Dynamics of Ocean Structures
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Lecture - 5
Steps of Analysis Using Software

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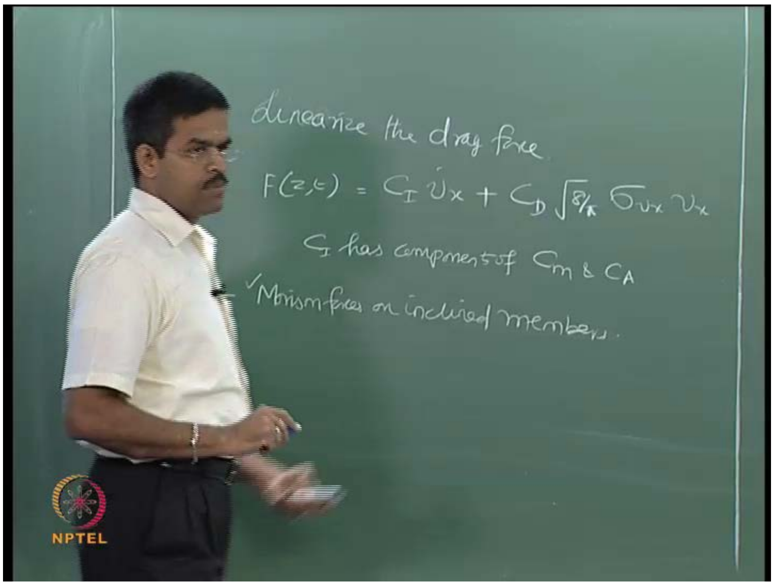

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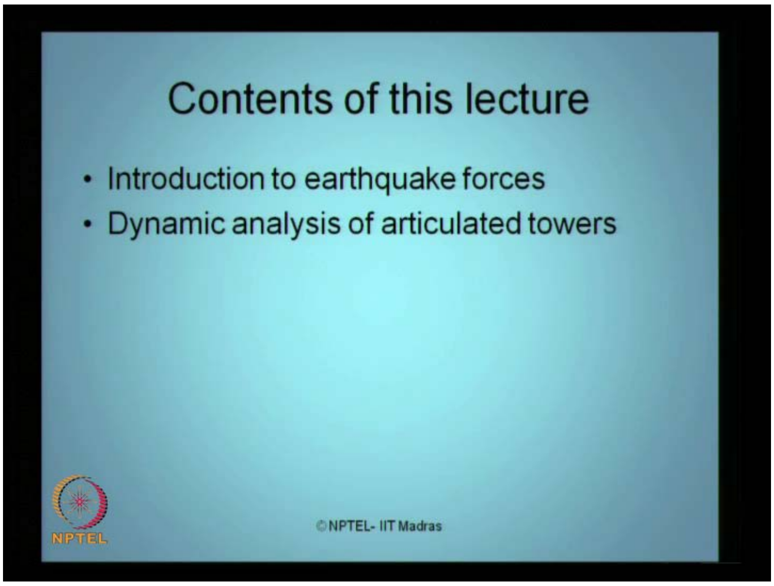

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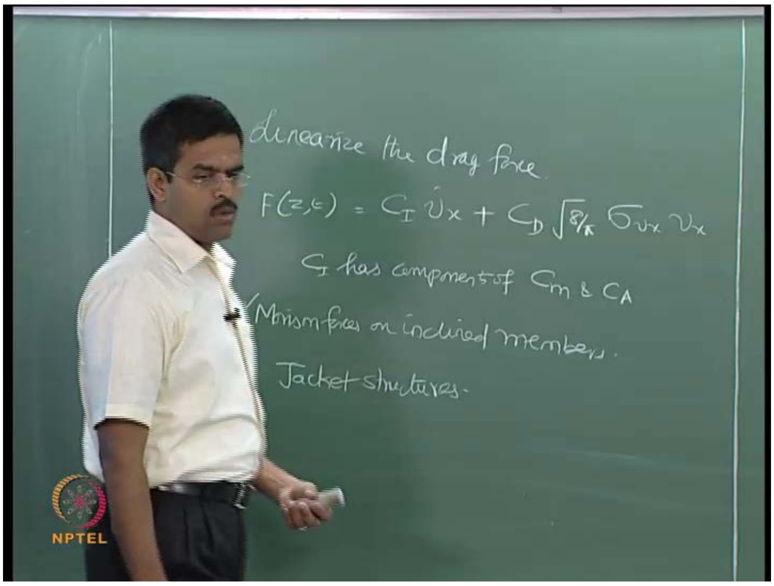

This is the fifth lecture on second module where, we are talking about application of dynamics of offshore structures. In the last lecture we discussed about how to linearize the drag force. We already said that drag force of z of t after linearization can be given by C I plus C D root of 8 by pi sigma v x n x and C I has components of C M and C A. We have also found out how to find Morison forces on inclined members in the last lecture. In the present lecture we will talk about the introduction to earthquake force and we also start introducing to the dynamic analysis for articulated towers. We have already seen one example in the last lecture where, we did dynamic analysis for jacket structures. We talk about the formation of the problem of our articulated towers and then, we will see some results of dynamic analysis done for in this lecture.

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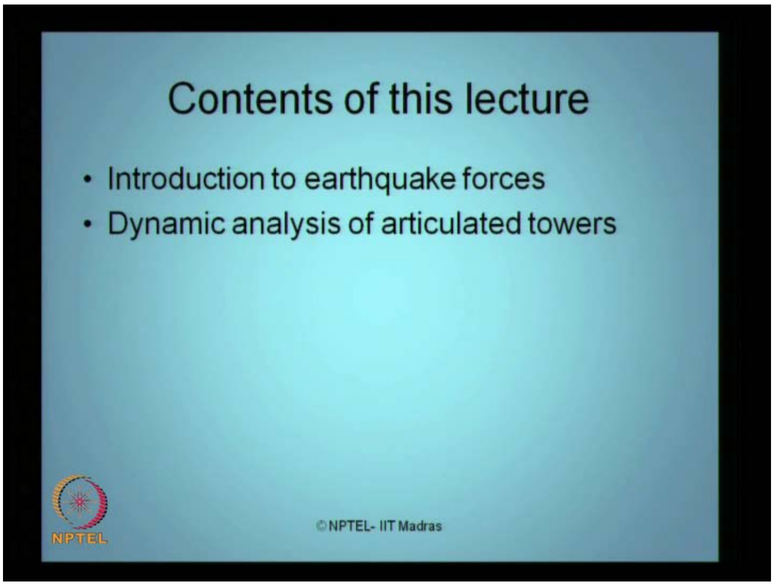

