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

Hello friends, I hope you must have seen the introductory video on the online course title Risk and Reliability of Offshore Structures. I am Prof. Srinivasan Chandrashekaran from ocean engineering department, IIT Madras, who will be coordinating this course for you in NPTEL in online series. The course as discussed in the NPTEL site will be discussed and deliver in three different modules; module one will focus on the classes related to probability, possibility theories, uncertainties and error estimations. This is the first lecture in module one; in this lecture, we will talk about introduction.

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So, we are talking about risk and reliability. Now, the interesting part is the application of this will be purely advocated to offshore structures. So, we will talk about the module one now in this lecture I will give you an introduction to the course and I will also take forwards some of the lectures in first module.

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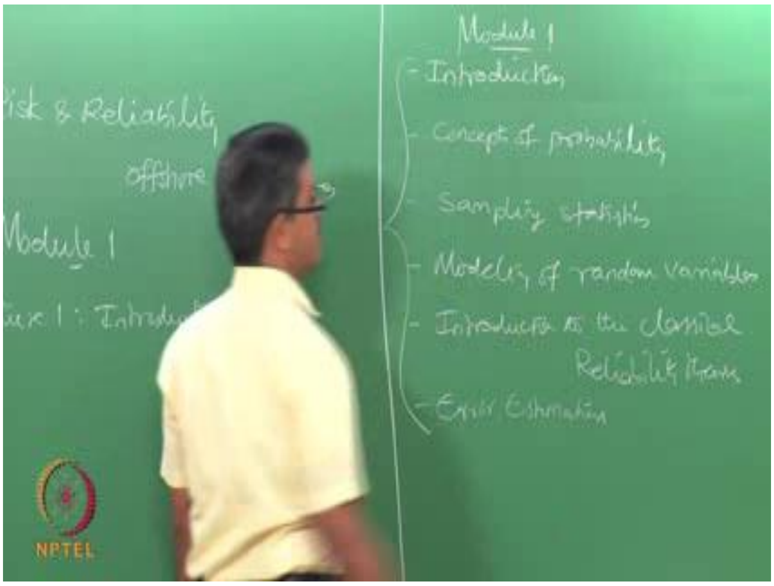

In this lecture, we are going to talk about details of different uncertainties; however, this module will include different outlines on reliability and risk estimates as related to will talk about introduction. We will speak about concepts of probability; we will also talk something on sampling statistics. We are going to discuss about modelling of random variables. We will also talk about the classical reliability theories; we will introduce you about the classical reliability theories. We will also discuss about error estimations. This will be the content what I will be discussing in the first module.

Today, we will start in the introduction to the first module, and some important topics related to uncertainties. Regarding the detail list of textbooks, which are required for this course, please refer to NPTEL website we have given detail list of textbooks and reference books. We have also listed very important journal papers and conference proceedings papers, which may be useful for you throughout the length of this course. So, kindly use them as an additional and parallel support material along with the lectures notes what will be following in the black board and through power point presentation in all the lectures.

This course will approximately have about 40 lectures; we will also give you tutorials at end of each module along with the solutions, which we discussed in the blackboard. At the end of the course, you can also take up an exam which is online certification exam offering a degree or offering a certificate by NPTEL, IIT Madras, if you qualify the examination with qualifying marks as mentioned in the website. So, if you do not have any clarification and doubts, I will proceed with lecture, in case if you want to contact me or you want to write to me please write through the web portal of NPTEL of this specific course after your registration is finally approved by the NPTEL board. So, we will talk about introduction to reliability, explaining why reliability is a very important tool in analysing offshore structures.

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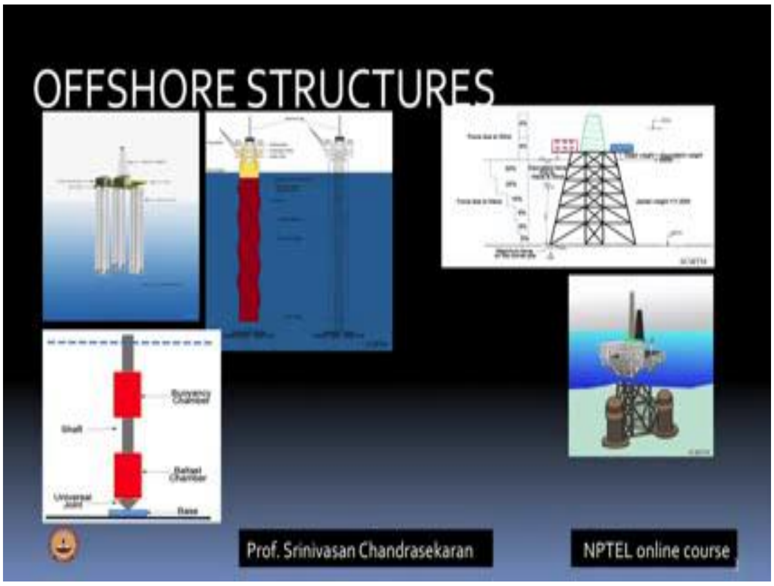

