Advanced Marine Structures
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Lecture - 2
Introduction to Reliability II

We are talking about introduction to reliability in the advanced marine structures program in module 3. In the last lecture, we said that, the reliability analysis cannot be 100 percent accurate because of mainly three reasons.

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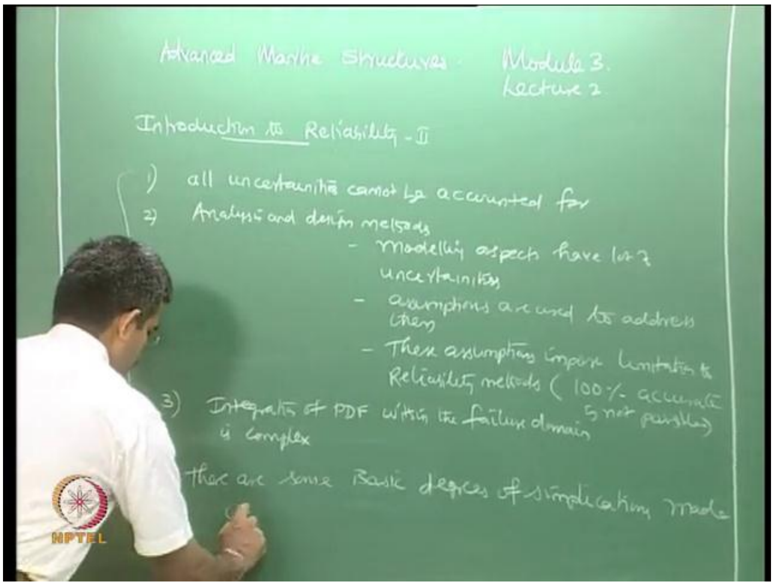

The first reason what we understood was, all uncertainties cannot be accounted for. It is not practical to account for all uncertainties in the analysis and design, associated with the material characteristics as well as the load effects. The second reason why the reliability methods cannot be 100 percent accurate is the analysis and design tools. I can also say, the modeling aspects, because analysis requires modeling have lot of uncertainties. Generally, they are handled by idealizations or structural assumptions to address them and these assumptions impose limitation to reliability methods not making them 100 percent accurate.

The third reason, why we said it cannot be 100 percent accurate is the integration of the probability density function within the failure domain is complex. So, because of these three associated reasons, one can say that the reliability methods cannot be 100 percent accurate. Therefore, there are some basic degrees of simplification made in the reliability analysis. So, one must agree that the reliability analysis or reliability methods of analysis and design is not 100 percent accurate there are some degrees of simplifications made in this.

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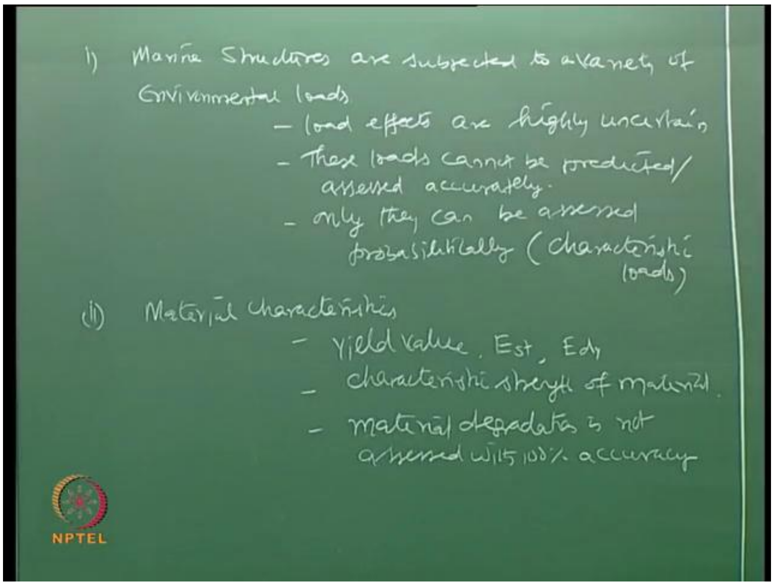

Now, let us ask the next question, which is question number 1 in this lecture is that, why reliability is important for marine structures? Why is it important for marine structures? There are many reasons but we will talk only about the critical reasons. Why they are important? one marine structures are subjected to a variety of environmental loads, the load effects are highly uncertain. We have understood from the first module, that these loads cannot be predicted or assessed accurately, only they can be assessed probabilistically, that is what we call as characteristic loads.