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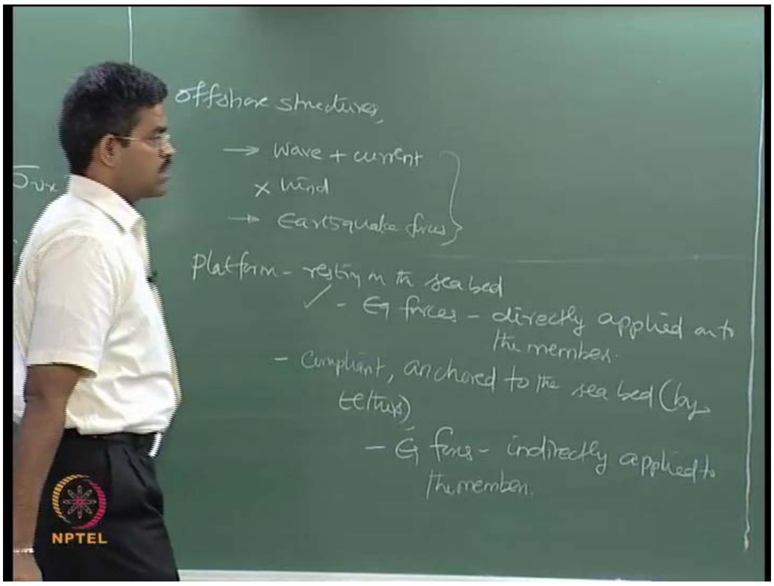

So, we already know in case of offshore structure 2 important forces are applied; one is from the wave plus current and of course, form the wind and also the earthquake forces. If I do not consider the aerodynamic response then, wind force may not be consider of course, the wave force will create the lateral force or the wave effectively create the lateral force on the member plus of course, the earthquake forces are got to be definitely consider in the offshore structures. Whereas, in land based structures this can be an optional criteria to add the earthquake force to the lateral forces coming in the system. Whereas, an offshore structure as we have seen in the previous module lecture it is mandatory that I must consider the earthquake forces coming on the system. Now, the moment I said earthquake force, if I got a platform which is resting on the sea bed then, earthquake forces can be directly applied on to bed then, earthquake forces can be directly apply on to the members.

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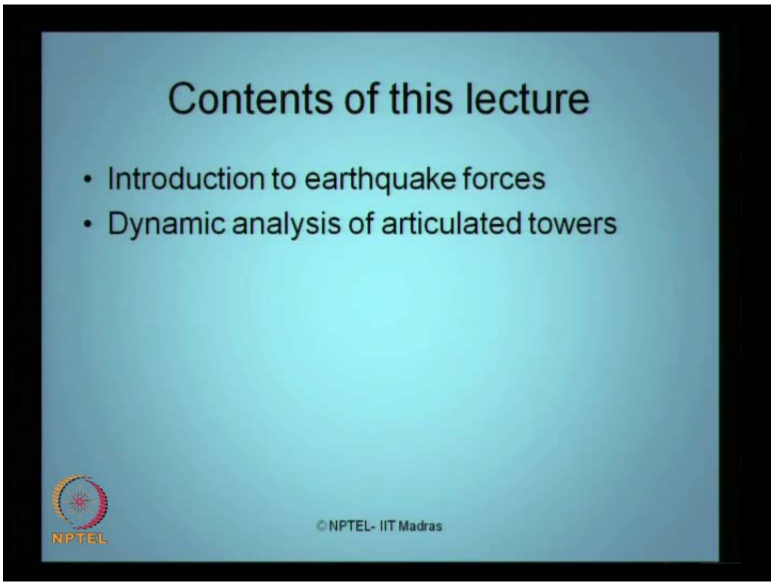

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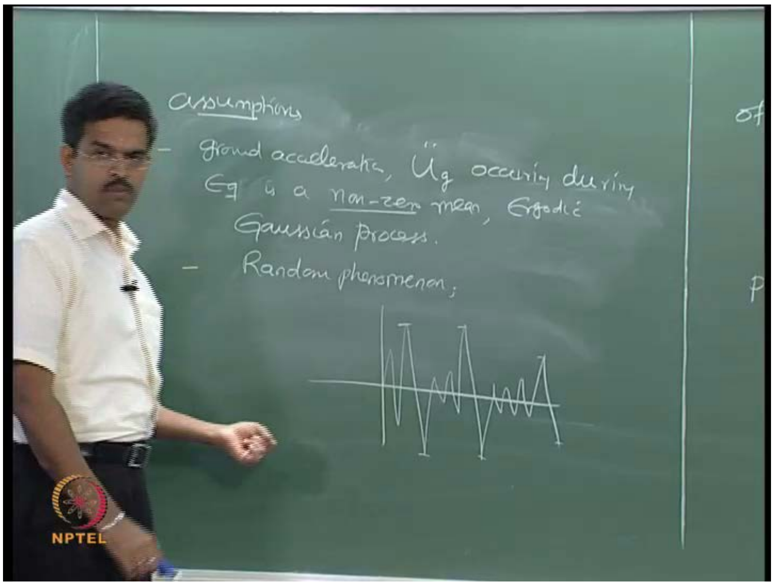

If the platform is compliant and anchored to the sea bed let say for example, by tethers then, apex forces are applied indirectly applied to the members. First, we will take an example that how we do apply the direct forces then, we speak about this in this lecture and then, we will talk about the dynamic analysis of mathematical model on articulated tower in this lecture and consequently in the next lecture. Now, there are some basic assumptions for what we make when we working out the forces on earthquake forces on the offshore structures resting on the sea bed. They say the ground acceleration u double dot g, basic assumptions what we make in case of applying earthquake forces on structures or offshore structures resting on the sea bed. We say that the ground acceleration which I said u double dot g occurring during earthquake is non-zero mean, Ergodic Gaussian process. We all understand that the earthquake is the random phenomena; so, whenever there is random phenomena uploading and loading we must use the statistical tools to find out the equivalent force as applied so, one generally people do spectral analysis for that. So, there is a basic assumption in my loading that is the non 0 mean what does it mean is, if you have got a plot what are may be the however may be the variation if the positive and negative amplitude sum brings to mean to 0, I call that process the zero mean process. But, when the positive or negative amplitude is higher and my mean does not come here but shift either upward or downward, I call that was the non 0 mean process. So, it means the positive and negative amplitude of the random time history of the force is not equal with respect to any mean activity. So, it is a non 0 mean process and of course, in statistical terms the process is Ergodic and we can apply the Gaussian rule to this. So, we say it is an Ergodic Gaussian process.

