Offshore structures under special loads including Fire resistance
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Lecture – 13
Ice Loads – II

Friends in this lecture number 13, we are going to discuss the further aspects of ice loads by defining ice spectrum, various complexities involved in estimating ice forces and the effects caused by ice loads on offshore platforms. This is lecture number 13 on NPTEL course title offshore structures under special loads including fire resistance design.

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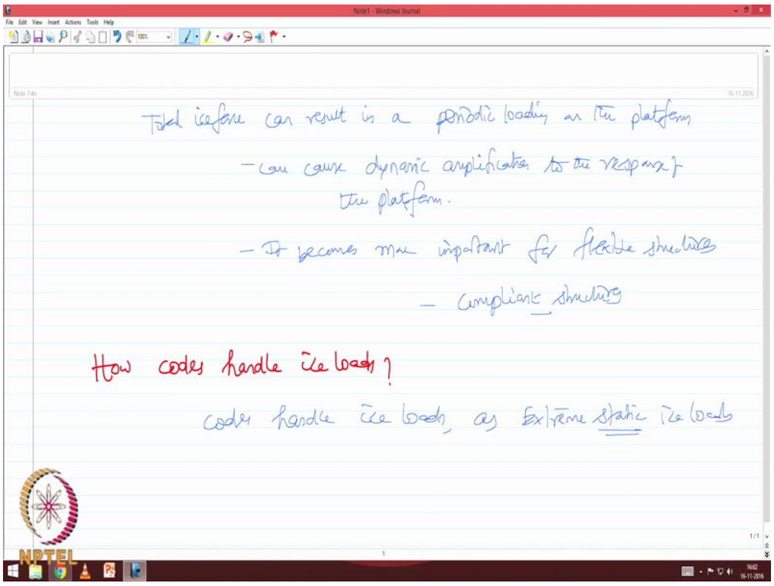

In the last lecture we said that ice loads is characterized essentially by the frequency of interaction between the platform and ice. Total ice force can result in a periodic loading on the platform, which can cause dynamic amplification to the response of the platform. It becomes more serious becomes more important for flexible structures to be very specific, it is very important for compliant structures.

The next question comes in designers mind is, how total provisions handled ice loads? Codes handle ice loads as extreme static ice loads.

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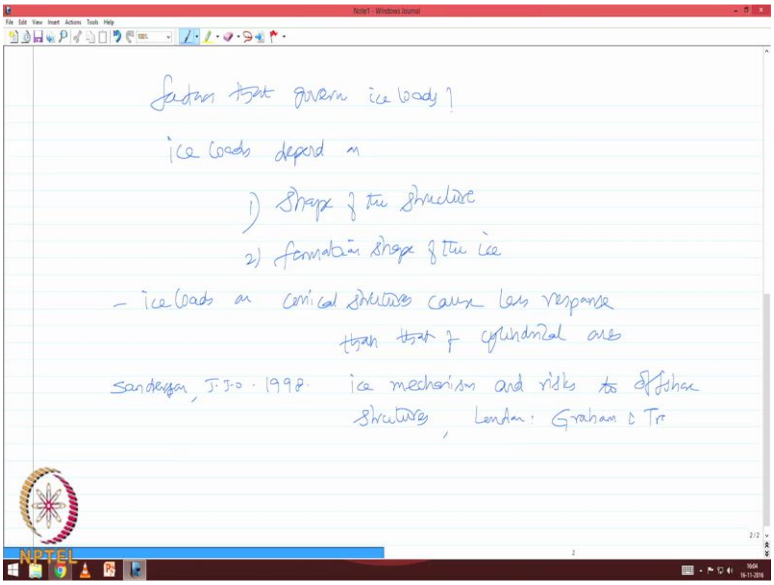

Let us ask a question what are the factors that govern ice loads? Ice loads actually depend on; one, shape of the structure and formation shape of the ice, it is interesting that ice loads on conical structures cause less response than that of cylindrical ones. This is a very interesting reference which I will advocate to you to read for more information, Sanderson T.J.O 1998 ice mechanism and risks to offshore structures, published by Graham and Trotman limited London.

Interestingly one would like to know intuitively what could be the reason for this statement.

