Risk and Reliability of Offshore Structures
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Module – 02
Reliability Theory
Lecture – 01
Introduction

Friends, welcome to the classroom course on Risk and Reliability of Offshore Structures. We are continuing to discuss lectures on module 2. I hope you would have understood the lectures on module 1.

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In module 2, we are going to discuss lectures related to reliability theory along with it is applications to offshore structures. So, lecture-1, we will talk about introduction to reliability theory or structural reliability. In the last module, we discussed about lectures where we compare risk, failure, safety, reliability index. We talked about uncertainties; we talked about how to probabilistically model them. We also spoke about plausible reasoning, we spoke about error estimation, we understood clearly from the exercise examples solved in the class in module-1 lectures.

A basic theory about introducing risk and reliability and comparing them in terms of safety, in this particular set of lectures in module 2, we will slightly elaborate the discussion and look more in detail about the reliability theory, structural reliability and couple of example problems in detail talking about their applications in offshore structures.

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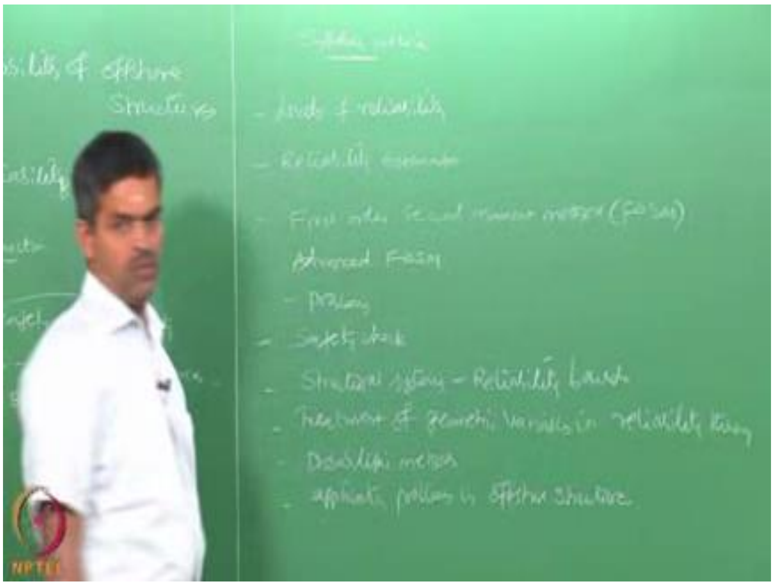

So, let us quickly look at the syllabus outline for module 2. For module 2, we will talk about various levels of reliability, we will talk about reliability estimates then we will focus on first order second moment method, where we so expand this FOSM. We talk about advance FOSM and some problems related to this. Then we will talk about course of practise of safety check. We will also talk about reliability bounds of structural systems. We will discuss how to treat the geometric variables in reliability theory. We will talk about probabilistic methods of code calibrations. We will talk about application problems in offshore structures in this module.

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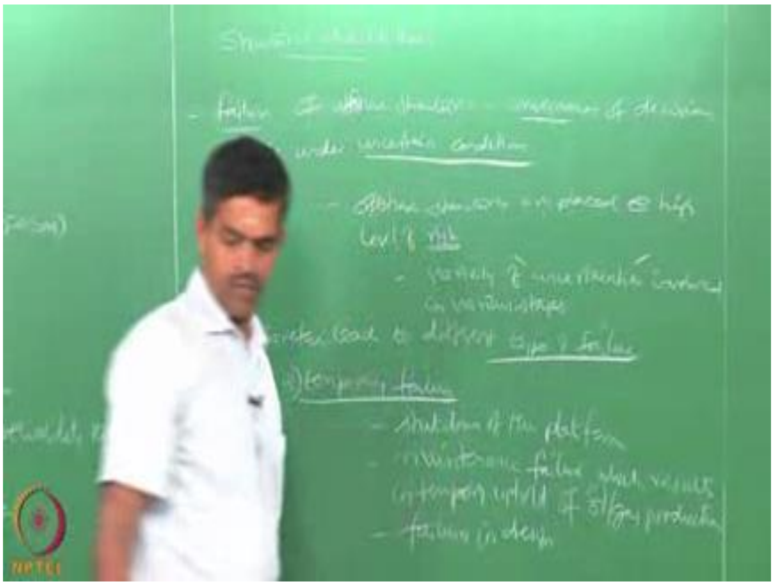

To start with, let us try to define and revisit the reliability theory as applicable to offshore structures now. Let say structural reliability theory, friends as we understand from the last set of lectures in module 1, failure of offshore structures is actually a consequence of decisions made under certain uncertain conditions. So, failure, I am underlining the keyword as we keep on realising the importance of their applications in reliability analysis, failure of offshore structures are actually consequences of decisions made under uncertain conditions, I should put like this. So, we understand a very important subset of statement from this main statement that offshore structures are placed at high level of risk.