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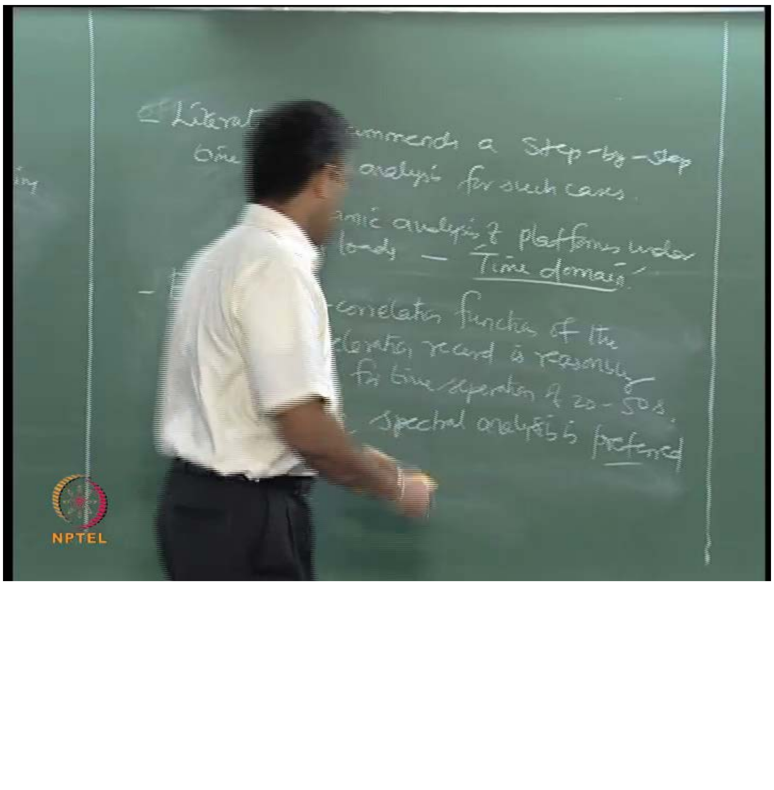

Therefore, literature recommends a step by step time history analysis for this for such cases. So, on the other hand the dynamic analysis of system of platforms under earthquake loads is usually carried out in ‘time domain’. But, the auto-correlation function of the acceleration record, you have an acceleration time history record u double dot g which is the time history. The auto correlation function of the acceleration record is reasonably small for time separation of 20 to 50 seconds; it has been estimated form the existing record that, the auto correlation function is reasonably small for this time separation. And hence, one can do spectral analysis so one can do spectral analysis. In this case the moment I say spectral analysis then, I must define a spectrum based on which my earthquake loading will be computed or the energy uploaded on the system under earthquake loading will be computed.

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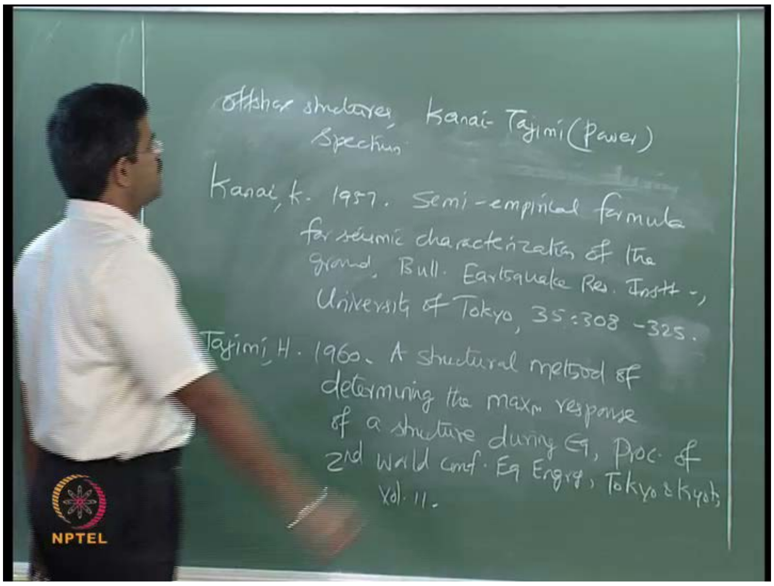

So, in offshore structures people have used famous Kanai-Tajimi spectrum, some people call this power spectrum so, I am writing it in a bracket which is given by Kanai K 1957 for seismic characterization of the ground published in bulletin of the earthquake research institute university of Tokyo, volume 35, 308-325. And subsequently, given by Tajimi in 1960: A structural method of determining the maximum response of the structure during earthquake, proceeding of the second world conference on earthquake engineering held on Tokyo and Kyoto volume 11. So, based on this 2 references a power spectrum has proposed and referred in litterateur as Kanai Tajimi power spectrum which is quite often been recommended for obtaining the earthquake forces on offshore structures. Again, remember we have got 2 options the offshore structures can rest on the sea bed where, earthquake force were imposed.

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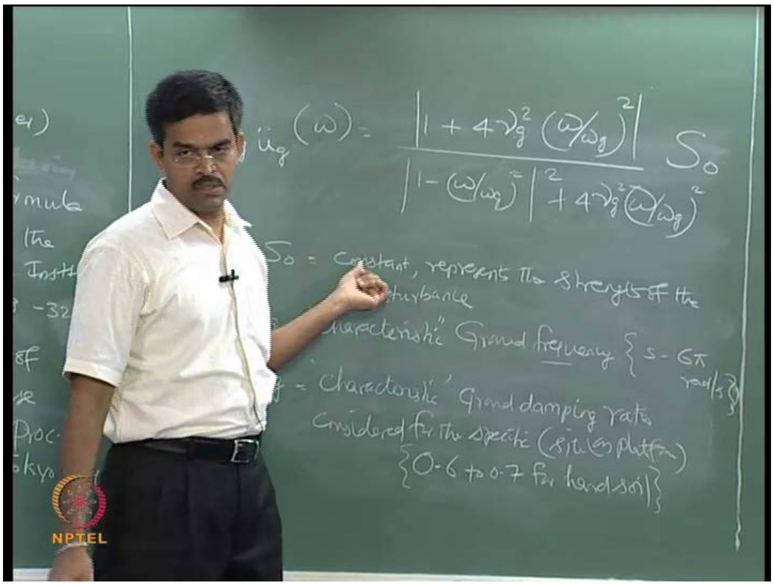

We do an analysis; offshore structures can be anchored to the sea bed using tethers or any cable system. Then, again earthquake is applied on the sea bed how will you transfer. So, we are looking for the option A where, offshore structure resting on the sea bed. So, the spectrum is given by S u double dot g u double dot g of omega where, omega is the frequency content of this.

