Offshore structures under special loads including Fire resistance
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Lecture - 17
Earthquake Loads – I

Friends, welcome to the 17th lecture. In this lecture we are going to talk about the earthquake loads as applied to offshore structures and the analysis procedure under earthquake loads, this our first part of the lecture. In the second part of the lecture we will take up a specific case study which is applied on a tension leg platform and show you the procedure how the analysis could be carried out and what could be the interpretation of results or on the other hand consequences on complained structures under these kind of special loads, which is earthquake loads.

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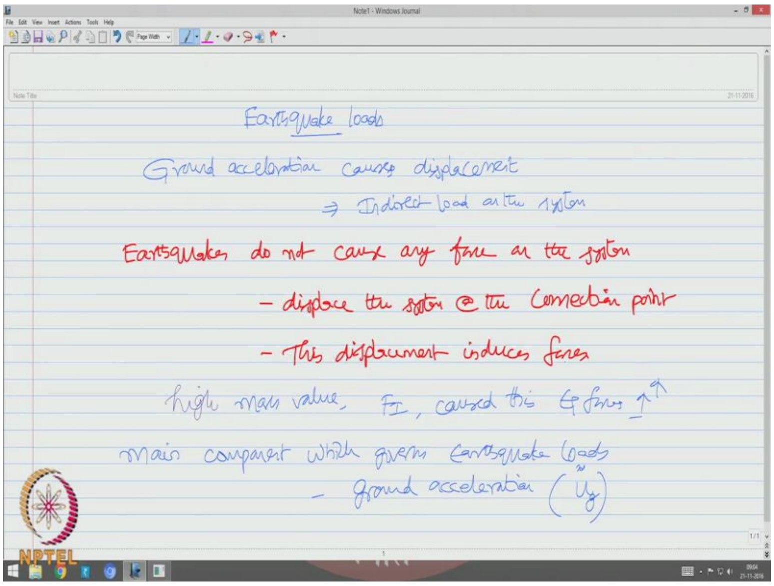

The moment we talk about earthquake loads, we understand that ground acceleration, causes displacement and that is a indirect load on the system.

On the other hand it is interesting to note that earthquake forces or earthquakes do not cause any force on the system. In fact, they displace the system at the connection point and this displacement induces forces; obviously, when the system is with high mass value, inertia forces caused by the earthquake forces will be also relatively high. So, the main component which governs earthquake loads can be the ground acceleration, which we express as U double dot g.

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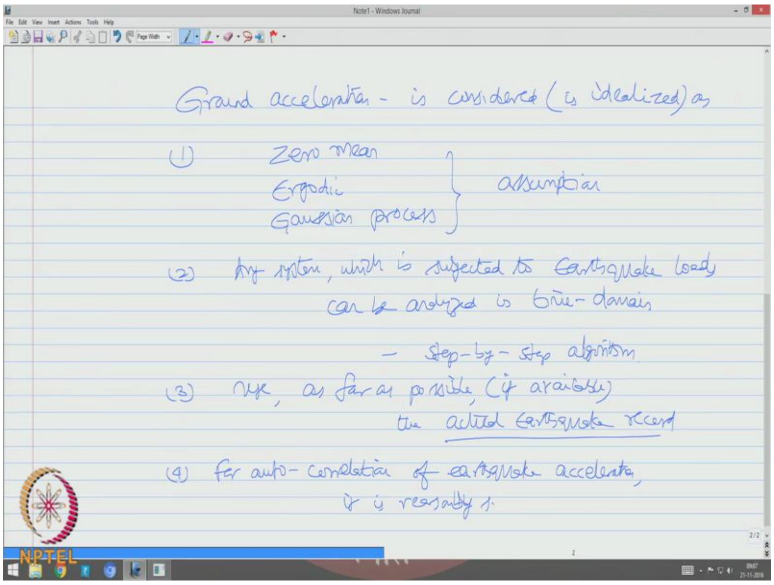

The ground acceleration is actually considered. In fact, I should say is idealized as zero mean ergodic and Gaussian process that is a basic assumption, which we make to model this earthquake forces for dynamic analysis. So, that is the first stage we have.

The second stage is any system which is subjected to earthquake loads, can be analyzed in time domain using your step by step algorithm. Many researchers have supported this statement and they have implemented this in dynamic analysis, I will show you couple of references later in this lecture.