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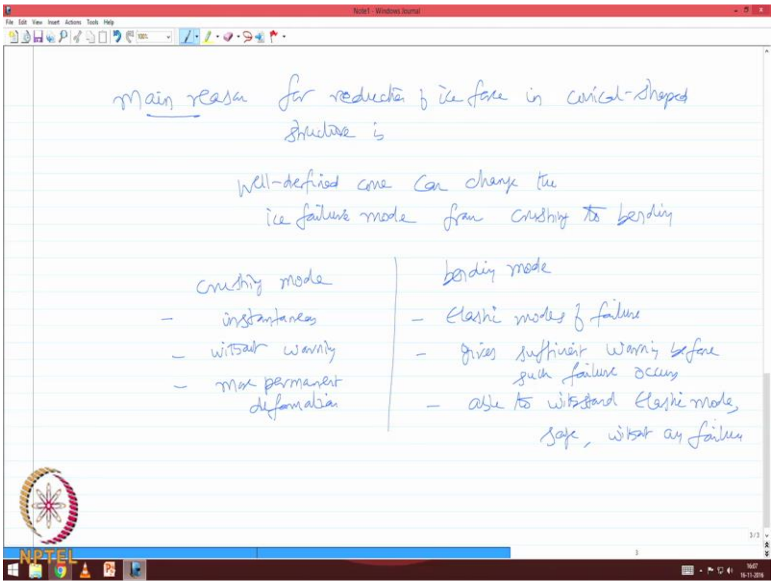

Main reason for reduction of ice force in conical shape structure is a well defined cone can change the ice failure mode from crushing to bending.

Now, comparing the crushing mode of failure with that of bending mode, this is more or less instantaneous and this occurs without warning this causes more permanent deformation whereas, bending mode refers to one of the elastic modes of failure, at least initially until the plastic hinge is formed. Any elastic mode of failure gives sufficient warning before such failure occurs. Thirdly if the material is able to withstand elastic mode, the material may remain safe without any failure.

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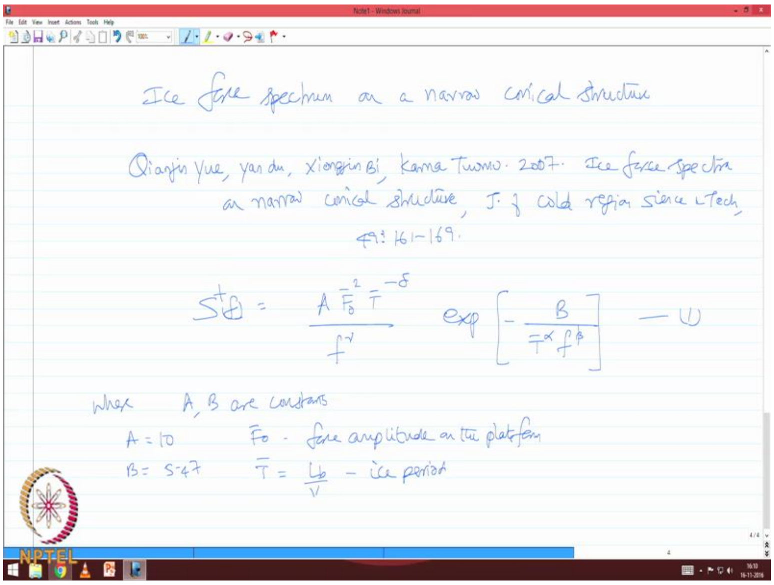

So, now ice force spectrum on a narrow conical structure is given in the lecture Qianjin Yue, Yan du, Xiongjin Bi, Karna (Refer Time: 08:25) 2007 ice force spectra on narrow conical structure, journal of cold region science and technology 49. 161-169. So, this says ice force spectra is given by A F 0 square, T bar raise to the power of minus del by f nu, expression minus B by T bar alpha f beta; where A and B are constants A is generally taken as 10 and B is taken as 5.47, F bar is the force amplitude on the structure, on the T bar yes Lb by v which is called ice period.