Now, you want to prevent on protect the directionality so, it take the mode value of this where, S 0 is a constant which represent the strength of the disturbance. So, here people do a factor that, if the offshore structure is not directly resting on the bed which is subjected to seismic action then, S 0 can be a factor which can e multiplied to the powered spectrum of the Kanai Tajime to find the reduced effect of the spectrum on the superstructures. So, S 0 is constant which represent the strength of the disturbance applied on to the structures resting on the or in the sea bed directly usually researcher take this as 1. Omega g is the characteristics ground frequency. Remember, I am using the characteristics they have got a specific meaning in statistical analogy. For example, f c k, f c k in concrete is characteristic compressive strength of the concrete it means, it has got a specific definition what do you mean by characteristics strength in statistical term. I am looking this because I am assuming that this is the non 0 Gaussian process the statistical term. So, omega g is the characterizes ground frequency ranging from phi to 6 pi radians per second that is, the range ranging from phi to 6 pi radian per second of course, omega is the frequency content of analysis in the spectrum and gamma g is the characteristics ground damping ration, it is a ratio. Considered for the specific site or platform whatever you want to take which can generally vary from 0.6 to 0.7 for hard soil. So, for a given characteristics ground frequency of any value for a different range of omega for the specific characteristics ground damping ratio, I will be able to plot this spectrum if, I assume any disturbance by number its nothing but, the constant. I will plot this spectrum that will give me the energy where, I am going to apply on to my platform.

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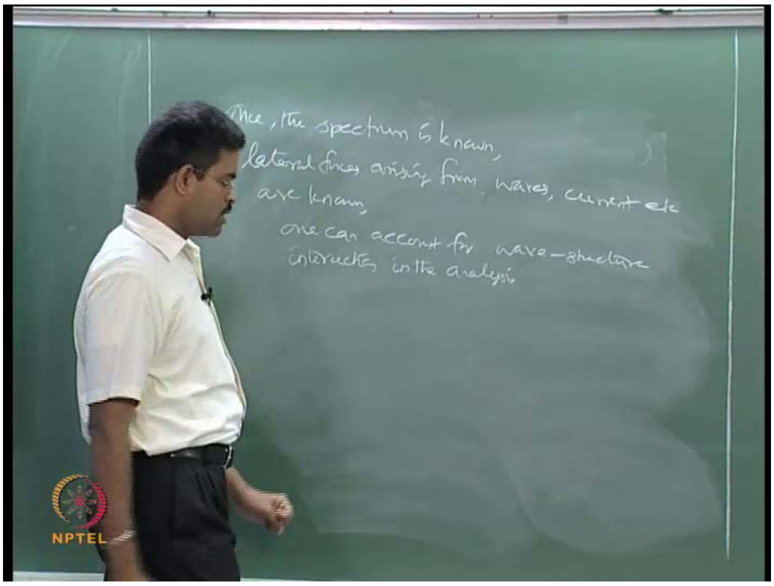

Now, once spectrum is known and lateral forces arising from wave, current etceteras are known then, one can account for the wave structure interaction in the analysis. We will quickly see very briefly how the equation of motion can be written in this case.

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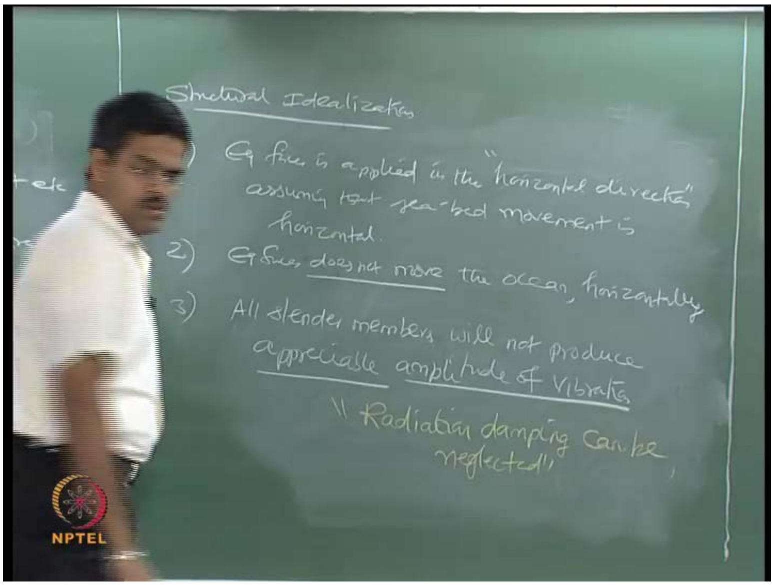

Now here, there are some basic structural idealization we do, let see what are they? 1: The earthquake force is applied in the horizontal direction in the horizontal direction assuming that sea bed movement is horizontal. So, the vertical direction we do not impose that is the idealization what we do in analysis. I will come to this explanation why it is so later. Let us try to understand that the sea bed movement is considered to be horizontal. The moment I said sea bed is moving with respect to sometime history then, one can wonder whether the water body will also move. Second assumption is; the earthquake force does not move the ocean horizontal it is very important. 3: Obviously, when I place a slender cylinder in a fluid structure medium. When, the cylinder is very slender, the cylinder will also starts vibrating and this vibrating motion will also cause some additional force because of this vibration, the third assumption is pretending to that. All slender members all slender members will not produce appreciable amplitude of vibration.