So, third issue is to do an earthquake analysis, use as far as possible if available, if available as far as possible the actual earthquake record. Now here is the issue as for as land base structures are concerned, the earthquakes are measured in amplitude and duration by various means by using accelerograms and people have records and they have past histories whereas, earthquake occurs on seabed, there were no such measurements available in the literature therefore, no real record where earthquake occurred on seabed is available for in the form of past records for analysis.

The forth issue could be for auto correlation of earthquake acceleration, it is said that it will be reasonably small.

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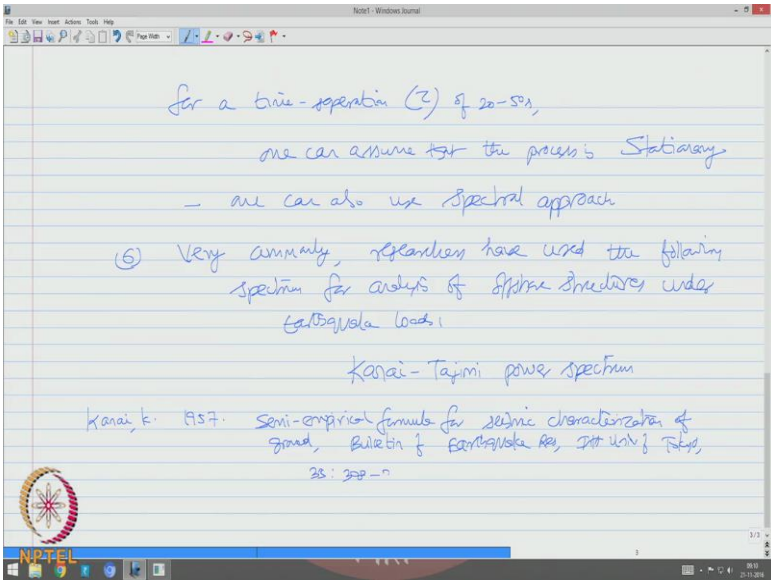

For a time separation that is tau, you know auto correlation function is taken for two samples with the time interval of a specific define interval, let us say tau and for a time separation of about 20 to 50 seconds, it is stated that one can assume that the process is stationary.

Therefore one can also use spectral approach. So, very commonly researchers have used the following spectrum for analysis of offshore structures under earthquake loads, people are used what we call Kanai-Tajimi power spectrum. The Kanai-Tajimi power spectrum as a very interesting reference; Kanai k 1957, semi empirical formula for seismic characterization of ground Bulletin of Earthquake Research, Institute University of Tokyo 35: 308 to 325.

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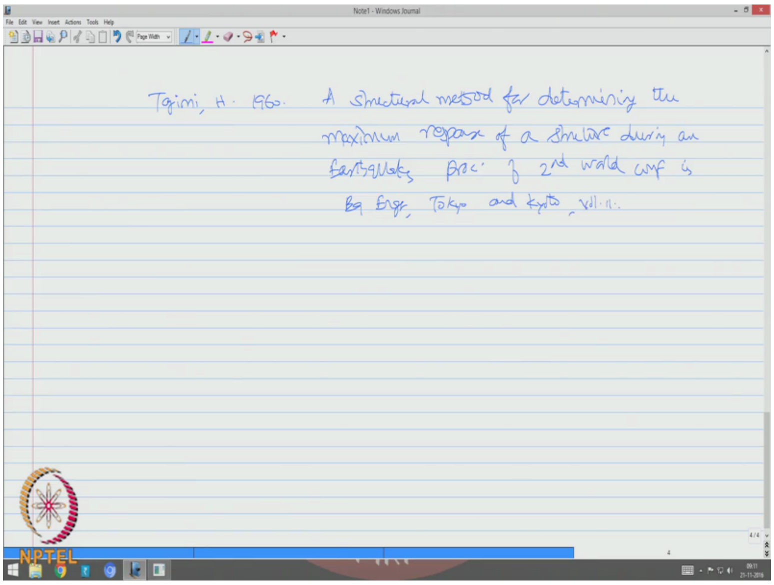

Tajimi, H. 1960: A structural method for determining the maximum response of a structure during earthquake proceedings of second world conference in earthquake engineering, Tokyo and Kyoto volume level.

