Computer Methods of Analysis of Offshore Structures
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Module - 02
Lecture - 19
Articulated Towers (Part - 01)

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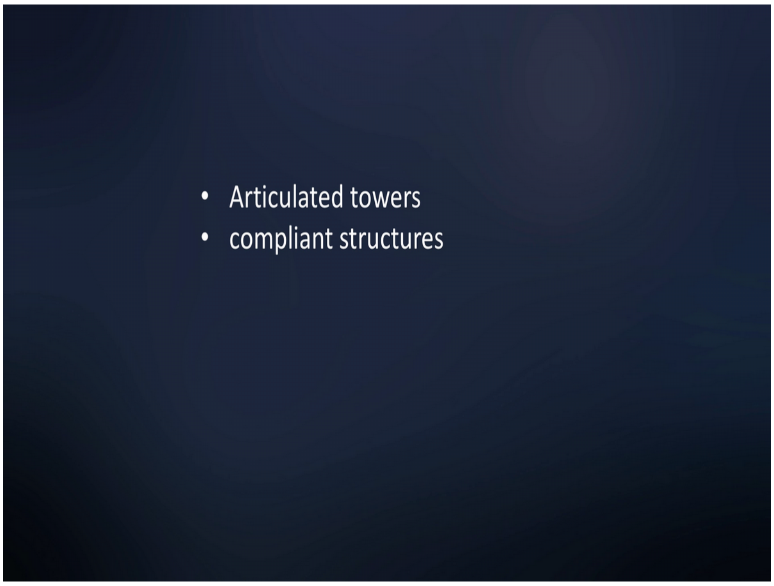

Friends, in the last lecture we discussed about an equation of motion for dynamic analysis for example, let us say an equation of motion of this order. Where, the right hand side of equation of motion has got a dependent variable which is to be solved after knowing the left hand side.

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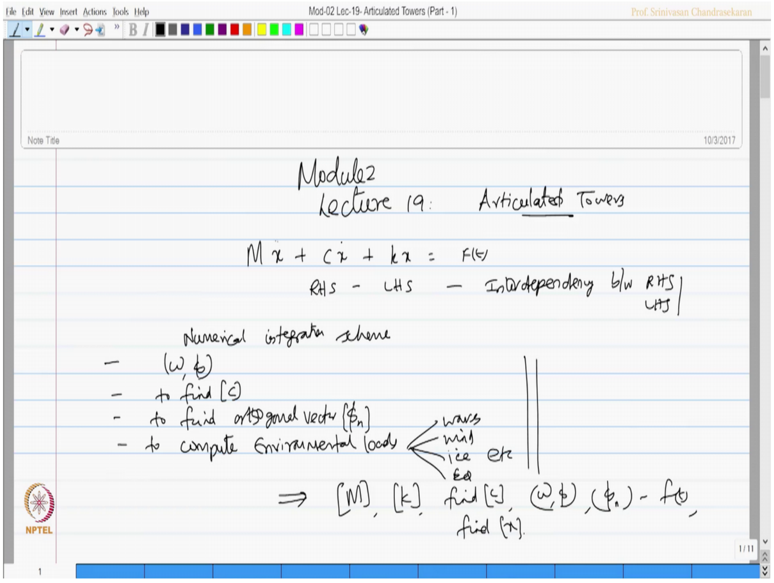

So, there is a very strong interdependency between right hand side and left hand side of this equation of motion. So, we have used numerical integration scheme to solve this problem. Now friends we already have programs to compute omega and phi to find the damping matrix c. To find orthogonal vectors phi normal to compute environmental loads that arise from waves, wind, ice, earth quakes etcetera.

We already have programs of this in pieces. Now we will apply this to couple of example problems and see how I can derive input matrix mass, input matrix k and then find c and then compute omega and phi and then compute phi n and for a given f of t find the response that is our idea now using computer program.