Please looked at the slide projected on your screen now; offshore structures actually have varieties of complexities. The one what you see is combination of different kinds of platforms which has been pictorially shown in the screen now. You can see one of them is resting on trust legs, which we call as jack of rigs. The one, which you see in the middle, is a spar platform; the one, which you see on the right top, is a typical jacket structure, which shows different kinds of loads that are acting on this kind of structure. The one what you see in the right bottom is again a typical sketch of an offshore platform the one what you see on the left is an articulated towers with the buoyancy chamber and the ballast chamber indicated in red in colour.

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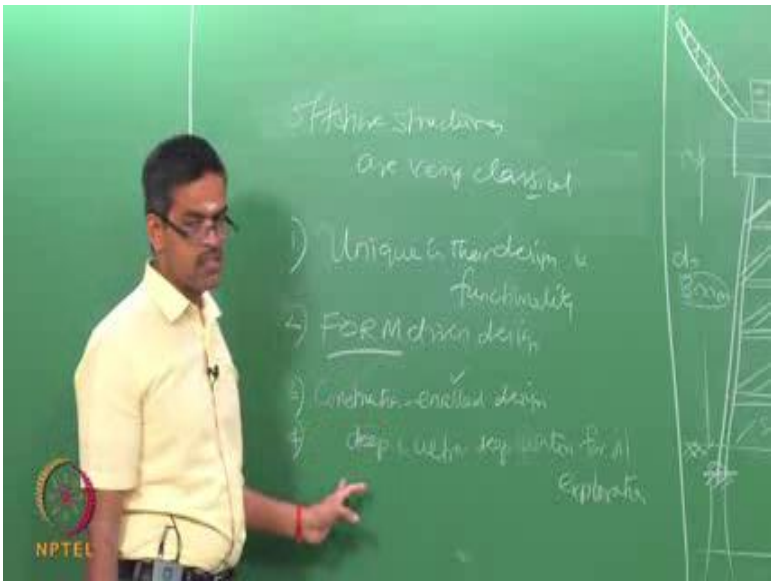

These pictures will give you an idea that offshore structures are very classical in nature. Now, what are the specialities of these kinds of structures? There are many reasons why offshore structures are called a special class of structures. One, they are unique in the design and functionality, because you know offshore structures are actually designed according to the functional requirements.

There are exploratory platforms, there are drilling and production platforms, there are platforms are processing in storage what we call as FPSO, FSRUS drilling rigs, drill ships, tension leg platforms, spar etcetera. However, this course does not give you an overview of different structural systems used for variety of functions in offshore field. You can look into the good references listed in the NPTEL website of this course to get more parallel idea about different structures, which are used in offshore engineering.

So, let us come back to the point. Offshore structures are unique in the design. There is no two similar structures, which are used for a same function because of very specific reason all offshore structures are unique because they are all sight specific characterization, which makes them unique. So, they are unique in the design and of course, as I said they are uniqueness in their functionality as well. Most importantly, they are form driven design. What do you understand by a form driven design. The geometric form of the system commands the design, for example, I will quickly draw a line diagram of the jacket structure and a tension leg platform both are typical offshore structures.

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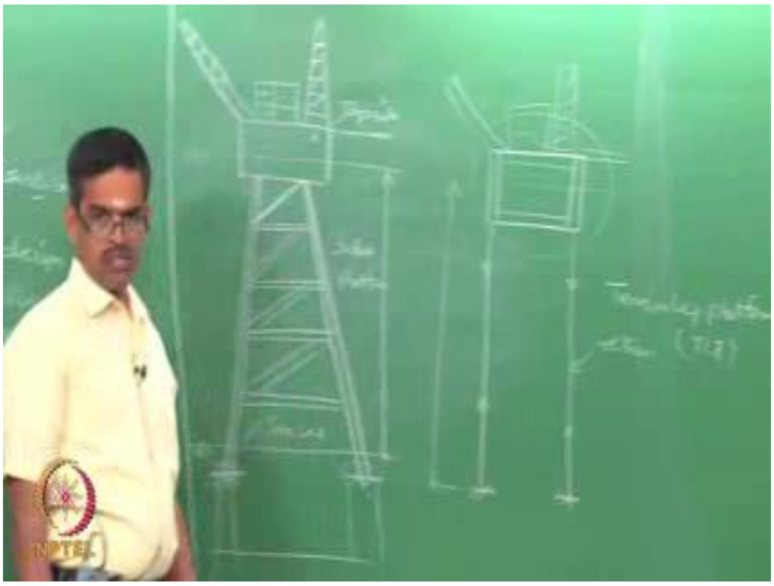