Characteristic load by definition, gives me a meaning that the load associated or assessed by these technique is said that they will not exceed beyond 5 percent of exceedance of the values. What you used for the designed calculation with a 95 percent, they will agree with the values whatever as a there is always a probability of only 5 percent of these floods getting exceeded in the service time. The second reason why reliability studies are important for marine structures, one aspect is about the load effects, the other aspects is material characteristics in terms of the yield value. The Young's modules, I should say Young's modules static, and I will also say Young's modules dynamic.

We will talk about this in this lecture today. You may wonder, sir, are we are using steel as one of the most advantageous and let us say friendly material for marine structures for steel? Generally, yield values or Young's modulus are well defined, why we are using this as one of the importance for using reliability because reliability is a term associated with probability. Then why are we using this? We already understand that, we also use what we call characteristic strength of material. What does it mean, is the material strength will not very beyond 5 percent. In a given sample, ninety 95 percent the strength will agree or the materials, will agree to the estimated value of these.

So, there is a 5 percent probability variation, therefore we say that the material characteristics will of a very thirdly material degradation, that is loss of material strength with respect to age, is not assessed with 100 percent accuracy.

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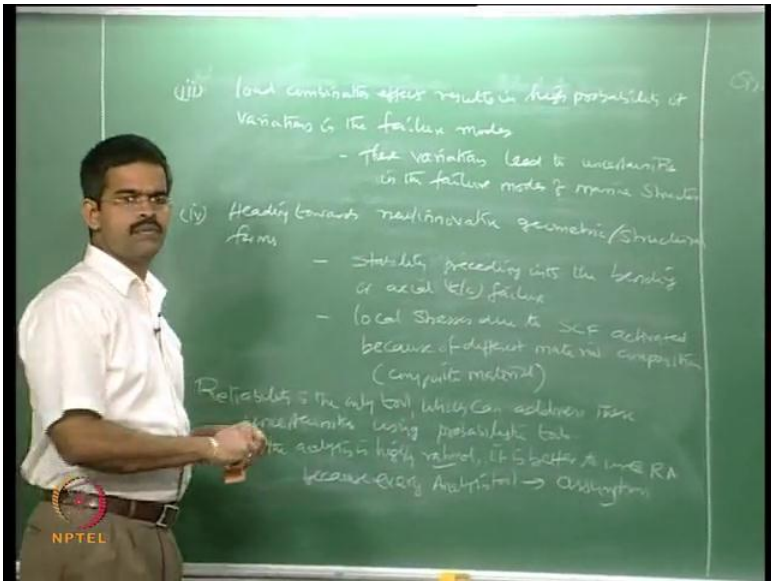

There is a problem, thirdly the load combination effects, results in high probability of variations in the failure modes. We have already seen, this failure modes under axial tension axial compression failure mode, in shear failure mode, in torsion failure modes, in buckling combined with axial load, they are all different here is a high level of variation. So, these variations lead to uncertainties even in the failure modes of marine structures. More interestingly and most importantly marine structures are heading towards new, I should say innovative geometric forms or I should say structural form in such forms. The basic problem is, stability preluding or let say stability presiding with the bending or axial tension or compression failure formation of local stresses due to stress concentration factors activated because of different material compositions.

What I mean to say is, composite material because composites are used now, in a very larger order for new form of marine structures. Now, they should be a mechanism to account for all these uncertainties, all these probabilitic values, probabilistic values in terms of load effect in terms of material strength in terms of new form, geometric form of structure as well as account for different modes or methods of failure. So, reliability is the only tool which can address these uncertainties, using probabilistic tools. Hence, reliability study is very important and very critical for marine structures. Now, more interestingly we can also make another statement, even if the analysis is highly rational you may think it is highly accurate, the analysis what your using is highly accurate or very highly mathematical and rational, even if it is highly rational.

It is better to use reliability analysis because every analysis tool will have assumptions and these assumptions will always lead to uncertainties, and these uncertainties can very well mathematically and effectely handle in reliability methods. Therefore, it is very important that I must use reliability technique for analyzing marine structures, any questions here?