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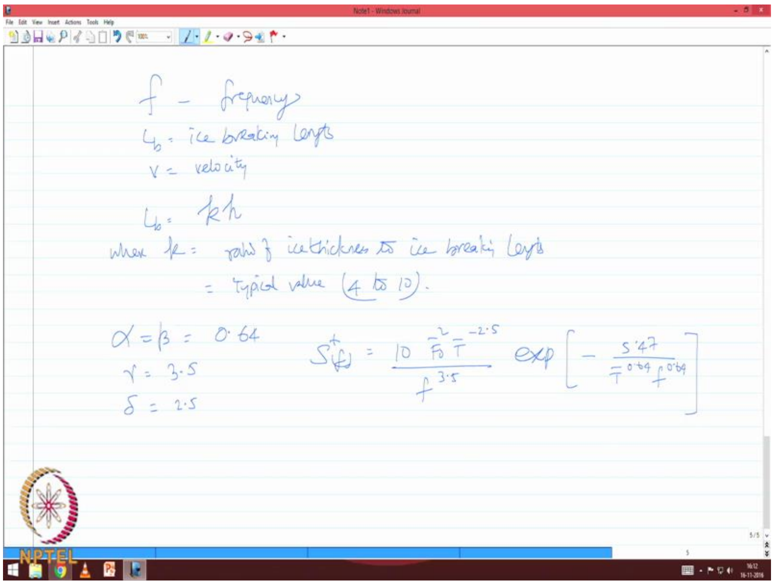

F is the frequency, Lb is called ice breaking length and of course, V is the velocity, Lb the ice breaking length is given by k into h where k is called ratio of ice thickness to ice breaking length typically it varies between 4 to 10. Now alpha and beta are taken as 0.64, nu is taken as 3.5 and del is taken as 2.5, which makes the spectrum as 10, F bar 0 square, T bar minus 2.5 by f 3.5, expression minus 5.47 by T bar 0.64 and f 0.64.

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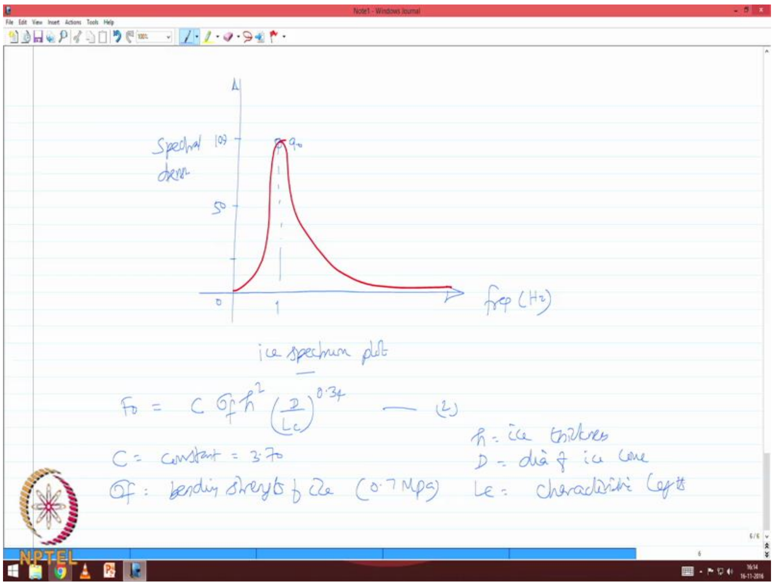

A typical spectrum is plotted like this, let say frequency is plotted in hertz and spectral density is plotted let say 0, let say 50, let say 100, the typical spectrum looks like this. So, the peak occur about 1 and this value is about 90. So, this is a typical ice spectrum plot F 0 is given by C sigma f h square D by L c raise to the power of 0.34, where C is a constant taken as 3.7. And sigma f is called bending strength of ice, which is actually to equal to 0.7 mega pascal, h is ice thickness, D is the dia of the ice cone and L c is called characteristic length.

