Risk and Reliability of Offshore Structures
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module – 02
Reliability theory and Structural Reliability
Lecture – 03
Levels of Reliability

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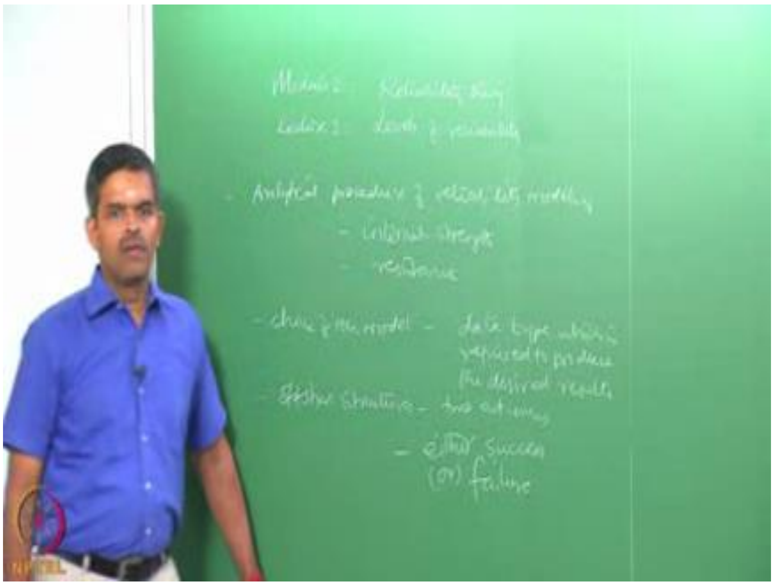

Welcome friends to the third lecture on levels of reliability. So, we are talking about lectures on module two on the online course on risk and reliability of offshore structures. Module 2 is focusing on reliability theory. In this lecture-3, we are going to talk about levels of reliability. So, in the last lecture, we said that one should be able to identify the design point in addition to obtaining the reliability index, so in statistical sense it means that I must be able to locate whether my reliability function or the performance function is lying in the safe domain or in the failed domain.

So, analytical procedure of reliability modeling depends on two factors analytical procedure of reliability modeling depends on two factors one is of course,, the internal strength and resistance. It all depends upon what is the choice of the model the choice of the model of the reliability study is going to depend on the data available or the data type which is require to produce the desired results. Now, in case of offshore structures, let us specifically down this model to an outcome; in case of offshore structures you have got two set of outcomes; there are two outcomes one either success or failure.

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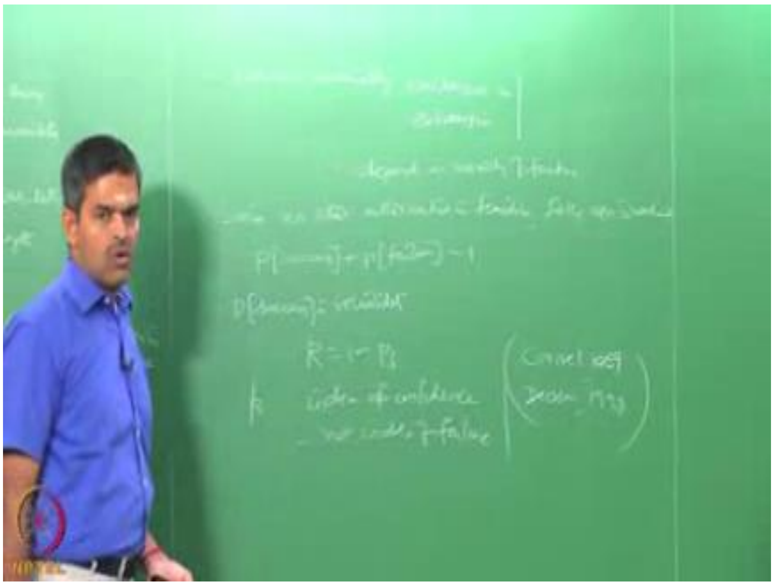

But interestingly, both are mutually exclusive and exhaustive that is required for the data qualification. This is due to the fact that both of them are dependent on varieties of factors. So, they depend on variety of factors. Now, either success or failure, there is no other alternative, so as no other alternative is feasible. One can write the following statement, since no other alternative is feasible that is except success or failure, no other alternative is feasible following equation is valid that is for a given system probability of success plus probability of failure should be one.

