Advance Marine structures

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Lecture - 10
Other loads-II

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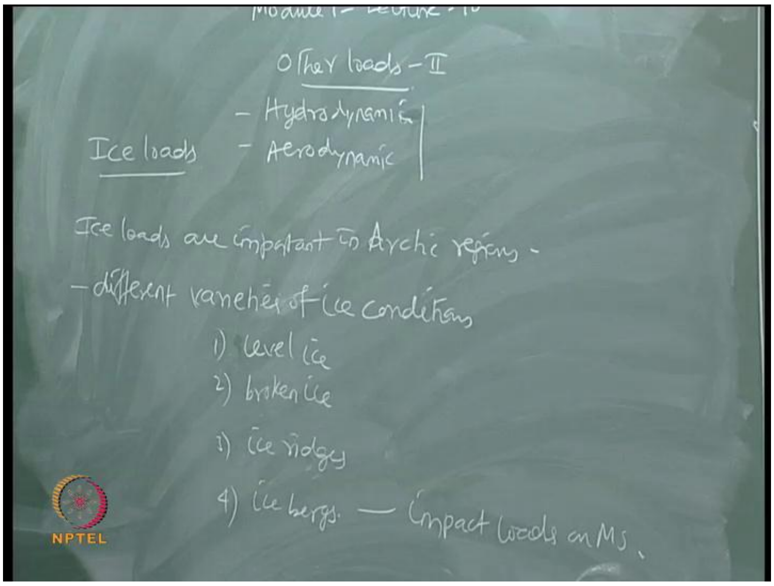

So now we will talk about the next lecture, which we speak about the other varieties of loads, which are acting on marine structures. So far we discussed about hydrodynamic loading, and aerodynamic, so we are seeing different application, where which spectrum can be used appropriately what kind of structure. The ice loads are predominately important, in arctic regions. There are different varieties of ice conditions that can cost loading; one is, what we call as level ice, other is broken ice, ice ridges, and of course ice burgs, they are responsible for causing impact loads on marine structures.

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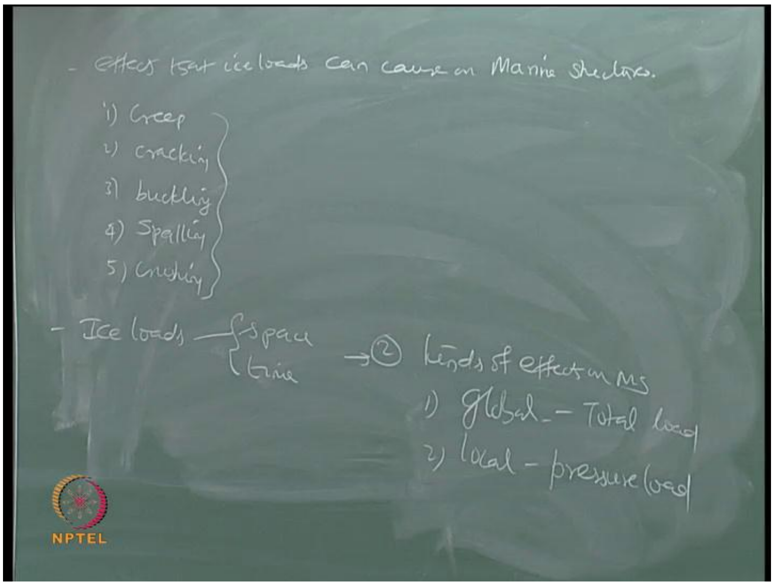

Now, let us quickly see, what are the effects that ice can cost or ice load can cost on marine structures. It can result in creep, cracking, buckling, spalling, and crushing. These are different consequences, what ice loads can cause to the marine structures. Interestingly ice loads vary with space and time. They generally cause two kinds of effects on structures; one is what is called global, other is called local. The global effect is also called as total load in the literature, the local effect is also called as pressure load in the literature.

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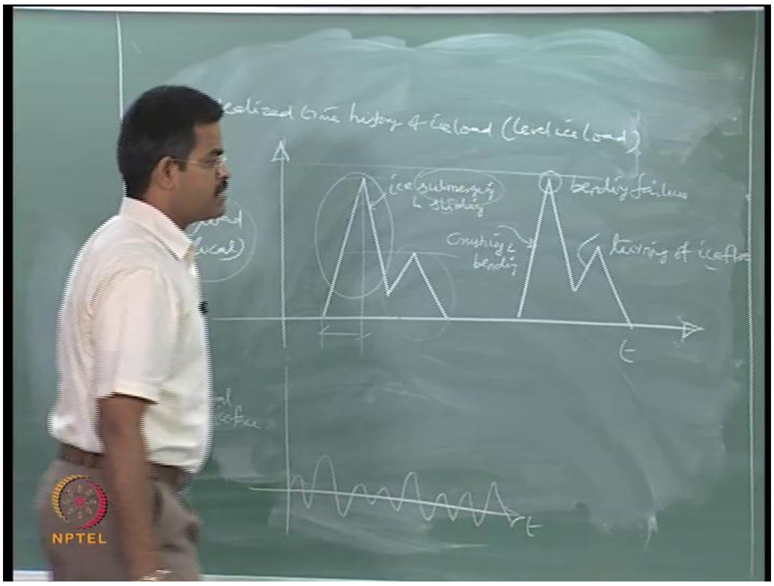

Let us now look at the idealized time history of an ice load, I am talking about the level ice load, this is local. I also have another figure, then will talk about the total. So the loading, this is what we call loading due to ice submerging, and sliding. What does it mean is, the ice load starts applying its maximum pressure, at a very instant of time, then the load is released, then as the load is released, the ice is not sliding, and that is creating another kind of force; of course, the magnitude of the sliding, is much less then the top submerges.

So this part is mainly due to submergences of ice, this part is mainly due to sliding of ice. If we look at the behavioral in terms of it is failure, then a similar curve is also existing, this is what we call as wending failure; say maximum, in terms of it is loads, and this curve, or this ascending line of the curve, is related to crushing and bending together, it keeps on increasing. And this load, is mainly due to turning of what we call ice flow, turning of ice flow, this creates an additional load on the marine structures, this is about the local effects. Talk about the global effects. It is random phenomenon, which varies with time as well as in space.