Let us say this is my top side, which may have your drilling brick which may also have a crane boom which may have some living quarters which may have a helipad as well which will be supported on a template system which is actually the jacket legs which will be founded using pile foundation into the seabed. This is my seabed. To strengthen these legs because of the water depth being very large, we also insert bracings, and we call this assembly as typical jacket structures. So, we call this as a jacket platform. On the contrary, for example, there is a water line here this is my mean sea level, I call this as my top side and so on.

On the contrary, if you talk about platform which is also used for deep water exploration and production, we have a typical platform called tension leg platform which has vertical columns and horizontal members, which are pontoons which are actually supported to a sea bed only by tethers, what we call as tenders or simply axially stressed cables. Now, look at the geometric the topside of course, going to be common as similar to this; the functionality is more or less similar because this is also used for oil production and exploration; this is also used for oil production exploration.

Now, there is a limitation in water depth for this kind of platform because for the entire water depth the whole structure system needs remain in packed; whereas, in this case the water depth can be much pretty higher because only cables are extended to hold the system down to the seabed. If the cables are disconnected from the seabed, for example, the whole system remains a float that is why we call this as a complaint system. So, offshore structures are form driven design; no specific geometry will have commonness for their functionality or to resist their external loads.

So, therefore, in this example, as we just now discussed tension leg platforms what you see on the right here are structurally or geometrically different from that of a jacket platform, of course, both platforms may have similar functional requirements. Therefore, offshore structural design is unique because it is formed driven; it is not function driven therefore, one cannot compare the response behaviour of one platform of different structural form with that of another platform whose structural form is entirely different in its behaviour in its material usage etcetera.

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The next issue is very interesting construction enabled design, what do you understand by construction enabled design. For example, let us talk the same case of a jacket platform or your tension leg platform. Let say jacket platforms have been identified in the literature to be useful up to a maximum water depth of about 300 meters. So, if I am want to go for a water depth of about 300 meters, which is indicated as small d in the literature because capital D will indicate the diameter of the members.

Naturally I cannot have a single material or a single member of this length because transporting this, fabricating, erecting and commissioning becomes a very tedious job because I am talking about all this issue insist in a sea which is 300 deep. So, they will be constructed in modules. Therefore, one as to decide what is our crane capacity, what is a barge holding capacity in terms of size of the member, what is a crew capacity which is going to install the member in position which will decide whether the construction enabled design is feasible. This also makes offshore structures something unique. More interestingly gentlemen, offshore structures are now focusing towards deep and ultra deep waters for oil exploration.

As we all understand the oil reserve in shallow waters is almost exploited. So, people are looking for deep and ultra deep waters, the moment I say deep and ultra deep just to give you a clue I am talking about the water depth in terms of 1000 meters, 2000 meters and so high. So, obviously, your structural form which can suffice 300 meter depth cannot be used as it is for 2500 meter depth a structural engineer as an engineering mechanics graduate you all agree with my statement. There needs to be some major modification of the design or the structural geometry, which can enable the construction feasibility and of course, the survivability of the platform as the platform installation goes deeper and deeper. Therefore, any new offshore structure design today or will be design tomorrow or in the near future will also remain as a unique challenge because the oil exploration is driven towards deep an ultra deep waters.

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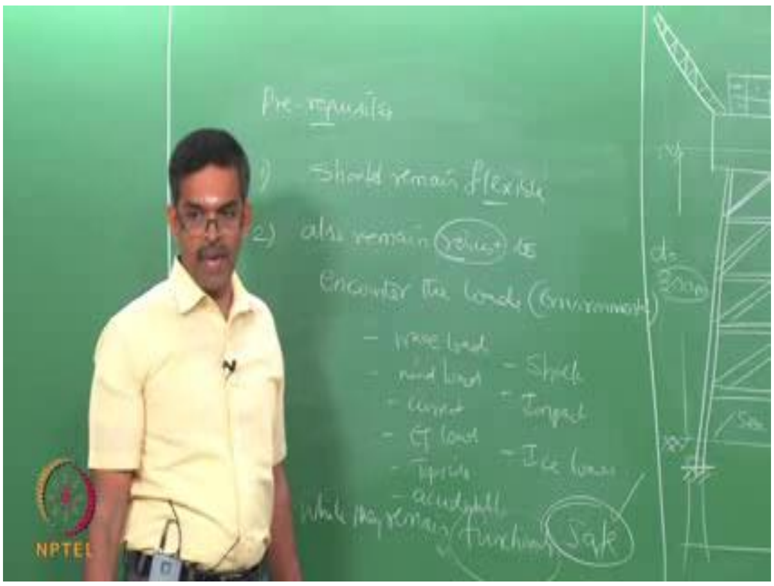