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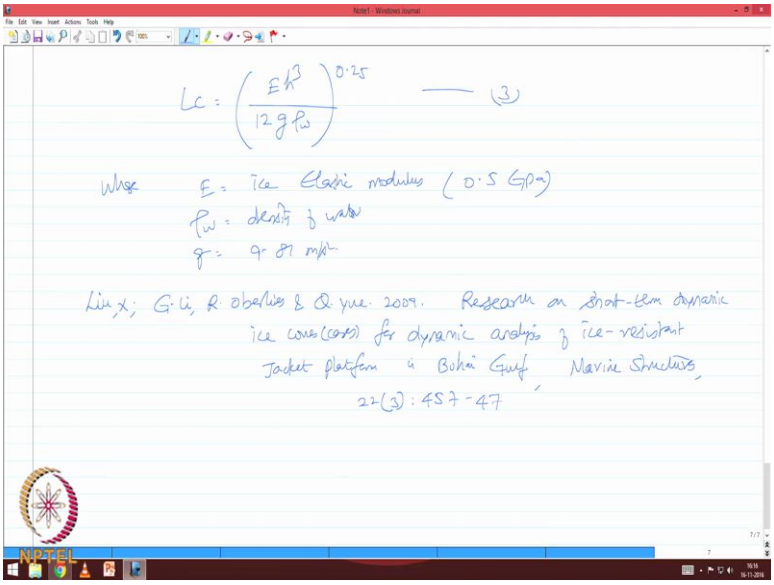

Which is given by E h cube by12 g rho w raise to the power of 0.25, where E is ice elastic modulus which is taken as 0.5 mega pascal and rho w is density of water and g is 9.81 meter per second. One can also have more interesting inference and information on the reference now available on the screen, Liu x, G li, R oberlies and Q yue. 2009 research on short term dynamic ice cones that is ice cases for dynamic analysis of ice resistant jacket platform in Buhai Guif, Marine structures, 22 3: 457- 479.

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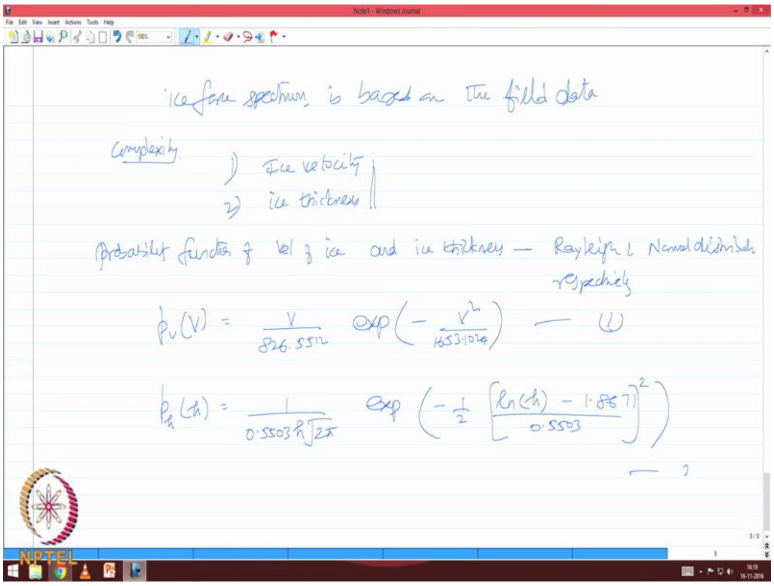

The ice force spectrum what we just now saw is actually based on the field data of Buhai Guif. Now, if you include parameters in estimating this ice force spectrum it causes confusion; let say what is the complexity in the ice force spectrum, one if you include the ice velocity and ice thickness, this is include both these parameters it make it highly complex.

So, probability density function of velocity of ice and ice thickness are usually taken as Rayleigh and normally distributed respectively. So, probability function of small v of capital V is V by 826.5512 exponential minus V square by 1653.1024 probability density function of ice thickness is given by 1 by 0.5503 h, 2 pi exponential minus half natural logarithm of h, minus 1.8671 by 0.5503 raise to the power square.

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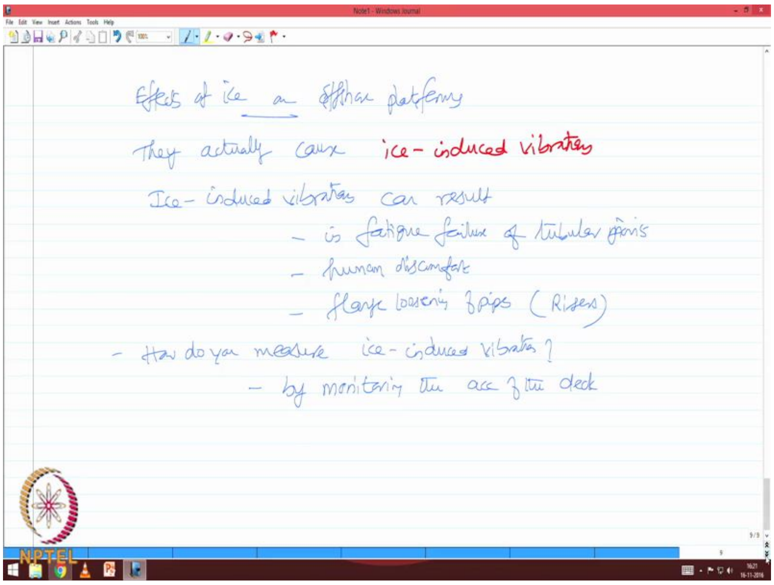