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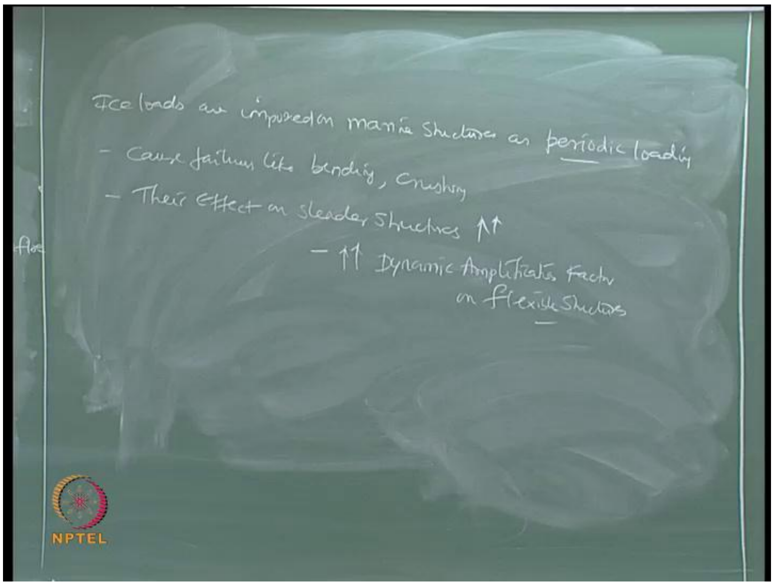

Therefore, ice loads are impost on marine structures, as periodic load. They can cause failures, like bending, crushing, and their effect on slender structures, is very high. It means, this increases the dynamic amplification factor, on f is say flexible structures. More interestingly, to quantify the ice load people have done the search, how the ice load can be quantified. While they did this work, they founded very important parameter, which governs the ice load.

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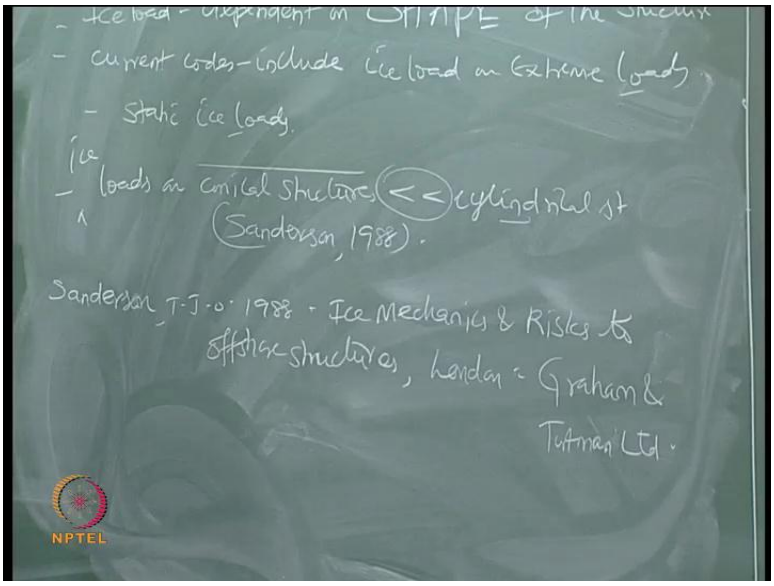

So, the most important parameter which governs the ice load is, shape of the structure. If we look at the current codes, they include ice loads on extreme loads category, and they are considered as static ice loads, there is no dynamic effect in this; that is what the current code and provisions are. People have shown some interest in studies saying that, loads on conical structures, I should say ice loads, on conical structures, are far lesser than cylindrical loads. Reference can be, Sanderson 1988; Ice Mechanics and Risks, to offshore structures, London Graham and Tutman Limited. So Sanderson showed from studies that, ice loads on conical structures, are far lesser than that of a cylindrical shape structures. Now, one can say what is the main reason for this kind of difference in behavior in the ice loads, which is shape dependent.

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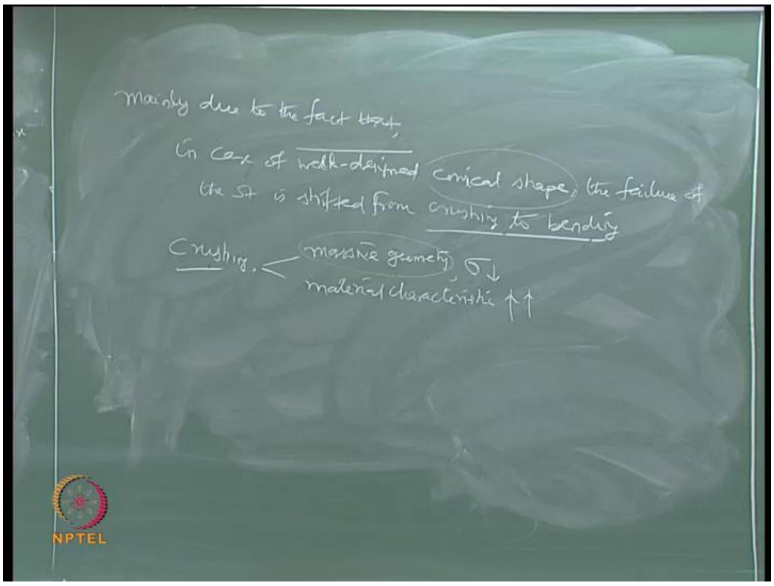

It is mainly due to the fact that, in case of build design conical shape, I am putting an adjective here, well designed conical shape, the failure of the structure is shifted from crushing to bending. So, if you really wanted to design any structural system, or any geometry, to resist crushing, this has got two aspects; for example, to resist crushing you require either a massive geometry; that is shape and size should be very large, so that the stresses are very less, so it is safe against crushing. The second requirement is, the material characteristic; that is material resistant against crushing, should be high, it should use the special kind of material. Both ways it is not possible, because massive geometry can decrease stresses, can be saved in crushing, but our structures are having large buoyancy reserve. So large size will affect the buoyancy considerably, which will affect my whole kinematics of the system, so I cannot afford to have a large geometry.

