Offshore structures under special loads including Fire resistance

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Lecture – 12
Ice Loads – I

Dear friends, let us talk about the 12 Lecture titled- Ice Loads under the NPTEL course titled Offshore Structures under special loads including Fire Resistant Design.

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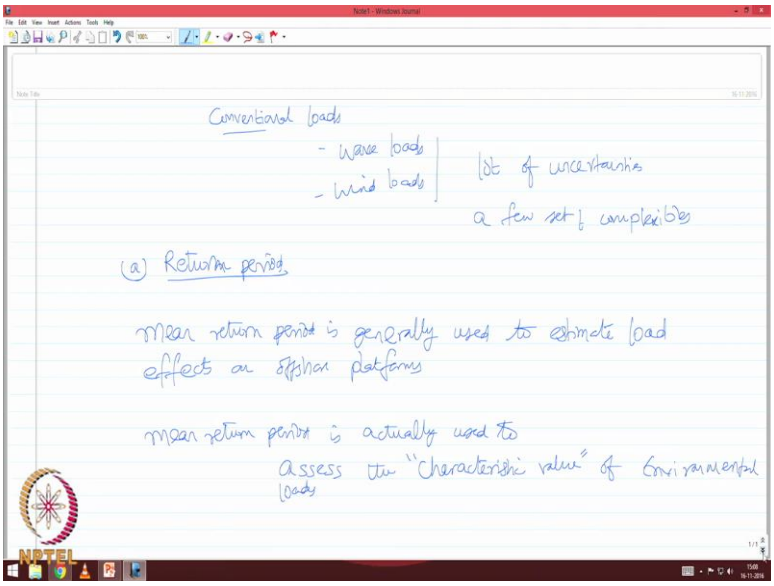

In the previous lecture we said though the conventional loads, let us say for example wave loads, wind loads have lot of uncertainties which leads to a few complexities. Estimate of these forces and the reflects on offshore platforms lead to a lot of experience based decision making processes which makes the design of offshore structures probabilistic in nature. What could be the fundamental reason that these loads though being conventional and well established in the literature cannot be estimated with a greatest possible accuracy be eliminating the probability of exceedance of these forces. The foremost issue which circumcises a calculation of these in probabilistic terms is return period.

So let us ask a question, what do we understand by return period? Mean return period is generally used to estimate load effects on offshore platforms. Mean return period is actually used to assess the characteristic value of environmental loads.

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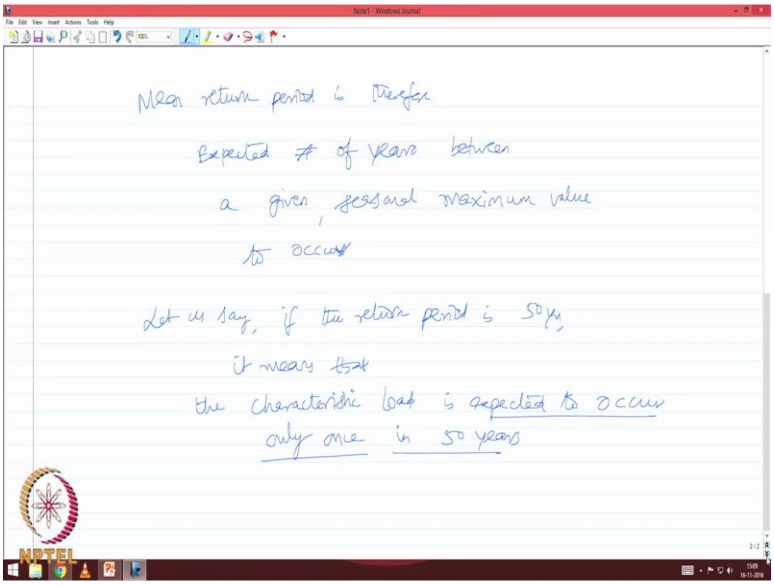

Mean return period is therefore, expected number of years between a given seasonal maximum value to occur. Let us say if the return period is 50 years it means that the characteristic load is expected to occur only once in 50 years; that is very very important.

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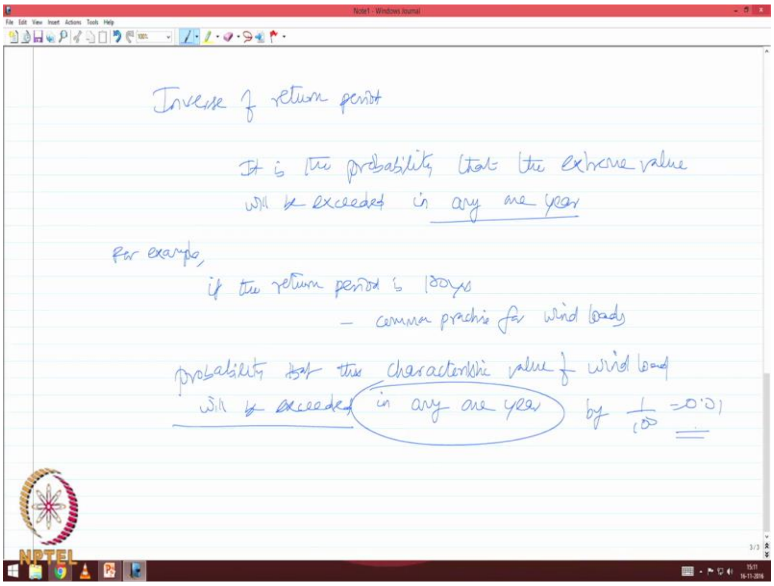