Having said this let us discuss some classical problems or some special features which makes offshore structures much more interesting. There are some prerequisites to make the offshore structures safe while they remain functional. The most important is it is expected that the option should remain flexible because any rigid system is always tend to attract more forces. The attraction of more environmental forces coming on the system will improve the stress on the members which results in failure of the members, where the reliability of the existence of the platform functionality can be question. On the other hand, if the structure remains flexible the structure adapts to the environmental loads, which makes the system more interesting, therefore I need a flexible system.

At the same time, we should also remind robust. To encounter the loads, I will also say very clearly environmental loads; there are varieties of environmental loads which act on the structure or after the structures. I can give a classical examples in detail later, but for your understanding essentially in predominantly wave loads, wind loads, current loads, the earthquake loads, topside loads, accidental loads, shock loads, impact loads, ice loads, we can keep on adding the list. The structure should remain robust to encounter these loads while they remain functionally safe that is very, very important. Safety is a foremost issue here. So, functional safety becomes a key factor in offshore structural design. However, a geometric forms chosen for any specific water depth. However, system remains flexible and robust to encounter the loads.

If a structural system does not remain safe when it is performing its intended function for example, you may ask me a question, what is so called intended function, the structure should perform. The intended function the offshore structure should perform basically is the either oil exploration and production or storage and reproduction etcetera. So, while making these functional issues important, the structure should remain same. So, safety in terms of functional existence is a key factor in offshore structural design which may not be true in almost all other classical design of structures. Therefore, offshore structures make or made unique in nature. Let us look into other complexities, which make the whole analysis or the safety getting challenged.

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Let us say other issues. There are other issues, which can directly challenge the safety of an offshore structure while they are functional. What are these issues? One, many new and innovative material are being used, for example, aluminium, titanium and their alloys etcetera have become very commonly getting used in offshore structures. Now, one may ask a question what is very curious about this, this demands detailed understanding of their mechanical properties.

The moment I say detail understanding of their properties as far know we have been studying steel and concrete as a very common construction material for which more or less almost all characterization of material properties are known to us through laboratory experiments, whereas we take up a new composite material which being recommended by a designer for a unique structural form in offshore structures. It becomes mandatory for the engineer and the team to understand the detailed mechanical properties of the material at different temperature at different stress concentration factors at different load combinations etcetera, because the material can fail at critical combination of loads, which becomes very important because safety is a primary concern here when the structure remains in use.

The next issue could be variety of environmental loads. The environmental loads when they get combined gets more complex, and all of them lead to, what all of them lead to one - the uniqueness of the design, two - the material advancements, three - the environmental loads and their complexities will lead to varieties of uncertainties. In physical terms, what you mean by uncertainties uncertainty is a variable or a parameter, which is not known to you for sure. You know the value, you can guess the value, but you not know amongst the value from x to y, what would be the value of the variable may be the material property, maybe the load magnitude, may be the strength in a member etcetera. Under given point of time, under the given combination of load, at a given age of the structure, you do not know. A very large bracket of this value, but within this range what is that value exactly the material or the member is assuming at that age at that period is not known to you this what we call physically as uncertainties.

Interestingly, ladies and gentlemen, if you do not know very clearly - what is the value of the material property or the load magnitude at any specific location, time and age etcetera it will be very difficult for you to ensure safety of the member and the material under the given combination of forces. If you are not able to ensure the safety of the material or the member of the structure, the structure cannot be called a reliable one. So, reliability of offshore structures is circumscribed importantly around a major factor called uncertainty. As a good mathematician, you would have guessed by this time wherever we have uncertainties in mathematics and engineering we always use probabilistic tools and statistical methods.

You may ask me the interesting question under the given mathematical accuracy of numeric modelling, analytical studies, various wave theories, various engineering mechanics solution available, why still at this age of engineering we say we are not understanding very clearly with certainty about the properties.