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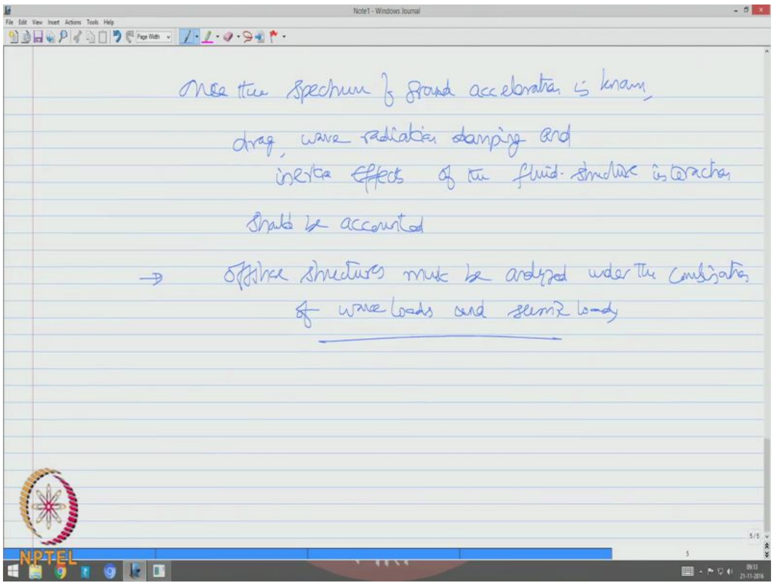

Interestingly once the spectrum is known, spectrum of ground acceleration is known, drag, wave radiation damping and inertia effects of the fluid structure interaction should be accounted. On the other hand the basic idea is offshore structures must be analyzed under the combination of wave loads and seismic loads that is a very important statement we have.

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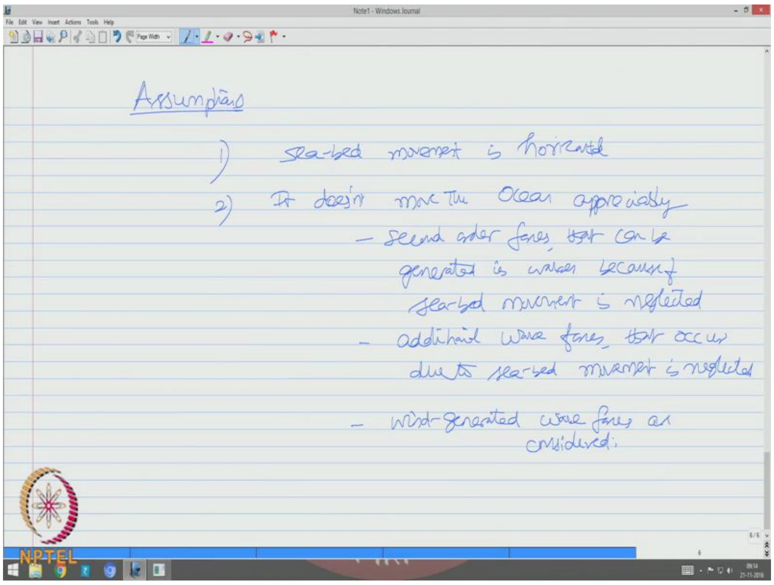

So, while doing, we make certain assumptions; one we assume that the seabed movement which causes ground acceleration is horizontal. Second, it does not move the ocean appreciably; what is it mean is the second order forces that can be generated in waves because of seabed movement is neglected, that is additional wave forces that generally occur due to seabed movement is neglected, only wind generated wave forces are considered.

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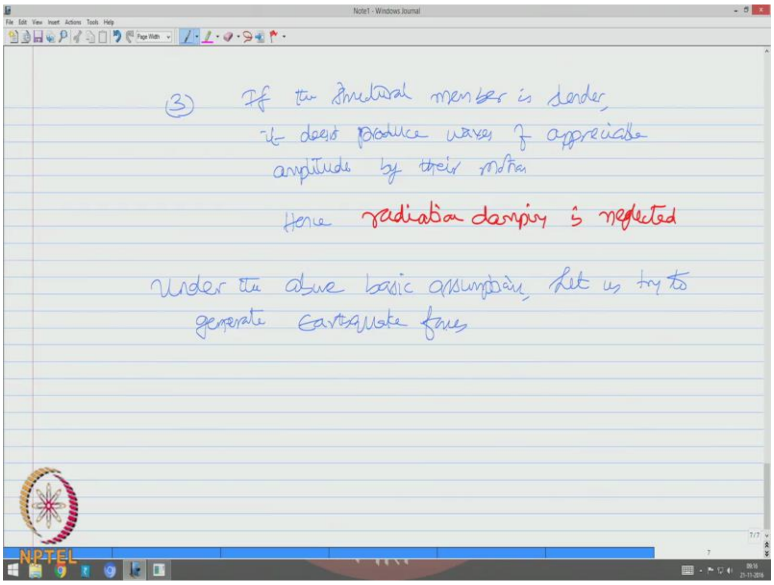