Inverse of return period is slightly of very interesting nature, let us take the inverse of this. It is the probability that the extreme value will be exceeded in any one year. Say for example; if the return period is 100 years which is a very common practice for wind loads; probability that this characteristic value of wind load will be exceeded in any one year by 1 by 100 which is 0.01.

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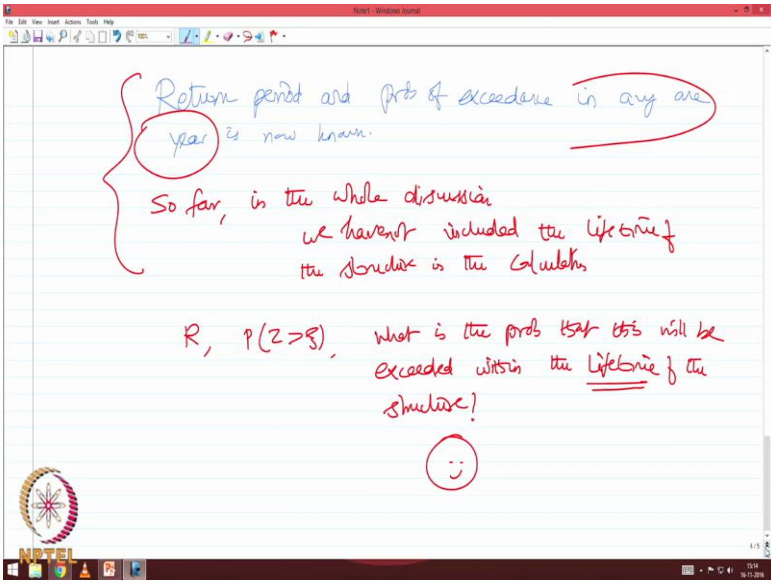

Now, interestingly return period and probability of exceedance in any one year is now known, but so far in the whole discussion we have not included the life time of the structure in the calculation. The question asked here is, what are may be the return period, what are may be probability of exceedance of the return period compared to any value, what is the probability that this will be exceeded within the lifetime of the structure.

So, as a designer one is interested in this question he is not interested to know the conventional probability of exceedance of any specific event in any one year, but he would like to know will that any one year will happened within the lifetime of the structure. So, it is very evident and mandatory that one should now link the lifetime of the structure with the return period or probability of exceedance of that event within the lifetime of the structure.

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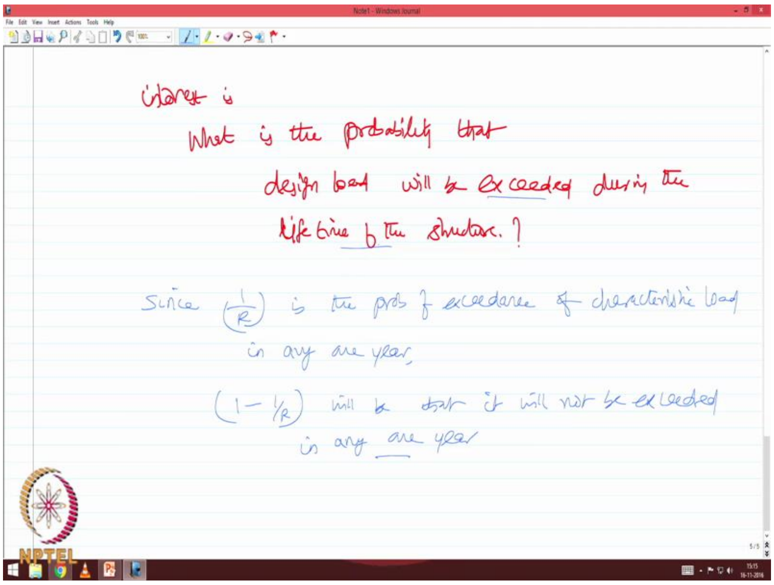

So now the interest is; what is the probability that the design load will be exceeded during the lifetime of the structure. So that is a question now. Since, 1 by R is the probability of exceedance of the characteristic load in any one year; 1 minus 1 by R will be that it will not be exceeded in any one year, is it clear exceedance 1 by r.

So, 1 minus 1 by R will be the non-exceedance of that in any one year. He may be wondering that why we are looking at the non-exceedance value when we are going to focus on exceedance value in the lifetime; I will come to that point.