I cannot also have a material characteristic, which are having a very large string in crushing, because my predominant load, which is acting on and of the structure or marine structure, is not crushing, I always design it to be safe against bending. So, by creating a geometric shape, which shifts my failure mood, from crushing to bending, it is advisable, it because of these reasons you will see, in arctic region, most of the structures, or most of the elements and structures will be trapezoidal, conical, or pyramid shape, because on these shapes, you will see that the load is lower, and the fielding, and the bending, the failure Moore is shifted from crushing to bending, which has been studied and indicated by Sanderson. So, in the literature you have got ice load spectrum, like we have got wave spectrum, wind spectrum. We have got ice load spectrum available in the literature, which is been used to compute ice loads on marine structures and arctic regions.

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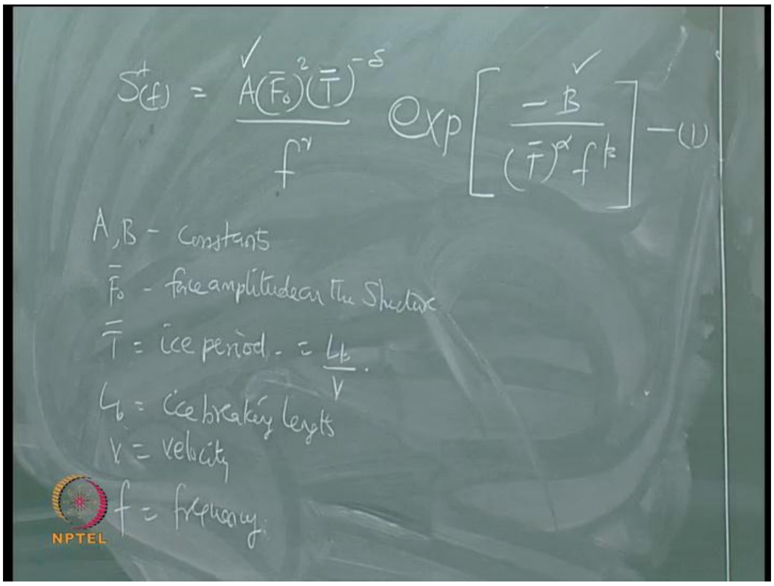

Of course, this is applicable to narrow conical structure, I already said ice load depends on the shape of the structure. A, this is t bar by f nu exponential, call this as one. Whereas A and B are constants, f naught is the force amplitude on the structure, f is the frequency at which the spectrum is plotted, f is the frequency at which the spectrum is plotted, because it is function of f, t bar is called ice period, which is given by L b by v, L b is called ice breaking link. Of course, v is the velocity with which the ice cubes, or the ice bergs move. In this argument f is, of course the frequency, at which the spectrum is plotted, L b is also given as k h.

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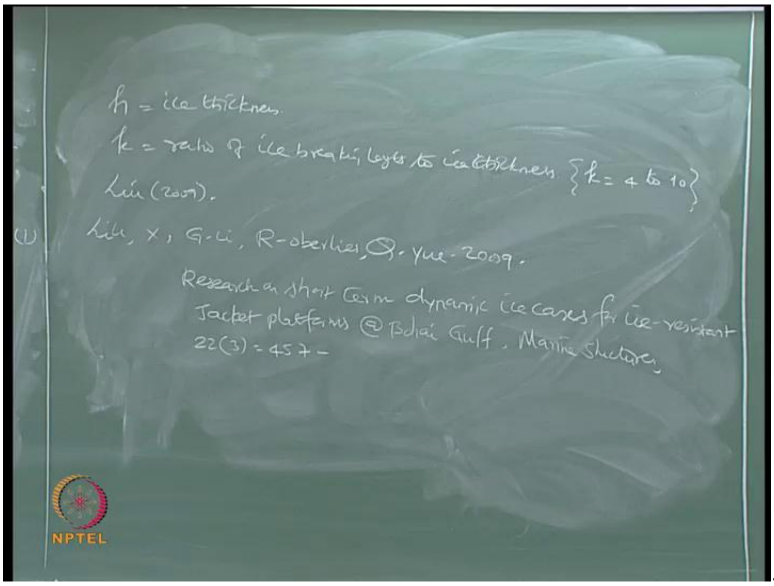

Where h is called ice thickness, and k of course is the ratio of ice breaking link, to ice thickness, which is usually a value between four to ten. So ice breaking link is approximately, four times thickness of the ice to, ten times thickness of the ice. So this spectrum was suggested by Liu in 2009, so Liu x, G-li, R-oberlies, Q yue, 2009, research on short term dynamic ice cases, for ice resistant jacket platform at Bohai Gulf marine structures.Now Li Attle also gave certain values of these parameters, based on which we will spot the spectrum for this.

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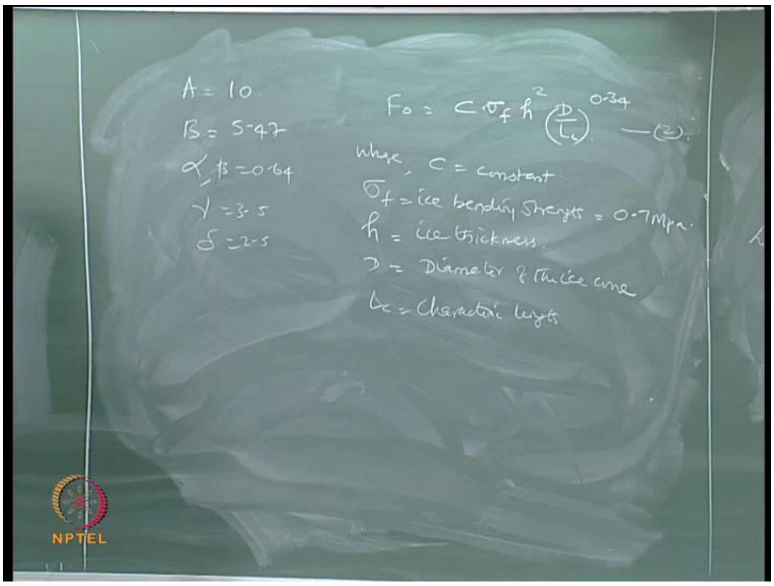

He said A can be 10, B can be 5.47, alpha and beta 0.64, nu 3.5, delta 2.5, and f naught which is used, f naught is the force amplitude on the structure, is given by c sigma f h, where c is again the constant, depending upon the type of the structure, this is sigma. Sigma f is called ice bending strength, which is generally taken as 0.7 mega Pascal, h of course, is the ice thickness, d is the diameter of the ice cone, L c is called characteristic link. We call this equation number two. Now, the characteristic link which is to be used in the spectrum, is given by further another equation.

