Risk and Reliability of Offshore Structures

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Module – 01
Lecture – 02
Uncertainties

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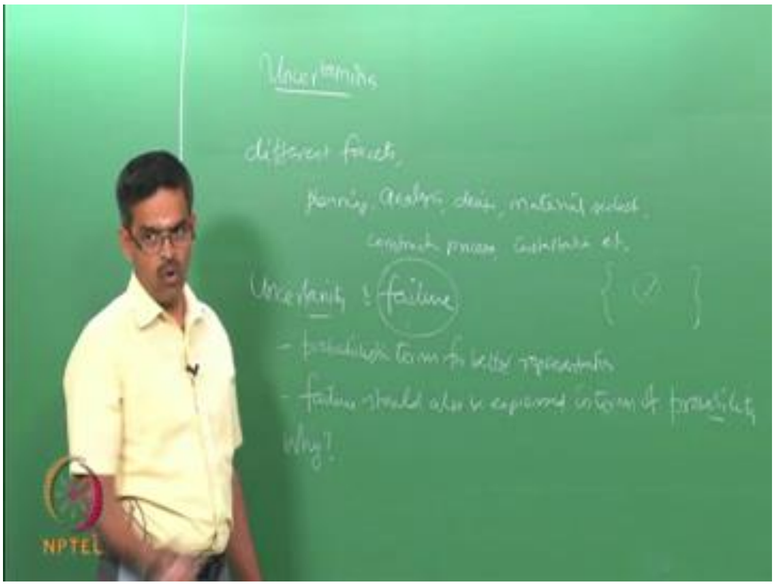

Welcome friends to the online course title Risk and Reliability of Offshore Structures on to the brace of NPTEL, IIT Madras. I am Prof. Chandrashekaran. Let us look at the second lecture. This lecture we will focus on important parameter what we learnt in the earlier lecture, which is uncertainties. We already said that in different facets of offshore structures namely analysis, design, in fact planning, material selection, construction process, installation etcetera there are difficulties there are complexities associated with these stages, so that the entire scheme of offshore structural engineering cannot be made accurate.

In sense that you can only give a value or assume a value within a given brace, but you will exactly do not know what is that value being assigned to the member of the material or the system at any given point of time during the space of life of the structure. So, this is what we actually call physically uncertainties. Uncertainties in sense you know them, but you do not know them for certainly what is the value of associated you can only guess. And we all know in mathematics or in engineering applications wherever you have difficulties of guessing we generally take the help of probability and statistics.

So, in the first lecture, we saw that probability and statistics can be very useful; and reliability as a tool can be very efficiently possible to handle these uncertainties associated with different walks of offshore structural engineering. There are many advantages of various reliability methods, which we summarised in the first lecture; however, reliability methods also have certain limitations. So, we summarised in the first lecture that reliability studies or circumscribed are on one important term what we call uncertainty estimates.

So, let us talk about uncertainty in lecture number 2. Let us try to differentiate uncertainty and failure; very interestingly one can try to find out an answer for this saying if I am not certain about anything will it lead to a failure, because we already said reliability is to ensure success during operation or installation or functioning of the problem or of the platform. So, we are not talking about failure at all. So, uncertainties need to be expressed of course, in probabilistic terms for a better representation. Uncertainties will be expressed in probabilistic terms for better representation. Since, it is so let us try to also make this as a comparable platform for failure. Therefore, we say failure should also be expressed in terms of probability.

Immediately a question can come in mind, why failure should be probable, why should have to guess a failure, because one can always say an engineering strength or the knowledge known to a person of his experience can say this system is sure to fail. So, there can be a surety, there can be a guarantee, there can be a conformability associated to a failure in general that is what engineering community feels.

Therefore, why failure should also be associated with the probability, the answer is very simple. The question what we try to ask is why failure should be addressed in probabilistic terms; we have no question asked of the same order to uncertainty; we already said uncertainty is likelihood of variation of the values therefore we can try to guess them in a given bandwidth. So, we accepted probability as an important tool or reliability is an important methods to express this in a more engineering manner, but we are yet to be convinced why failure should be associated in probabilistic terms because failure and uncertainty are interlink psychologically.

