Risk and Reliability of Offshore Structures
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Module – 02
Reliability theory and Structural Reliability
Lecture – 19
Risk and Reliability

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Welcome friends to the 19 lecture on module-2, where we are focusing on reliability theory and structural reliability. In this lecture, which is the 19th lecture, we will try to talk about some extension of reliability in terms of a fatigue studies. We will continue in series of lectures now. So, here we are trying to compare the risk and reliability again as we discussed in the earlier module lectures.

In the last couple of lectures, we gave an example study of how to understand the performance of a specific system structural system and reversed combination of environmental loads. We took example of a tension leg platform which is designed to be a compliance system with large displacements permitted in the system, where the relative displacement between the water particle velocity and that of the structural velocity is reduced, therefore structure has gained a very good re centering ability under the lateral forces caused by waves and wind.

When you look at the system under the reverse combination of forces, where in the second case we talked about distinctly high sea waves and seismic loads where the seismic loads cause indirect change in tension and that affects the system reliability. In the earlier case, we spoke about the math stability issue on tension leg platform. We picked up a real example and tried to compare the stability of the system, which is the part of the reliability study, which essentially checks the performance of the system and its intended function under the given environmental loads for a specific period of time.

So, now I will get back to the concepts of comparing risk and reliability and safety, then we will move onto these studies slightly more in a mathematical manner. We all know that environmental loads that act on offshore structures are not completely deterministic; only a few features of the loads are known, maybe that is one of the interesting critical features of analyzing offshore structures for reliability study.

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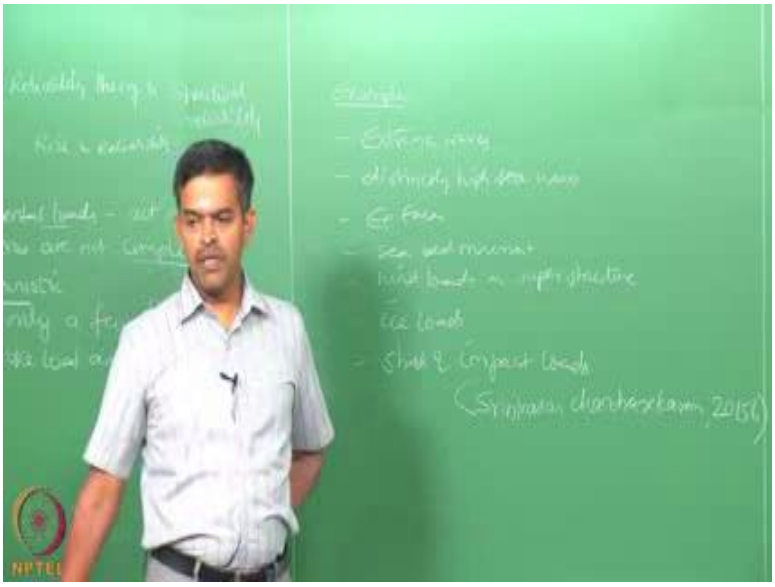

We can always quote certain examples to verify this statement some of the examples such as extreme waves distinctly high sea waves, the earthquake forces, sea bed movement, wind loads on super structure, ice loads, shock and impact loads. Interesting examples of extreme combinations which can always ascertain this statement that, environmental loads acting on offshore structure or not all the time completely deterministic.

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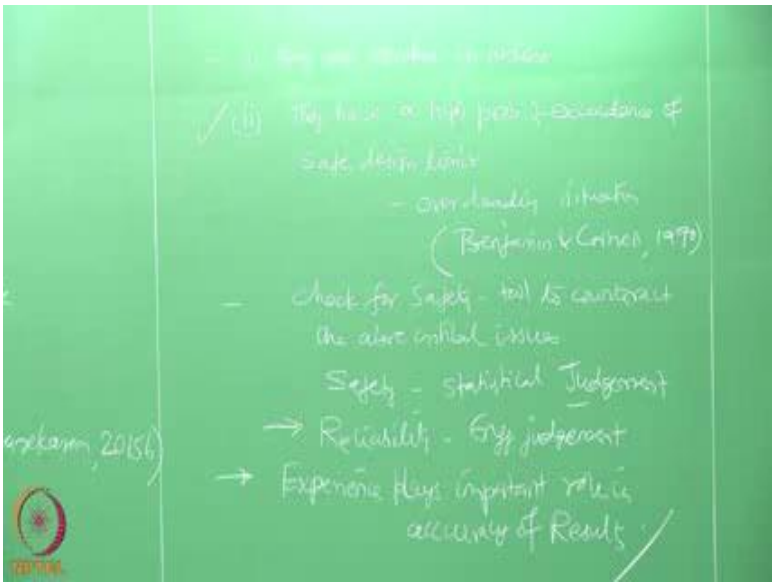