Let us now try to understand what are the effects of ice on offshore platforms? They actually cause ice-induced vibrations, ice induced vibrations can result in fatigue failure of tubular joints; it can cause human discomfort, it can also cause flange loosening of pips especially in the case of risers.

The question comes how do you actually measure ice induced vibration? The answer is you can measure this by monitoring the acceleration of the deck.

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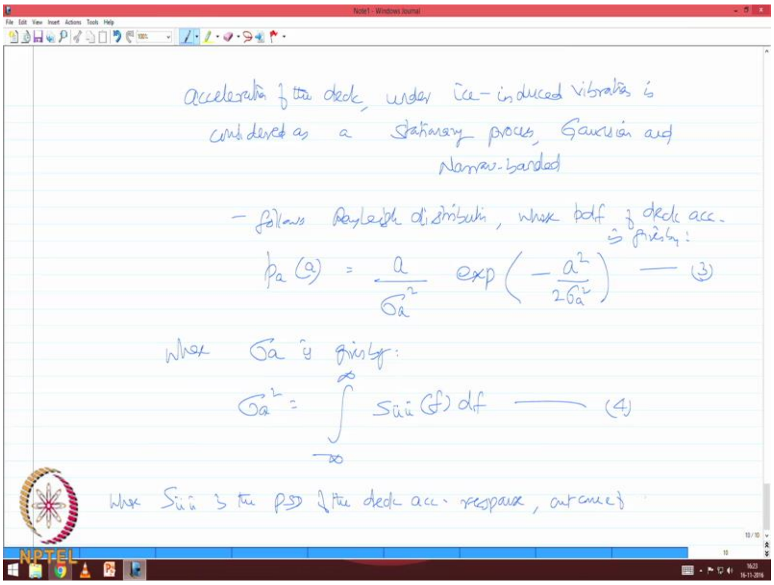

Now, once you want to measure the acceleration of the deck, acceleration of the deck under ice induced vibration is considered as a stationary process Gaussian and narrow banded. It also follows let say a Rayleigh distribution whose power spectral density function can be given by whose pdf of deck acceleration is given by a by sigma a square expression minus a square by 2 sigma a square; where sigma a is given by integral minus to plus infinity df, where Su double dot u double dot is the power spectral density function of the deck acceleration response which is an outcome of ice load on the platform.

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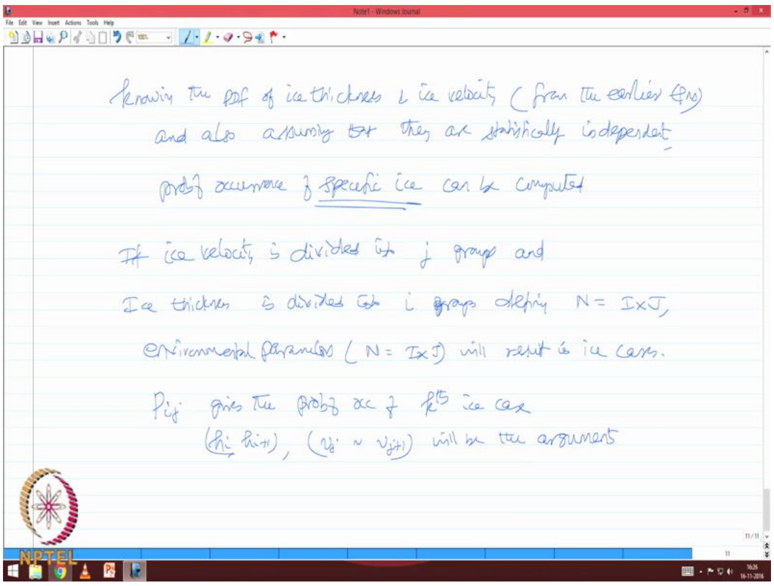

Now, knowing the power spectral density function of ice thickness and ice velocity from the earlier equations and also assuming that they are statistically independent, one can find out the probability of occurrence of a specific ice can be computed. Now what do you mean by specific ice combination? If ice velocity is divided into j groups and ice thickness is divided into i groups, defining N is actually I cross J, various environmental parameters of I cross J will result in different ice cases.