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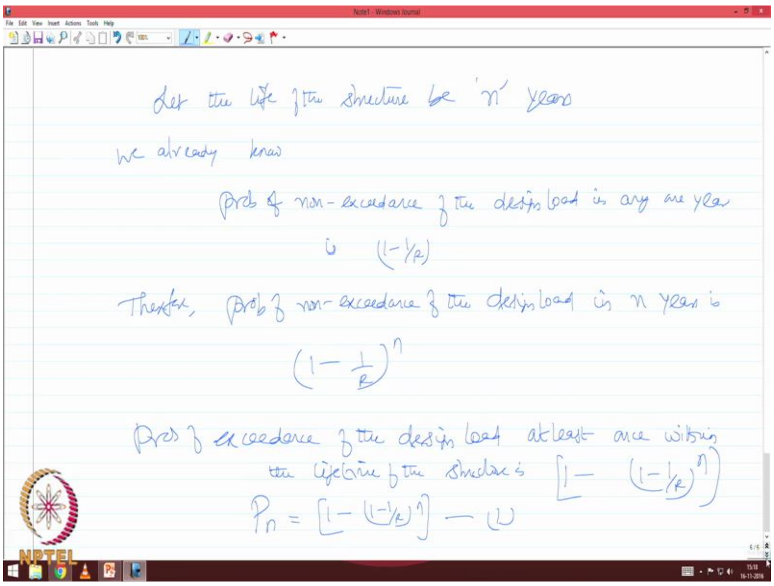

Let the life of the structure be n years we already know probability of non-exceedance of the design load in any one year is 1 minus 1 by R. Therefore, probability of non-exceedance of the design load in n years is 1 minus 1 by R raise to the power n. But as a designers interest we are came to know; what is the probability of exceedance of the event within the lifetime of the structure.

Now, probability of exceedance of the design load at least once within the lifetime of the structure is very easy, because of probability of non-exceedance in n years is 1 minus 1 by R. So, probability of exceedance will be 1 minus 1 minus 1 minus 1 by R to the whole power n. So, I should say now probability of exceedance of the design load at least once within the lifetime could be 1 minus 1 minus 1 by R raise to the power n.

Let us understand this complexity with a straight example.

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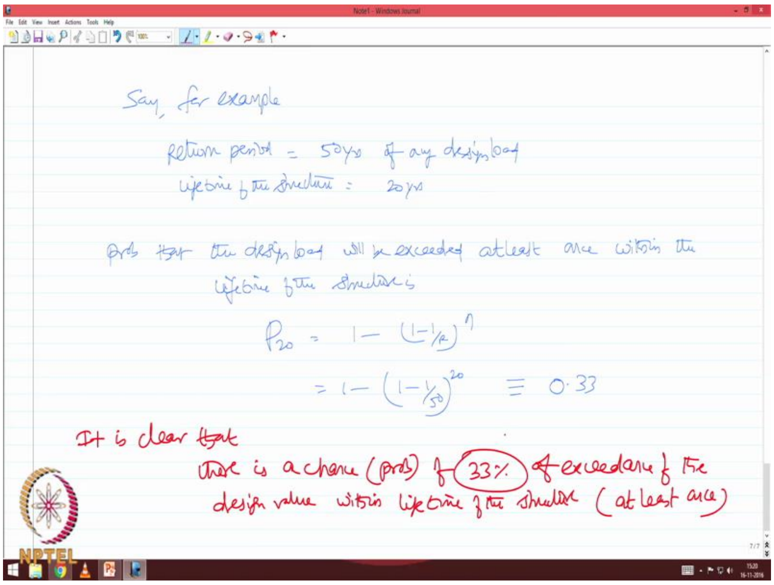

Say for example, return period is 50 years of any design load, lifetime of the structure is 20 years, therefore probability that the design load will be exceeded because that is the interest of the designer at least once within the lifetime of the structure is given by let say P 20, because 20 is the lifetime of the structure 1 minus 1 minus 1 by R to the power n 1 minus 1 minus 1 by R to the power n 1 minus 1 minus 1 by 50 to the power 20 which will be equal to 0.33.

It is therefore clear that there is a chance that is the probability of 33 percent of exceedance of the design value within lifetime of the structure at least once. The value of 33 percent is significantly high even though the occurrence of event is once in 50 years. This leaves a strong message to understand more on the return period.

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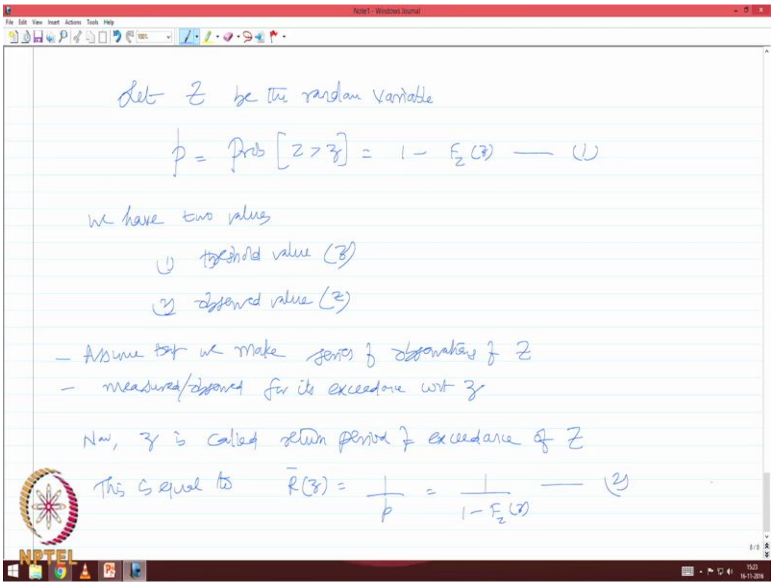