Now there are issues related to this particular combination of forces which we will say apart from being random in nature one issue is they are random in nature. The main issue which is very critical as far as we are concerned is they have a high probability of exceedance on the safe design values which is one of the very serious botheration as far as reliability is concerned, because they will lead to what we call overloading situation. Now, how to encounter this particular issue, because we know that the loads acting on offshore structural system are not completely deterministic you do not know the complete prescribed loading of the system because apart from being random in nature, the very serious problem in these kind of load combinations or loads is that they always have a very high probability of exceedance from their safe designed values.

So, now to counteract this we generally look at the safety. So, check for safety is a tool to counteract the above critical issues, but unfortunately safety is actually a statistical judgment. Therefore, I can confidently say reliability is also based on engineering judgment. Therefore, one can say in general in reliability studies the experience plays a very important role in the accuracy of the results. Apart from the loads being nondeterministic in nature, apart from the loads have high probability of exceedance from the safe design values, there is one more complication.

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The complication is while applying reliability to offshore structures. We will say while applying reliability to offshore structures, it is important to include complexities let say all complexities that are of economic importance what we call as level 4 of reliability. So, a reliability applied offshore structure is not only an engineering judgment of ascertaining the performance of a function intended for a specific purpose under the given specific time for a specific period.

In addition to that is having one more class of importance where economic perspective needs to be also addressed. We also know that a variety of uncertainties as explained in earlier lectures; do not guarantee a deterministic approach; presence of variety of uncertainties we can say it does not guarantee a deterministic approach for reliability analysis. These uncertainties clearly indicate that the reliability assessment offshore structures shall be done only in probabilistic point of view.

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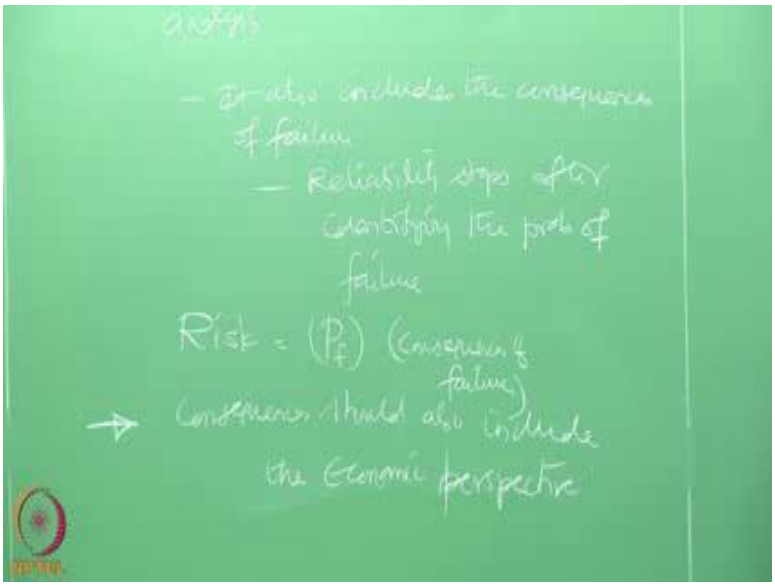

As said earlier, one can say that risk is an extension of reliability because it also includes the consequences of failure, whereas, reliability stops at or after identifying the probability of failure we know that risk actually is a product of probability of failure of occurrence of an even into consequence of failure. More interestingly, when reliability or risk is applied to offshore structures the consequences should also include the economic perspective. So, therefore, in engineering practice, one routinely encounters situations that involve some event which has got a particular probability of occurrence; and if it occurs has a specific set of consequences. With experienced engineering judgment, one should be of course, able to assign a suitable probability to the occurrence of an event and of course, some quantified magnitude or the cost effect to the consequences if that event is occurred.