Probability of the success of the structure is reliability; therefore, reliability is 1 minus probability of failure. It is important interesting to note the reliability is expressed in terms of confidence built up on the system in a positive sense and it is not index of failure. So, reliability index is index of confidence, and not index of failure. This is one of the better ways of looking at the failure theory as given by Cornel in 1969, as also mentioned by Densen in 1998. So, do not look at the failure look at the success of it. There are different variables in reliability study.

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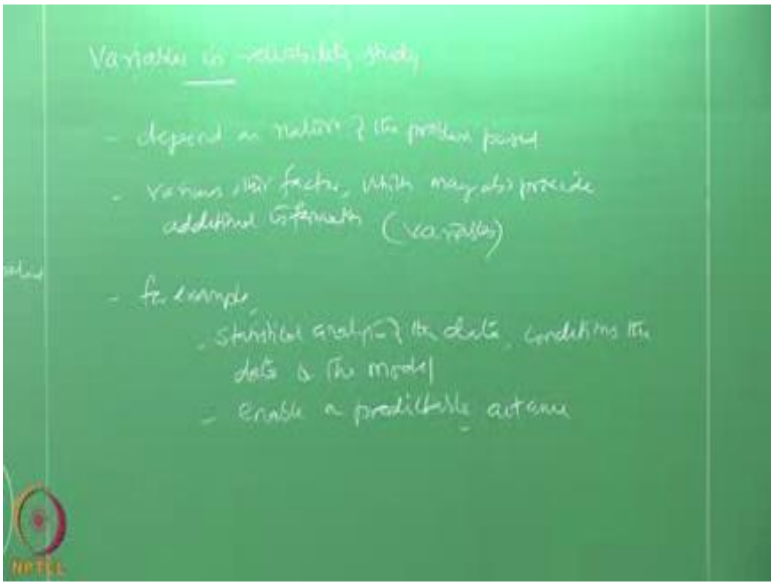

The variables are as per the choice they depend on the problem or the nature of the problem posed. There is also a high exchange of interaction between the various specialties that provide additional information to the decision maker. There are various other factors, which may also provide information, and they also should consider as variables. Let say statistical analysis of the data, let us say for example, the statistical analysis of the data conditions the data and of course, the model; both which will enable a predictable outcome. So, probability engineers propose the methods and tools for the calculation.

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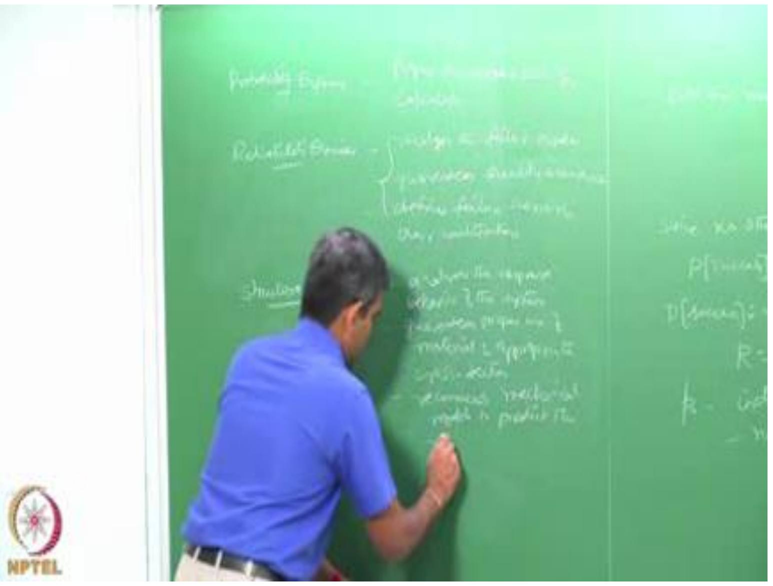

Propose the methods and tools for calculation. Reliability engineer analysis the modes guarantees quality assurance defines failure scenario because he must either follow limit state of serviceability, ultimate limit state etcetera. He can also look into their combinations. A structural engineer analyzes the response behavior of the system guarantees proper use of material, and appropriate cross section and recommends, mechanical models to predict the response. So, each of these players have a variety of variables.