The third assumption; if the structural member is slender it does not produce waves of appreciable amplitude by their motion. Hence, effect of radiation damping is neglected. So, under the basic assumptions, under the above basic assumptions let us try to generate that earthquake forces.

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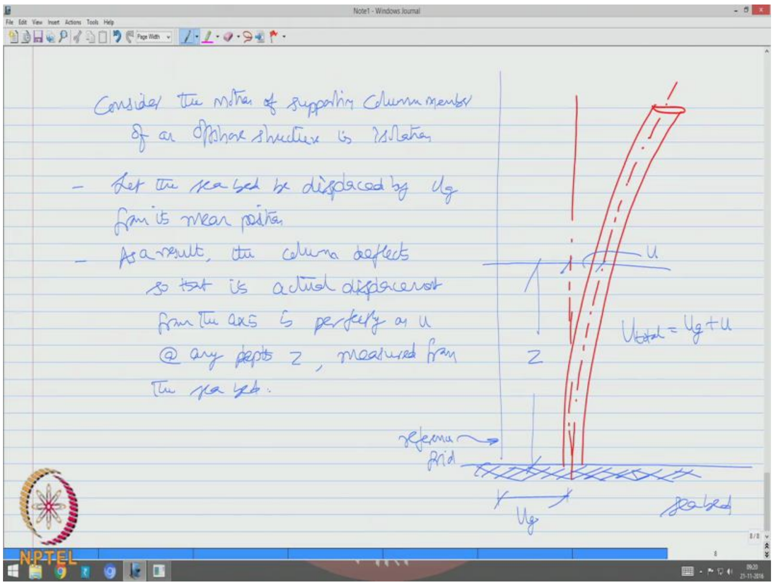

Let us try to draw a figure to understand how the displacement causes forces. Let us say this is my origin of reference, let say reference grid, this is my seabed. I have a cylinder cylindrical body, which bends let us say initial displacement of this is U g, at any Z from the height at any Z we say the displacement caused is u therefore, one can say u total is actually ground displacement plus displacement caused by the load.

So, let us now consider the motion of supporting column, column member of an offshore structure in isolation, let us talk only about the supporting column member. So, let the seabed be displaced by U g, from its mean position which I call as a reference grid, as a result the column member deflects. So, that its actual displacement from the axis is perfectly as U at any depth Z, measured from the seabed let say (Refer Time: 19:01) z measured from the sea.

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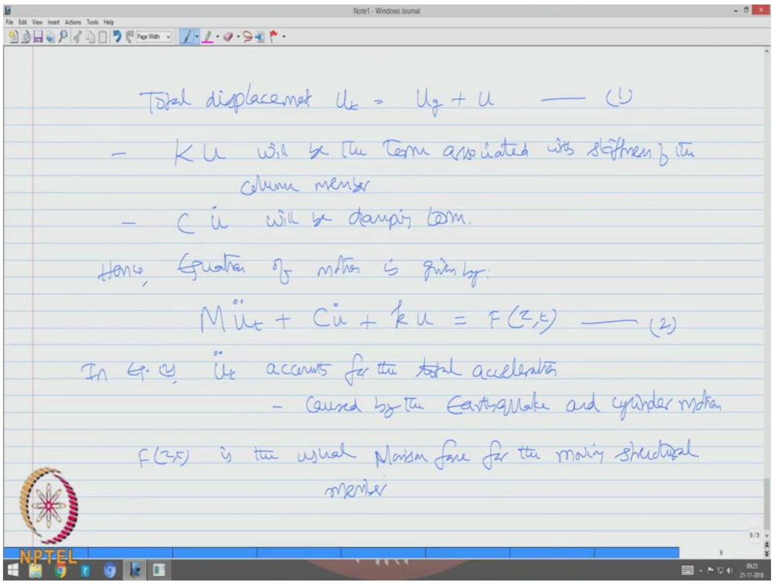

Total displacement U total is ground displacement, plus the displacement of the cylinder. K into U will be the term associated with stiffness of the cylinder says the column member. C into U dot will be the damping term, hence equation of motion is given by M u double dot t, plus C u dot, plus k u is F z of t because z is varying along the height or water depth and t of course, on the time frame equation 2.