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Question number 2, when we talk about reliability we always talk about the converse of failure. Let us now compare or contrast failure and reliability. Let us compare and contrast failure and reliability. Now, if you look at the definition of failure, it is generally expressed in probabilistic terms. Now, you may ask me a question, why it should be a expressed in probabilistic terms? What is the necessity? Why in a given design, which is being done as an outcome of an effective intelligent efficient analysis. You cannot say the structure is going to fail, for sure the moment you say failure is 100 percent going to happen to the structure either the design is wrong or the analysis methodology is wrong, you can always make a guess.

What is the probability that the structure may fail? So, is failure always expressed only in probabilistic terms now? It is assessed failure, is assessed as inability of the structure to perform its intended function and with adequate capacity for a specified period of time under specified conditions is very, very interesting to understand the key words of this definition. First I am talking about failure, we have already said failure cannot be a expressed in definite terms, because if the failure can be expressed in definite terms, either your design is wrong or the analysis methodology based on which you design the structure is wrong. So, structure cannot be conceder as 100 percent to fail under any given instance.

So, you can always express only this in a probabilistic term, right? So, failure is a method of assessment, it is not analyzing, it is assessing, you are estimating now a structure is designed to perform certain function. The structure is designed the performed certain function, the structure is failed. That is why it is called failure, the structure is fail to perform that function adequately. It is performing, but not a satisfactory limit addictively, and when you say the structure as fail to perform its function adequately only within a specified period under specified conditions.

So, you must specify the condition at which or under, which the structure should perform. You should also specify the period up to which the structure should perform satisfactorily and under the definition of period and condition. If the structure has shown its inability to perform, then we can say the structure has failed probably. So, most importantly failure cannot be assessed on a structural system for an infinite period of time under any guessed condition. So, the period of time is generally, what we call as life time of the structure or service period of the structure or annual period, whatever may be the period of your design, we can call that as a specific period of time.

So, it is very, very clear in the definition itself, that failure cannot be assessed on a system on infinite period of time. It is specifically the period of time, on the other hand when the period of time is exceeded, if the structure has shown its inability to perform its function adequately after the time is exceeded, it is not called as failure. Alternatively it is happening within the period of time, but the specific condition of loads, boundary condition, the sea state, has exceeded here predicted values, even than it is not consider as failure. Now, you have structure, you designed a structure based on critical analysis methodologies, the structure is within a the service life time, may be you are designed it for a 25 years, it is twentieth year running of the structure.

The structure is showing or indicating its inability to perform the function, now the conditions have altered because you have not designed it for a specific wave period or wave height or a specific sea state. Now, the sea state is attacking or encountering the structure, in a specific site. So, the structure has to fail, right? It is shown its inability, but you cannot call that as a failure because it is happening within the period. And, you think it is happening within the specific condition, you think you may not know actually the specific condition is varied. So, then how will you address this failure because you cannot call this is a failure at all by definition.

Therefore, such situations are handled rationally in the discussion by using term reliability. Reliability is the rescue term for failure. Now, interestingly instead of saying you are fail a class of 100, instead of saying 10 percents are fail, there is a positive way of making these statement. The teacher can always say 90 percent of people have passed. So, elimination is always taken on the positive dimension, instead of saying you are fail, people can say you are not passed, meaning is same. Now, definition of failure is given on the contrary, instead of saying failure I will say reliability. The moment I say reliable, it means it is having some belief, some confidence.

Then, the definition should be slightly modified, so definition of reliability is that it should be expressed again in probabilistic terms, because I am connecting failure to reliability. When failure is in probabilistic term, I should always say this in probabilistic terms. So, probability is associated to reliability because of two reasons, first and foremost reason is there are verities of uncertainties which we saw in the last discussion which cannot be handled otherwise rationally except tools of probability. So, probability is one of the important and efficient tool through which reliability studies are conducted or carried out.

Second reason is, failure cannot be given definite terms, failure can be only stated in probabilistic terms, why? If you say the structure is going to definitely fail then people will say either the design is wrong or analysis methodology is wrong or construction techniques are wrong. So, it is an error, it is not a failure, failure is only when the inability of the structure is demonstrated, explicitly it is not able to demonstrate the adequate load carrying capacity within a specific period of time, under specific conditions. Now, I am looking this aspect in a positive dimension because failure is a negative dimension, so that is what reliability is it will be expressed in probabilistic terms.