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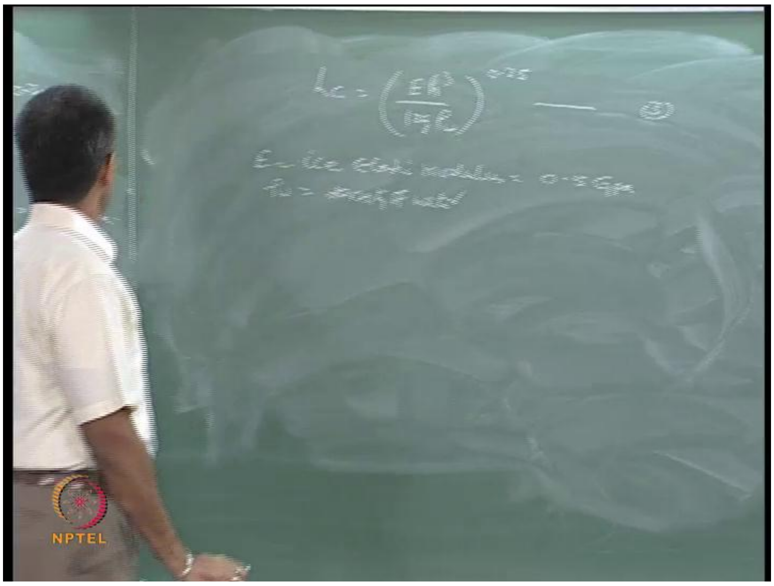

Whereas e is the ice elastic models, which is taken as 0.5 giga Pascal, and rho w, of course a density of water, equation number three. So all parameters I know L c I know,constant of course, depends on the type of the structure, f naught is known to me, and the parameters are known to me, now I can plot the spectrum, and can get the ice load coming on marine structures; so any questions here. The fourth kind of load, which we will discuss, will be the seismic loads.

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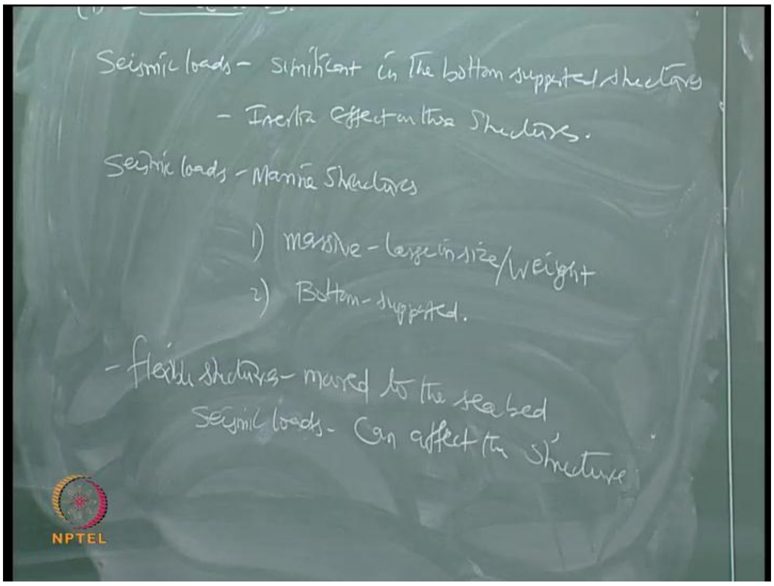

We have already seen that, the seismic loads are significant in the bottom supported structures, they cause inertia effect on the structures, and seismic loads are very common in marine structures, because of two reasons; one, marine structures are massive, large in size, and off course I should say weigh. Two, generally they are bottom supported, but interestingly, if you have flexible structure, which is moved to the sea bed, then also seismic loads can affect the structure, we will see that quickly in few minutes from now, how this can be influencing. So not necessarily the structure need be bottom supported, if the structure is moored to the sea bed; for example, like a tension like platform, still those structures can also be excited, seriously by seismic loads, because we understand that both the conditions are violated in case of flexible structures, they are neither massive, nor they are bottom supported, even then the structures can be also excited very significantly, by seismic loads, we will just discuss it after few minutes now in this lecture.

Now the fundamental question asked is, what do actually seismic loads do on structures. What do they do, because if we talk about wind loads, they create wind induced vibration, talk about wave loads, they create a drag force and a lift force. If the structure is compliant, it again generates radiation forces and diffraction forces, because of the movement. The structure is stiff, it attracts more forces; therefore, the stress concentration and the members becomes high, because of this kind of lateral loads. Whereas, earthquake loads are actual acting at the foundation, where the structures are resting, they are not actually lateral load directly on the structure, is it not. Whereas wind load, wave load, and ice load on impact let us see, there are direct loads on structures. They can come and hit the structure, the structure can feel the passage of these loads, and they to respond this. Whereas seismic loads are actually acting at the sea bed, where the structure is resting or founded, so what these structures can, or what these forces can do to the structures.

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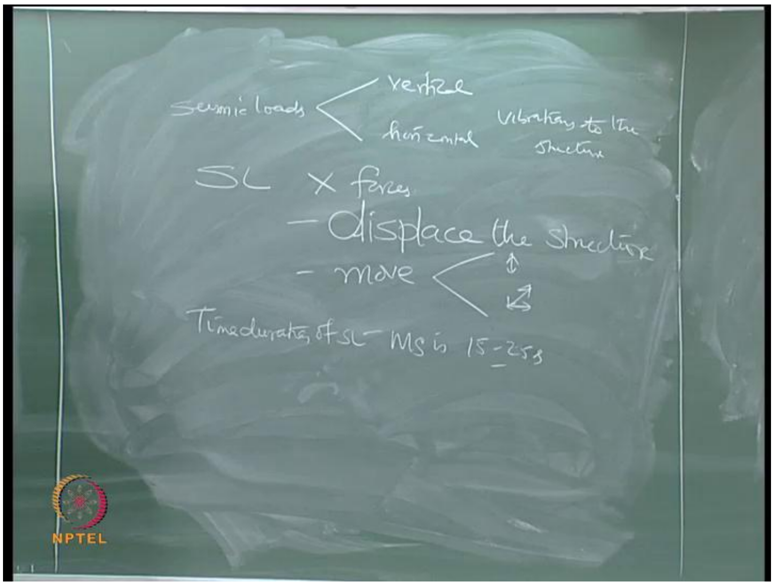

Importantly, the seismic loads can cause vertical and horizontal vibrations to the structure. Essentially what does it do is, remember importantly seismic loads are not forces, they are not actually forces, what they actually do is, they try to display the structure; that is try to move the structure, in vertical and horizontal, may be in both the direction in horizontal. A typical time duration of seismic load, which acts on a marine structure, is about 15 to 25 seconds; that is the time. So just now we saw that seismic loads can display the structure in all the three principle degrees of freedom, or three principle axis.