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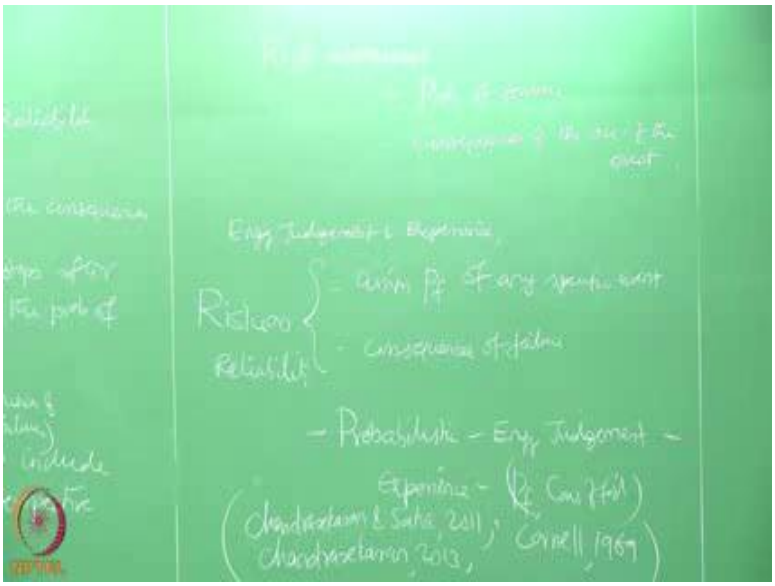

So, for risk assessment, we have two parameters; one is the probability of failure of a specific event which is undesired; the second could be the consequences of the occurrence of the event; if the event occurred what could be the consequences. So, based on engineering judgment and experience, one should be able to assign probability of failure of any specific event in a given system and also one should be able to correlate the consequence of failure if the event occurs.

So, essentially you know reliability study or risk is probabilistic is engineering judgment based on experience. And of course, it has got a method of assigning probability of failure and consequence of failure as said by 2011, 13 and Cornell 1969. Therefore, in system reliability or in general in reliability theory, the combination of uncertain events and the adverse consequences is a determinant of risk.

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Determinant of risk depends on is the combination of uncertain event and the adverse consequences. Alternatively, to express the condition of a structure in a positive manner reliability is considered. So, alternatively as we understand now to consider the performance or assessment of a structure in a positive manner reliability studies are conducted.

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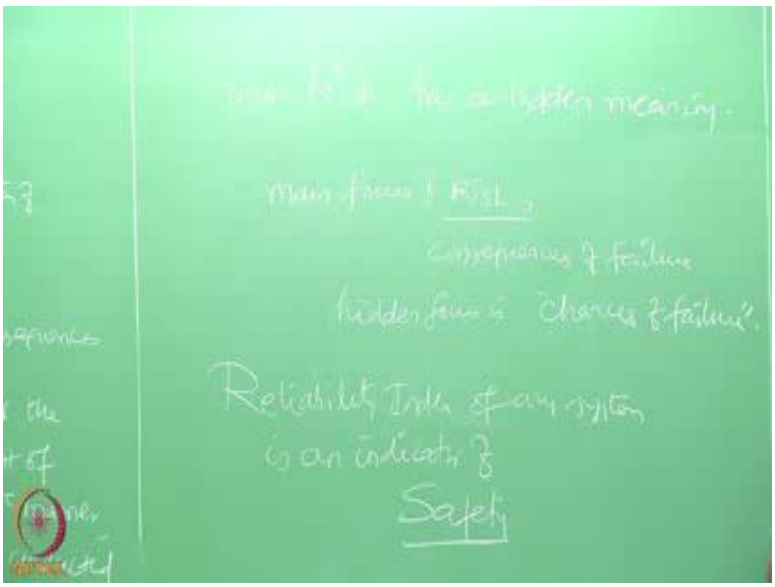

Now, the term risk has a hidden meaning. The main focus of risk is consequences of failure; the hidden focus is chance of failure. So, therefore, one can say reliability index

of any system is an indicator of safety. So, one can say that risk is an extension of reliability which addresses the consequences of failure which is the focus of risk analysis, whereas reliability stops at identifying the chances of failure. So, reliability terminates at the stage of assessing the probability of failure while risk continues to address beyond this point. Therefore, it is important for us to know that risk conveys the financial component of unsafeness that is very important.