Therefore Pij actually gives the probability of occurrence of k-th ice case, in which hi, hi plus 1, vj, vj plus 1 will be the arguments.

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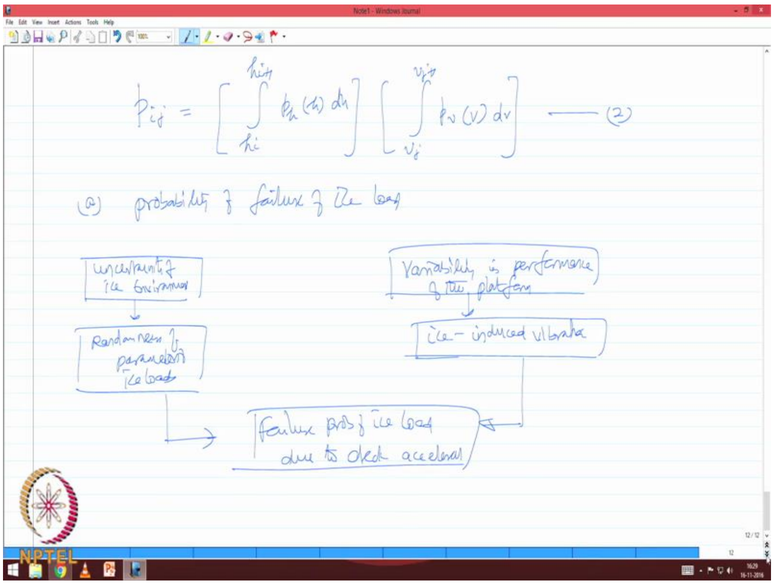

So that probability I j is given by integral hi, hi plus 1that is ice thickness, probability of h of h of dh into integral ice velocity vj plus 1, probability of velocity v d v.

Let us try to understand a flow chart which is used to assess the probability of failure of ice load. So, let us say to understand probability of failure of ice load. So, you try to first find uncertainties of ice environment, which may lead to randomness parameters of ice loads.

On the other hand you try to also check what was the variability in performance of the platform? And what will be the factors induced ice induced vibration? Now these 2 will actually lead to what we call failure probability of ice load due to the deck acceleration.

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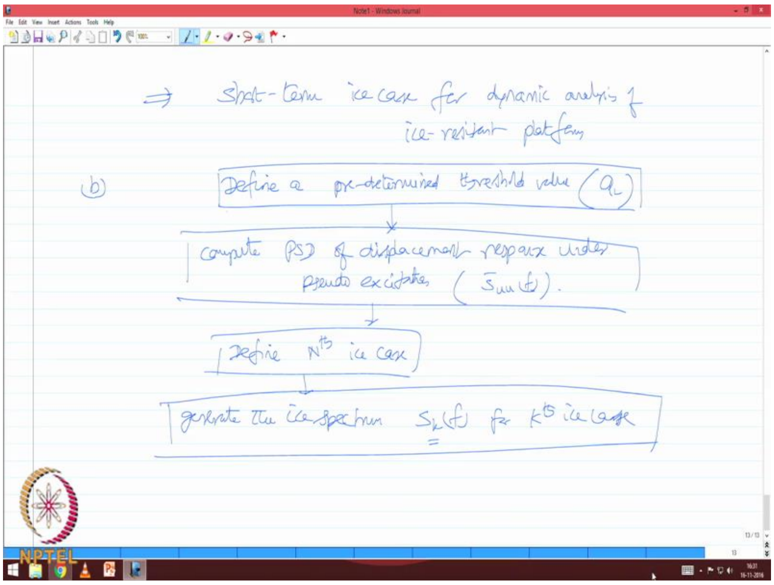

Ultimately this will result in what we have short term ice case for dynamic analysis of ice resistant platform. Further investigations will lead to define a predetermined threshold value which I call as a L.

