees of freedom we already spoke about that just to reiterate what is important let us mark the 3 axis.

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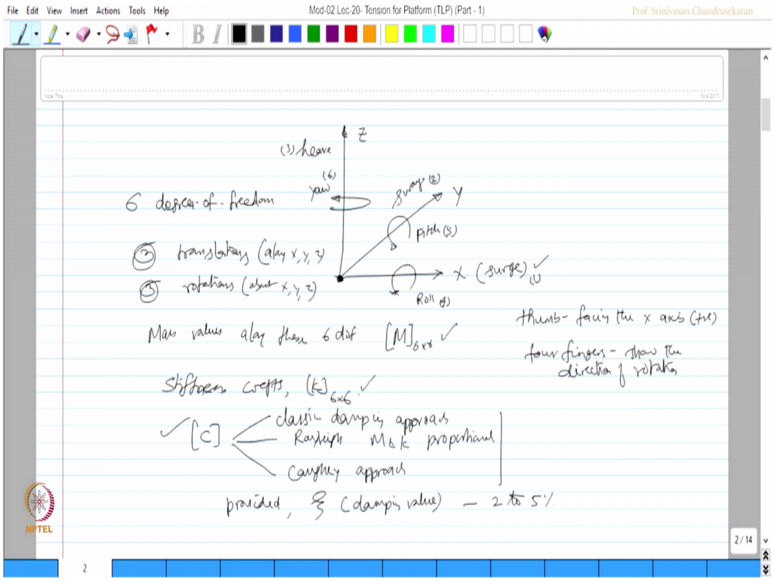

Let us say these are the three axis x y and z let us say we have displacement along x as surge displacement along y axis as sway displacement along z axis has heave use your right hand now keep your thumb facing the x axis in the positive sense remaining four fingers will show you the direction of rotation for example, if I keep my thumb along the positive axis of x this now becomes my roll direction.

This becomes the pitch direction and this becomes my yaw direction. So, there are 6 degrees of freedom the platform has three translations and three rotations, this is along x y and z this is about x y and z. So, since there are 6 degrees of freedom, I need to establish the proportionate mass values along these 6 degrees of freedom. So, my mass matrix is expected to v size of 6 by 6. Similarly, I should derive the stiffness coefficients and then the stiffness matrix which will also be a size of 6 by 6. Once I have the mass matrix and stiffness matrix for a given system of TLP, you can always find damping matrix using the classical damping method or I can use Rayleigh's approach which is mass and stiffness proportional.

You can also use Caughey method to get my C matrix provided I know the damping value. In terms of percentage usually it is 2 to 5 percent of that of the critical. So, friends for a given problem how do you actually determine or derive the mass matrix and stiffness matrix from first principle, which should be based on some computer method. So, that I can write a simple analytical coding to create this mass and stiffness matrices and then do the analysis for this particular structure.

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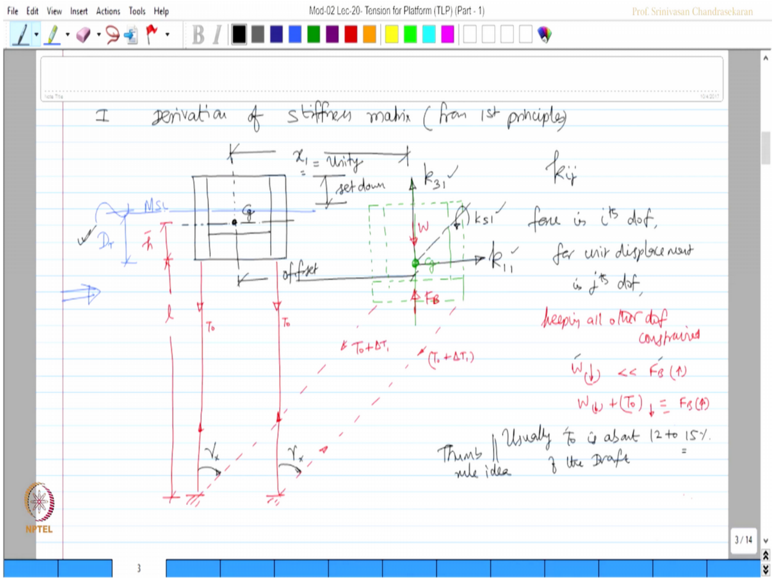

So, let us talk about derivation of stiffness matrix from the first principles. In the first module we have learnt how to derive stiffness matrix for various kinds of boundary conditions and the problems, we will now apply that algorithm back again to a TLP, let us say I have a tension leg platform of a specific dimension which has got a column member and a pontoon member whose C g centre of gravity are the mass centre is lying same by here this is my centre of gravity. So, as I know this will be subjected to or commission to the sea bed using tethers, which has initial pre tension net value is T 0 ok.

Now, the length of the tether is marked as l the distance of the Cg from the keel is marked as h bar this is my mean sea level the depth of immersion is marked as D r when I apply a force or a lateral load in terms of wave load to the system the system will not respond because it is complaint in nature it will start moving towards its right.

Let us say hypnotically it is moved to this much the restoration will again happen whereas the cables or by the tendons the tension in the cable will be T 0 plus delta T 1 there is an increase in tension, because of the displacement we believe and assume that the tension in this cable is also of the same amount which is T 0 plus delta T 1. So, what we have done is we have given a displacement of x one to the system ok.

Now, the tethers undergo an angle of rotation which is gamma x now what is k i j? K i j is a force in the i-th degree of freedom for unit displacement in j-th degree of freedom keeping all other degrees of freedom constrained, that is how we can derive the stiffness coefficient k i j is actually is the force, we want to find the force in all degrees of freedom by giving unit displacement in the j-th degree of freedom. So, I have given unit displacement in the first degree of freedom because surge you see look at this equation surge is the first degree, sway is the second degree, heave is the third degree, roll is the fourth degree, pitch is the fifth degree and yaw is the sixth degree.

So, I have given unit displacement along x I should say this displacement should be unity. I want to find the forces what will be the forces generated in different components of degrees of freedom. So obviously, you will have a force which is the stiffness coefficient in the first degree because of displacement given in the first degree you will also get the stiffness coefficient in the third degree, because of unit displacement given in the first degree because you know there will be a set down effect this is called set down in TLP dynamics and of course, this is called off set.

And further it will also give me rise to moment k 5. In addition weight will be acting downwards buoyancy will be acting upwards; we already know that weight which is acting downward is much lower than buoyancy which acts upward. So, weight acting downward will be compromised with T 0 which is also acting downward to equalize this to the buoyancy force which acts upward which we already said we already said that.

So, that is has the thumb rule for our understanding we must know that usually T 0 is about 12 to 15 percent of the draft, you know you design the draft value you know the immersed volume from the immersed volume you know the load or you know the weight take about 15 percent of that that is going to be a T 0 it means w and F B are separated or let us say differenced by a value about 15 percent of that of the immersed volume, that is an approximate thumb rule idea it may vary from different TLPs, but to know an idea we should have a guess now having said this particular figure. We now are interested in estimating the values of. In fact, deriving the coefficients of k 11, k 5 1 and k 31. So, looking at this figure I can now write the increase in tension.