Structural Reliability

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Lecture –153
Capacity Demand Component Reliability (Part 01)

With this lecture we start Part C of our course. So, let us recap what we have done so, far and let us lay out the plan for this third part of our course.

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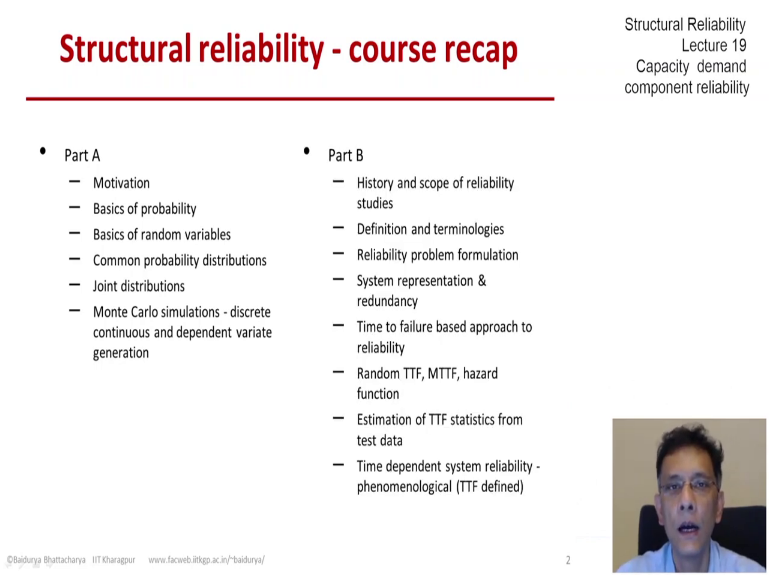

So, part A covered the motivation why we are learning this course we discuss the basics of probability basics of random variables. We discussed quite a few common distributions that occur in reliability and structural reliability in particular both discrete and continuous types we discussed joint distributions. And we ended part A with Monte Carlo simulations particularly a generation of discrete continuous and dependent random variants.

In part B we discussed how the subject came to be the subject reliability the early developments defined the relevant terms and then spent a good amount of time formulating the problems especially in the context of structures and then I went on to define a system in terms of its constituent elements and discussed the types of redundancy that occur in practice and how it can be compromised because of certain issues like common cause failure or dependence.

Then we spent a good amount of time in part b towards the end on time to failure and then time to failure-based approach to reliability in that context we discussed the reliability function the hazard function and metrics such as the mean time to failure. We also spent time on estimating these functions and statistics of the time to failure from test data and we ended part Bb with a description of system reliability from time to failure of the components.

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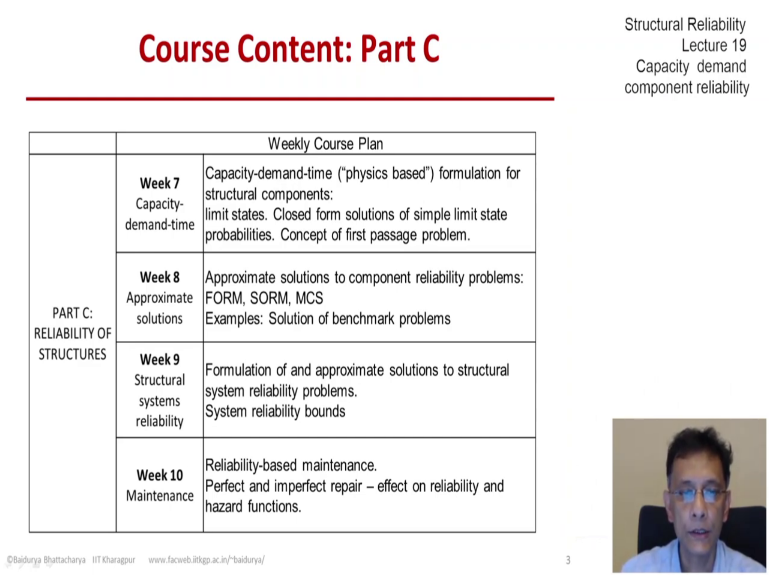