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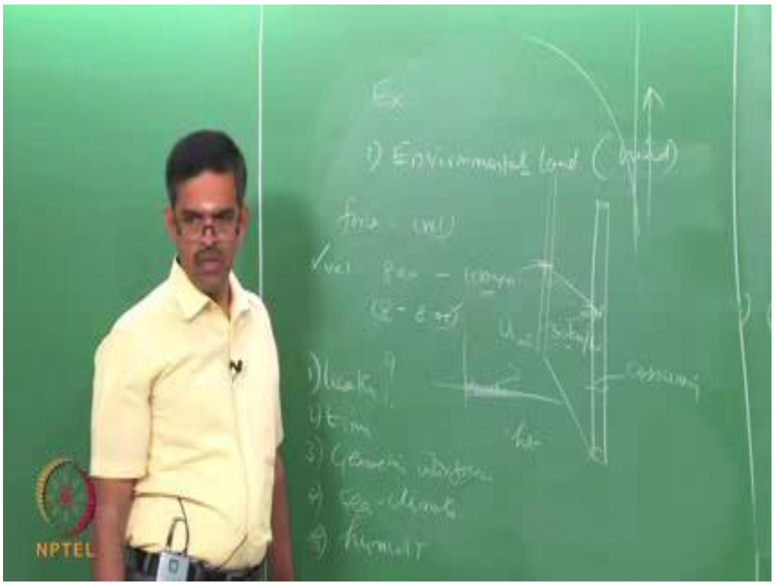

I will come to an example. Let us take an example of an environmental load say for example, wind. I will give you a very quick illustration of this. Let us say I want to estimate the wind force on a given offshore member to design the member. We all know when the force is known to me a given member when the thermal stress of the material are known to me I can always find the cross section properties of the member what we exactly call as a design. We assemble this member, we call this structural geometry; we fabricate the member, we make a platform and commission the platform for oil and gas production and exploration. I want to know the wind force on a specific member.

Let us take a member of a specific diameter, which we are assuming, we all know if you do not know the diameter you cannot find the force. If you have a doubt, let me explain this, wind force is actually a generation from the pressure which is proportional to the projected area. The projected area is of course, the functional of the diameter if it is a circle a member. So, you have to assume the diameter of member. When you assume the diameter the member based upon the engineering expertise, experience etcetera, you want to compute the force, now you are trying to find out the force which is dependent on velocity; and velocity depends on various parameter like surface terrain, height, time etcetera.

Let us say I take the velocity of wind are everyday 8 am for 100 years, everyday 8 am 100 years, I measure the wind velocity for 5 minutes. Let us say 8 to 8 o 5, I measure. I get a history; it is not of course, going to be constant, history. I get a mean, let us say the mean wind velocity mean wind velocity remain at 30 kilo meter per hour that is. Now this data is suitable and valid for a specific location, for a specific time, for a specific geometric interference, for a specific sea climate, for a specific humidity, for a specific height, because this depends upon height. We all know wind velocity keeps on varying as you keep on measure it higher and higher.

If you really wanted to measure this in a two-dimensional array, you can always measure another member and try to find the interference of this spacing of the member all the velocity of the member are this point as well as this point what we call cross correlation coefficient. Now if the data is taken at 8 o clock; obviously, if you take one more data 9, 10 and see you will find that the mean wind velocity or the speed keeps on varying considering all these factors. So, even for one specific load for a one specific moment has got so many variables which lead to uncertainty in estimating with the great degree of accuracy, the wind load on a given member.

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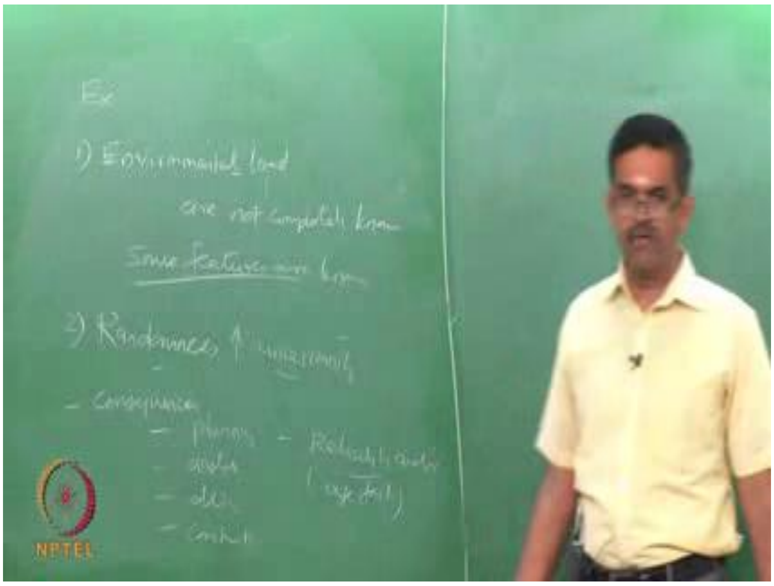

Therefore, we can confidently say environmental loads are not completely known only some features are let me put it like this. The second issue is the randomness. The randomness in the environmental loads increases the uncertainty, and this lead to the consequences in many facets of offshore structural design; one is during the plan, during the analysis, during the design, during the construction, and even during the reliability analysis, which includes the age factor. So, all these at all these stages we need to understand two issues that is during planning, analysis, design, construction, erection and commissioning, aging factors etcetera, I need to know two important things.