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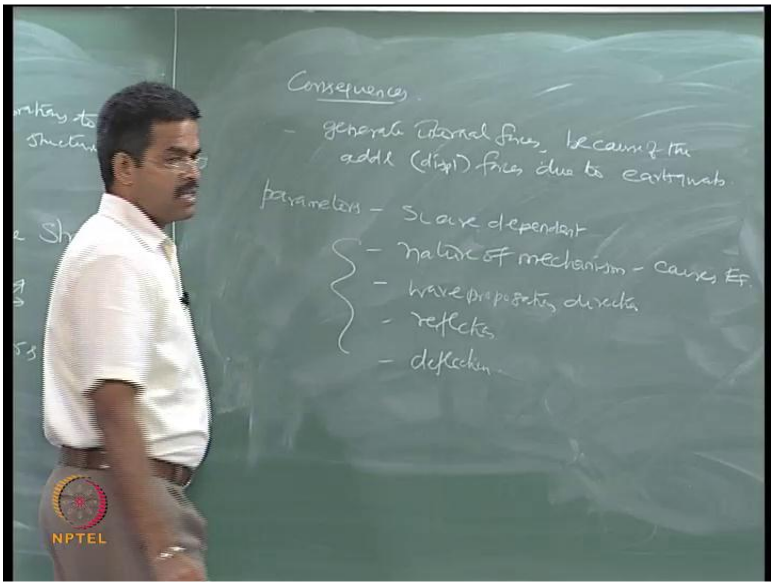

As a result of which, the structure has the following consequences, what will happen to the structure. Therefore, structure will generate internal forces, because of the additional I should say, displacement, but I am calling this as forces due to earthquakes. Now one may interestingly ask me a question; sir what are those parameters, based on which seismic loads can be concluded. So what are those parameters, on which seismic loads are depended; one, the nature of the mechanism, which causes earthquake, is very important; two, wave propagation direction; three, reflection of these waves; four, deflection of the sea bed. So these are the parameters, which affect the seismic loads formation, or seismic loads on a marine structure.

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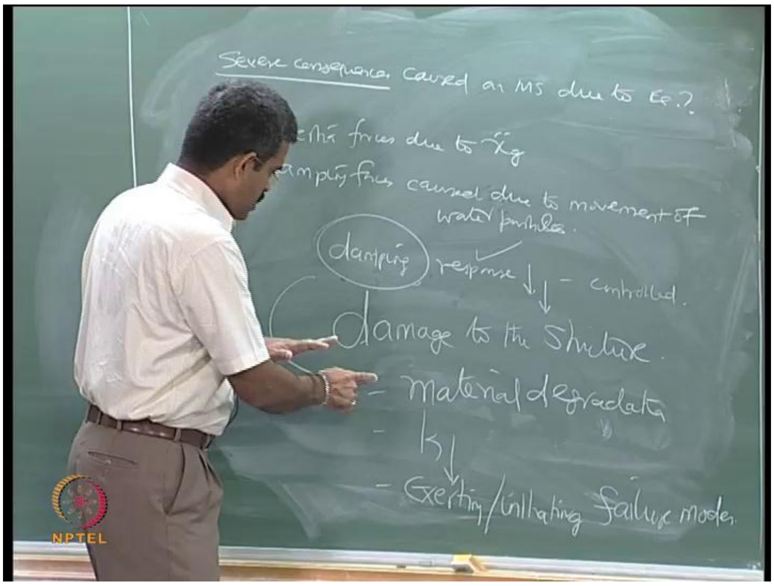

What are said as severe consequences, caused on marine structures, due to earthquakes, what are severe consequences, very critical. One, inertia forces, due to, I should say x double dot g, is nothing but the ground acceleration, two damping forces, cause due to movement of water particles, so far you have been understanding that the damping, is always an added advantage, of reducing the response. One can always say, the movement I have damped in a system, the response of the system, be it is a single degree, be it a multi degree, we are not looking dynamic prospective of this course. The moment I introduce the damping in given system, I understand that response in system is reduced, and can also think the response structure is, controlled.

What we are not understanding or what we feel to ignore is that, it is causing parallel damage to the structure, in terms of material degradation, two stiffness reduction, three exerting or initiating failure modes, which are otherwise not predominant. We will initiate special failure modes, which are otherwise not predominantly seen in the structure. So damping, though it reduces response in the outer profile of the structure, implicitly it is causing many negative aspects to the structure. So earthquakes will introduce damping forces, because of the movements of water particle, which can cause damage to the marine structure. So the literature say that, seismic loads are effective, only on bottom supported structures, but that is seen in almost all literature, you can refer to any standard literature, which has been referred in the NPTEL website on this course, for understanding the effect of seismic loads on fixed jacket structures for example.

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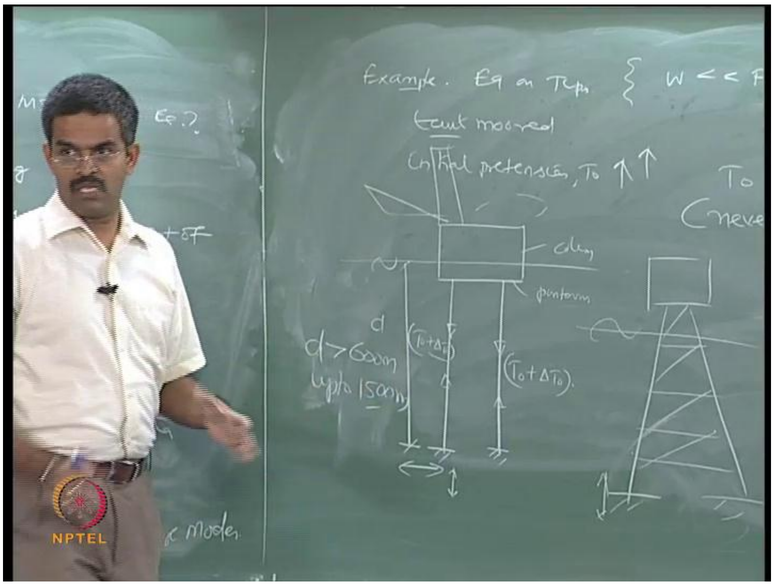