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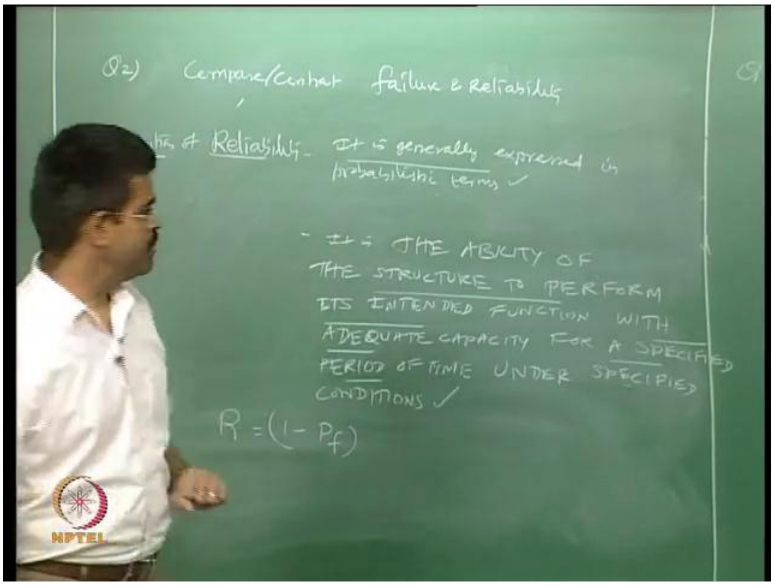

Therefore, it is the ability of the structure, to perform the intended function with the adequate capacity, for a specific period of time under this is R, under specific conditions. I am not altering any of the statement except saying, I am saying a it is a ability it is the capacity, therefore, reliability is generally one minus probability of failure, that is it general notion, what people have in mind. Now, interestingly I have a very critical question; let me see who can answer this?

What is the difference between safety and failure? First question is, what is the difference between safety and failure, or do you think are they same safety and failure or unsafe and failure? To be clear, because they are they are different, means in what sense how are they different? Why two terms should exist in literature safety and failure. Failure is a structure (( )).

Not necessary, you are telling only one dimension of this. This is a very interesting question one must understand. Experience from the failure, where the (( )) called. Exactly very good, failure is an assessment based on judgment. Safety is an assessment based on mathematical concept, or statistical concept. There is no judgment applied in safety, judgment is applied only when it is a failure. So, there are two different terms. So, failure is a converse of reliability or reliability is converse of failure therefore, reliability is a process where judgment need to be applied. So, it is a science it is not a method. It is a science, reliability requires judgment because failure requires judgment. First answered, second critical question.

When failure is understood very well universally by engineers, then why a new term is reliability explaining converse of failure should be introduced? What is the necessity? When the failure is understood by the people, engineering community has understood what failure is. When people have agreed on this statement, then why one should introduce a new terminology, the reliability expressing converse of failure. In the literature what was a necessity? To build a (( )). Very good, see instead of saying a negotiation accept on anything, reliability gives you a positive feedback of things, is that clear? As I gave an example in a class of 100 teacher may say 10 has fail, teacher is also say ninety of passed so saying 10 as failed is concept of failure saying 90 has passed is reliability. So, reliability is a science of better presentation of failure, they can put it like this, it is a better presentation of failure, so you will very well agree that whenever I speak about reliability analysis, I will always talking about failure only, but the answer is always given in terms of reliability, which is nothing but one minus probability of failure, that is all.

So, there is no hairline difference in the techniques are obtained for failure assessment than reliability assessment. Whenever I have to access reliability studies or methods, I will always talk about failure only, but when I give the answer I will give the answer in the control in the converse form, just to have a better presentation of the answer.