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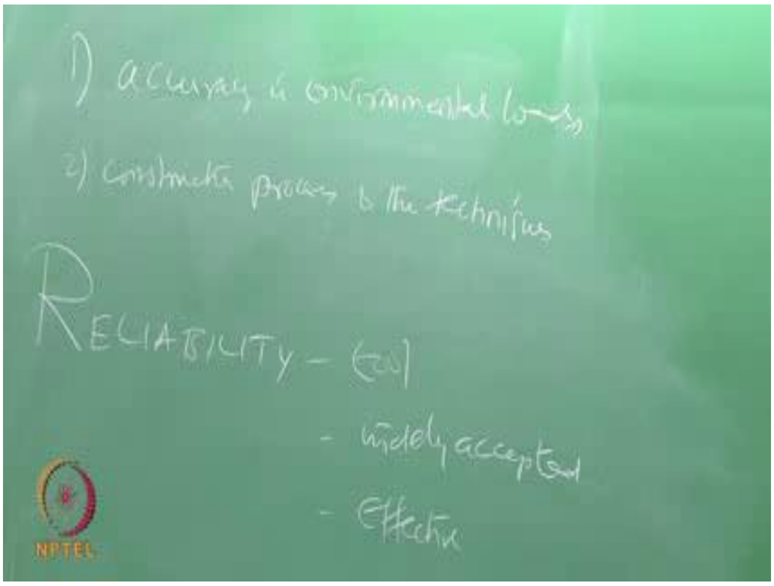

One, I must know how to accurately estimate that is accuracy in environmental loads is one issue which I am bothered. Secondly, the construction processes itself and the techniques. One can ask me a question interestingly, if one single variety of loads has so many complexities and uncertainties is anyway by which this can be handle in engineering manner in the offshore structural domain. The answer is yes. Reliability is a very interesting tool, which is widely accepted to handle such uncertainties very effectively. Many researchers are certified this by applying this to various problems of different complexities.

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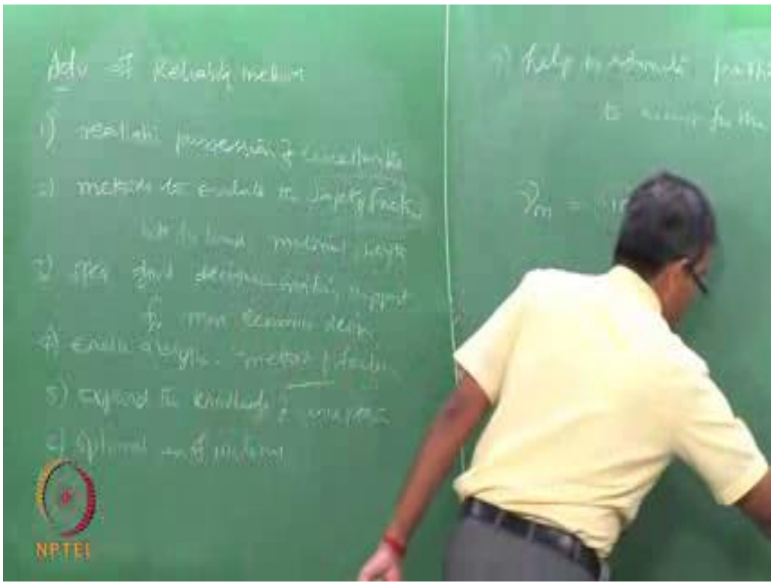

Let us now understand what are the advantages of reliability methods; advantages of reliability methods. One, they offer realistic procession of uncertainties; they offer methods to evaluate the safety factors both for loads and material strength. You must have studied limit state design you must have studied partial safety factors gamma m for the material and gamma f for the loads, all these partial safety factors are actually evaluated based upon reliability methods. They offer very good decision-making process or decision-making support for more economic design. They also enable analysis using different methods of failure that is very important part in reliability analysis. Can assume a failure state and check whether the member is crossing the failure state or within the limit state safety.

So, we can analysis the system for different methods of failure. You can also expand the knowledge of uncertainty because earlier you do not know what uncertainty is. As you keep on knowing it more and more can always expand your domain of knowledge in uncertainty; the moment you expand the knowledge many uncertain parameters in your analyse and design will appear to become slowly certain. They enable optimal use of material.