Once the predetermined threshold value is known; calculate or compute the power spectral density function of displacement response under pseudo excitation which I call as Suu of f. Once this is computed then try to define the Nth ice case; for the Nth ice case generate the ice spectrum which I call S k of f, k indicates the failure case and S of f is the spectrum. So, generate the spectrum for k-th case.

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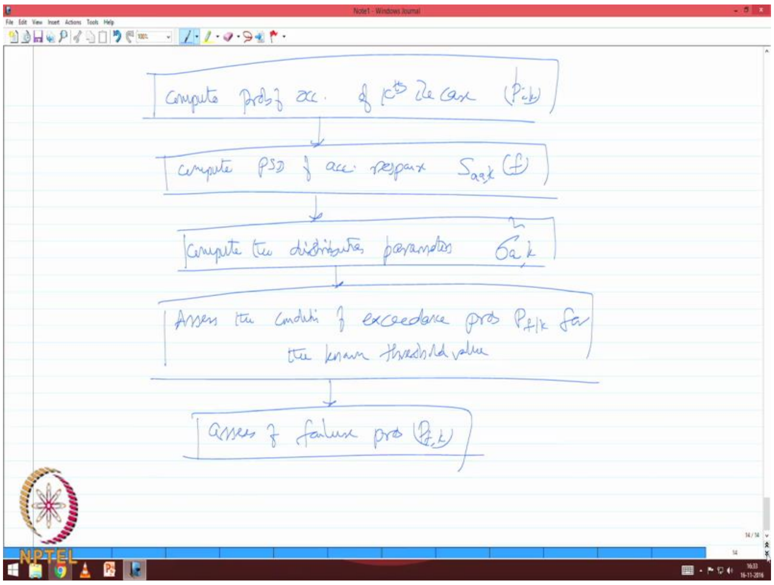

Once this is done, move to estimate probability of occurrence of that particular ice case which I call Pik, also compute probability density function of acceleration response of the deck which I call S a k of f.

After computing the power spectral density function of the acceleration response of the deck, compute the distribution parameters, sigma a square. Once you compute this then try to assess the condition of exceedance probability pf given k for the known threshold value because in the whole exercise we have already fixed the threshold value, this will lead to assessment of the failure probability P of k.

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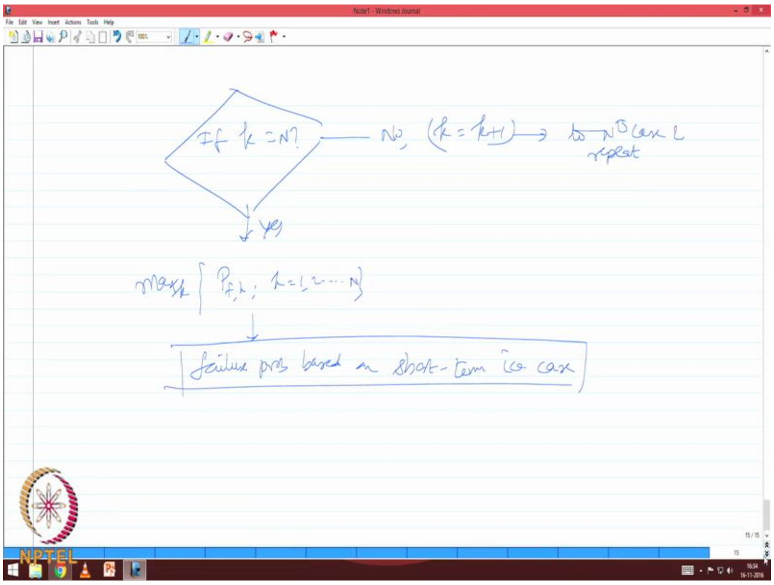

For a k-th case check if K equals N? If it is no then say k equals k plus 1 and again take the loop to the Nth case and repeat; if it is s then find the maximum k that is probability f of k for k equals 1,2 etcetera till N and that will give you the failure probability based on short term ice case.

So, interestingly ice loads on platforms.