Now, the question is why failure need to be addressed in probabilistic terms, because there will always be some degree of uncertainty in conforming the failure of any given structure. Since, you are not sure hundred percent that the system or the structure will fail under the given combination of floats when you are going to guess an order of failure, obviously failure need to also be addressed in probabilistic terms.

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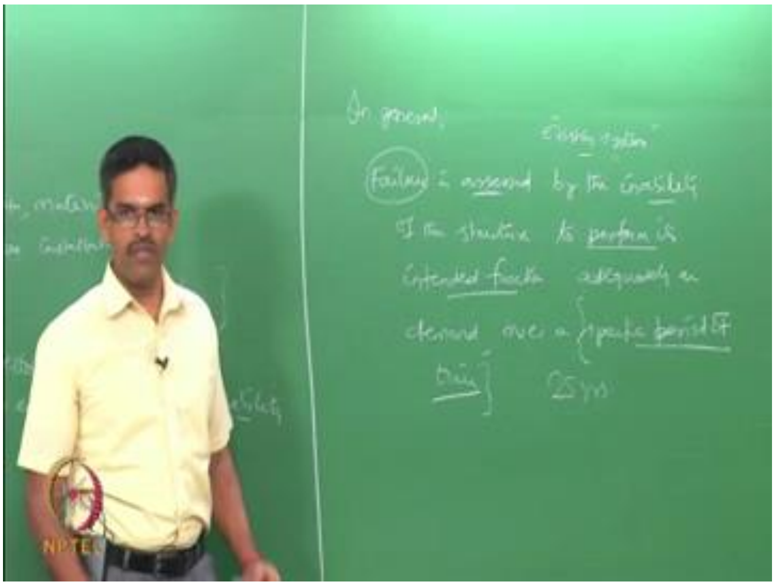

Therefore, in general failure is assessed by the inability of the structure to perform its intended function adequately on demand over your specific period of time; this period of time can even addressed as life of the structure. So, failure is actually an assessment which is done on an existing system which tells what is the probability that an existing system cannot perform its intended function, within the given specific period of time when it is demanded to execute or to perform this function under a given specific period of time. Therefore, failures as well as uncertainty both are connected only within a specific timeframe. Please understand this, ladies and gentleman, there is no infinity time associated to failure analysis within a specific period of time.

For example, let us say you are designing a structure for a life span of 25 years starting from today, if the structure has fail to perform its intended function, what is an intended function let say drilling operation, production and execution, if it is not able to successfully perform the intended function within its life span, when it is demanded to perform then one can say the structure as fail. Failure does not always mean only a structural failure; failure can also mean your functional failure. So, looking at the safety of the functional system, not the safety of the structural system, the reliability and risk assessment in offshore engineering is not exclusively applicable only to the structure engineering part of it, but predominately applicable to the functional use of an offshore structure under the given specific period of time.

However, in the life of the structure has crossed to the life span - design span of 25 years, if the structure has fail to perform as intended function, I would not call that as a failure neither I would call the deterioration property of the structural member as an uncertainty. So, both estimates of uncertainty and the link of uncertainty to a failure are connected closely only within a specific band of time, it is a very important definition we all to understand to really define uncertainty.

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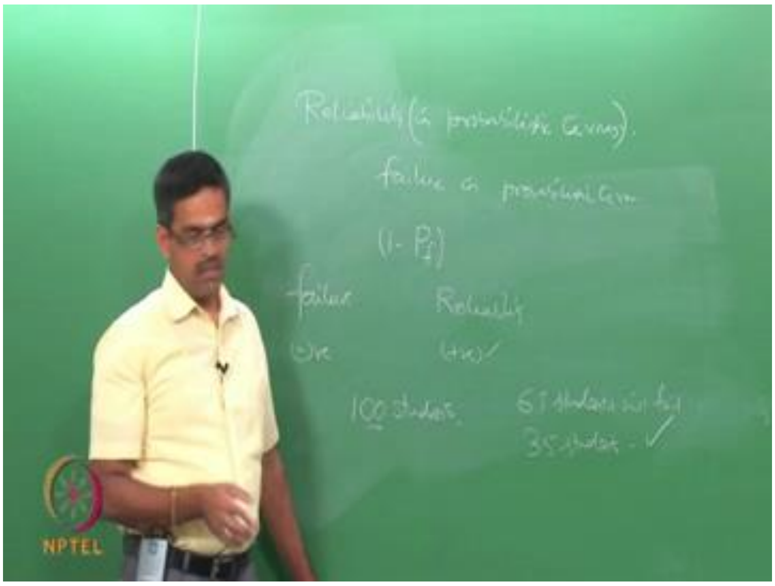