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Interestingly, they also help you to estimate partial safety factors to account for the uncertainties. Now one may ask me a question what is speciality about this. Interestingly, let us say you have a partial safety factor gamma m as 1.15. Now, the number 1.15 is derived based on the material properties of either concrete or steel or composite or an alloy by testing various cross sections under various conditions and estimating the mechanical characteristics, and then finding out the safety factor of material strength.

Now, without knowing the uncertainties in this variation, your partial safety factor is recommend in the codes, which can be used as a tool to account for uncertainties without even knowing the knowledge in detail about these uncertainties. So, reliability can also add as a silent supporting team which can educate the engineering designer to account for an unknown parameter, which he or she has never heard of, but still he or she will land up in a safe design.

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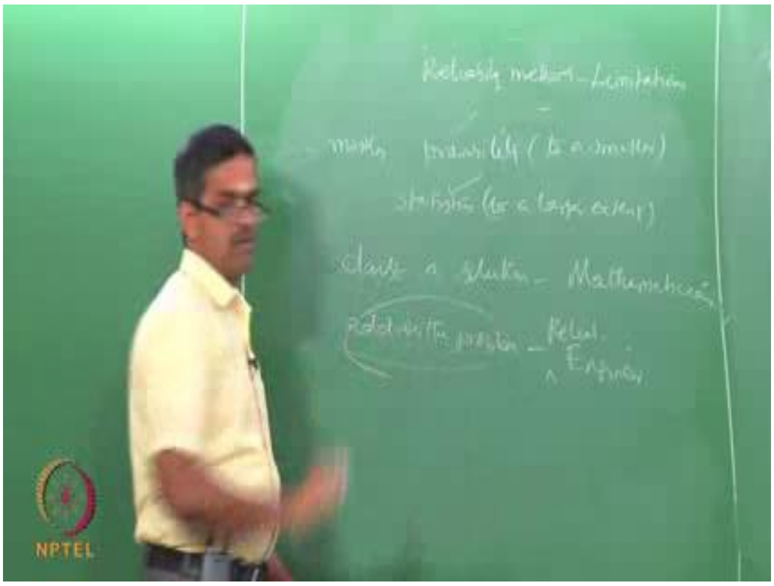

Interestingly, reliability methods have certain limitations. They are mostly belongs to family of probability to a smaller extent and family of statistic to a larger extent. The moment I say this one will be interested to know a stretch of knowledge about this. If you are mathematician, who is a very good knowledgeable person in probability and statistics, you can always doubt a solution based on the knowledge of probability and statistics if you are a mathematician. But if you are in engineer doubting will not help you, you have to address the solution. So, reliability engineer who extends the theory of probability and statistics as a tool for reliability analysis, needs to ultimately land up in an effective solution for the problem which has got lot of uncertainties.

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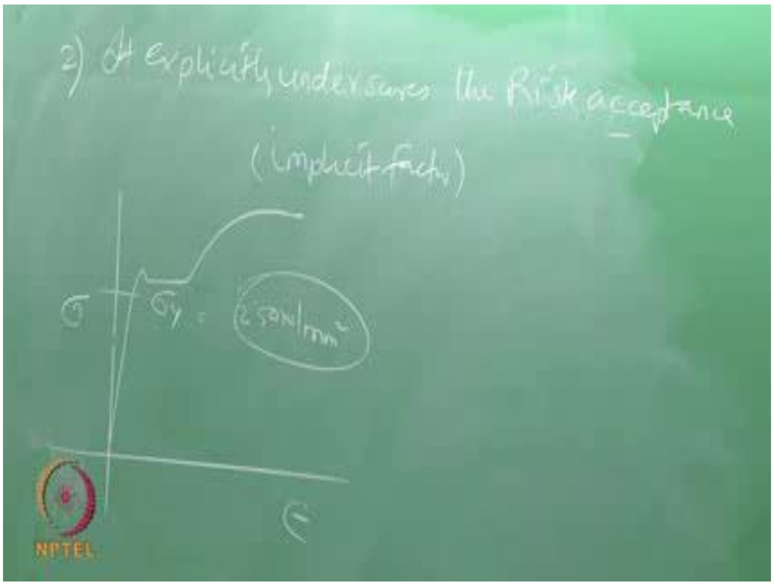

The second limitation could be it explicitly underscores the risk acceptance. Now, I am using a new term what we call as risk acceptance; interestingly, many researches said the risk acceptance criteria eta is an implicit factor. I think you agree what is an implicit factor it's inbuilt actually. Any material strings, if you say take for example, mild steel, plot stress-strain curve of mild steel. And if you try to find out the sigma y value for mild steel and fix up this value as let say 250 Newton per mm square; with some certainty you say that the yield strength of the material used is 250 Newton by mm square.