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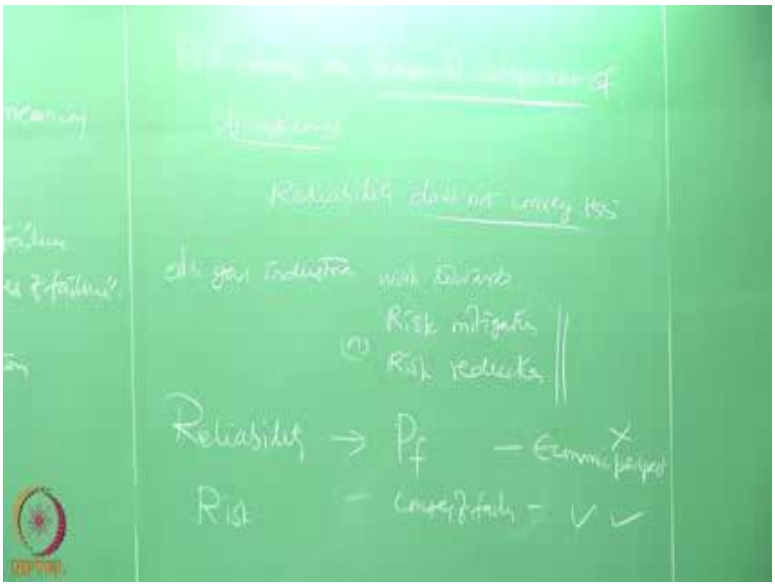

Risk conveys the financial component of unsafeness, whereas reliability does not conveys that is why generally friends risk analysis is more popular on engineering structures compared to reliability. Of course, we agree now that risk is an extension of reliability which focuses on the consequences of failure; and to a greater extent on economic perspective that is why risk assessments are essentially more popular and more authenticate compared to reliability analysis. As a common practice in oil and gas industries and offshore structures in general, risk assessment is very important because an oil and gas industries work towards what we call risk mitigation or risk reduction, they do not work towards reliability analysis at all.

So, in reliability, the focus is probability of failure in risk the focus is consequences of failure. Reliability does not give me the economic perspective, whereas risk focuses on economic perspective. Then one can ask me a question how about level 4 reliability; level 4 reliability is related to those type of structures whose economic importance is

higher; however, whatever studies you conduct on level 4 reliability analysis on structures of higher importance, but still in those analysis also the economic perspective of the consequences is not addressed. So, more or less risk analysis invades supersedes reliability assessment.

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There are reasons for this. Risk covers a broad spectrum of adverse effects or you can say better estimates in comparison to reliability analysis, because they cover a broad spectrum of adverse effects like adverse effects on the society what we call a societal risk; individual, what we call personal risk or individual risk. It also talks about adverse effects on financial status; it also talks about adverse effects on processing plant on its asset management. So, risk analysis addresses towards the CAPEX investment on a project, whereas reliability does not touch the CAPEX part. Reliability focuses on only the operational expenditure or the failure towards operation, whereas risk analysis can even address to some extent the asset management which related to the CAPEX investment of the whole project.

Having said this that reliability and risk are comparable, risk has a precedent stage of reliability study because probability of failure needs to be assessed for a given structural system. So, reliability is a focus on assessing the performance failure of a given system against it is intended function over a specific period of time under specific conditions. So, you always pick up a structural system impose certain combination of forces or loads

or certain degradation effects or aging effects on material then asses the performance of the structure. The moment I say the performance of the structure, we always talk about the load carrying capacity, the sustaining on material, displacements or stress induced by large vibrations and displacements all are essentially engineering properties. Whereas we all agree these properties cannot be linked directly to the cost effect at all.

Whereas, risk picks up the probability of failure as assessed from the reliability analysis identifies the consequence of this failure in economic perspective as well and try to give overall picture about the asset management of the given project therefore, risk analysis generally supersedes the reliability studies. So, risk analysis more or less in the financial perspective reliability is more or less in engineering perspective now when we talk about reliability analysis there are two types or extreme types of structural elements which are common.

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So, when we talk about let us say structural reliability, there are two types of fundamental analysis one can carry on structures, because structures in general or structural elements in general can be divided into two namely brittle members, ductile members. An element is considered to be a brittle element, which becomes completely ineffective after it fails or those elements which become completely ineffective after failure. While ductile elements are those elements which is able to maintain which can maintain its load carrying capacity or I can say in general intended function even if fails.

Now, in general a special case involves a system in which the correlation coefficient is same for all pairs of elements.