Let us say, let Z be the random variable probability of Z exceeding small z is actually equal 1 minus F z of small z. Let us say we have two values; one is the threshold value let us say small z other is the observed value capital Z. We want to know given the set of observations what is the probability that the observed value exceeds the threshold value that is very interested in. Assume that we make series of observations of Z; these values are actually either measured or observed depending upon the process for its exceedance with respect to a threshold value small z.

Now the threshold value is small z is called return period of exceedance of z this is equal to R bar Z which is 1 by p we already know that which is actually 1 by 1 minus F z of z.

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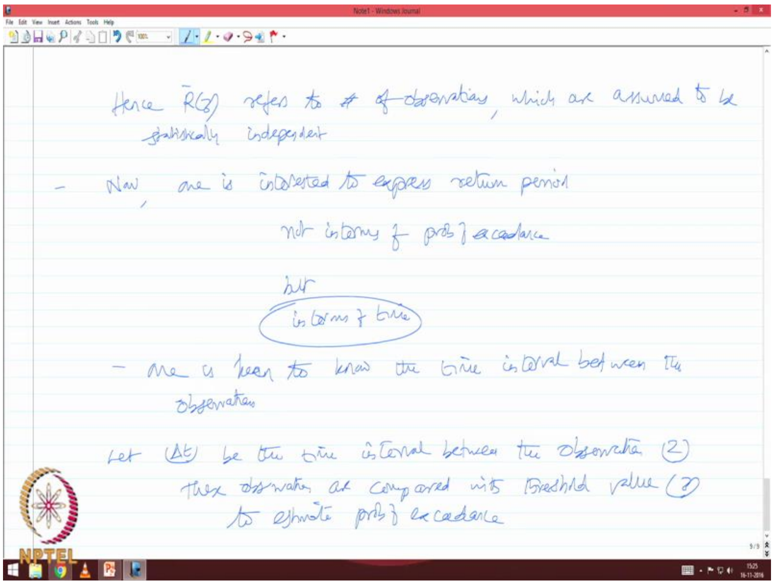

Hence, R bar Z actually refers to the number of observations which are assumed to be statistically independent. It means one observation does not have the influence of the prior and post assumed value. Now, one is interested to express the return period, not in terms of probability of exceedance but in terms of time, that is one is keen to know the time interval between the observations; let delta t be the time interval between the observations capital Z. These observations are actually compared with threshold value small z to estimate probability of exceedance. We are trying to determine the return period of the exceeded value carefully.

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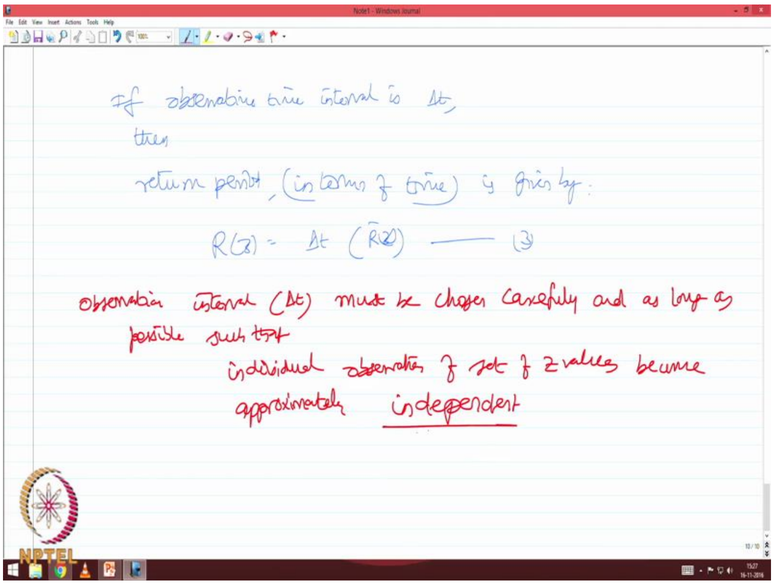

Therefore, if observation time interval is delta t then return period in terms of time, not in terms of probability of exceedance is given by R z is delta t into R bar. So, deeply the very important comment. The observation interval delta t must be chosen carefully and as long as possible such that individual observations of set of Z values become approximately independent.