If the material does not have uniformity in is manufacturing in its grain structure, in its cross sectional thickness etcetera all those are inherently taken care of when you do the testing in the laboratory to get the yield values as 250 Newton per mm square. So, there is a risk acceptance of accepting this number a design value which is implicit, but reliability will show this as an explicit value, so that is a limitation in the study.

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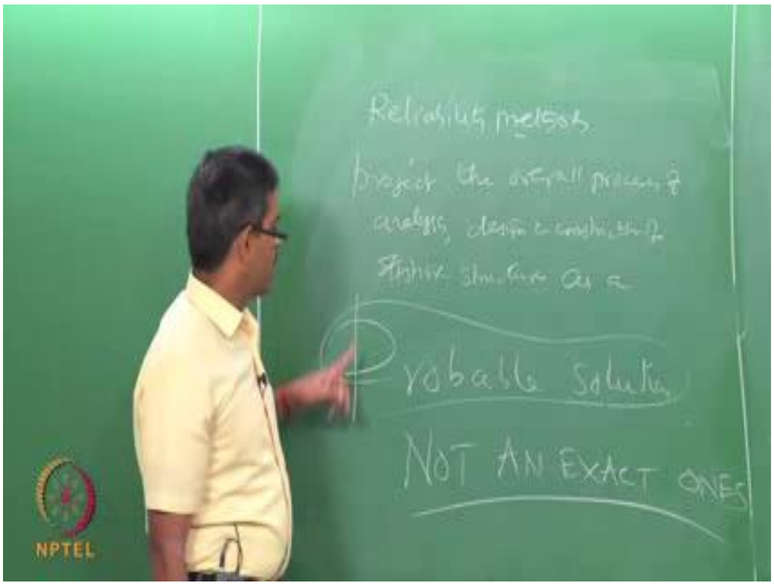

Therefore, in general reliability methods actually projects or project, the overall process of analysis, design and construction of offshore structures as a probable solution, but not an exact solution. So, reliability based design is or will lead to a probable solution of the problem, but if you ask what is the guarantee that the solution arrive as a structural form based on reliability solution is suffice what is the guarantee the guarantee will always remain as a guess because it is having an probability tag to it.

Any probable term is always subjected to its accuracy and tools used for guessing this value. Therefore, to accept this solution, you need engineering decision which based on experience the moment you have a probable solution will always have a doubt is there in alternative for the solution or not. The moment the solution is not unique which has more challenges, which can have suspicious alternatives then you do not rely on the solution, so reliability as this as one of the important and serious limitation.

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Therefore, reliability solutions need to be supported by engineering based experience packed judgements you cannot accept the solution of reliability theories or reliability problems as such you have what apply a tool based on your experience you have to correct the solution and recommend this with of course, a factor what we call a safety factor or reliability index.

So, we stop the lecture here. In this lecture, we made a short summary of different types of offshore platforms. We said why they are unique what is formed driven design, what are the complexities and challenges involved in the construction installation etcetera, what are the innovativeness in the material and why they are required.

Therefore, in the reason advancements how offshore structures can lead to different levels of uncertainties if uncertainties are surely present in a given system how they can be handled we understood something about reliability. The moment we say reliability can handle these uncertainties more effectively then we looked into the advantage of this methods. But of course, we also saw serious limitations of this method which actively tells me the solution given by reliability theory cannot be blindly apply any structural system, but it requires the support you recommendation which is purely driven by engineering based experience packed judgement which ultimately tells me the reliability index of a given system.

Therefore, reliability can be used as an assessment tool, for example, an existing structure need to be accessed in use reliability theory or reliability engineering in assessment tool. So, reliability can also be used as a design tool, what we call probabilistic based design, performance based design can be used in either way the recommendation finally, to be made to the board or to the client depends also on the recommendations made by the engineer judgement by the reliability engineer. So, this makes a clear understanding to you the reliability engineer needs to gain experience in offshore construction, design, planning, analysis, commissioning, erection, decommissioning all facets of engineering problems to really understand or really make you as a successful reliability engineer.

So, in this course, we will talk some of this important tools or software enable with this tool to make you to understand theoretically the reliability at risk assessment applied to offshore structures. However, to make you a really a good risk engineers reliability engineer depends on how do you practice this profession with enthusiasm and sincerity and gain experience so that your decision made on certain issues or basically depend on your practical experience on similar problems.

Thank you very much.