Now let us try to understand reliability in probabilistic terms. So, how do you understand reliability in probabilistic terms? If you really wanted to understand reliability in probabilistic terms, you must understand failure in probabilistic terms. So, I am looking here for something call probability of failure. Now, I can define failure which I saw here. So, failure of any structure is true only under specific conditions, conversely reliability is expressed in terms of success of a system the sustain demand expected from it.

So, now I can say failure and reliability actually are converse to each other; one talks about a negative aspect of the problem; one looks at the positive side of the problem.

Ladies and gentleman, in engineering economic or engineering management all of us strongly do agree that instead of stating a problem with a negative vision or a statement, it is always encouraged to present the problem in a positive mode. So, I do not talk about probability of failure, I wish to talk about 1 minus probability of failure which is my reliability. So, reliability is a converse of failure. So, we do not measure failure directly; we talk about reliability indirectly in terms of measuring failure in probabilistic terms and then taking converse of this, because we are interested in presenting the positive accept of the problem.

For example, instead of a saying in a class of 100 students in a course, it is probably or likely that 65 students will fail, which will give a negative impact to the class, which will discourage a students, because it is a large sum. The teacher or the faculty or the advisor can always tell to the class in the other way 35 students or likely get cleared of the course. So, the answer is on a class of 100, when the faculty says only 35 would clear the course, it goes without saying that the remaining 65 will be below average, but the way of expressing the statement will give a positive sign. So, reliability is that aspect in engineering which tells the positive notion of the failure. Failure as such cannot be a positive notion because failure itself psychologically will be a negative impact; fail, it is a negative impact; pass is a positive impact. So, reliability is a method of presenting the positive convention of failure.

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Reliability is therefore, expressed in terms of probability; they are some vital parameters, which are important and that should be mention in reliability analysis. What are they vital parameters in reliability analysis? In fact, even if you write instead of reliability failure analysis you would accept to me a agreeing that the statement is instead of saying failure analysis, I am trying to write the positive note of the failure. So, vital parameters used in reliability analysis of the following; one could be the quality of performance. Under the quality of performance, one can talk about the degradation of strength of material. In offshore structures, the predominant factor responsible for degradation material is corrosion.

The next key factor which one must adjacent reliability is over an expected period of time, because we already said failure is also specified within the period of time, it is not over an infinite period of time. Therefore, probability of non-failing, non-failure case which is reliability should also be therefore, expressed over an expected period of time. The third parameter could be to perform intended function not to fail to perform to perform successfully intended function under specific conditions; the specific conditions could include the considerable sea state, the considerable wave climate etcetera operational loads etcetera.

So, you have to specifically very clearly declare in the beginning, what are those conditions under which the structure is expected to perform, what is the period over which the structure is expected to perform, what is the quality you are expecting a structure to perform. You are going to declare these vital parameters in advance to really do your reliability analysis of an offshore structure.

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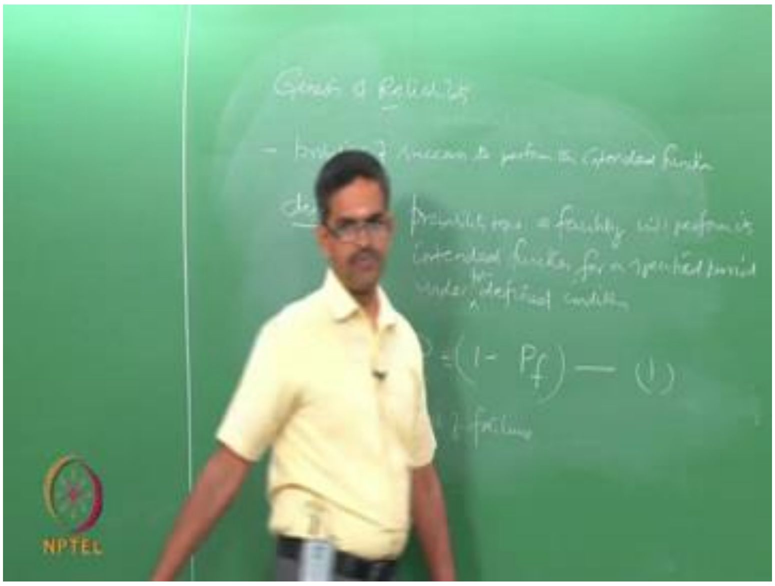

Now, let us ask a fundamental question what is the genesis of reliability, from where this reliability is been origin from; it is the probability of success to perform an intended function let us put it like this. Reliability originates from a statement saying that it is the probability of success to perform the intended function.