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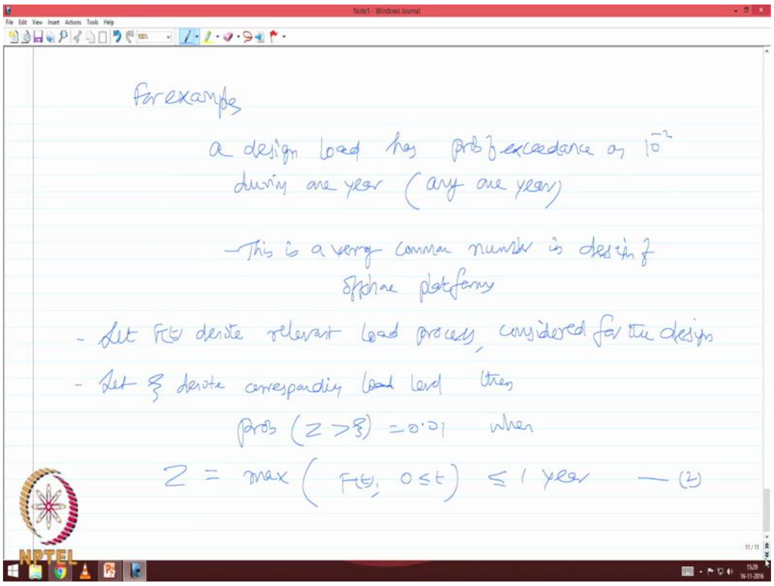

Let us try to understand this complexity by an exam. A design load has probability of exceedance as 10 power minus 2 during one year. To be very specific, any one this is a very common number in design of offshore platforms. Let F of t denote relevant load process, what are may be the load, the conventional load, wind, wave load etcetera which is considered for the design.

Let zeta denote the corresponding load level then probability of z exceeding zeta is 0.01, because that is the probability of exceedance when z actually equal to the maximum of the observed values or the force value for anything less than time, less than one year.

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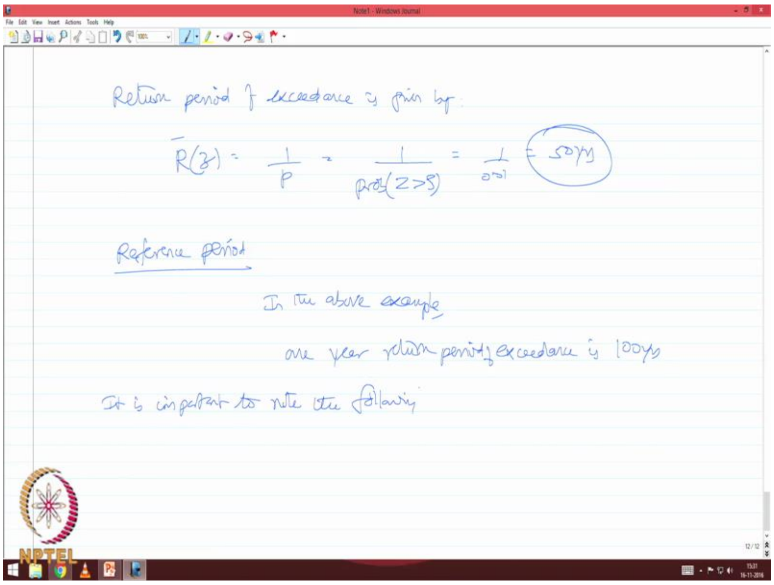

Return period of exceedance is given by return period bar is 1 by probability which is 1 by probability of z exceeds zeta 1 by 0.01 which is 50 years. Now you see return period of exceedance is given in a time period, earlier this was told in terms of probability of exceedance.

The second important factor which is considered to create complexity in the load process is reference period. What is a reference period? In the above example, what we discussed just now we said; one year return period of exceedance is 100 years. Therefore, it is important to note the following.

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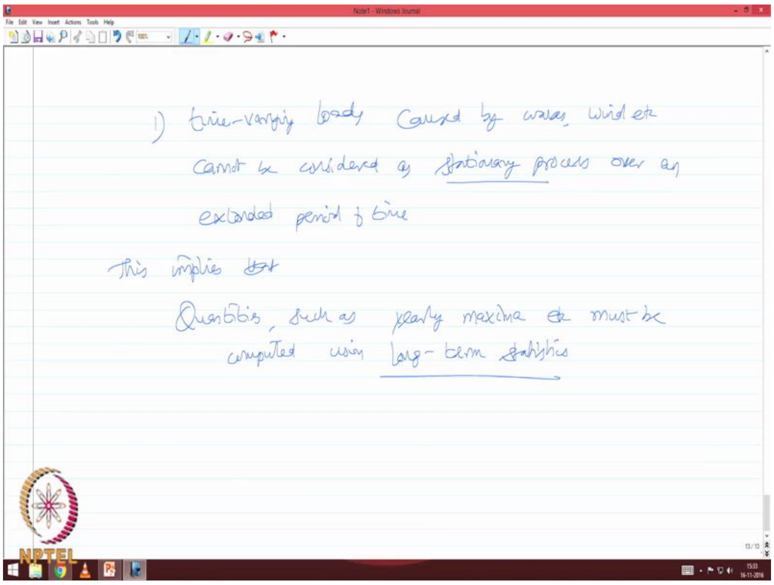

One, time varying loads caused by waves, wind, etcetera, cannot be actually considered as stationary process over an extended period of time. You cannot extrapolate the service life or the return period because, the condition of stationarity does not hold good beyond the time boundary considered for the analysis. So, this implies that quantities such as yearly maxima etcetera must be computed using what we call long term statistics; that is an important statement we have.