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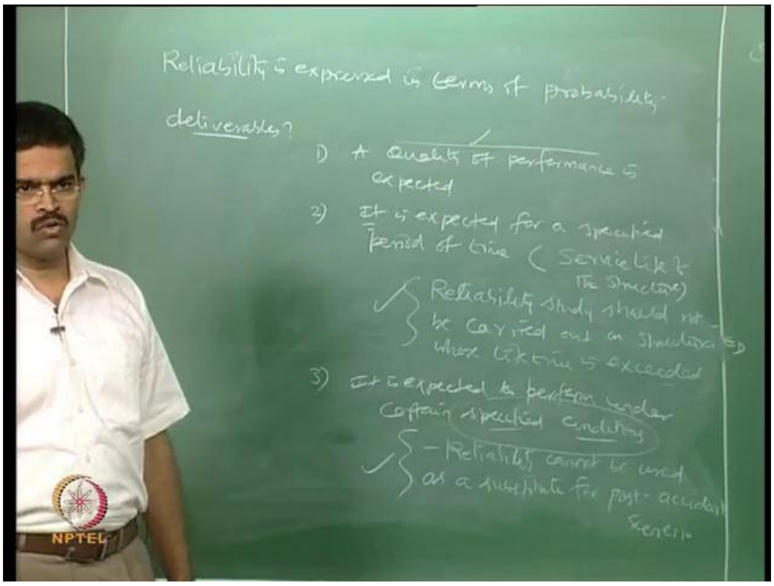

So therefore, I can say, reliability is expressed in terms of probability because failure is always probable, cannot be definite. Now, what are the deliverables of a reliability study? If a conductor reliability study, what you must get your answers. The foremost result what you must get from reliability study is, a quality of performance is expected from the structure. What is it mean, when you say the structure is reliably, when a 90 percent you are guaranteeing, certain quality of functionality to the structure is expected from the study two it is expected, which is excepted the quality of performance is excepted for a specified period of time.

Usually this specific period of time is what we call as service life of the structure. What does it mean? It very clearly tells me that, reliability study should not be carried out on structures, whose lifetime is exceeded, is it clear? It should not be carried out the third deliverable of reliability study will be it is expected to perform under certain specified conditions. Therefore, reliability study is cannot be used as a substitute for post accident scenario, what is it mean?

When the platform has already failed because of accident from the, on the plat from, you cannot conduct reliability study. It is not an accident modeling at all, why under accident modeling? The specified conditions of the design are exceeded or altered, that is why accidence is occurred on such situation and reliability should be not conducted. Now, you will understand very clearly under this condition and under this condition generally failure cities are conducted.

When the platform has fail because of accident, you conduct a failure. Study, if you really wants to assess the capacity of the structure after the service time is concerned, you talk about failure, but I say reliability is not recommended, can you tell me why? Now, it is a deviation from failure and reliability, why? why? Answer is within the definition of reliability itself, please recollect this answer, I will give you the answer, the answer is very simple. Once a service life or the conditions are exceeded or altered failure, study can be involve to diagnose the reasons, why the failure is occurred agreed because some study has to be carried out reliability, cannot be carried out because though it is a converse of probability of failure.

Mathematically, it cannot be done because of a simple reason the characteristic effects of load and material strength are altered seriously. So, reliability is only within a specified defined value of probability, that is the load should not exceed beyond 5 percent of your calculated value and the strength should not deteriorate or degrade less than 5 percent of your characteristic value. If these conditions are altered under that specified condition, reliably should not be applied very clear, is it very clear. Therefore, reliability is a failure study, in the positive dimension under given specified conditions within a specific period of time, which usually people called a service life of the structure.

Now, reliability studies cannot be extrapolated to extend the service life of the structure.Then, the fundamental question comes, why at all your study should be carried out? What is the necessity? What is the necessity, which cannot be carried out when the service conditions are altered or the specific conditions are altered? It cannot be carried out extrapolated, the service life of the structure is it safe or unsafe safety and reliability are different things, we already seen in the last lecture. Then, why we conducted reliability? The question is again in the last lecture, the answer is very simple.

I will give you the answer reliability is a part of risk assessment, the risk is nothing but the probability of failure multiplied with the consequence and the reliability one minus probability of failure. One is always interested to know, what is the risk beyond a service life of a structure? What is the risk in the present state of service condition of the structure? The moment I say will use failure study for this risk is 100 percent, because I am saying is this failed, I have to look this risk study in a positive presentation, than which is reliable, is it clear? So, reliability is having still it is importance to claim or to declare the risk associated with the platforms because risk is having a product of consequence or failure.

And probability of failure consequence of failure can be financially societal, which we have saw yesterday, but failure studies can be addressed in the converse manner using reliability. So, other one can say the risk is 80 percent, it means 20 percent more or less is reliable instead, saying 20 percent or 80 percent failed, 20 percent safe instead of saying the use thing term failure, that is in the term reliable. We are saying 20 percent reliable and so on so forth. So, it is having still a very deterministic meaning in terms of structure engineering applications on service life of the structure or extent modeling etcetera.