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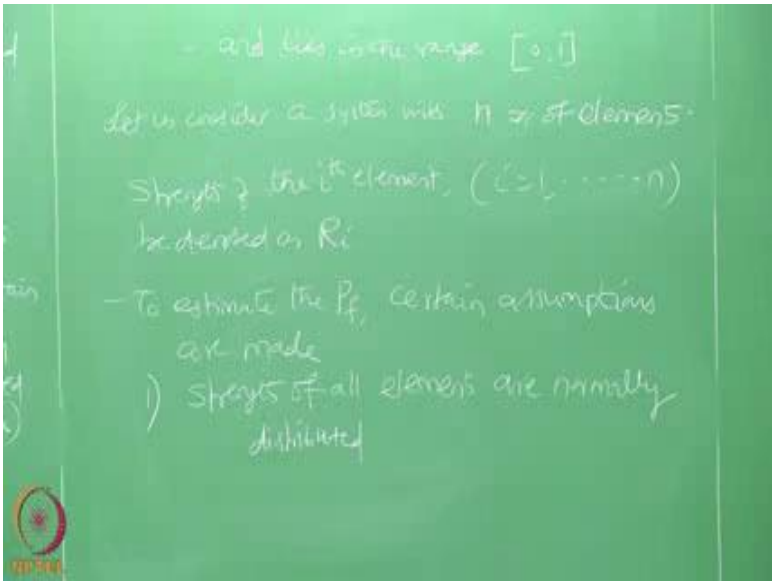

Here let us take a special case. The special case in sense it involves a system containing pairs of elements whose correlation coefficient is same, and lies in the range 0 and 1. Now, let us consider as system with n number of elements. One can say strength of the ith element where i is equals 1 to n be denoted as R i. To estimate the probability of failure we have to make certain assumptions. One, strength of all elements is normally distributed.

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Two - strength of all elements are equally correlated; three - all applied loads are deterministic and time invariant; and lastly all elements are designed to have the same reliability index which we call as beta. So, now, we are moving from element level or component level analysis to the structure level analysis, we are talking about structural reliability. So, these assumptions are generally made when you perform structural reliability on a given system whereas a focus is not on the elements now we are talking about the overall failure of the entire system under the given combination of forces.

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Now there are two systems possible system in series system in parallel. Let us say system in series, which has got equally correlated elements. Now, for n elements of a system in series probability of failure as given by Stuart 1958 is probability of failure is 1 minus integral of minus infinity plus infinity phi of beta of the element plus t root p divided by 1 minus this is rho root raise to the power n phi of e dt - equation 1. In this case, beta e is a reliability index of each element phi indicates the cumulative distribution function and probability density function; rho of course indicates the correlation coefficient.

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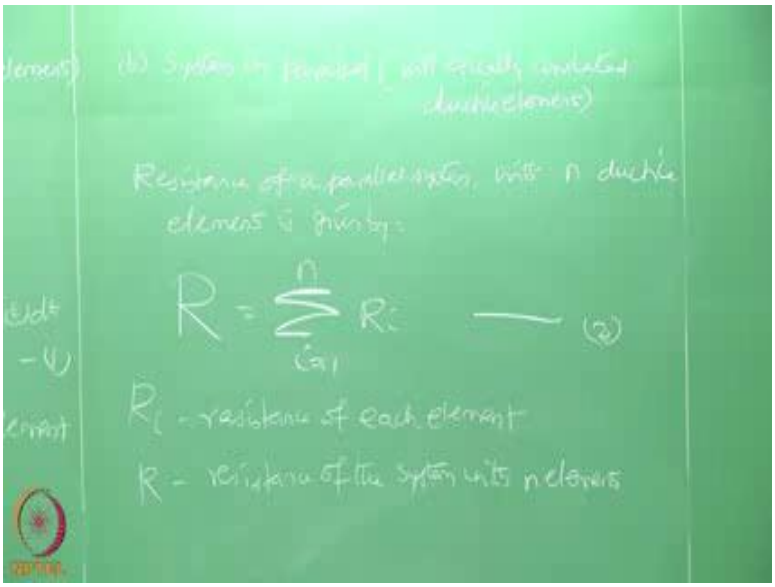

Alternatively, we talk about system in parallel with equally correlated ductile elements. One can say resistance of a parallel system with n ductile elements is given by R equals summation of i equals i to n of R i because we know ductile elements can perform the intended function that is the load carrying capacity even after they fail ,because they have a sufficient reserve capacity. Now we can say here R i is the resistance of each element; and R is the resistance of the system with n elements.