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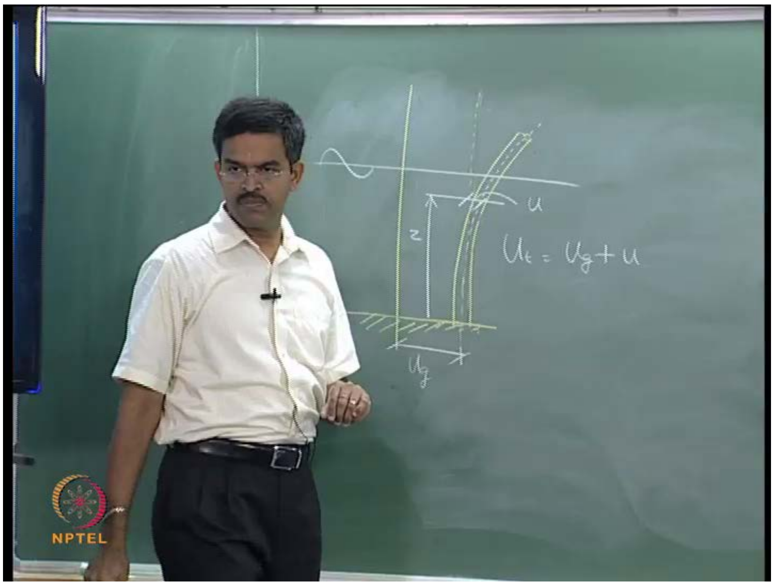

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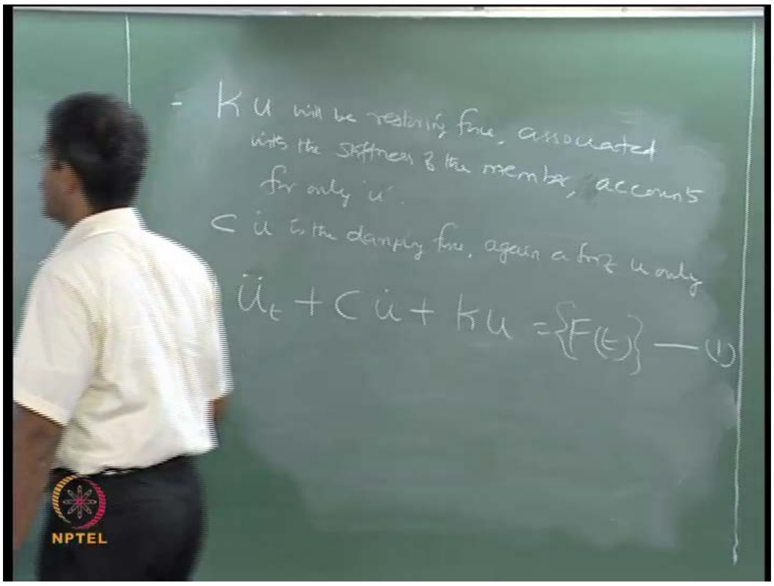

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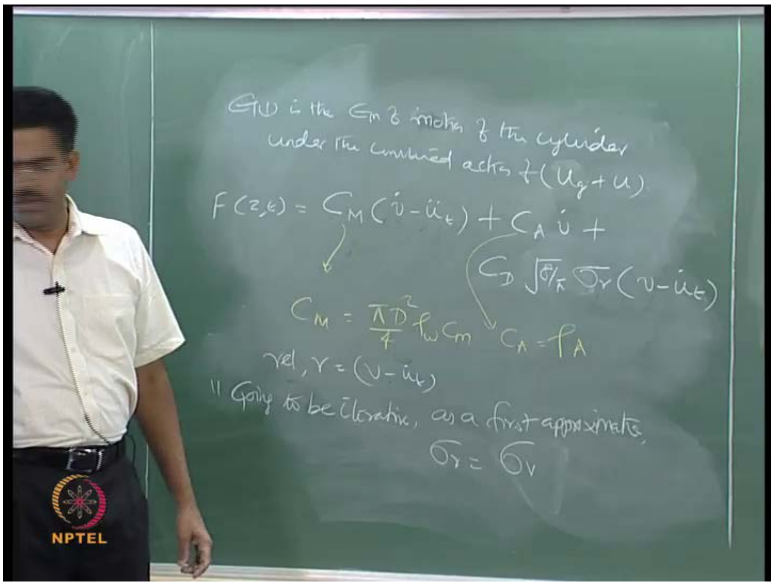

So, what does it mean this says that the radiation damping can be neglected, that is the count effect of this assumption. So, have been said this. Let us pick up a cylinder member and write the equation of motion for the under earthquake forces. Let us say, at any section z from here, let us say a member has moved by u. Of course, there is displacement of the center line of the member because of the u g displacement because I said this sea bed movement. So, I now say the total displacement is sum of the ground displacement plus the displacement of the body because of the lateral forces action. Now, interestingly K u will be the restoring force associated with the stiffness of the member which accounts for only u be careful it is not u g it is the stiffness of the member only for the displacement u, u g plays no role in stiffness. And of course, C u dot is the damping force, again a function of u only. Having said this, we can now say M u total double dot plus C u dot plus K u is F of t that is my equation of motion 1. So, equation 1 is the equation of the motion of the cylinder under the combined action of u double dot g plus u, that is because of displacement by the lateral force and u double dot g is the accelerated force or simply we can say u g displacement because of the sea bed movement. We already know F z of t, we already know f z of t I am replacing it here form our previous expression each can be given by C M of v dot minus u double dot total. There is a confusion here, I am talking this v dot as acceleration u double dot is acceleration total because of the sea bed movement and the acceleration of the cylinder under lateral forces so, that is why there are is there is no double dot here because I am using the same convention as we wrote the equation the pervious lecture with v dot. Ok.

So, that is C A v dot plus C D root 8 by pi. I am looking for a linear drag on a slender cylinder I am talking about slender cylinder here, sigma r statistical property v minus u dot v is again a velocity here, it is not displacement. And we already know that this C M accounts for pi D square by 4 rho double C M and the C A accounts for rho A we already know this. And the relative velocity now, which is r as you see here as a subscript is: v minus u dot. So, as a first approximation this scheme is going to be iterative when we use a time domain analysis solution this will be iterative so, going to be iterative as the first approximation because in the first values will not have sigma because you will have only 1 set of value, when you iterate you will get more and then you can use this. But, initially sigma r is taken as sigma v directly do not impose the relative value here the start with, to start with no relative is done.