The main fundamental reason why we make this statement is that because of a variety of uncertainties involved in various stages as we saw them from the lectures in first module. Therefore, under certain conditions which are not known to us clearly, what we say as uncertain; we make certain decisions and these decisions can lead to series of consequences which can result in failure of offshore structures. The moment i say the failure in fact I am compromising on safety. On the other hand, I am challenging the risk level of offshore structure.

Therefore, it is very important that the decisions made under uncertain conditions lead to different type of failure. So, this therefore leads to different types of failure. The moment I say different types of failure let us try to elaborate this. One we can call as temporary failure, where we say it can result in shutdown of a platform. It can also cause some maintenance failure, which is also of course temporary which result in temporary uphold of gas production. It can also be resulting from failures in design.

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What would be the consequence when you talk about failure and design? So, the specific consequence arising from failure in design will result in reduction in payload. It will cause insufficient operational conditions so all these temporary failure need to be addressed in the preliminary stage itself, so all these need to be addressed the moment I say it is a failure it means they are at risk. Therefore, in all such cases if you look at them in detail whether it is a shutdown of the platform, whether it is maintenance failure resulting in temporary uphold of production, whether it is a functional failure arising from a wrong design, whether it is reduction in payload capacity of the platform topside because of wrong design or wrong preliminary analysis etcetera, in all these cases it is very important to note to understand definition of failure.

So, where to define the failure the moment I said defines the failure we must define this in probabilistic terms. Why, because failure with uncertainties cannot be describe in deterministic terms, we already said that in first module lectures these uncertainties, which are inherently present in offshore structural design and analysis, construction, planning, execution etcetera or in functional problems like production, explanation etcetera all these can be handle comfortably with probabilistic tools and plausible reasoning. Therefore, definition of failure will also come through probabilistic tools or in probabilistic terms.

So, therefore, we already said that let us reiterate this statement so failure of a platform is inability to perform, so I should say failure is inability to perform the intended function adequately on demand when it is require to perform, it should perform. For a period of time, because the period of time is very important it cannot remain adequately performing for infinite period of time, so for a period of time under certain specify conditions that is very, very important.

There are many classical points when you define failure; these are the classical points which are important when you define reliability also. So, what are those points period of time, so reliability is applicable only for a period of time window, under certain specified conditions? So, you have to pre-specify the conditions under which the performance of the system is not satisfactory when it is intended to perform on demand. So, failure actually it is not a catastrophic or structural failure, or usability or destruction etcetera. It is actually inability to perform the function, it is not a failure of a structure cause, let say it is completely collapsed.

So, we are not talking here about the collapse scenario of the platform a structures at all; we are only talking about the inability to perform the intended function, I am not talking about the structural failure or collapse of the system at all. I am talking about a functional inadequacy the structure is not able to perform the intended function, when it is demanded to perform under certain specific conditions over specific period of time only, so reliability analysis is very important and therefore, it is also applicable and constrain within a specific time window. So, now the converse of this, now this is about the failure converse of probability of failure is nothing but the reliability I can undoubtedly write reliability is 1 minus probability of failure.

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Therefore, reliability is defined in terms of success of a system. So, let us define reliability then therefore reliability of a system of a structural system is a probability of the system performing it is required function adequately for a specified period under certain stated conditions. So, one can clearly say reliability is an assessment tool, it is used to check whether the system is performing its function or not. So, it is a checking process. Therefore, probability of failure, which is going to give me the converse meaning of reliability or on the other hand reliability is the converse of probability of failure is always defined in terms of success of a system. So, when you deal with design, uncertainties are unavoidable as you understand from the previous lecture of first module.