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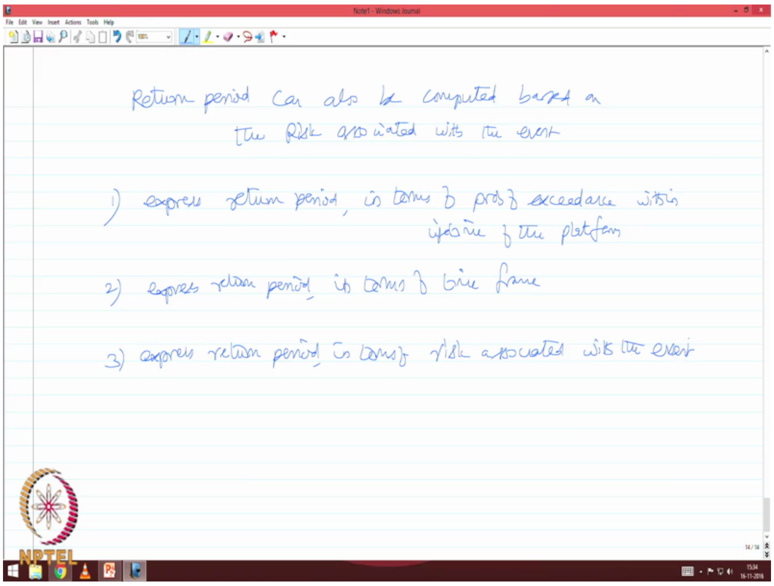

Thirdly, return period can also be computed based on the risk associated with the event. Please note; we have already learned how to express return period in terms of probability of exceedance within lifetime of the platform. We have also learned how to express return period in terms of time frame. Now we will learn how to express return period in terms of risk associated with the event.

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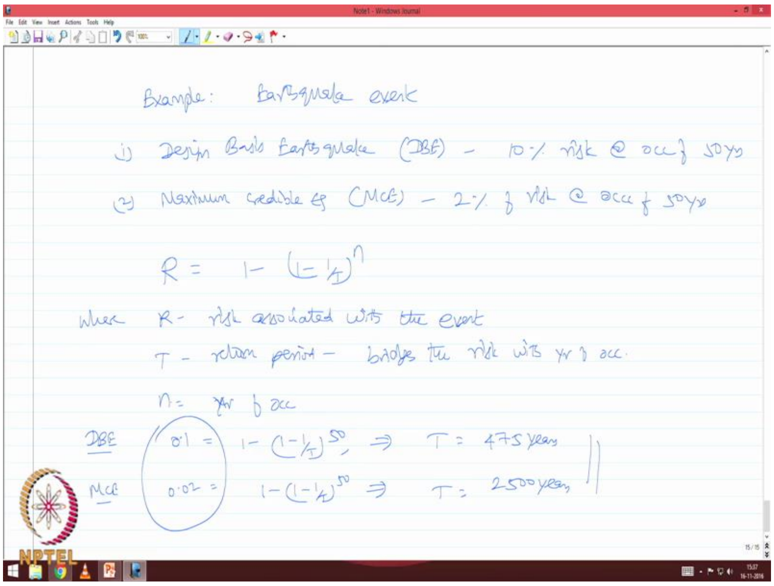

Let us take an example of an earthquake event. The moment we say risk it is better we assume a sisonogical event. We know in earthquake risk and design, design basis earthquake which is abbreviated as DBE is that earthquake magnitude associated with 10 percent risk at occurrence of 50 years.

The second one is maximum credible earthquake; MCE. This is an event associated with only 2 percent of risk of course at an occurrence of 50 years. Therefore, R is actually 1 minus 1 minus 1 by t to the power n. Where, R in this case is the risk associated with the event, t will give me a return period which now bridges the risk with year of occurrence; so n is the year of occurrence. So, if we use it for DBE let say 0.1 should be equal to 1 minus 1 minus 1 by t of 50 which implies that the return period of that event is about 475 years. If you do it for MCE 0.02; 1 minus 1 minus 1 over t of 50 which implies that the return period is as high as 2500 years.

So, friends we have also learnt how to estimate return period in terms of risk associated with any specific event as in the cited example.