I will take up an example here, which talks about, the effect of seismic loads on T L Ps, the T L Ps are the flexible structure. It is large in size, but it is not massive, because members are font to on sand columns are hollow, it is large in size, but it is not massive, and it is designed for excessive buoyancy weight is very low, I think you all agree the T L P has got very specific special design phenomenon, where the weight is much lower than buoyancy is it not; that is why when you try to upload the structure in sea, because of the buoyancy the structure is pushed up, just to hold it down, you provide cable and teeters; that is why they are called as tension legs, so weight is much lower than the buoyancy. So buoyancy is coming from submerged volume, weight is low because it is hollow. So as the weight is low it is not massive, m is not very high, m is w by g, it is not very high.

Unlike fixed type structures or bottom supported structures, these are very light in weight, and they are not supporting directly, or they are not resting directly on sea bed. They are taut moored, what u mean by taut moored. It is the initial pre tension given to the tendense, the initial pre tension t naught, is of a very high value, is a very high value; that is t naught never will become zero, what you understand by this. The teeters will never slack, they will always be in tight moored, they will never slack. There is always initial tension given to this, and that value is given very high, it is pretty high, compare to the waiter’s platform; that is the design phenomenon of T L P s. So in such kind of structures, how earthquake loads will become be significant; that is very interesting question, because it is violating both the conditions, the structure is not resting on sea bed, the structure is not massive.

Then how does seismic loads, activate this kind of platforms. I mean where is the code, how did you find the spectrum, and how did you compute the forces, and how you transferred the forces. Interestingly look at the problem here, I have a structure which is supported, by cables or tethers, and the earthquake is happening here, and this is the water body.So, how this force is getting transferred to the super structure; of course, these are in tension, I should say this is t naught plus delta t naught, this is also t naught plus delta t naught; of course, these are all column members; these are all pontoons we already know them etcetera. And of course, you all top side detail, which are not very common for any production (()) operational platform in a marine system.

If I have jacket structure, I can say the structural system, is resting on the bed; therefore, these members will be activated, by the earthquake loads, and these members will transfer these forces to the super structure; therefore, it is important, I can understand that. Whereas in this system I have got earthquake loads here, there is huge water body, because compliant structures are defined or say designed for depth, exceeding 600 meters up to, now presently 1500 meters, the very large and very deep water body; therefore, it is seen physically that, the water body, or the water depth will try to damp in the effect of earthquake on the super structure; that is the general phenomenon what people have. So we will take an example very quickly in few minutes to explain, how the force are transferred to the super structure, what is the spectrum being used. So, interestingly, when this thought actually came to researchers mind why earthquakes on flexible structures become important.

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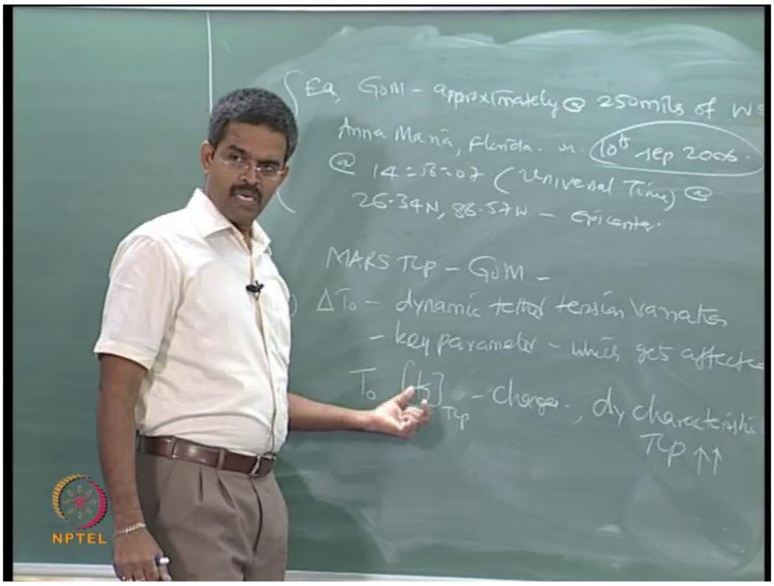

There was an earthquake in Gulf of Mexico, approximately at 250 miles of western side of Anna-Maria Florida on 10th September 2006, at 145607 universal time, at the geometric location 26.34 north, 86.57 west, which is the epicenter of this earthquake. And interestingly, it is on the same location closer to this Mars T L P was located. So this incident for example, it is not the only, this incident trigged off the researchers to find out actually, what would be the effect of the consequences of such an earthquake, on a platform like T L P, for which this is not designed, because generally people have been thinking, that if the structure is not bottom supported, if the structure is not stiff or rigid, the earthquakes will not affect these kinds of structures; that was the phenomenon actually earlier people thought. So, it is after this period, or subsequently closer to this, may be in early 2000 or late 90's, people started thinking what would be the effect of this, on structures like this.

So the foremost idea which came to researchers mind, is that the delta t naught, which is nothing but the dynamic tether tension variation, is one key parameter, which gets affected by earthquake. The dynamic tether tension variation, will change, with respect to time, and one may wonder say what will happen if this changes, interestingly I am not talking about T L P dynamics here, you can look into the table give the reference later. Interestingly, if t naught changes, the stiffness co efficient of T L P changes. If the stiffness co efficient of the T L P changes the whole dynamic characteristic of T L P alters. So, interestingly, though the force not directly applied on to the system, it is applied only to the sea bed where the tethers are anchored, still the delta t naught value, which is changing significantly under these forces, affect the response very badly. Now one may wonder, what would be that significance of this change, the results showed that delta t naught, or the dynamic tether tension variation, changes to the tune of about 65 percent.