Reliability is defined as the probability that a facility will perform is a classical definition of reliability now, which I am stating; probability that the facility is a general term, we can even say a structure will perform its intended function for a specified period under defined conditions. Even one can say predefined conditions, what I already said specific conditions. Therefore, reliability is expressed as 1 minus P of f where P of f is call probability of failure. Therefore, reliability implies estimate of limit state probabilities of a structure under critical demand. Safety is generally used to indicate reliability, which is a traditional concept.

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Now, let us ask the question how reliability risks are compared. In the earlier part of the lecture, we compared reliability and failure. Now, we are comparing reliability and risk. We already said reliability is actually the probability of success to perform the intended function, whereas risk actually is a measure of magnitude of hazard, risk is actually a measure of magnitude of a hazard.

Now the question comes what is a hazard. Hazard actually is the scenario; now there are two vital parameters involved in risk; risk has got two parameters now involved. What are those two parameters; one is the probability of failure; two could be the frequency of failure. Therefore, this cannot be generalised, this has got to be applicable to each and every event. So, the whole offshore structural problem should be discretized into different varieties of events, and each event should be associated with the probability of failure of the event if at all it fails what would be the frequency of that failure.

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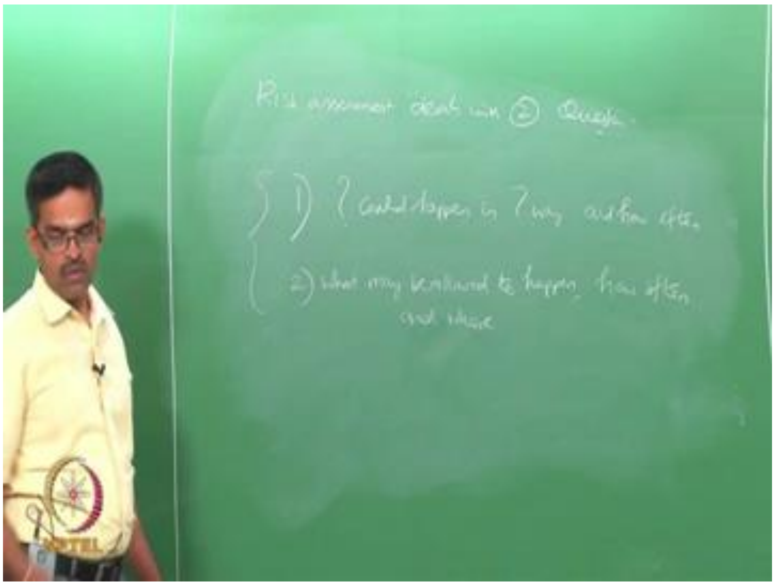

Therefore, risk assessment deals with two fundamental questions; deals with two questions. One, what could happen in what way and how often; what could happen in what way and how often that is a first question. The second could be what may be allowed to happen, this what we call as risk acceptance. What may be allow to happen, if it is allow to happen, how often that is a risk tolerance and where risk acceptance criteria; can it happen to all vital functional components of a given system, where you can allow risk acceptance, how often you can allow or permit risk acceptance and what may be allow as risk acceptance. So, these two questions become very important to get an answer which will lead to what we call risk assessment. Therefore, ladies and gentleman answering these two questions will lead to risk assessment. For an offshore structural engineer, if the assessment turns out to be negative, he needs to answer further questions, let say what are they.