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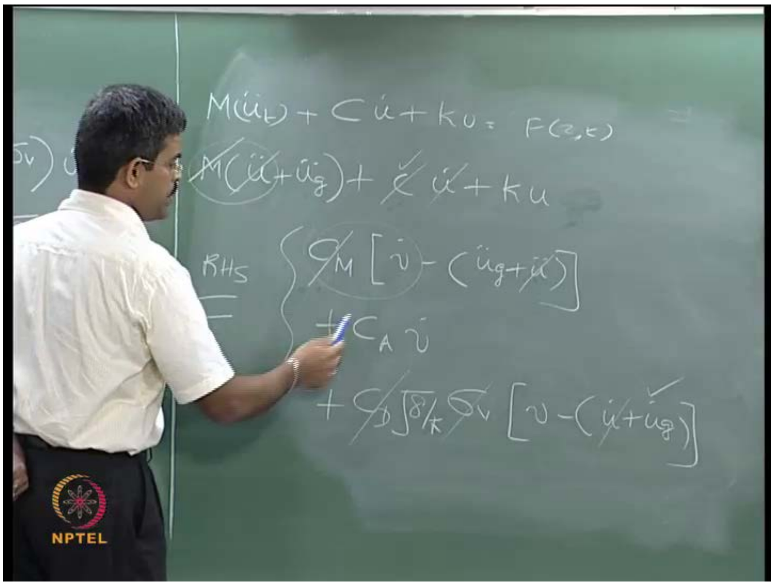

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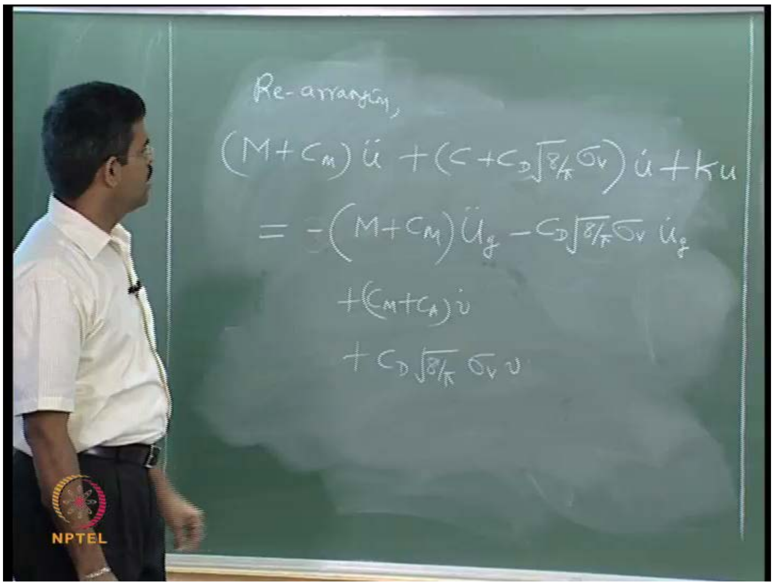

Let me rewrite this equation again, M u double dot total plus C u dot plus K u is F z of t. I am saying this as M u double dot plus u double dot of g plus C u dot plus K u as C M is equal to C M v minus of u total u double dot total which is the ground acceleration plus the cylinder acceleration plus C A of v dot plus C D 8 by pi root sigma v that is what my initial approximation is just now I said this, multiplied by u total is here so, I should say v minus u plus u dot. Any question here? I rearrange this term slightly in a different form. any question here I rearrange this term.

So, M plus of course, it is on right hand side I should say equal to this is RHS this is RHS, this is LHS this is equal to sign here I just remove this right it here I bring this term to my left hand side. I will write here, M plus C M of u double dot. Let us keep on checking. This term goes away, this term goes away. Plus there is a u dot term with C here so, u dot term with C D here this is negative on the RHS. I bring it to the left hand side C plus C D of let say C D has got the multiplied here, root 8 by phi sigma v of u dot. So, let say this term has gone, this term has gone. Plus K u is equal to, one what you have left we take it to the right hand side so, there is u double dot g here it goes here minus.

So, minus of it is a minus of M. There is already a minus term on the right hand side e double dot with C M. Plus C M of u double dot g. There is a negative term here with u dot g with C D. So, minus C D 8 by pi sigma v u dot of g, that is this term. So, I have v dot here with C M, I have one more v dot with C A. So, plus C M plus C A of v dot, this goes away and of course, one more term of C D 8 by pi with v, plus C D 8 by pi sigma v. So, that is my modified equation of motion. It is a classical form how people write the equation of motion when, the structure or the body is subjected to the earthquake acceleration. How do you check that? Whenever there is a negative sign on the RHS taking about u double g it is a classical form of writing the equation of motion with ground acceleration. So, whenever you see any equation of motion written with ground acceleration you will find that there is a negative sign on your RHS talks about u double dot. So, there is a classical form which we derived or which we assembled or rearrange form the original equation of motion. This is the class A where, my structure or the platform is resting on the sea be where, sea bed is moving horizontal ocean does not move horizontally slender cylinder will vibrate will cause vibration and they will also cause movement that is neglected. Therefore, radiation damping term is not there in system only viscous damping is there. So, classical form of equation of motion is this.

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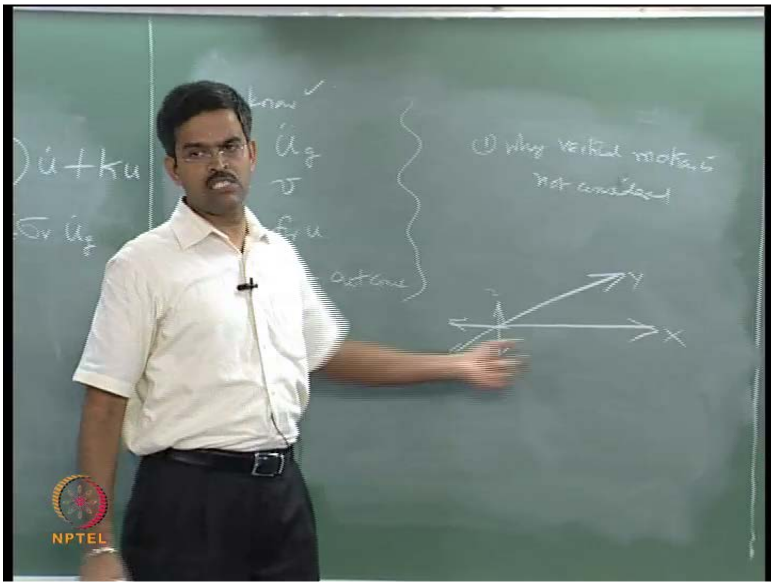

Now, once what we know from this equation and what we will solve. Any question here? So, what we know from this equation? u double dot g should be known to you, otherwise you cannot solve this, forcing function. And of course, v what is v water particle velocity or water particle kinematics, we should know this at any instance of time or any member position z form the sea bed, I must know. We can use any appropriate theory to get v we have seen this theory so, I must get v. So, let us see this equation back again I have this with me of course, C D, C M are known to me, I am not talking about that. All we know this there are various international codes which will advise me what C D, C M should I use for depth in variation or what approximate values should I use for a specific sea state a p a for example. So, C D, C M is known to me. Of course, C A is also known to me. As it is a linearized drag I know this and therefore, I know this also. What I will solve is solve for u, which is actually the displacement of the cylinder. Since, I am getting solution for u actually conscious equation of motion looking about displacement. So, what I will get here will be the displacement time history, will be the output because the forcing function everything is time dependent, v is time dependent, u double dot g it is a derivative, it is a time dependent, I will get the displacement in time dependency. So, how to solve this and what will be the scheme to solve this in time domain we will see in the next lecture. We will take up a time iteration scheme advice by Newark's beta method we will take up this scheme and there are many other schemes suggested recent Wilson theta method etcetera. We will look into those scheme in the next lecture and see what scheme will apply and how do I actually the scheme makes iterative we will see that and of course, we will solve the problem here I will show you the results and solution for this particular case. Any question here? This is how I am handling problem where, my structure is resting on sea bed and sea bed is moving horizontally.