So, people conduct external studies, which we call has quantitative disassement extant modeling etcetera, where reliability studies are a part of this, any questions here? Now, we spoke about reliability as a effective scheme of addressing different uncertainties.

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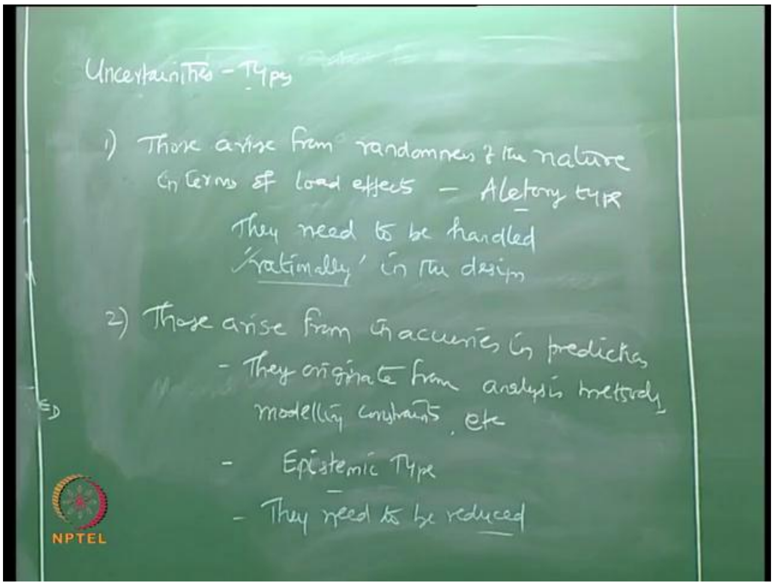

There are two types of uncertainties, first type which arises from are those, arise from randomness of the nature, in terms of load effects because these are the natural phenomenon, which acts on the structure. For example, wave loads, wind loads, wind direction, wind speed, wave direction, wave velocity, wave height, wave period, swelling effects, these are natural phenomena and all of them are random in nature. That is a high randomness associated with the load effect there is a first type of uncertainties. We call this as Aletory type, this specific problem are difficulty with this kind of uncertainty are, this type of uncertainty is, they need to be handled rationally.

In the design there is no other way you cannot get it of this type of uncertainty, it is never possible to make this variation certain, it will be uncertain. So, how to handle this rationally? How we use characteristics values associated with these loads and different combinations? Also we have seen that, also when they acting independently, when they acting combinely, then the effect of the combination is also seen in the codes as the different values, which we have seen in the unit 2 and the module 1. So, they are handled rationally in the designed there is no other mechanism, by which this randomness in nature can be addressed.

Remember even today there are no methods mathematically available, to address this kind of uncertainties or this type of uncertainties in the more effective manner. The second aspect, those arise from, inaccuracies in prediction. They generally come from, they originate from analysis methods modeling constrains etcetera. This type is called epistemic type, spelling please check. This this epistemic epistemic type, they need to be reduced. One should control or reduce effect of these kinds of uncertainties or this type of uncertainties in the reliability analysis, one is beyond control to handle them rationally.

One is under control handle them intelligently using effective mathematical tool, so there are two types. I am not giving examples for these, I think you very well understand from the first module from environmental loading, 1, 2, 3, 4 and for material strength lectures in module 1 you have understood, that how you can give examples of randomness in nature varying from the load effects? And how we can say that the modeling aspects can be varying or originating? From the modeling constrains and how they can create uncertainties?

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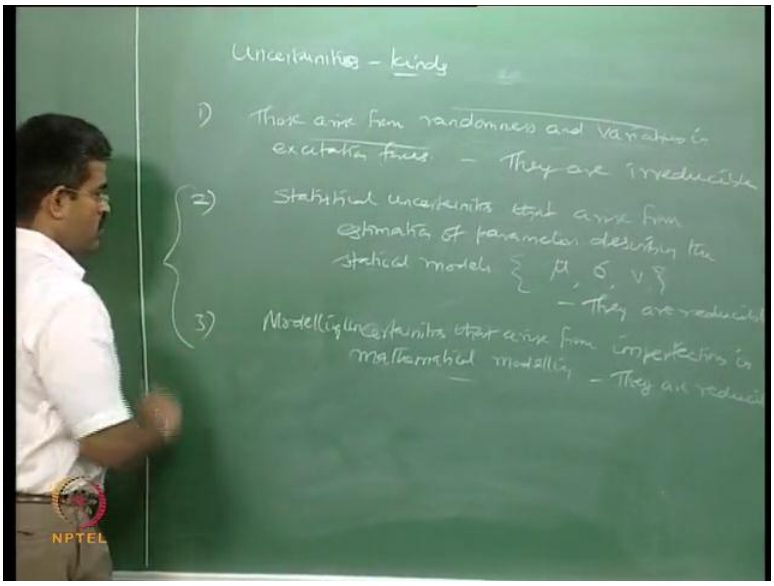