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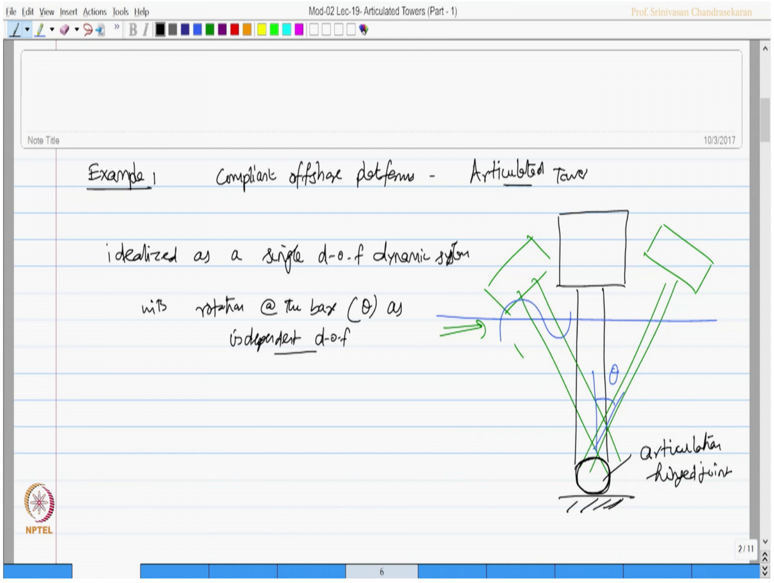

So, we will take an application problem in offshore engineering and try to solve this by different methods. So, the example problem what I am going to solve now is one of the compliant offshore structures articulated tower. We know that articulated tower is an compliant platform where the deck of the platform is supported by a tower and the tower is connected to the base; the sea bed using articulation which is nothing but a hinged joint.

We all know that tower is compliant because under the action of waves the tower can have an action of an inverted pendulum or can have an action of an inverted pendulum this way and so on. Now, for a given sea surface elevation, you know the degree of freedom what the tower has independent rotational degree of freedom.

So, this tower can be idealized as a single degree freedom system model, dynamic system with rotation at the base as independent degree of freedom. To solve the problem in the equation of motion we need to know the mass matrix, the c matrix the k matrix and f of t which I am going to do for this specific problem.

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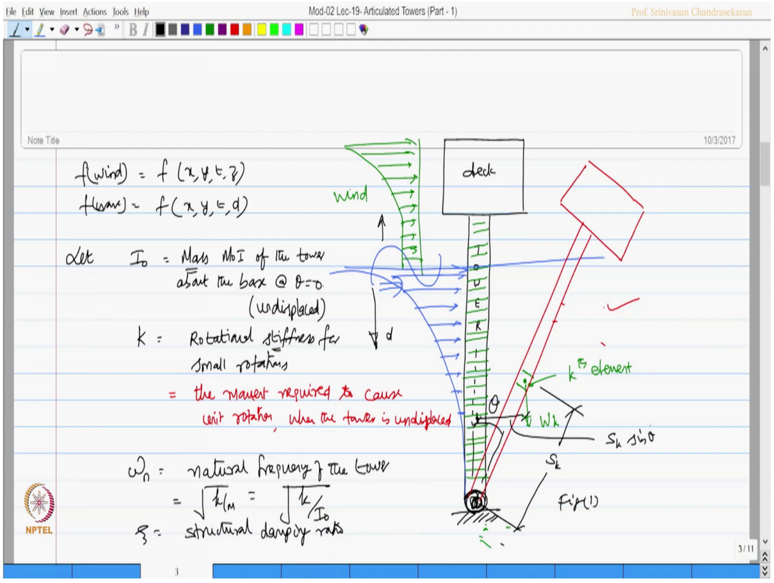

So, let us draw initial portion of the tower, which is hinged at the bottom which is subjected to wave direction of this order, which is subjected to wind loading, which varies non-linear this is the wind load, the wave loading, which again there is non-linear. So, this is the deck of the tower and this is the tower.