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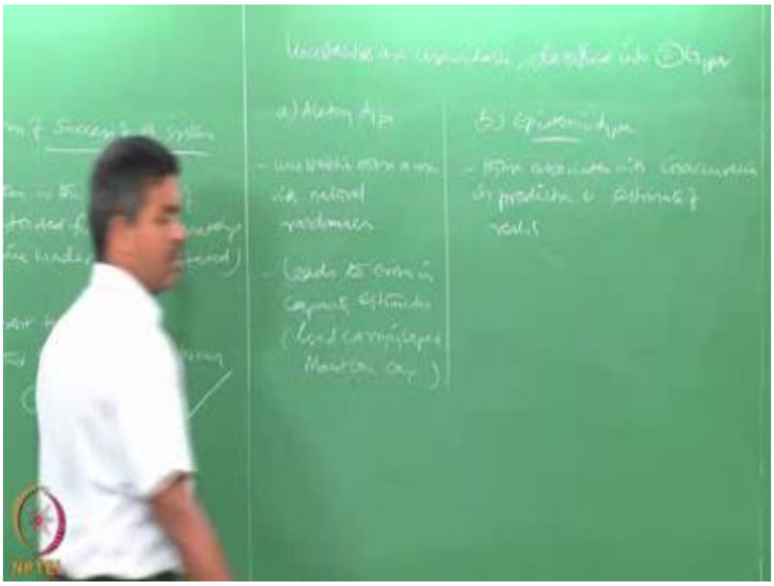

Now when we are insist that uncertainties are unavoidable, then how can we say with guarantee that reliability is going to assess the safety of the system. So, you understand, now I am trying to link reliability to the safety or guarantee that the system will perform its function. So, when there are uncertainties present which are unavoidable in the design then how one can guarantee the safe functionality of the system because you really do not know under what conditions there can be design failure?

So, uncertainties which are unavoidable are classified into two types. One is what is called the aletary type; the other is called epistemic type. Aletary type are those associated with the natural randomness; uncertainties those arise with natural randomness or classified as aletary type. Uncertainties those associated with inaccuracies in prediction and estimate of reality are called epistemic type. Essentially, aletary type leads to capacity estimates leads to errors in capacity estimates for example, load carrying capacity, moment carrying capacity etcetera. Interestingly, one can see from this classification of uncertainties, it is associated more with the randomness and it is central to the design and randomness.

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So, uncertainties are central with respect to design and randomness. Therefore, one to make the decision, one has to decide which is either of two is limited and incomplete amongst the above two because these are seems to be the centre of uncertainties, one is on the design one is the randomness that is what you see there.

Therefore, reliability estimates are assessment of safety functionality of a given system needs to be supplemented by traditional deterministic methods. So, reliability study or reliability theory is always supplemented with classical deterministic methods of analysis because we are talking about design, which uses statistics and probability theory. In addition, it also requires human intervention in terms of decision making during planning, design, material choice or material selection, construction phases etcetera.

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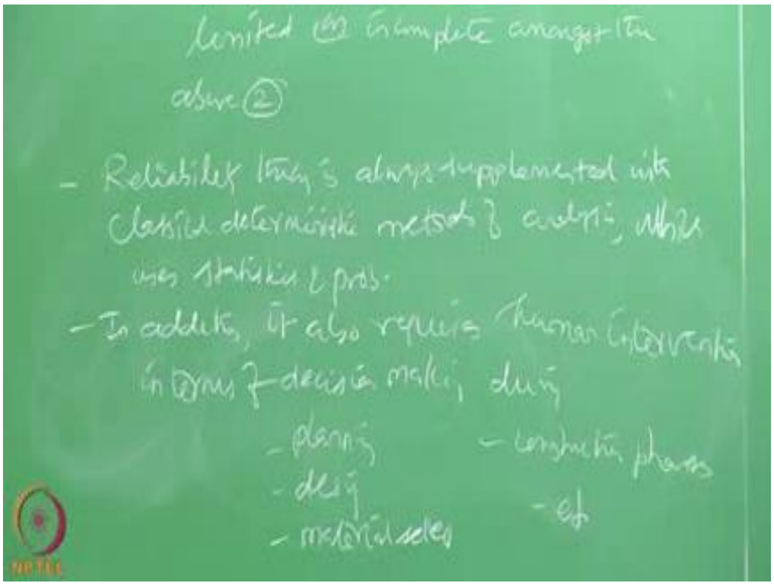

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It requires engineering judgements which essentially arise from practical experience. So, now in offshore structures let say what are vital. The vital parts are deterministic, classical tools of analysis; theories associated with handling of randomness; obviously, those theories of statistics and probability; engineering judgement, which come from practical experience which is a part of plausible reasoning which you have studied as an introduction in the lectures in last module.

So, the design of offshore structures is circumscribed with these vital parameters where reliability assessment becomes a checking process not as a design tool, checking process in the given circle. So, let us talk about uncertainties which you have already discussed in the last module, but we will expand our discussion slightly to a particular case of application.