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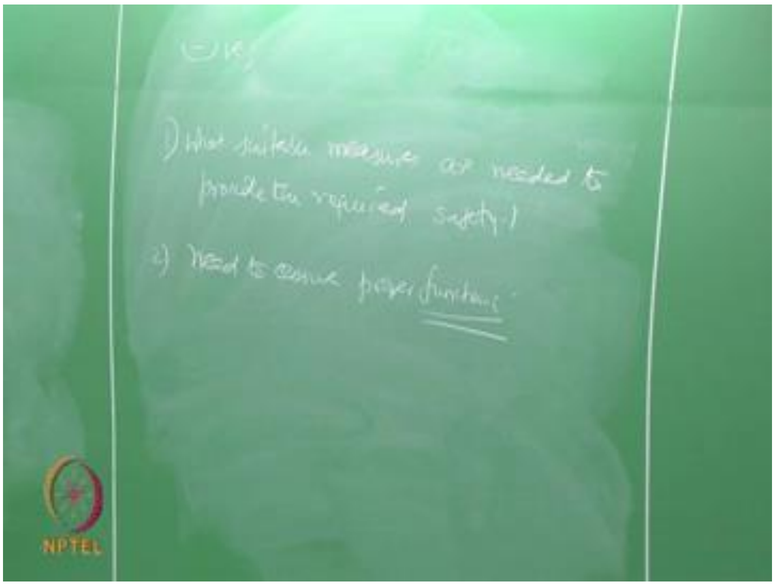

What suitable measures if the answer appears to be negative, then an offshore structural engineer needs to answer further more questions. What suitable measures are needed to provide a required safety that is the first thing what does he ask. The second could be he has to ensure that appropriate measures are taken in place to guarantee the proper function. So, as you clearly see risk also ultimately circumscribed to satisfactory functioning of a given system which reliability also says. So, reliability and risk are two different facets of understanding failure; reliability addresses failure in a positive notion, where as risk addresses improper functioning in a direct notion, we answering couple of questions which deals with risk acceptance criteria are risk limitations.

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Having said this, let us quickly make an interesting statement. Therefore, reliability in offshore engineering means to assess functional safety. It is not directly and explicitly only for the structural safety. It is predominantly focusing on functional safety. There are now few important factors, which we must consider to ensure functional safety. Reliability is generally focused on those problems that are not realised with the society directly, but those challenge the safety indirectly. It is interesting to know that risk assessment from failure analysis does not guarantee or generate discussions, but only leads to rules and recommendation.

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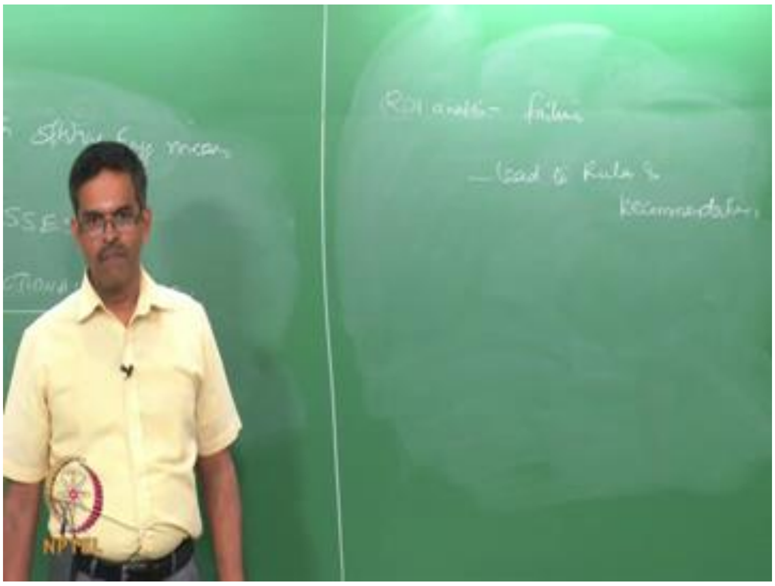

The risk analysis based on failures - past failures will lead to making of rules and recommendations; it is more or less in the strategic profile; whereas, reliability is more or less on the generic profile. Reliability actually opens into an engineering questioner that shall lead to a better understanding a probability of failure; instead of understanding and then framing the rules not to fail or not to cause failure, reliability rather helps to understand why the failure has happened.

So, it is a more intrinsic, more diagnostic method of understanding failure in part and parcel, whereas risk is an explicit, cut short direct, crisp, sharp method which ultimately concludes to certain rules and regulations which can avoid such kind of failure. So, risk leads to risk assessment or analysis leads to recommendations; reliability analysis leads to understanding a failure. Uncertainties, of course, govern the use of reliability tools to judge the safe performance of offshore structures.