Now, there are interesting question being asked. 1: Why the vertical motion of the earthquake is not considered because we are talking about horizontal movement only. The earthquake has 3 directional movements. What are they? Along x, along y and along z, when I am talking about unidirectional force, I will take either a along x or a along y. I can do analysis on both form and see which is the maximum response you want to combine this 2 then I is 893 says takes x plus 30 percent plus of y only.

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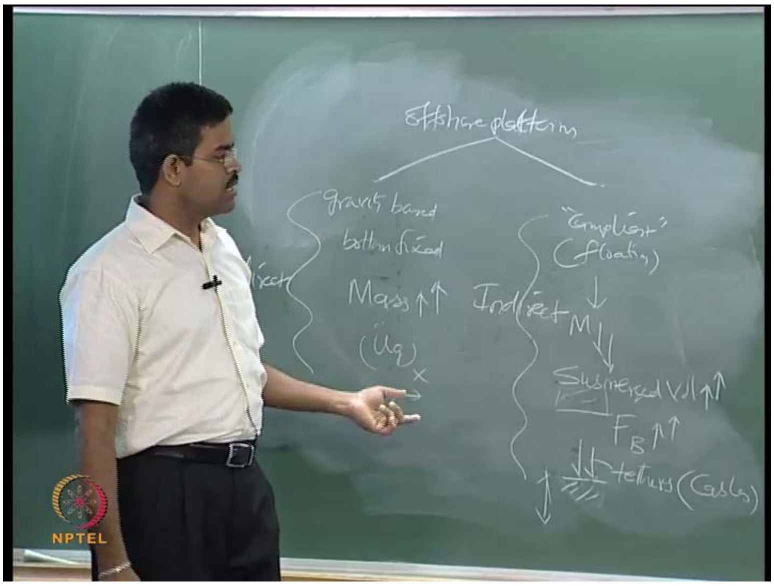

You can combine this also. Why the vertical force is not considered in offshore structures? We are talking about this why. There are many reason for this, these are interpretation from the research papers. Many of the discussion what we have in the lecture here are interpretation and studies made by different researchers they may not have a direct reference on the black bond here. Look upon literature you will find these are relevant application in an offshore structures. The main reason for this is, if you look at offshore platforms. Let us say which is gravity based or bottom fixed or which are compliant which in layman's language is 'floating', technically 'compliant', non-technically 'floating'. To resist the lateral forces if you want to bottom found the member the member will have enormous mass.

When the member is having enormous mass u double dot g in x axis will cause inertia force on the system, u double dot in the z axis will be counteracted by the mass. So, the member will have indirect effect but, the mass is very large compare to the amplitude of this motion need not be considered. If, you look at the floating structures, very simple the mass is very less but, the submerged volume is very high because they are buoyancy dominated.

The buoyancy domination in this platform is generally very high to counteract. This buoyancy, I generally hold it down to my foundation using tether or in a layman's language cables. The inertia force will be attractive only when they are acting on a respective mass now, tethers will have more mass at the foundation point. And this vertical acceleration cannot be directly imposed on tethers or on the system which is floating because they are restricts. So, there is an indirect effect cause on the system because of the vertical motion or horizontal motion though the cable or though the tethers. So, it is an indirect process whereas, in this case it is a direct process.

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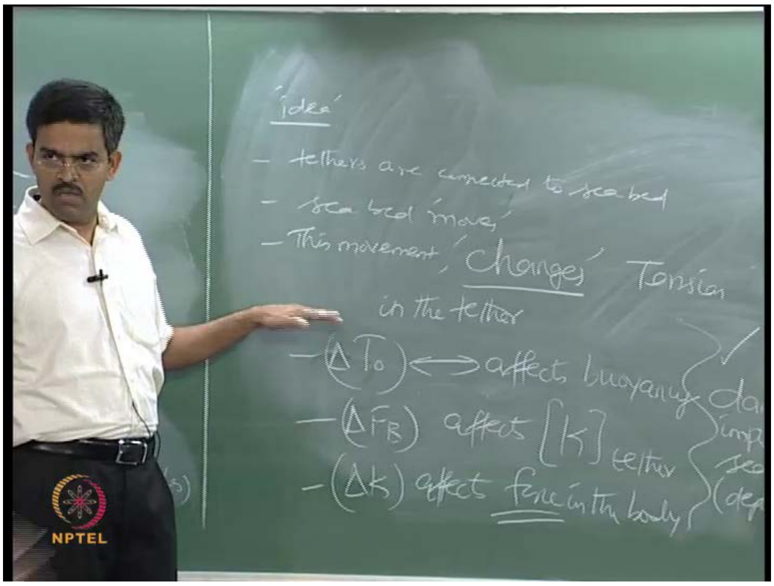

So, vertical motions are not generally considered in the analysis of let us say, the seismic action for offshore platform. The second question comes, how do I do the indirect action in a platform which is floating. We will derive the equation of motion for this separately in successive lectures as we derived it for fixed based structures. But, the idea is tethers are connected to sea bed, a sea bed move that is what we already see. This movement actually changes the tension in the tether, the change in tension what I call as delta T not. The change in tension affects buoyancy, the change in buoyancy affects stiffness in the teeth, and the change in stiffness affects force in the body and this is the force which is directly applied form the earthquake movement to the body. This is the force. So, it is not directly applied it is indirectly transfer to this mechanism and it is applied.