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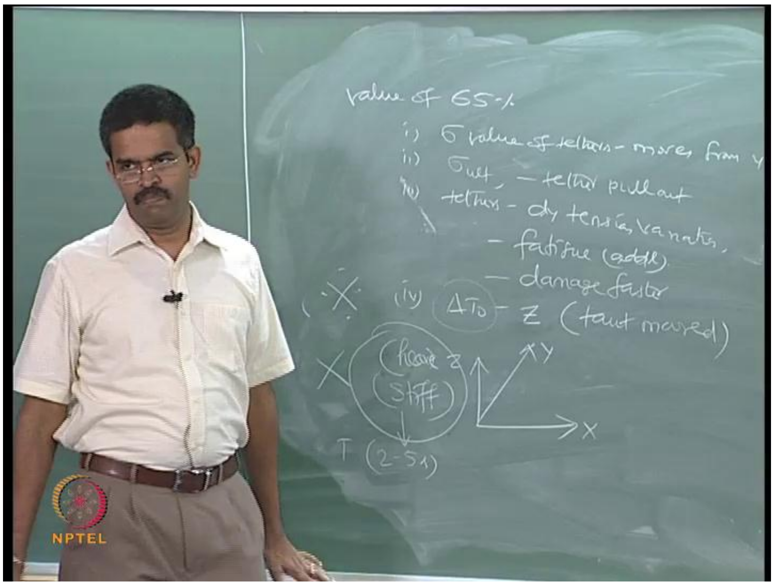

One may wonder, whether the value is significantly high, there are many reasons why this value is very high; one, the stress value of tethers move, from yield to ultimate. So these results, or this initiates a plastic deformation in tethers, two if tethers are not designed sustain that ultimate stress, it can result in what we call tether pullout, tether can come out of the structure. Most importantly, tethers are subjected to dynamic tension variation, because of earthquakes.

The movement I said dynamic tension variation, is always not positive, can be negative also, the variation is there. This introduces additional fatigue in the tethers, and tethers can damage much faster than the tougher traditional life or service life. And further most importantly, the delta t naught variation, happens in the vertical axis, because why, it is a taut moored system. Taut moored means, it is always tight vertical, and you all agree, the T L P has got six degrees of freedom, along x y and z, where along z what we call heave, the displacement degree is considered generally to be a stiff degree, why the period of heave, is from two to five seconds, when the period is larger, it is considered to be a stiff degree, now here is the catch.

When the tension variation is super imposed on the vertical axis of the member, this will accelerate the heave degree, which is considered to be one of the stiff degree of the platform. Now this problem is similar to any structure, which is resting on the ground, because the vertical motion of the sea bed, is trigging the structure, as if the structure is directly resting on the sea bed, it is happening exactly here same. So the stiff degree is trigged off, because delta t variation, where delta t varies means structure will be either pulled down, or loosened up, it means heave degrees is getting activated. When heave degree is getting activated, suppose to the stiff degree, this kind of behavior, is not expected in a T L P; T L P is always designed to be compliant only in surge, sway, and yaw. It is always expected to remain stiff and rigid in heave, roll, and pitch.

But when this phenomenon was noticed in the research, saying that heave degree is being trigged off, it is very important outcome, which may makes this study very important. Now the question comes, how we can now mathematical model these forces on the T L P, based on the incident available at gulf of a Mexico, because the question now comes, what spectrum will he suggest, because I want to analyze it. You cannot say I can do a simple case study on a T L P at Gulf of Mexico, and adopt the same design phenomenon for all T L P's anywhere in the world, that should be a spectrum which will govern me. Like we have spectrum for ice load, we have spectrum for wind load, we have spectrum for wave load, we should have spectrum, which will define such incidents, which can be used on a flexible system, like T L P or a articular tower, or a guid towers etcetera. Now Kanai Tasimi developed a spectrum for this.

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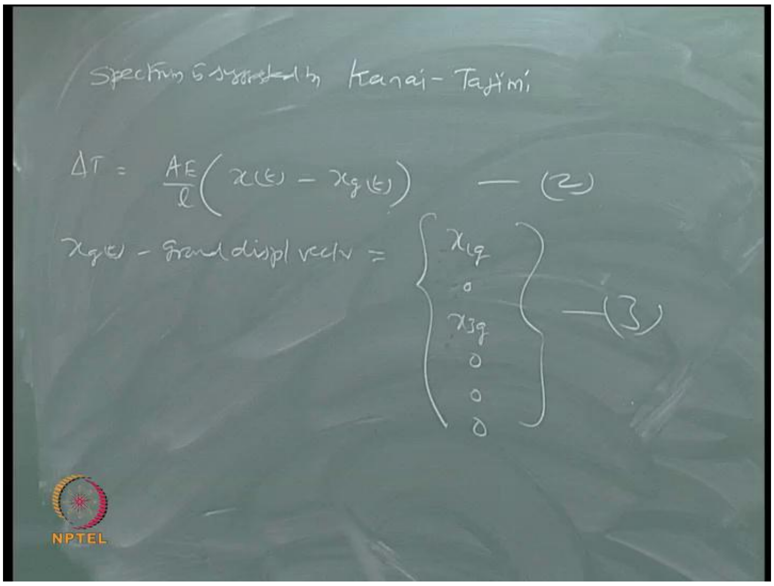

The Spectrum Was Suggested By Kanai Tasimi Called As K T Spectrum. Before that let us see that how this delta t, is vary delta t naught, this varies as a function of a e by L multiplied by x of t minus x g of t, where x g of t is called the ground displacement vector, which is nothing but x 1 of g x 3 of g, and remaining all degrees are zero. It means it is considered in sway and the heave axis, I mean the sway axis is surge and heave axis, sway axis is eliminated, and there are no other axis at which (( )) is considered, so I will call this equation number two, three.