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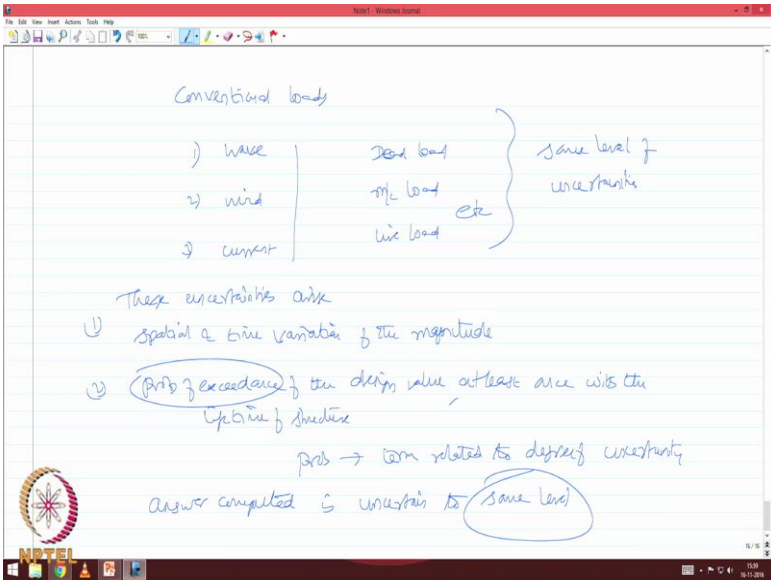

So, we now realize that conventional loads which arise from waves, which arise from wind, which can arise from current, other than that the dead load, the machinery load, the live load, etcetera are all associated with some level of uncertainties. Please understand these uncertainties arise due to many reasons; the foremost reason is, the spatial and time variation of the magnitude. Two, probability of exceedance of the design value at least once within the lifetime of the structure; the moment I say probability of exceedance probability is always a term related to some degree of uncertainty.

Please note I am not calling this as a wrong answer, I am saying the answer computed is uncertain to some level. So friends, being look forward now to understand the probability of occurrence and uncertainties in complexities associated with special loads. We will start our discussion with ice loads in this lecture and continue the next lecture as well.

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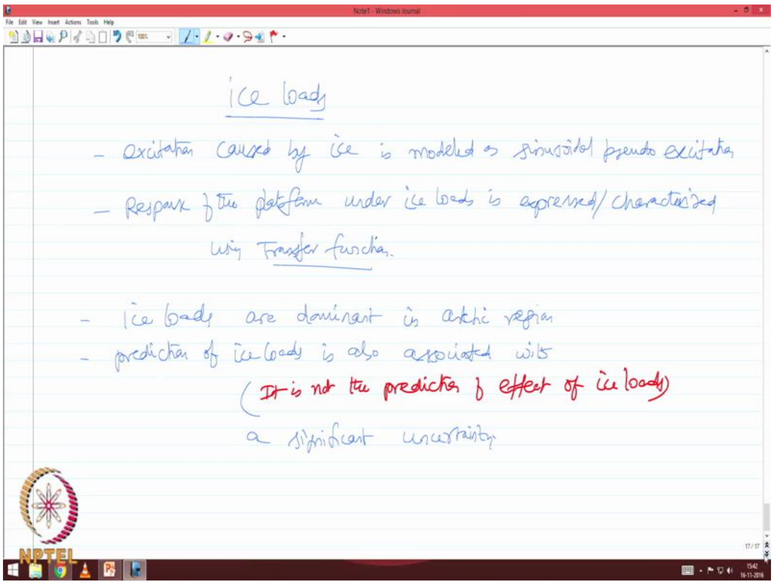

The moment we talk about ice loads, excitation caused by ice is modeled as sinusoidal pseudo excitation. The responses of the platform under ice loads are expressed or let us say its characterized using transfer function. We all agree that ice loads or dominant in arctic region. Now we can proudly say with a clear understanding that prediction of ice loads. Please understand it is not the prediction of effect of ice loads, it is actually the prediction of ice loads itself; prediction of ice loads is also associated with a significant uncertainty.

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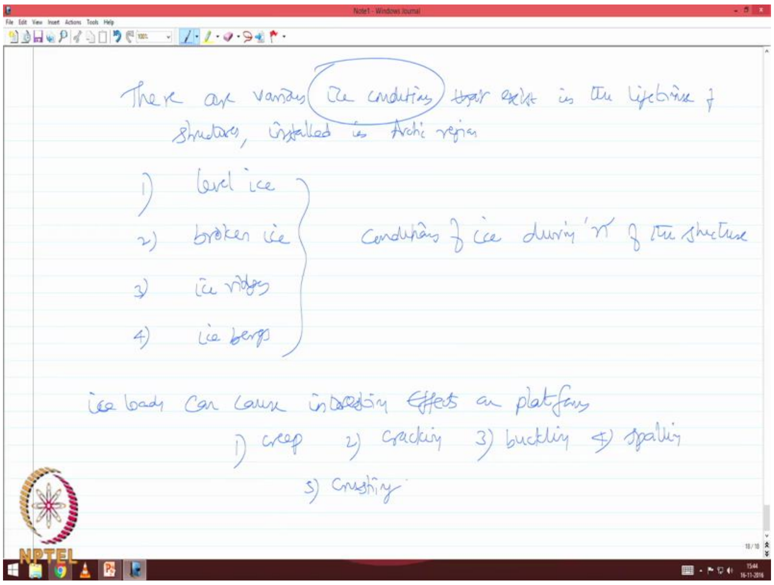

Let us see, what are those conditions which lead to uncertainty. There are various ice conditions that exist in the lifetime of structures installed in arctic region. For example, you can have something called level ice, you have something called a broken ice, ice ridges, and ice bergs. These are different conditions of ice that may exist during the lifetime of the structure.