Now, the tower under the given action of lateral loads will be displaced. So, degree of freedom what you are measuring with respect to the central line which is theta, since I am going to measure the forces or the loads at different intervals because you know wave load will vary along the depth wind load vary along the height. So, if you look at the wind load it has got variations along x along y along t and along z.

If we look at the variations of wave load it will vary along x, along y, along t, along d that is this variation. So, now, to attain the forces at any point of my choice either on the super structure or on the sub structure, I need to divide this in a different number of elements. I pick up any one such element look at the cg of the element I call this as k-th element ok.

Now, this element has a weight which is wk and this element is located at distance sk from the base. So, now, let I 0 be the mass moment of inertia of the tower about the base at theta equal 0, that is un displaced position. Let k be the rotational stiffness for small rotations.

Being in analysis course, we should understand what is rotational stiffness. Rotational stiffness is defined as the moment required to cause unit rotation when the tower is un displaced. Once I know mass moment of inertia and rotational stiffness I can find the natural frequency of the system, which going to be square root of k by m which in my case going to be square root of k by I naught structural damping ratio.

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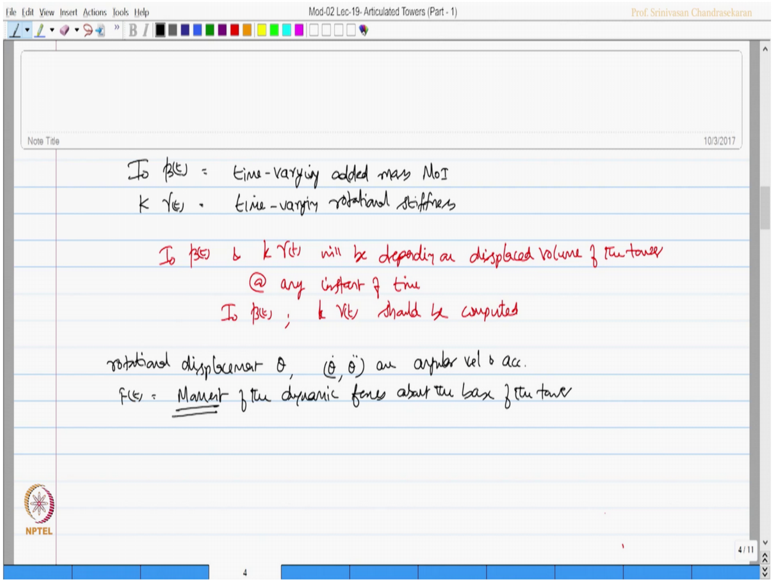

Let I 0 beta t be the time varying added mass moment of inertia and k into gamma t be the time varying rotational stiffness. So, it is very important to know that when the tower is getting displaced I 0 into beta t and k gamma t will be depending on the displaced volume of the tower at any instant of time. So, they should be computed.

So, I 0 beta t and k gamma t should be computed. Now the degree of freedom rotational displacement is theta therefore, theta dot and theta double dot are angular velocity and acceleration respectively. So, f of t actually is the moment of the dynamic forces about the base of the tower, say it is the moment it is not the force.

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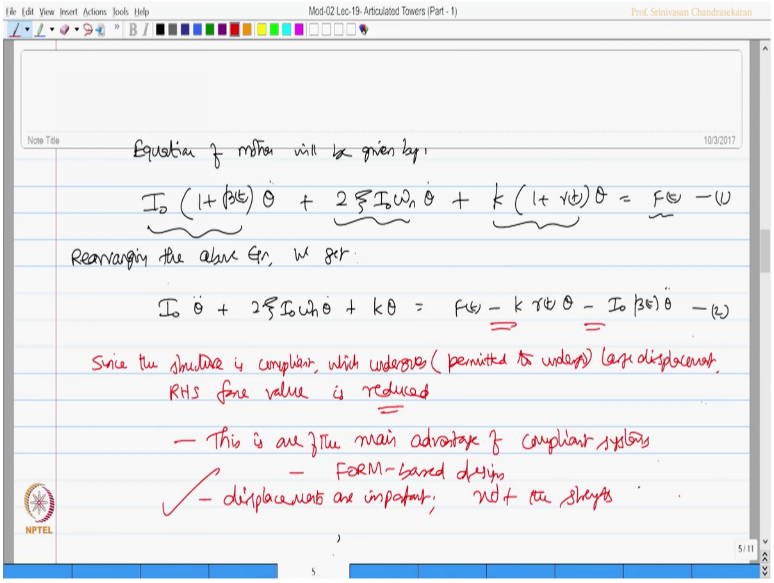