	Weekly Course Plan	
PART C: RELIABILITY OF STRUCTURES	**Week 7** Capacity-demand-time	Capacity-demand-time ("physics based") formulation for structural components: limit states. Closed form solutions of simple limit state probabilities. Concept of first passage problem.
	Week 8 Approximate solutions	Approximate solutions to component reliability problems: FORM, SORM, MCS Examples: Solution of benchmark problems
	Week 9 Structural systems reliability	Formulation of and approximate solutions to structural system reliability problems. System reliability bounds
	Week 10 Maintenance	Reliability-based maintenance. Perfect and imperfect repair – effect on reliability and hazard functions.

So, we now start part C and let us see what we had presented as part of the course plan when we started the course in the very first lecture. So part C is going to be the longest part four weeks in all. And so, we want to cover the capacity demand and particularly capacity demand time approach to reliability. So, in the context of that we are going to discuss limit states and close some solutions of simple limit state problems approximate solutions like FORM which is first order reliability method SORM which is second order reliability method application of Monte Carlo simulations.

And then some variance reduction techniques such as important sampling because in the; end we are actually trying to estimate rare probabilities. Then we also want to discuss some system reliability formulation and that will be time invariant we are going to just look at a structural system in terms of its constituent elements it could be both functional components of the structure like beams and columns and others.

Or it could be the logical elements of a structural failure like bending failure shear failure deflection failure at several critical locations. Then we want to end part c with reliability based maintenance. So, we are going to bring back the time to failure based approach once again but that will be derived from the capacity demand approach. So, that is where the capacity demand time is the central theme of this part.

And we will discuss effects of repair and effects and the how that affects the hazard function and the reliability function. So, with that in mind let us recap some of the key aspects that we covered in the last part which is part B.

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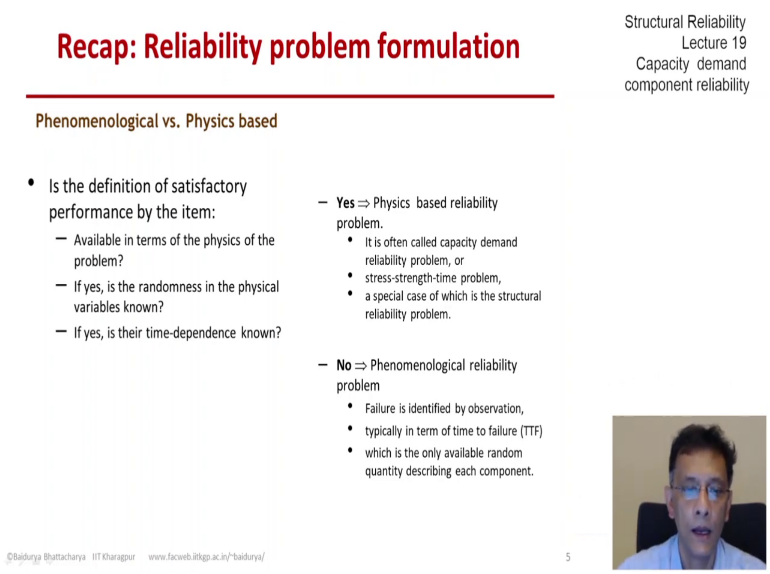

So, we had a way to differentiate a system reliability problem from a component reliability problem. So, this is how we approached it is the item of interest that we are trying to solve reliability for is it made up of two or more units that are logically or physically connected. So, that the item's performance can only be described and that is key can only be described in terms of the unit's performance.

And then obviously do I have data or model of these unit failures. If the answer is yes we have a system reliability problem where each unit that cannot be reduced further in this fashion is an element or a component. If it is not then we have a simpler problem and it is an element reliability problem and that is what we are going to start this part with. So, we are going to start with capacity demand and capacity demand time a formulation of just an element.