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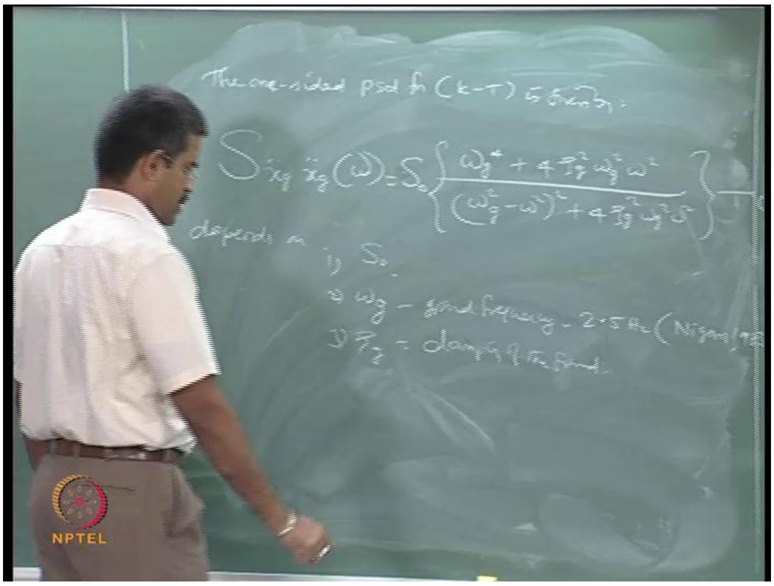

The one sided power spectral density function of the k t spectrum, is given by equation number four. You can see that, it depends on three parameters; one is what is called as s 0, other what is called omega g, and third one is zeta g. Omega g is called the ground frequency, this is taken as 2.5 hertz, 2.5 hertz the reference can be Nigam, N C Nigam 1983. N C Nigam refers the ground frequency to be this value only when you apply this for a stiff system. Why we are using in literature stiff system, because now as I explained you in the previous discussion, that delta t naught is directly super imposing, the values of earthquake exertion, on a stiff degree like heave; therefore, it is as good as, the structure is resting on the sea bed, under the delta t naught; therefore, we have used 2.5 hertz, as the ground frequency. Zeta g is called, damping of the ground acceleration.

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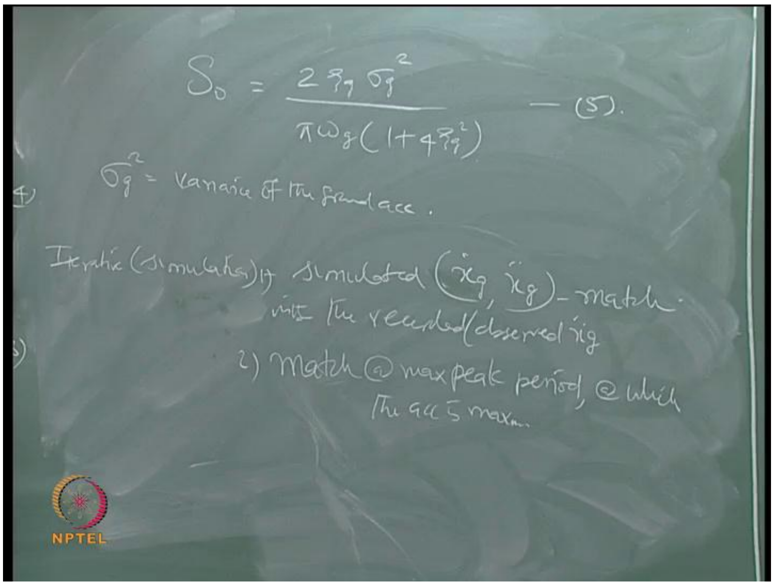

S naught is the spectral parameter, which is given by this equation.Call this as equation number five, where sigma e square is the variance of the ground acceleration. Now the question comes, you must select the spectral value, what are the spectral dependence parameters, the spectrum or the (( )) spectrum depends on three parameters; s naught, omega g, and zeta g. Omega g is 2.5 as applicable to ground frequency for a fixed base. So you must choose s naught and zeta g, such a way that, the generated spectrum should stimulate, a time is three which is recorded as specific site, so it is (( )). So what you have to know is, what would be the measured acceleration velocity at the specific site, and what would be, the acceleration velocity which I get, from this spectrum, they should match. So you have to stimulate a signal, in such a manner, that the stimulated velocity;

that is x dot g x double dot g match, with the recorded or observed x double dot g; that is one case,two which will also match at the maximum peak period, at which the acceleration is maximum. So, it should not only match the signal amplitude, but also the time,so seismic loads are not direct though we have a spectrum. The spectrum is depending on three parameters, you must select these parameters at random. Now the question comes, how do you select these parameters, which can help me, to stimulate a signal, which is matching with that of the value observed at site.

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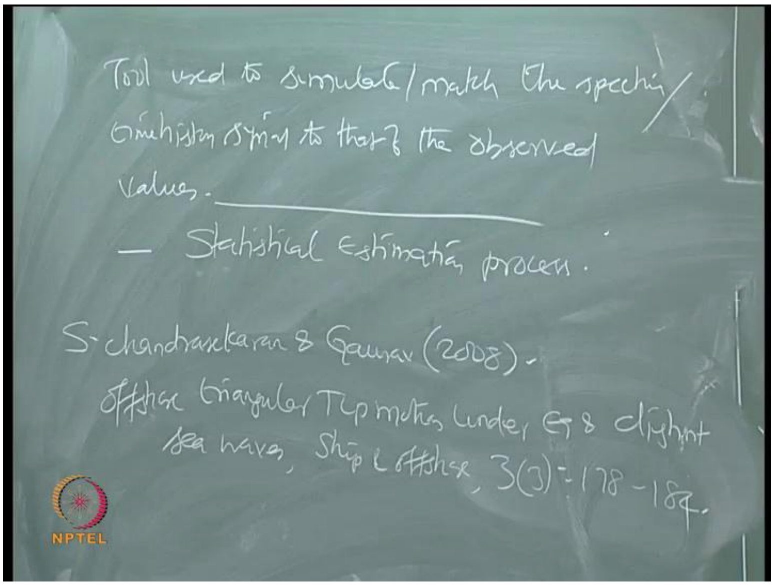

Now the tool used, I should say to stimulate, or to match this spectrum, or time history signal, to that of the observed values, using statistical estimation process. Why statistical, s not depends on the variance, variance can obtained only when you have got a statistical parameter. So it should be depend upon statistical estimation process, so one can use any specific stimulation available in the literature, to generate a signal, check or generate the variance of the value substitute s not generate the signal, complete the time history, and check the amplitude, and the time or matching without the observe, not matching change the parameter keep on doing it, iterative stimulation. So detail of this is available in…

So, there are studies carried out by the researchers, showing that how the earthquake loads, can also be causing significant impact, on flexible structure like T L P, which makes study interesting and important for the of the structures. You have got few more loads, which are acting on the structural system. We will discuss in the next lecture along with ultimate load design technique, which we will discuss in the next lecture.