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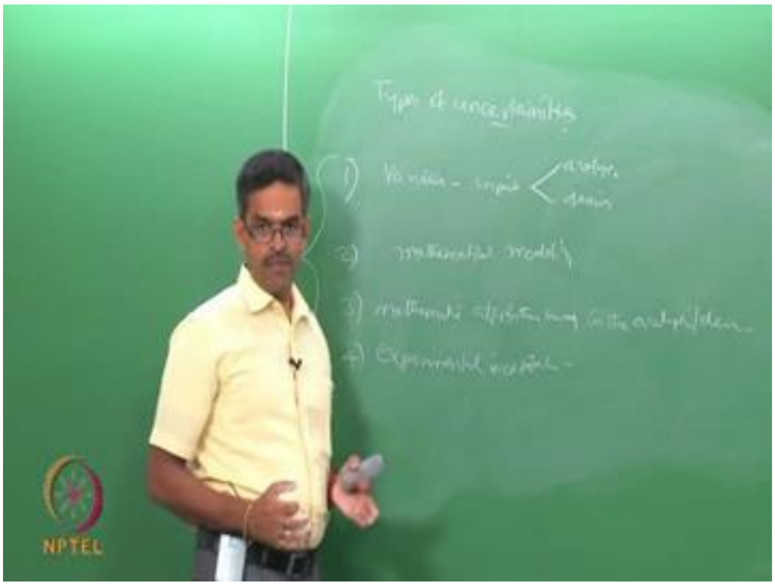

There are varieties there are many, many types of uncertainties, which we will now see. Summarise from the variables that are vital input for analysis and design. So, they arise from the variables, which are input for analysis and design. Some of them may arise from mathematical modelling. Some of them may arise from the mathematics algorithm use in the analysis and design. Some of them may arise during experimental investigations. So, there are many, many types of uncertainties which can arise from different facets in a given engineering sphere, which need to be looked into in detail to classify them as we are going to do now.

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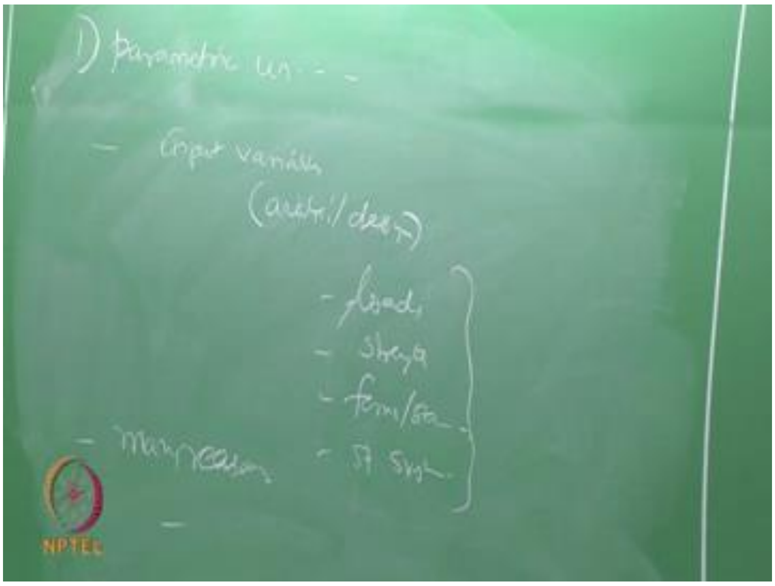

Let us first take parametric uncertainties. They generally arise from the input variables of the physical, mathematical or numerical model used in analysis and design. So, they essentially rise or arise from input variables, which are essentially used in analysis and design. I can give an example. What are the general input variables which you generally use or require for an analysis, let say loads, material strength, cross sectional form, geometry, structural system. All these are a sort of a input which is used either for a preliminary design what we call as free front end engineering design on offshore structures or for analysing to find out the critical values for which they should be design. So, they are all input variables, what we call as parametric uncertainties.