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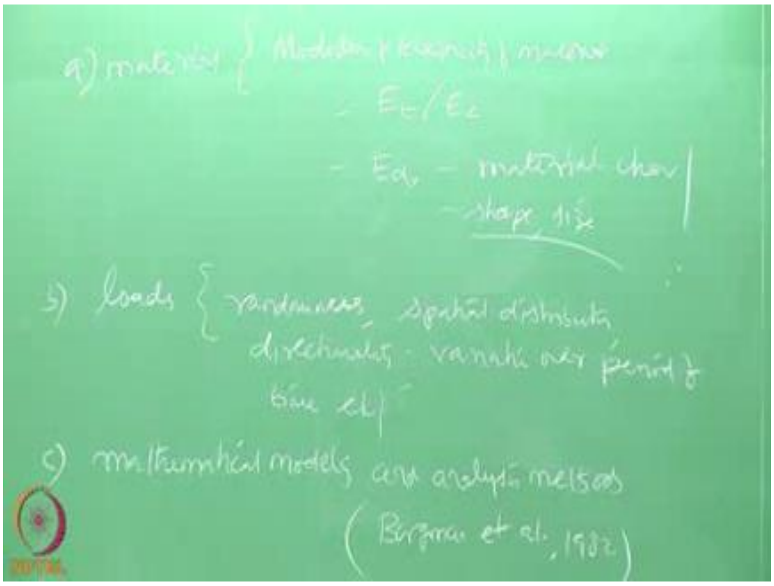

Let us say uncertainties assumes to be important, because that is how the associated which actually creates here known guarantee condition in operation status or functional status of a given offshore structure system. For example to be hypothetical, if all are known with certain order of degree and accuracy, reliability estimates are not require at all, because reliability is converse or failure and when you do the design, analysis, planning, construction everything with high degree of certainty the system is not going to fail at all in its function. I am not talking about structural failure at all, in its functional failure because failure in this case is defined very carefully as fail to perform intended function adequately on demand over a period of time under certain specific conditions only.

So, when we do handle everything with certainty then we need not have to bother about reliability at all, because it is not going to fail at all. Since, uncertainties are inherently present in offshore structural design scheme; we have to talk about reliability. Let us take a one example of material let us say uncertainties are inherently present let us say material. One can ask me a question how uncertainty can arise from material. You can have problems with modules of elasticity of material to be very specific; one can look at E value in tension and E value in compression, one can look at young's modulus in dynamic state there is a dynamic modulus of elasticity which depends on not only the material characteristic, but also the shape size and grain distribution and other properties of the material. So it is very intrinsic.

So, the first classification can come from or the first set of problems of uncertainties can arise from material. The second set of properties can arise from loads. For example, randomness, spatial distribution of loads, directionality variation over period of time etcetera. We also have another problem; problems are uncertainties can also arise from mathematical modelling. And analysis methods used as pointed out by Borgarnan 1982.

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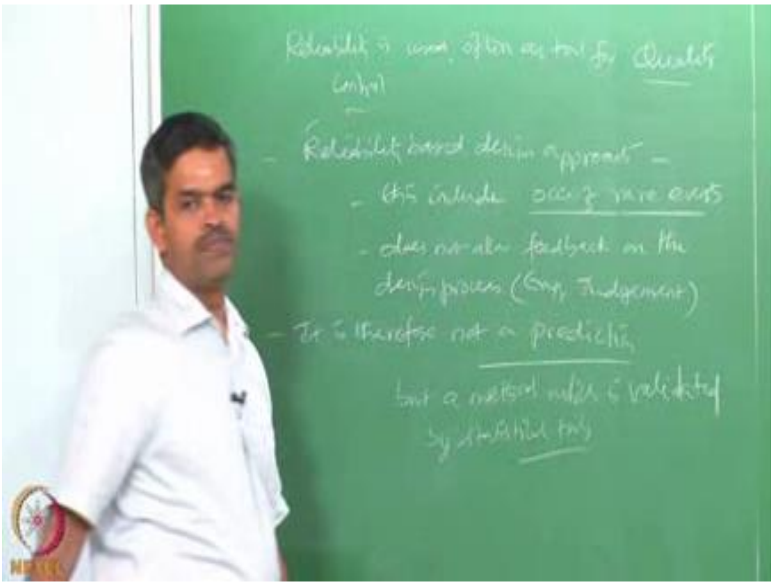

Therefore, if you look at reliability as a check or assessment tool in broad sense reliability is used often as a tool for quality control. Why I am saying quality control because this is related to decreasing the degree of uncertainty influence on the design and randomness which may come from material choice, selection, type, grade, loads and mathematical modelling and statistical methods of analysis which has been used in the whole theory of formulating the problem.