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To deal with there is no commonness between them. So, they should give a meaningful output, ultimately the decision maker considers the best possible outcome to reduce the risk in the process. As we said reliability is looking at the success on the identified probability of failure scenarios, then it is very important to know the reliability will also be circumscribed using a probabilistic approach.

Therefore, probabilistic models should have a basic objective; they aim at the range of outcomes from the study for the given input data. Therefore, they should include the system randomness. We should not say system randomness; they should include the randomness of the data present in the system, let say like this. They should include uncertainties present in the system. Therefore, a probabilistic approach should aim at determining the probability of an outcome amongst the best possible outcome that can occur. So, probability can be expressed either in percentage varying from 0 to 100 or a number from 0 to 1. In engineering practice, it is very important that lower risk usually means higher cost.

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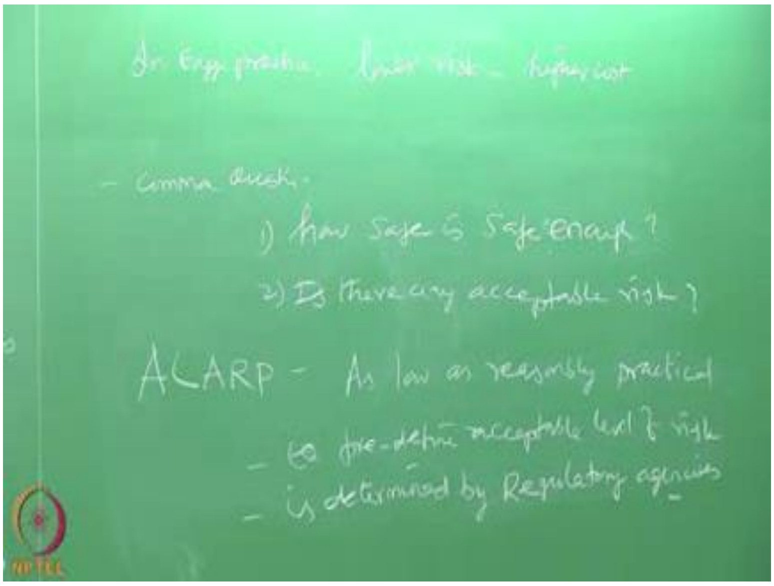

In engineering practice, we always believe that lower risk usually means higher cost. Hence a common question which comes in reliability engineers mind is how safe is safe. What level or how safe is let us say safe enough; on the other hand is there any acceptable risk. So, in offshore engineering very interestingly there is a common term called ALARP - as low as reasonably practical. This is very useful to define I should say to predefine acceptable level of risk.

So, risk acceptance is a pre condition which is imposed in offshore engineering domain based on which safety is only designed in such a manner that system does not become safer than the pre acceptable level of risk. So, level of acceptable risk is determined where a regulatory agency is prefixed. Of course, this is based on guidelines given by the number of researchers and reliability engineers who are involved risk assessment based on their experience and expertise the regulatory agencies advice a reasonable amount of acceptable risk to offshore industry, which is to be followed as a reliability or safety practice. So, therefore, there is a clue there is an indicator that the incremental risk should not be significant compared to other risks than that of the ALARP level.