Now, the question comes why they remain uncertain, cannot we predict, cannot we estimate to evaluate them correctly with higher accuracy, they remain uncertain because their exact values are not known for many reasons. Now, what are many reasons why the exact values are not known; one they are not known to the experimental investigation people? Secondly, these variables cannot be control during experimental investigations. Thirdly, these values cannot be exactly interfered or evaluated by statistical methods. There can be many examples we can give lets us looked into some classical examples where parametric uncertainties becomes vital.

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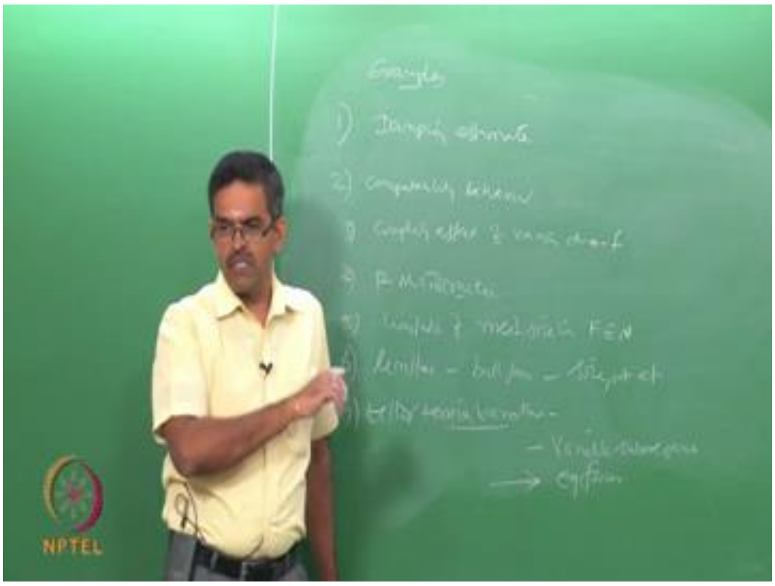

Examples, damping estimate in offshore structure. Secondly, compatibility behaviour at the connections or joins of members; thirdly, it could arise compatibility behaviour, can also arise from coupling effect of various degrees of freedom, can also arise from the effect of P-M interaction of the material characteristics. It can also arise from the limitations of infinite limitations of the mesh size in finite element analysis. Can also arise from the limitations because of ball joints in terms of its size, weight etcetera; can also raise from tether tension variations, which cannot be correctly predicted. Now the question comes when your tether tension variation will occur, when there is variable buoyancy created. This can arise because of variable submergence. This can also arise essentially and predominantly because of earthquake forces.

There is various interesting research papers referred in the NPTEL portal of this particular course, where earthquake motion can cause your dynamic instability only we altering that tether tension variation in combined systems like TLP. Please look at these papers; interestingly you will know that even a combined system like tension leg platform can be thrown to instable regime under earthquakes forces only because there is a dynamic tether tension variation happening in the support system. So, now we have understand and having said this there are many factors which will prevent you from estimating the values of input variables in analysis and design models.

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We can also have some other issues, which are important other than this. Inability to model exactly as design that is one important; inability to model I am talking about a numeric model or an analytical model to model exactly as designed. If you are not able to model exactly similar to the design what you have done, this will lead to lot of uncertainties in the behaviour in the response behaviour. So, parametric uncertainties essentially come from the input variables, what you supply during analysis and design.

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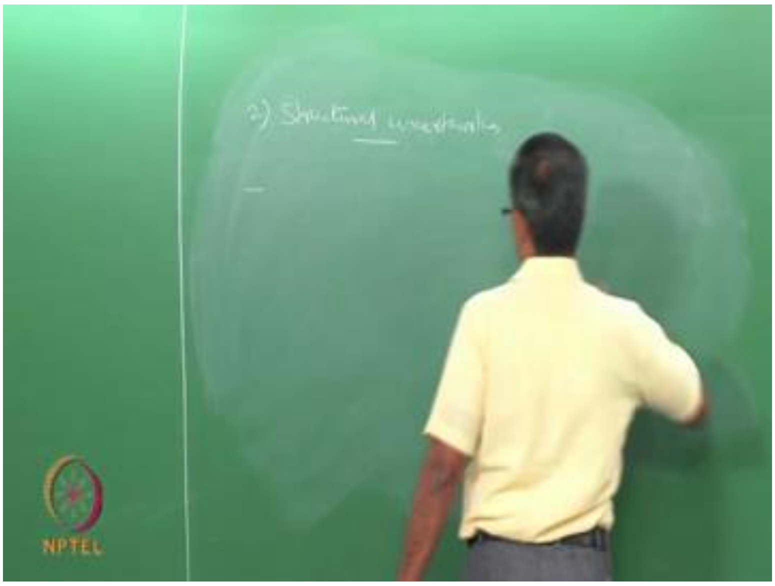