Now, let us talk about uncertainties. Different kinds there are, type's different kinds kinds of uncertainties. The first kind is those arise from randomness and variations in exciting or excitation forces. Now, what is the difference between the randomness, nature, which is one of the type of uncertainty and randomness in excitation force by this uncertainty of the kind one? What is the difference between these two? This uncertainty type talks about the process, this uncertainty type are kind talks about the mathematical representation of the process, this is originated in nature this is your difficulty.

Of course, they are irreducible the second kind, Statistical uncertainties. That arise from estimation of parameters describing the statistical models. Can you give me an example of this? Estimation of statistic parameters explaining the model, I am looking for a probability analysis. I would require the first order values at least, which is nothing but the mean, is sign a deviation. Mean is sign, a deviation or computer from ensemble sample of the material or the load effects etcetera. And there can be some statistical parameters like material, sorry mean mean standard deviation variance, which you have computed, which are all parameters used in statically models. There can be uncertainties associated in estimating this also, that the second kind of uncertainty, they are reducible, they are effective tools available.

You must use an appropriate model, it can reduce the effect in this, of this on the study the third one is modeling uncertainties that arise from imperfections in mathematical modeling. There can be some error in mathematical modeling techniques, they can also lead to certain uncertainties and of course, they should also reducible. Now, one the randomness and variations in the excitation force, which are essentially caused from nature. Though you have taken an effective process to filter them, what I mean to say is, you are looking for an 100 year return period of a design, wave the design. Wave is uncertain, there is a randomness asset with the design wave, but why?

100 period, 100 years, why not 50? You have seen a different codes in the module 1, if you look at Canadian codes is used 50 years outturn period and there are certain levels of probability acceptance, where written period can go as highest 275 years also for earth quick. For example, we have seen this, there are literature which can explain you this, I also written in a the equitation in the first molecule explaining, how the certain period can be computed If you know the service life of the structure, so these cannot be reduced, they reducible, fine? Now, at least these two which can be reduced which is essentially, what I call human errors. Errors created mathematicians statictions, engineers because the statically parameters are not estimated correctly.

The mathematical modeling is done properly it can create uncertainties, they should be reduced. Now, how are they handled? I am not explaining detail, I am giving only a tip because this lecture is not a talking about reliability alone, it is only a format of touching reliability as applied to marine structures In this course of advanced marine structures. Now, these type, these kind of 2 and 3 can be handled effectively. I can even say efficiently using Bayesian approach. You can use Bayesian approach to handle these, to address these. Now, immediately the question comes in mind is, what is Bayesian approach? We will not discuss in detail, but anyway, we will explain what is Bayesian approach is?

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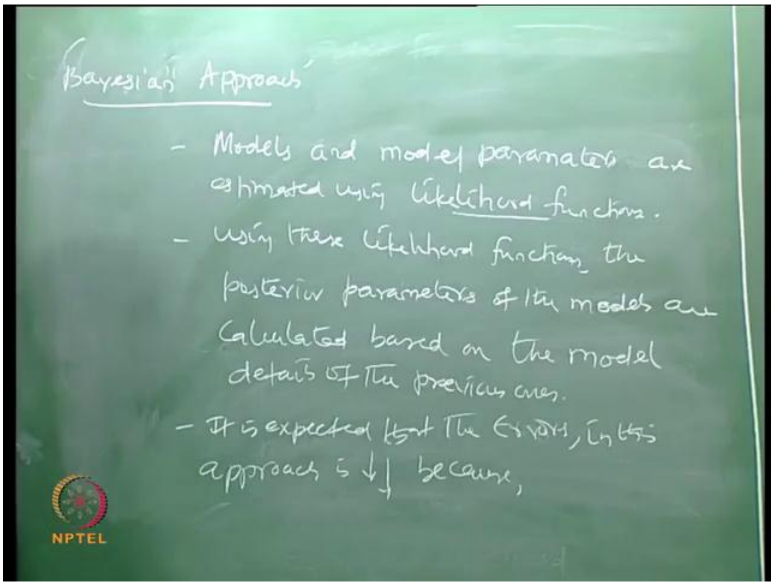