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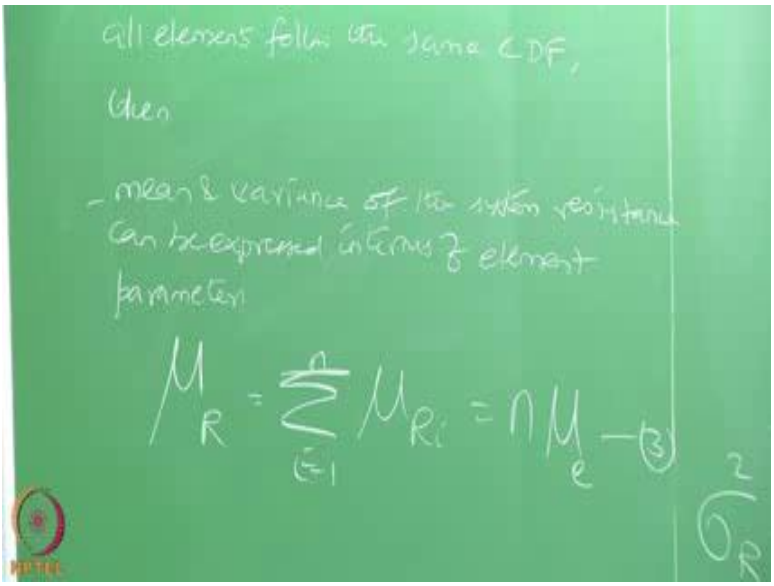

Now, once we assume that resistance of elements follow the same cumulative distributive function resistance of all elements follow the same cumulative distributive function then mean and variance of the system resistance can be expressed in terms of element parameters like mu R will be n mu R i is nothing but n into mu e.

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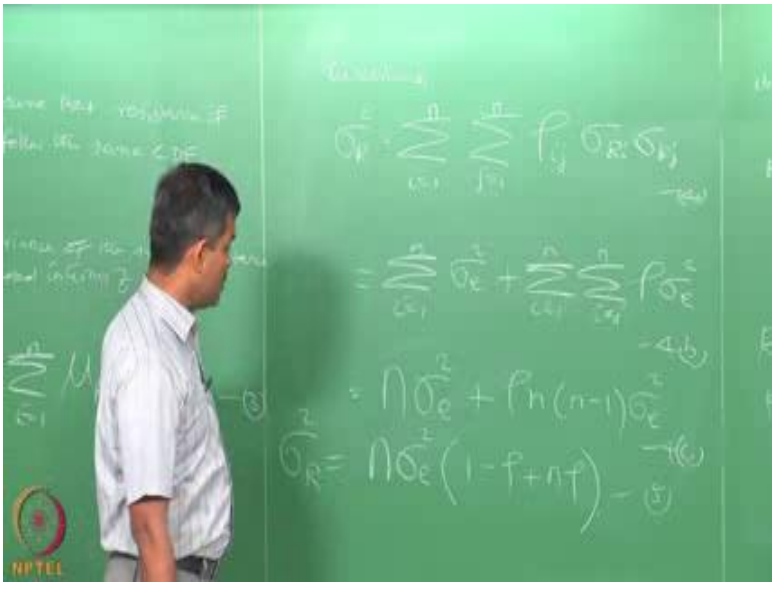

The variance sigma square R can be i equals 1 to n j equals 1 to n rho i j the correlation coefficient R j which can be said as i is equal to 1 to n sigma of the element square plus double summation i equals 1 to n i not equals j 1 to n rho sigma e square. This is 4 (a),

this is 4 (b), which can be said as n variance of the elements plus rho n n minus 1 variance 4 b sorry 4 c, so which now amount to n sigma e square of 1 minus rho plus n rho I call this as equation number 5.

So, the variance of the system is given by the variance of the elements if I know the correlation coefficient between the elements which are assumed to be equal as in one of the; be in assumptions in the whole derivation where n is a number of elements in parallel. Therefore, to determine the reliability index for the entire system it is important to assess the relationship of reliability of elements beta e to the mean and standard deviation of each element.

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Therefore, reliability index of the system demands estimate of reliability index of the element which of course, depends on mean and standard deviation of each element. So, friends, we are able to compare the risk and reliability analysis in general with a conceptual idea; and we also explained how risk analysis can supersede the reliability analysis to a greater extent at level 4 reliability demands in terms of offshore structures. We have also said how system reliability now can be interpreted if the element reliability is known to us for a system in series and system in parallel.

We will continue the discussion in the next lecture to really understand how to get the extension of reliability of the system, if I know the reliability index of the element whether the elements are in series or in parallel.

Thank you very much.