So, now equation of motion will be given by I 0 1 plus beta t of theta double dot plus 2 zeta I naught omega n theta dot plus k of 1 plus mu of t of theta as f of t, is a classical form of equation of motion where this is the master this is the restoring term and this becomes my classical damping term this my forcing function.

Rearranging this equation we get as follows. I 0 theta double dot plus 2 zeta I naught omega n theta dot plus k theta is f of t minus k mu of t theta minus, I 0 beta t theta double dot. Friends look at the form of equation 2 since the structure is compliant in nature which undergoes or I should say permitted to undergo large displacements.

The right hand side force value is reduced you see there is a negative term; the negative term reduces the force. This is one of the main advantage of compliant system which I should say they are actually geometric form based design. So, here displacements are important not the strength. So, one need to work out the displacement controlled design behavior which we spoke about this in the formation offshore structures as form based designs, ok.

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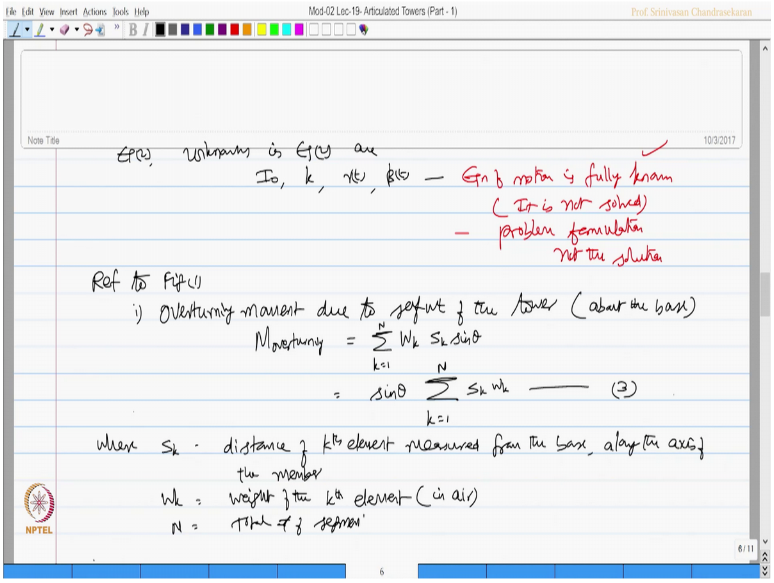

Having said this if you look at the equation 2, the unknowns in this equation are I 0 k gamma t and beta of t. If we know this then equation of motion is fully known please understand it is not solved equation is only known. So, actually it is related to problem formulation not the solution comes later first let us formulate the problem.

Having said this let us refer to this figure. So, I call this as figure 1, let us refer to figure 1 and work out the over turning moment, due to surfeit of the tower. Let us compute the moment about the base. So, I should say m overturning is equal to look at this figure. So, I am talking about wk and this distance is going to be Sk sin theta.

So, the overturning moment is going to be wk into Sk sin theta which will be in this form. So, I should say Wk into Sk sin theta this is only for the k-th element I want to do this for the entire tower. So, I should sum up this from k equals 1 to capital N, I can re write this equation as sin theta summation k equals N Sk wk equation 3.

Where Sk is distance of k-th element measured from the base along the axis of the member, Wk is weight of the k-th element in air and where N is the total number of segments.