Now, in equation 2, U double dot total accounts for the total acceleration, which is caused by the earthquake and cylinder motion, F z of t is the usual Morison force for the moving structural member.

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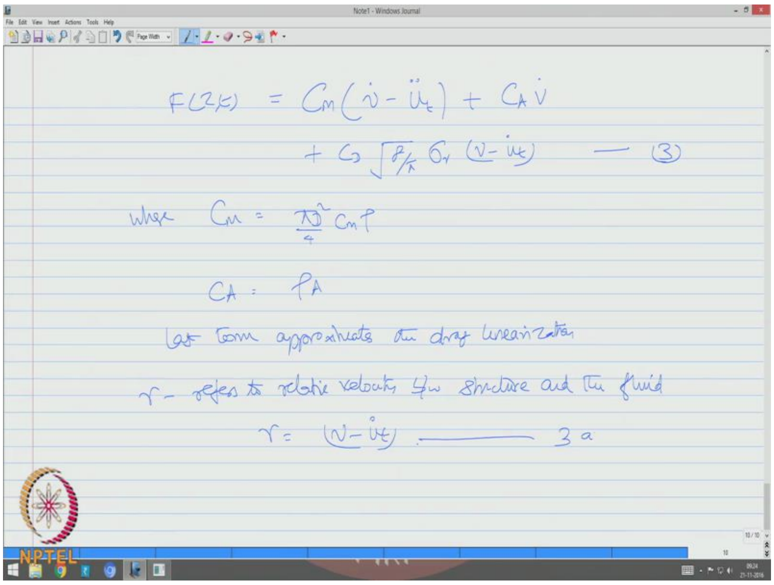

Based on a knowledge which we had in the last lecture, I can write F z of t as C m v dot minus U double dot t, plus C a V dot, plus C D root 8 by pi sigma r v minus u dot of t equation number 3, where C m is pi D square by 4, into C m into rho. C A is rho into a, and the last term approximates the drag linearization as we discussed in the last lecture, r refers to relative velocity term between the structure and the fluid. So, r is actually V minus U dot of t.

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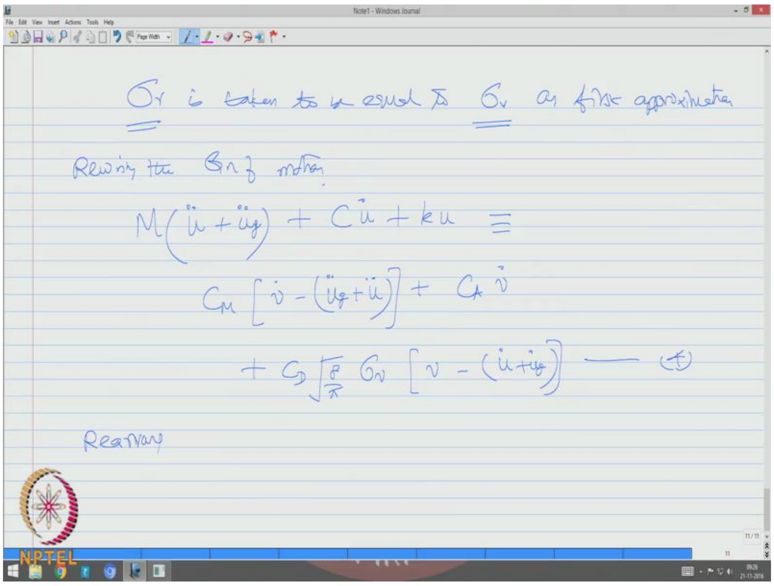

Sigma r is taken to be equal to sigma v as first approximation, because I want to know the standard deviation of the relative velocity term to start with I assume that the cylinder is a mean position and I say that this value is more or less equal to the that of the velocity only, but not the relative velocity between and the cylinder and the earthquake motion.

So, now I rewrite the equation of motion, I should say M, U double dot plus U double dot g that is m u total, plus C u dot plus k u should be equal to C m of V minus U double dot g, plus U double dot, plus CA, V dot plus C D root 8 by pi sigma V of V minus U dot, plus U dot g call this equation number 4.