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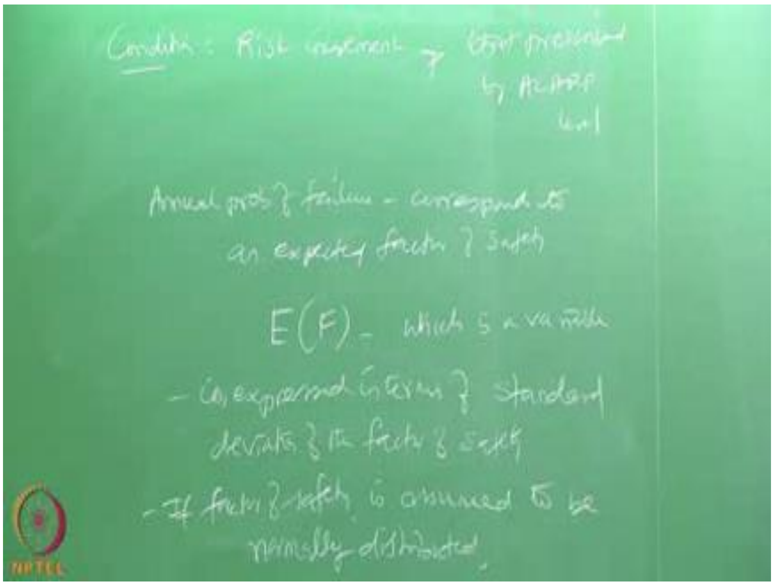

The condition here is risk increment should not be more than that prescribed by ALARP level. Let say annual (Refer Time: 17:19), let us say it corresponds to an expected of safety, let say this expect factor of safety is E of F. Of course, the probability of failure annual will be corresponding to this because this is prefixed as per the ALARP level which is of course, the variable now. And this will be expressed in terms of standard deviation of the factor of safety.

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Let us say if factor of safety is assumed to be normally distributed then reliability index beta is expressed as the expected value of factor of safety minus 1 by standard deviation of this. Let us try to plot the relationship between reliability index and probability of failure. Let us take the reliability index plot in the x-axis and probability of failure plot or the value variables in y-axis, let say it varies from 0, 1, 2, 3, 4 and 5. Let say this value is about 10 power minus 7, and this is about 1 that is 10 power 0 which is 1 and so on.

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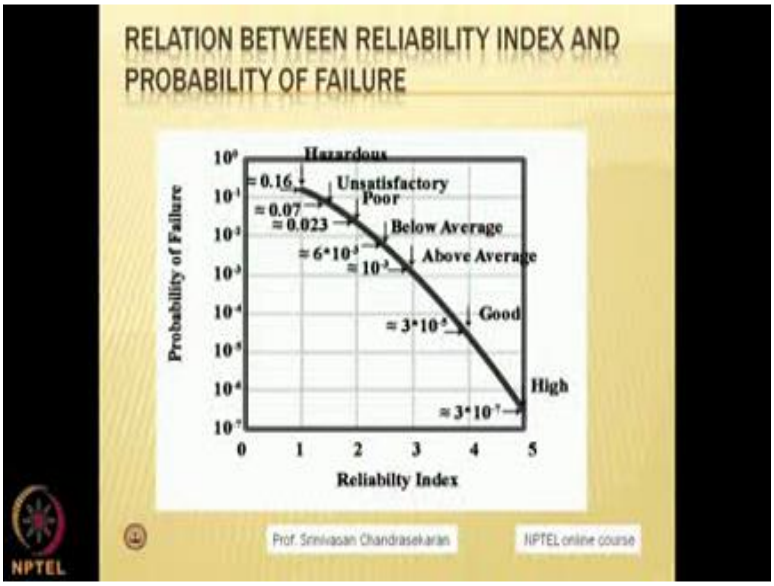

Friends please pay attention to the sketch or the graph shown in the screen. We can see here, it is a typical relationship curve, which is connecting reliability index to the probability of failure. So, one can see here for a system to have very high reliability index, the probability of failure will be as low as 3 10 power minus 7. So, we call this as high reliability index qualitatively, whereas if the reliability index is closer to one or whose probability of failure is closer to 0.1 then we say the system is hazardous.

So, one can see different category of hazardous, unsatisfactory, poor, below average, above average, good and high. So, system is generally classified as high, good, etcetera based upon two indices; one either based on reliability index or based on probability of failure. However, these two are connected by this relationship given in equation one. So, one can qualitatively say where the system is the reliability index of system is high or hazardous based on the number simply varying from indicated from let say 0 to 5 or based upon probability of failure which varies from one to as low as 10 power minus 7 as seen in the figure.