In Bayesian approach models and model parame. The moment say model, they are mathematical models not physical models. Models and model parameters are estimated using likely hood functions, using these likely hood functions the posterior parameters of the models are calculated based on the model details of the previous one it is expected, that the error in this approach is minimum because the parameters are estimated from an established or existing models of large data.

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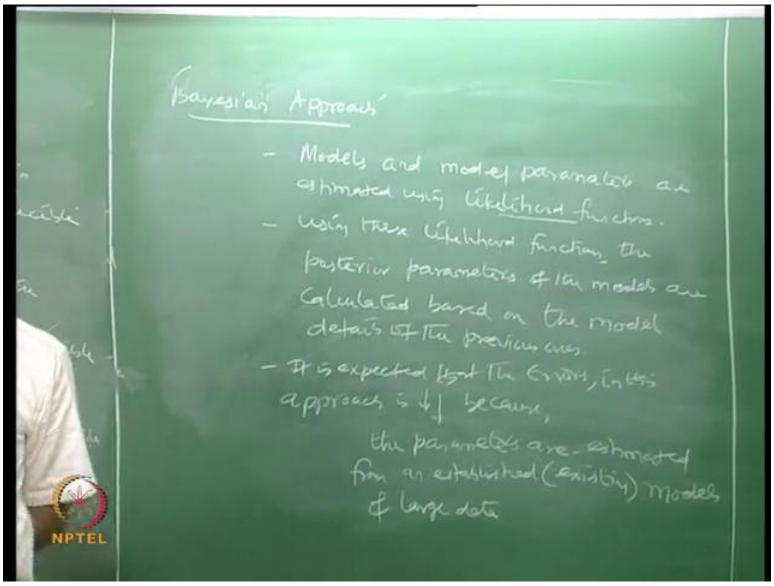

I can give a very simple example of this, very simple straight forward example. I want analysis deck plate, I can use different kinds of elements model. Elements I can use quad lateral elements, I can use a triangular element, I can use a shell element with 4 nodes, 8 nodes, 16 nodes, 24 nodes etcetera. There are different types of models available solid models and surface models mathematical values is available. All these are nothing but established existing models, which has got a large amount of data, which can now, we use as likely hood functions based on which you can derive these posterior parameters, based on the previous ones.

So, the errors can get reduced, so Bayesian approach is an alarmism, which recommends you to use the likely would function as applied to the existing models. And then derive the parameters as posterior information from the existing models. So, keep on improving on the model, instead you start a new model you pick up any one of the existing model or set of existing models and compare them whether the beast plain curve is better, whether the parabolic curve is fitting better? Look at these models, just on applying and minimize error as maximum, the is possible resulting from the mathematical formation of the problem in terms of modeling, that is what Bayesian approach is.

Most of the software which are used for modeling finite element modeling, see if the analysis etcetera use mostly this kind of approach, it is a very interesting analysis given the Bayesian. So, interesting Alvaridem, we are not discussing as I said in the beginning the Alvaridem in detail as applied to a problem, but that is how the error minimization happens. In one of the, are two kinds of uncertainties which are generally a high level of botheration in the reliability analysis because one cannot do anything with the irreducible kind of uncertainties. Instead of worrying about that, whatever I can minimize that will do, that that is how people are been doing in the engineering suspect, in there reliability study in the recent past, is that clear?

We will extended this lecture, in the next part speaking what are those parameters, which will influence the reliability? Study more in detail in the next lecture, so in this lecture we have understood that why reliability is important for the marine structure? Why reliability study are not 100 percent accurate? What is difference between failure and reliability? If failure is understood, well by an engineering community? Why reliability term is at all introduced in the engineering literature, how reliability cannot be applied to a existing structure, says crossed the service period. Then where is the question of risk applied to the structural system? Why do you estimate the risk giving system, than what are those kinds and types of uncertainties, which bothers reliability studding in detail.

Thank you.