Then the distinction that we made between the physics based and phenomenological or observation based approach to failure and reliability is basically the idea of satisfactory performance or failure of the item in question is it available in terms of the physics of the problem. In our case since we are dealing with structures the mechanics the underlying mechanics. If so, do we know the randomness is involved including the time dependence if we have time dependent processes?

So, if the answer is yes then we have a physics-based reliability problem and again structures basically come under that category. And if the answer is no then we have a phenomenological problem and that is what we actually discussed the previous week under part B um.

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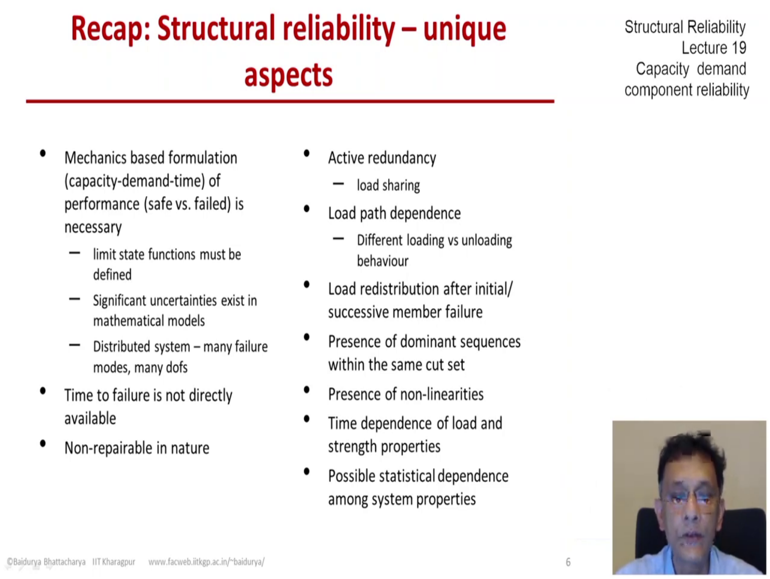

So, the next thing to recap would be. So, putting all of this together this component versus system or this physics based versus phenomenological where does a structure stand in terms of reliability. So, the first thing to note is that structures essentially pose a problem in terms of the underlying mechanics. So, the formulation has to be mechanics based and if time is involved. So, then we have capacity demand and time.

So, the capacity is in terms of mechanics the demand is also in terms of mechanics. So, we need that level of knowledge which means we are going to be able to define the limit state functions which we discussed in part B it is also true that uncertainties exist in our mechanics model. So, we have to be aware of that the systems are distributed in nature our structural systems there are many failure modes many degrees of freedom the time to failure as we saw in the previous slide is not directly available we cannot have identical structures loaded to failure many, many of them we do not have that luxury.

So, the time to failure is not directly observable these systems are non-repairable in nature we cannot just take them offline and replace with an identical new unit and restart the system that that does not work when I say unit I mean the whole system these are our structures are active redundant in nature because of load sharing and then there is load path dependence one of which is one of which manifests as different loading and unloading behaviour.

There is load redistribution because of this active load sharing aspect there is load redistribution after initial or successive element failures. And even if we are able to identify a card set the all the elements in the card set are not equally likely all the sequences are not equally likely. So, we need to identify which are the probabilistically dominant sequences within a cut set within a minimal cut set.

And obviously near failure structural behaviour becomes more non-linear in nature there could be time dependence because of aging effects and obviously because of time dependent hazards like natural processes wind waves earthquakes or even due to human behaviour some loads do vary randomly in time. So, that has to be taken into account and obviously the spatially distributed system properties whether it is elasticity or yield strength or other properties they could be there could be dependence in those properties distributed around the system. So, all of these things make structure reliability interesting and challenging to analyze.