So, interestingly in this process automatically the damping imposed by sea water or water depth is accounted. So, automatically accounted for how the damping will reduced the forces on delta T not and that will counter effect the buoyancy and buoyancy will counter effect stiffness and stiffness will counter effect the force on the superstructures on the deck. So, the damping imposed by the water depth on floating system because of earthquake action happening on the sea bed will be automatically accounted in this mechanism. So, it is an indirect method so it is an indirect method where as this is direct scheme. For a direct scheme, I already had the equation of motion shown to you, you can anytime iterate the scheme to solve this and get time history of the displacement of the platform or the structures which is founded in the sea bed. Whereas, for indirect scheme we will pick up an example problem and draw a right the equation of motion again then, we will see in stages how transfer mechanism take place and what do we actually at this stage, what will be the input at his stage we will see that in the scheme. That is how it is done in case of seismic action applied on as one of the lateral force which is mandatory for offshore structures other than waves and current. Any question here.

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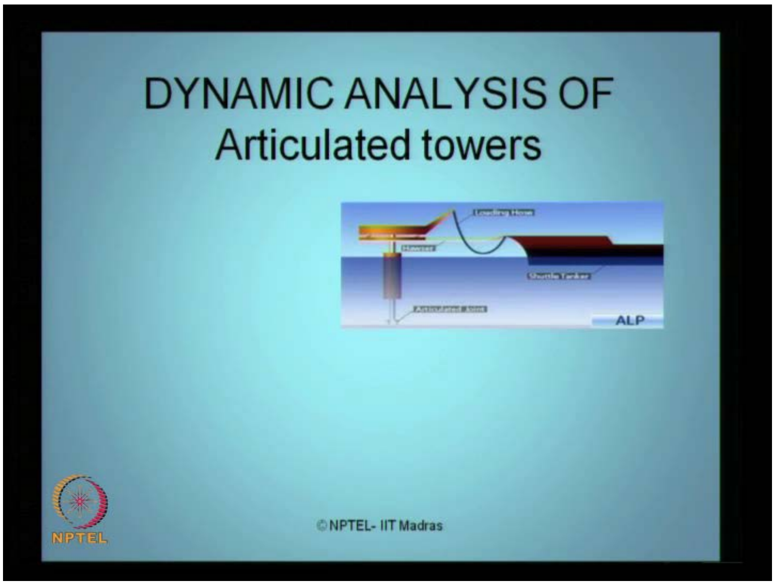

Five minutes only remaining may be three minutes. So, we will talk about quickly at least concepts of picture of articulated tower then, we move to the dynamics analysis in the next lecture. So, this is the conceptual picture of articulated tower. You may wonder where the tower is. This, is tower actually, this is the tower which is single leg. Why it is called articulated, there is a hinged joint here. Articulation is the technical name given for hinged joint. What is the purpose of this tower? This tower will have a deck you can see that there is a deck here, there is a deck here. The purpose of this tower is to anchored deflating or any shelter tanker. It is working as an anchor leg, I mean for anchoring purpose, articulated leg platform that is A L P. So, not necessarily articulated tower are used for or implemented or installed for production or drilling, they can also be used for anchoring. So, the majority of application of articulated towers in present scenario are used for crating temporary enable base in sea, you want to create an inspection base in sea enable base in sea I will go for A T because A T installation and decommissioning are as simple as that and they can be mostly reusable. And if you want to hold down a big tanker in the sea during F S O floating storage offloading process to hold it down I have D P S system dynamic position system in addition to that i anchor the shelter talker with an A T.

The third application is we have got deep water riser where the direction drilling is taking place in between the riser segment I have to hold down the riser profile otherwise, riser will be subjected to lot of lateral forces because of current and waves. To avoid this or to improve on dynamics of riser I support the riser’s in between using this kind of structures there are segmental applications for this. Obviously, A T cannot be a production platform but, surprisingly A T has been also attempted as production platform which will show you in the next lecture. Couple of production platform has been attempted in U S in golf of Mexico as using multi hinged, multi legged A T, M L A T. Why I picked up this example is that, A T has got high degree of freedom in term of response rotational response. So, people now start working on controlling this response using some artificial network or some artificial techniques where, they called as response control algorithm for articulated tower. So, we will pick up with an example as extended study of this in the due course of lecture.

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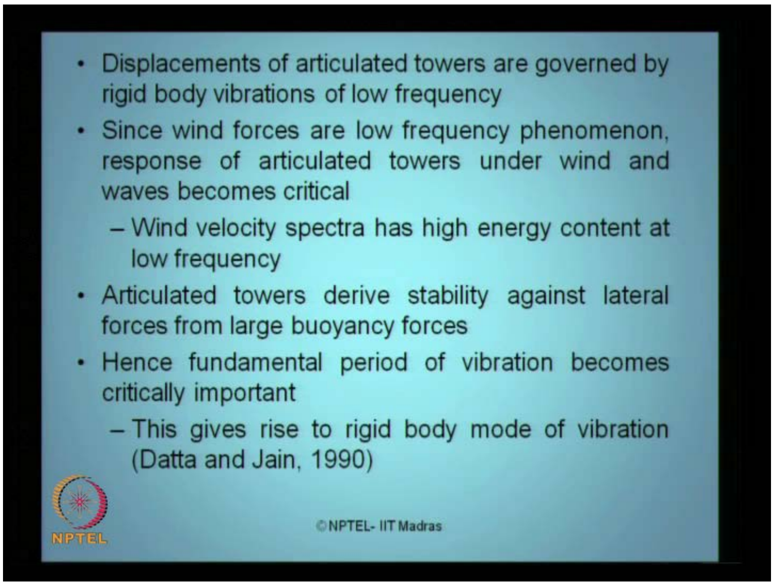

So, we are going to talk about A T in the next lecture the conceptual figure of course. Displacements of A T or governed with the rigid body vibration of very low frequency that is very important since, there is a low frequency mention here wind energy or wind spectrum which has got high energy the low frequency will be predominant. So, they are more versatile and susceptible to wind action apart from this. So, wind forces or low frequency phenomena therefore, wind velocity spectrum has very energy content at the low frequency. Therefore, aerodynamic response of A T becomes more critical. But, essentially we have seen in the first module A T derived stability because of large buoyancy forces, we have got buoyancy tank based on which A T actually derive the stability against lateral movement. So, the fundamental period of vibration A T become very critically important in our analysis, this gives actually rise to a rigid body motion which vibrates only in a specific frequency as expressed by Jain and Datta 1990. I think we will stop here we will continue with next lecture. We take up the mathematical model of A T, we will show you the solution, we will not solve it here of course, and it is not possible. I will show, I will go discuss the result of these particular structures in dynamics perspective in the next class. Any question, any observation in this lecture?