So, reliability is actually referred as a tool for quality control. If you look at reliability based approach design, reliability based design approach, if you look at this as a window, because this seems to be more genuine what is it mean this involves this should include occurrence of rare events and does not allow feedback on the design process, which is based on engineering judgement. Because the moment you allow this feedback based on engineering judgement, this will again amount back to uncertainty.

So, reliability based approach design will have to include the occurrence of rare events which otherwise in principle may not agree as a design. It is therefore, not a prediction, but a method, which is validated by statistical tools. So, we are not predicting anything we are not foreseeing any failure, please understand that. Many of the people in the design department do really feel that reliability index is actually a forethought of failure prevention, no, no it is not actually a failure prevention forethought at all, it is not predicting anything it is does not predict anything at all.

Of course, it includes the occurrence of rare events, but does not mean that rare events what has been included is end of the day. There may be other events, which you are over looked which you are not happened at all in the scenario which could occur in the platform in the service life which may again challenge the safety of the platform. Therefore, please understand reliability tools do not predict the service level structure at all they only estimate the safety of functional importance of the system under the given service conditions for a specific period of time under specified conditions.

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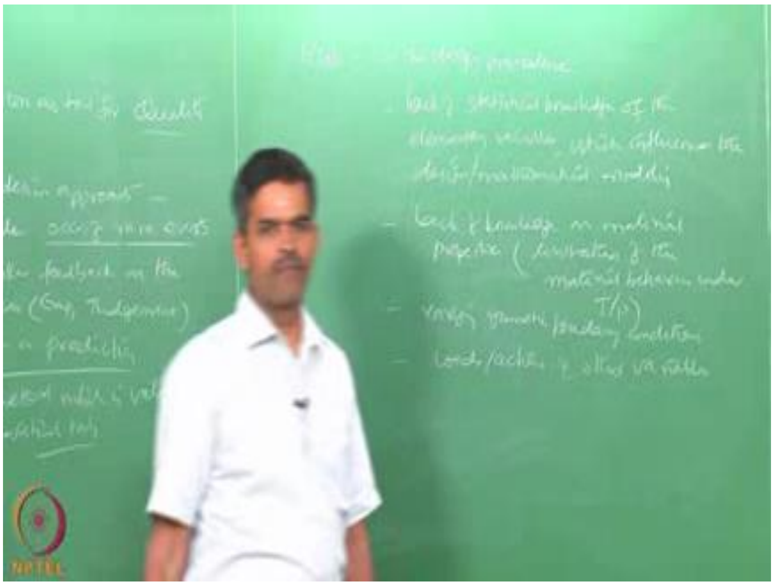

Now, let us talk about on the contrary what is risk based design approach. There is always risk in the design procedure. Risks in the design procedure arise essentially from the lack of statistical knowledge of the elementary variables, which influence the design and mathematical modelling. It also arise from lack of knowledge on material properties for example, let say the limitations of the material behaviour under various temperature and pressure, it also depends on varying geometric boundary conditions, it also varies on loads or actions and other variables.

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Therefore, a combination of elementary variables as listed here results in a complex model, but the model is deterministic though the variables are probabilistic that is a very interesting statement circumscribing the reliability theory.

In addition to this, we have one more issue, which also bothers and results in risk in the design. Mechanical behaviour of structures as a whole, in general cannot be studied, cannot be study using statistics of failure. You cannot say have I visited 100 structures out of which 30 structures fail, I have got statistics at every the mean of failure of this system is about so and so I cannot use that theory for actually as a saying, the mechanical behaviour of structures at all. Failure therefore, is actually a combination is actually a simple combination of complex components; it is not your complex combination of simple components.

So, what is it mean, since the components are complex reliability done at the component level is far better than that of reliability done at these structure or system level because the complexities essentially arise from the component level, and they get simply combined to form confusion or failure. So, therefore, system reliability and component reliability are to be equally looked at, so that a simple combination of complexities arising from the components can lead to a failure which can be assessed as a part of system reliability.

In the next lecture, we will again extend this understanding by identifying the players or the components or the factors involved in structural reliability theory, how each one of them can be looked into in more detail the manner we will see them in the consecutive lectures in module 2. We are just focusing on structural reliability theory as a whole.

Thank you.