If you look at the structural design of offshore structures, the design essentially relies on deterministic analysis, initially to arrive at appropriate cross sectional dimensions of the members to withstand the encounter forces. It is a well-known fact that the material properties and encountered loads in offshore structures are clear victims of uncertainties we have already seen that in various examples. Loads are highly uncertain due to the main of occurrence and materials are really highly uncertain due to the significant degradation in marine environment.

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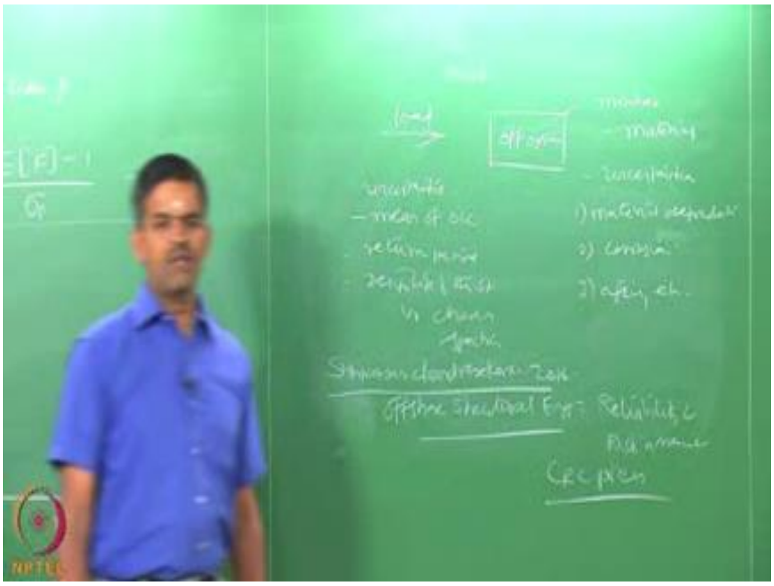

Let us say offshore structural system subjected to loading environment in marine environment let us say environment loads in marine environment. System of course made of members, members as cross sectional, dimensions and material, let us talk of material characteristics. We already know there are lots of uncertainties in estimating the material characteristics for the design purposes; one could be material degradation due to aging, due to corrosion, aging etcetera. Loads also have uncertainties. It can be due to the mean of occurrence return period, the design life of the structure versus the chosen spectrum, etcetera, they can be many factors.

We got a good reference, if you can refer to my own textbook Offshore Structural Engineering Reliability and Risk Assessment CRC press. I have listed this ISBN number etcetera in the reference of NPTEL website, you can look into more details (Refer Time: 24:46) those factors which can affect or contribute to uncertainty especially in the material front and in the loading factor.

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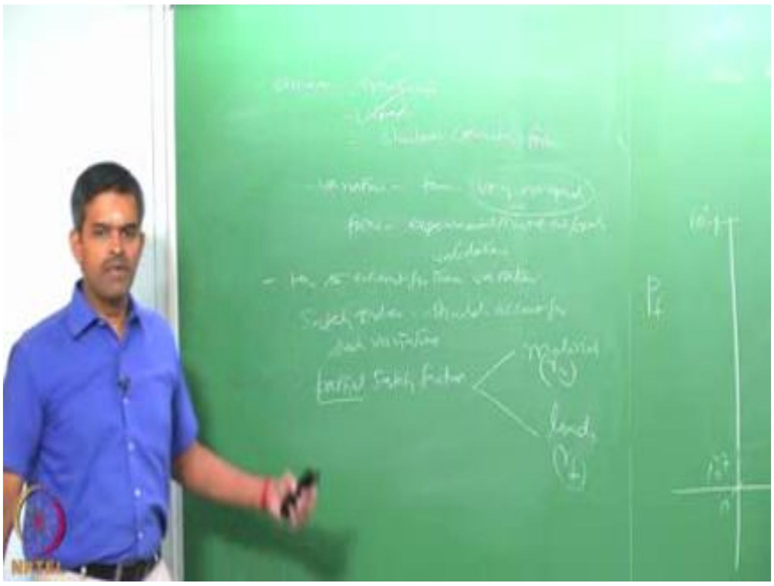

Therefore, we have variations coming from the material as we just now saw can also come from the loads. In addition can also come from structural forms that is the geometric forms, because this is usually based on sound experimental investigation scale model, so the variation which arrives from the structural form are very margin. So, they are not significant because people suggest structural forms (Refer Time: 25:55) detail experimental, numerical and analytical validations. Therefore, the variations in the structural form will be very marginal, when compared with that arise from material and from the loads.