Ice loads can cause very interesting effects on platforms. They can result in creep, they can result in cracking, they can result in buckling, spalling, or even crushing.

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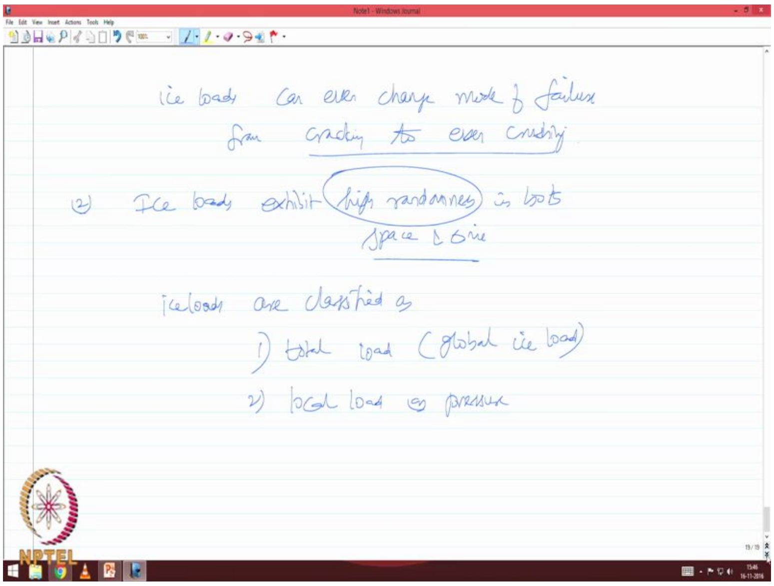

Interestingly, ice loads can even change the modes of failure from cracking to even crushing.

The second aspect which is very important ice load is that, ice loads exhibit high randomness in both space and time which is true for waves as well as for wind. However, for wind at least we compensated this variation by recommending and equivalent arrow dynamic admittance function or a gust factor. Based on this randomness ice loads are classified as; one total load otherwise called as global ice load, two local load or which results pressure.

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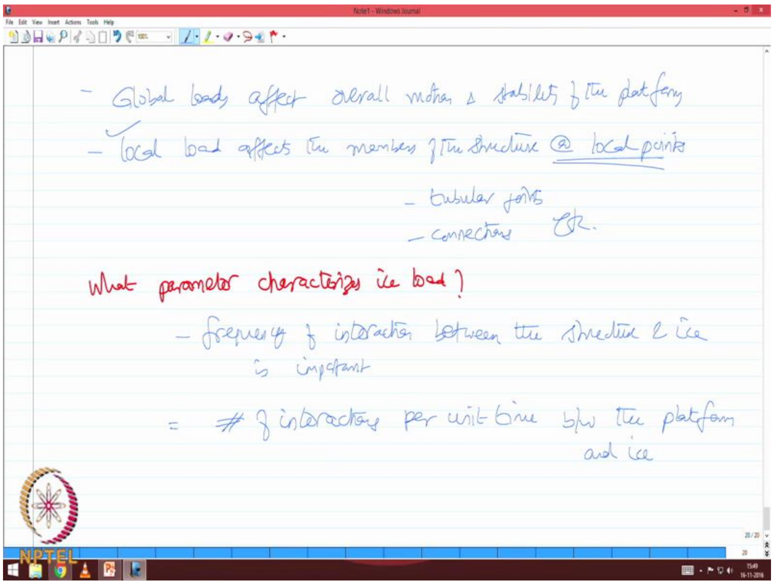

Now the global loads affect overall motion and stability of the platform, whereas the local load effects or the local load affects the members of the structure at local points. Now on engineering perspective, what are these local points where the local load can cause serious effects? For example, tubular joints, connections, etcetera.

Now, one can ask me a question, when ice loads are highly random both in space and time what is that important parameter which characterizes the ice load. Answer is very easy and simple, frequency of interaction between the structure and ice is important and this characterizes the ice load. So let us elaborate this, what we understand by frequency of interaction? It is actually the number of interactions per unit time between the platform and ice.

So, when ice interacts with the platform what kind of load is generated on the platform, it all depends upon what is the shape of ice, how the ice is causing impact on the material of the structure, how the member respond to this or what is effect caused by the ice on the member. We will discuss all these issues in the next lecture where we elaborate more about the ice spectrum and uncertainties involved in the ice loads.

Thank you.