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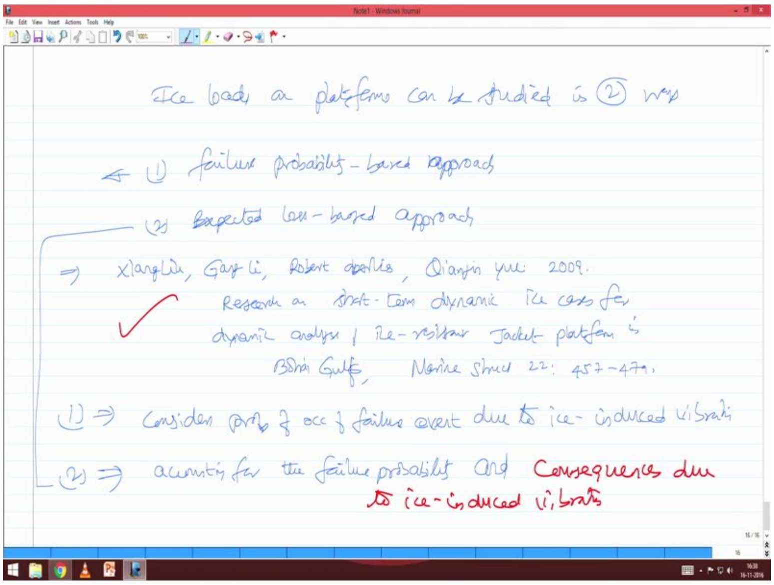

Can be studied in two ways; one you can use what is called failure probability based method or approach; a second approach could be the expected loss based approach. I request the readers to look into this reference research on short term dynamic ice cases for dynamic analysis of ice resistant jacket platform in Buhai Gulf marine structures 22 457 479. The first approach actually considers probability of occurrence of failure; event due to ice-induced vibration whereas, the second one leads to accounting for the failure probability and consequences due to ice-induced vibration. So, the authors have discussed excellently the comparison between these two approaches, I would like to request the readers to look into this paper and try to gain more information about the case study developed by the authors on jacket platform in Buhai gulf.

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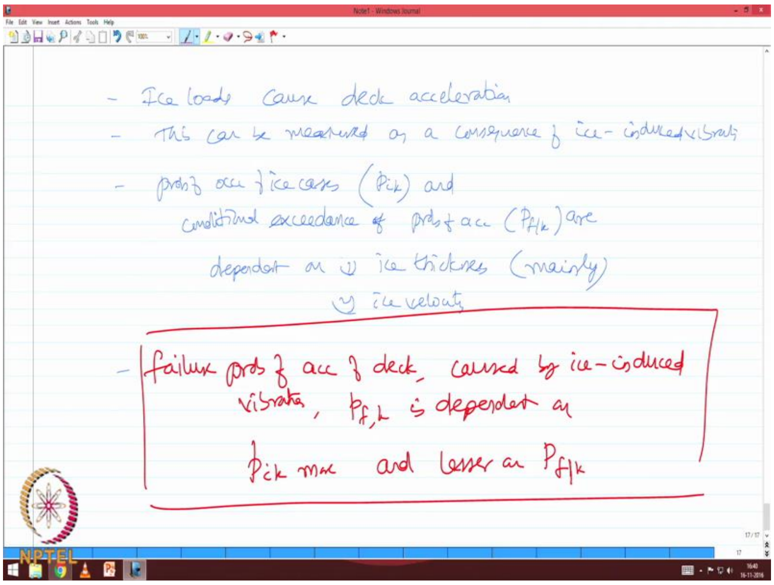

Now, as a result we understood that ice loads can cause deck acceleration, this can be measured as a consequence of ice induced vibration probability of occurrence of ice cases what I call as Pik and conditional exceedance of probability of acceleration that is Pf given k are dependent on 2 parameters; one is the ice thickness which is very significant and the second is ice velocity. So, as a result we can say that failure probability of acceleration of deck, caused by ice induced vibration which I say as Pf k is dependent on Pik more and lesser on pf given k. So, that is a very interesting conclusion we have for estimating the effects of ice loads on an example study of a jacket structure done with researchers in Buhai Gulf.

So, friend in this lecture we understood how the effects of ice can be classified very clearly and how an ice spectrum can be generated by making basic assumptions and how the effects of ice coned on a structure can be measured using the deck acceleration which is a significant characteristic of ice induced vibration, which depends more on the ice thickness and very far less significant on the ice velocity. So, in the next lecture we discuss about more details on the effect of ice on offshore platforms.

Thank you.