Therefore, it is important to introduce how now the question is how to account for these variations. So, therefore, it is important to introduce some index which can account for these variations, therefore safety index should account for such variations. Since, all variations cannot be accounted in one factor or one index people have used what is called partial safety factors. Partial is related to the meaning that the safety factors accounting the variations are not complete, a single factor cannot account for all variations, so people say it is partially accounting for.

There are safety factors for both which is seen in the international codes both material and that of the loads also; one is gamma m other is gamma f; m stands for material, f stands for forces let say loads. But please understand using partial safety factor does not guarantee an absolute measure of failure of probability that is very interesting.

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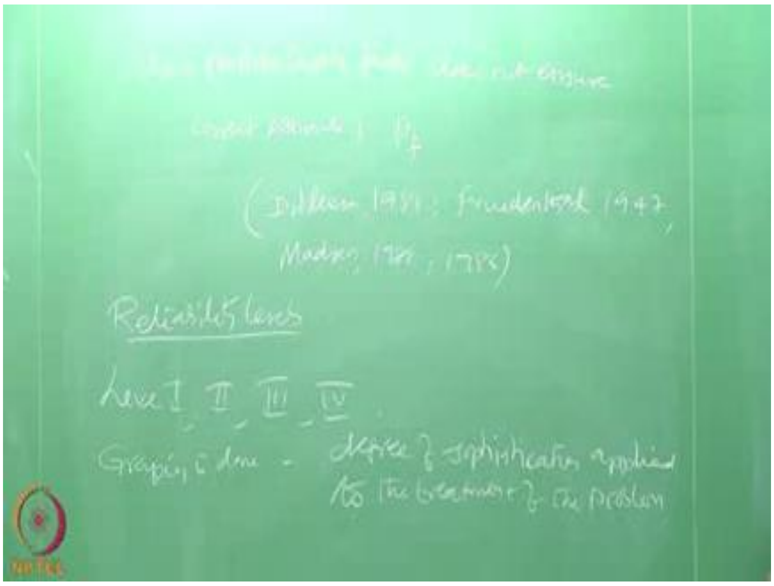

Using partial safety factor does not ensure correct estimate of probability of failure. It is very interesting statement. The Dit levson in 1981 Frudential 1947, Madison 1988 many people supported this statement 1986 etcetera references can be seen in the NPTEL website for details. Having said this one should be able to account for these variations in the reliability analysis. Therefore let us say various levels one can look at reliability.

There are different levels of reliability analysis, which can be used in the design methodology. They all depend on the important structure. The term level is characterized by the extent of information about the problem that is used and the data this is provided. So, they can be grouped in four level 1, level 2, 3 and 4; now four levels of reliability. Now the fundamental question comes how this grouping is done. So, grouping is done or level of reliability is chosen on the base of degree of sophistication applied to apply to the treatment of the problem in general that is what it is we will see specifically what do they mean.

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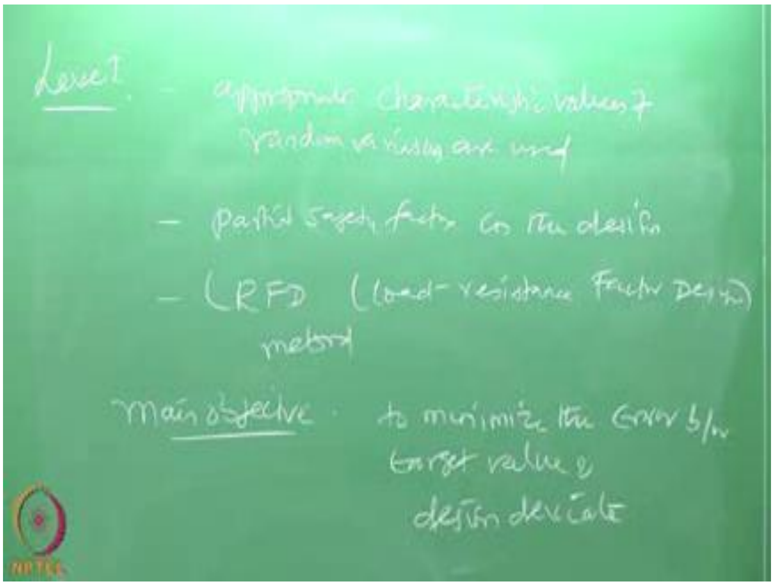