The second cause of uncertainty essentially comes from structural uncertainties. Essentially, they arise from the inaccuracy of mathematical model that shall simulate the real time behaviour of offshore structure under install conditions, because the real time behaviour of the system under install condition will be different from the top and uninstall condition in the laboratory scale because of the mass difference because of the sea state. So, numerical models therefore, can only predict approximate reality.

For example, it is difficult to model the behaviour of the pined connection in an articulated tower under the combined action of axial load and the moment. The second example could be there is an additional damping arising from the geometric interference of the member in the top side which can also cause a very serious variation in the wind load behaviour which cannot be mathematically model correctly. So, this aspects cannot be mathematically model which essentially arise from the behaviour of the members or the connections due to the structural uncertainties.

One can ask me a question what would this amount too, if there is a confusion and not exactly able to model the structural uncertainty what will lead to in certain cases very specifically, if these uncertainties are not known very clearly, your discrepancy will be there between the model and the true behaviour on the structure. So, you will be able to predict one response parameter which may not match under the given sea state for the real prototype system, there is going to be a miss understanding in extrapolate in the behaviour of a scaled model to that of a prototype. If it is experimental or if it is analytical and numerical the estimate what to try to make out from the uncertainty involved in the behaviour which are not able to model correctly will be lead to a wrong interference of the structural response characteristics.

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The third kind of uncertainty what we would see will be algorithmic uncertainties. They essentially from the approximations which are using for implementing the analytical model, used to implement the analytical model I can give certain examples for this lets say I want to predict the dynamic response behaviour of an offshore platform I try to write the equation of motion, the equation of motion requires iterative parameters to be solved. So, the solution of equation of motion generally becomes iterative numerical methods are used to solve such problems in engineering domain in dynamics we know that. Most models are too complicated to solve them exactly. Finite element method or finite difference method can also be used to approximately solve a partial differential equation, but this also introduces numerical errors.

Numerical integration methods inherently deal with infinite some truncation that is necessary approximation in the scheme of numeric implementation. So, you pick up any method for which you are solving the equation of motion or a problem from arising from partial differential equation etcetera, all these algorithms also introduce in parallel errors or approximations which we call them as algorithmic uncertainties.

So, in this lecture, we are trying to discuss in detail about varieties and types of uncertainties. We discussed the connectivity between reliability and failure. With reliability is a positive approach of explaining a failure. It gives a psychological satisfaction in making the statement more explicit saying it is going to be better by 10 percent instead of saying it is going to be bad by 90 percent. We are also connected in this lecture reliability and risk, risk is a post-mortem of a failure phenomena leads to framing of rules and regulations to avoid a failure. Whereas, reliability is a capacity building; it deals to make you to understand better about the uncertainties.

So, reliability is a knowledge bank; risk assessment is an application or implementation of the knowledge bank to frame rules and regulation, so that code regulations are based on risk assessment. Design analysis of new structural forms should be based on reliability analysis. So, we made to compare them. We also said reliability circumscribed with uncertainties. And varieties of uncertainties, we talked about parametric uncertainty, which essentially arise from the input of the variables used in analysis and design. Secondly, is a structural uncertainty essentially comes from the interaction of members under the given install condition third is uncertainty arising from algorithmic schemes used for solving the equation of motion may be numeric methods, may be finite differences finite elements methods etcetera all of them in parallel introduces approximations which are called as uncertainties in mean understanding.

So, we will continue this lecture in the next class discussing more types of uncertainties, and then we make a summary that what we should do and how we should deal with these uncertainties. Do you have any questions or doubts, kindly interact in the web portal, try to post your questions and share your understanding to the entire audience addressing or listening to this course. Do refer the material given in the references as textbooks and reference section in general papers. Do a capacity building in parallel try to put as many questions as possible to make the subject matter clear to understand therefore, will be able to appear for the exam and pass all tutorials very satisfactorily and indigenously.

Thank you, we look for the next lecture.