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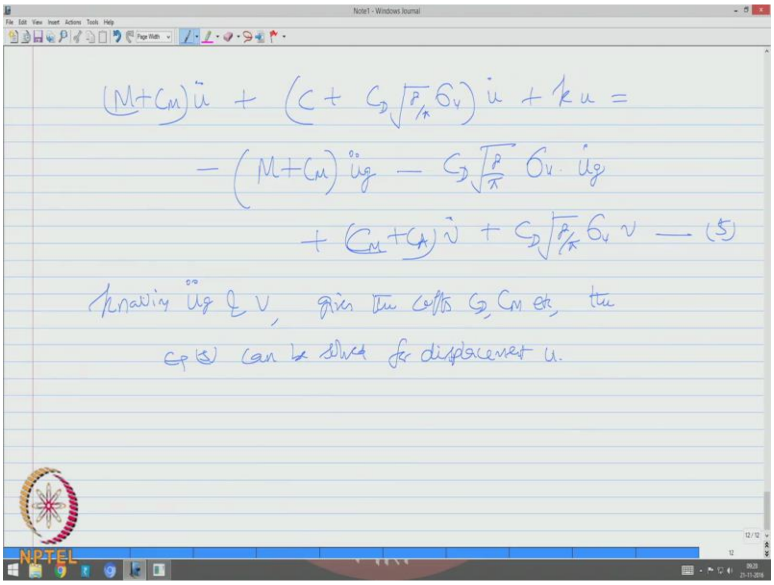

Again rearranging M plus C m of U double dot, plus C plus C D of 8 by pi sigma V, U dot plus k into u is now equal to minus M, C m, U double dot g, minus C D root 8 by pi sigma v U dot g plus sigma M plus sigma A, V dot plus CD root 8 by pi sigma V.

Now, knowing U double dot g and V, given the coefficients C D C m etcetera, the above equation can be solved for displacement U.

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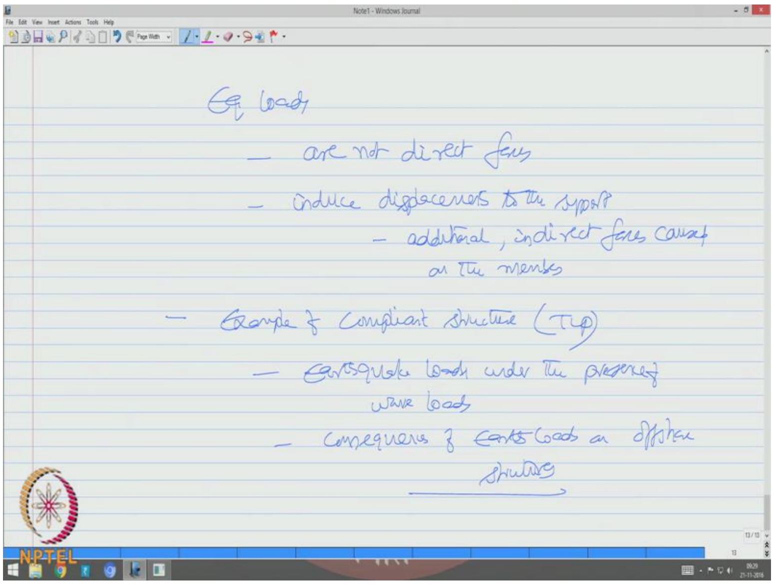

So, friends in this lecture we are able to introduce the earthquake forces, we said that earthquake loads are not direct forces, they induce displacements to the support and because of this there are additional indirect forces caused on the members.

In the next lecture we will take up an example of a compliant structure, let say attention like platform, apply earthquake forces under the presence of wave loads and see a study the effect of consequences of earthquake loads on offshore structures. So, we are entering into an (Refer Time: 27:58) interesting domain of understanding of behavior of compliant structures because fixed structures do not represent much of the displacement effect on the system. Whereas compliant structures we understand they always elevate the encountered loads, only based upon the relative displacement between the cylinder or the structural member and that of the wave velocity.

So, when they are remain compliant, when they are anchor to the seabed using mooring lines or (Refer Time: 28:32), the effect of the relative displacement place a very important role in counter acting the earthquake forces, but they also cause some adverse effects on the structural response, which will try to understand in detailed manner in the next lecture.

Thank you.