Level 1, people use appropriate characteristic values of random variables; characteristic values of random variables are used in level 1. They are used as partial safety factors in the design. For example, LRFD that is load resistance factor design method is a classical example of first level reliability analysis. The main objective in this level of reliability is to minimize the error between the target value and the design deviate.

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Level two implies two values of each in certain parameter use two values of each uncertain parameter. What are they, mean and standard deviation? For every parameter these two data are used to model the reliability problem; of course, they will also be supplemented by the correlation between the parameters. Talk about level 3, this method encompasses the complete analysis of the problem; it involves integration of multidimensional joint probability density function or integrated over the extent of safety domain. Reliability in this case is expressed in terms of reliability index and failure probability.

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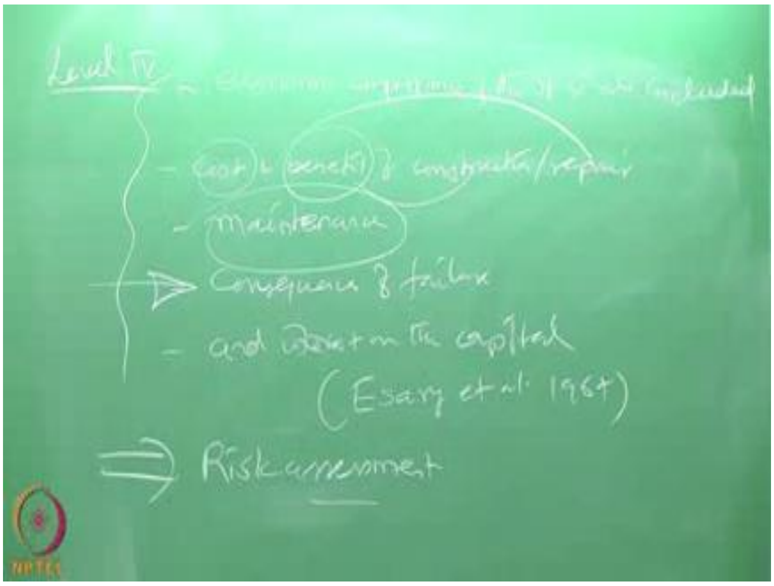

In level 4, the economic importance of the structure is also included. So, the reliability estimate will converge to become brisk estimates as well. It involves the principles of engineering economics under uncertainty; it considers cost and benefit of construction or even repair. It considers problems associated to maintenance; it considers consequences of failure without not even stopping at the stage of probability of failure, it also assesses the consequences of failure. Then of course, the interest on the capital investment as said by Esary etal 1967.

Sensitive projects like offshore structures do fall into this category; other structures could be nuclear power plants, transmission towers, highway bridges, they all fall in level four reliability study, where one has to look into the cost and the benefit of repair or construction, the level of maintenance. One should also look into the consequence of failure does not even stop estimating the probability of failure so it is essentially converging towards risk assessment.

So, friends, in this lecture, we understood various factors or various players in reliability estimates. We have tried to understand the connectivity between the probability of failure and reliability index and converting the whole mathematical scenario into relative qualitative statement saying high low etcetera using a graph as we saw during the lecture. We have also understood different levels of reliability, what are the players in each level and we realized that in level 4 the engineering economists encompassed in the reliability study, therefore it is anyway converging towards what we call risk assessment.

Further details we will see in the next lecture. I hope you have gone through the lecture loads of previous module and you are following this as well. I would urge you and request you look into the references cited during the lecture for their additional reading

Thank you very much.