NPTEL

Course On

STRUCTURAL RELIABILITY

Module # 01
Lecture 1

Course Format: Web

Instructor:

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1. Lecture 01: Introduction to Structural Reliability

The objective of any structural design is to ensure safety and economy of the structure operating under a given environment. For this purpose, designers always check whether the capacity of the structure exceeds the demand i.e.

$$Capacity\ (C) > Demand(D) \qquad 1.1.1$$

So long this condition is satisfied, the safety of the structure is ensured for the intended purpose for which the structure is built. Besides this, designers also ensure that there is an optimal use of the materials which, in turn, ensures economy. In this process, the designer uses some pre-fixed values of different design parameters like geometry, material property, boundary conditions and loads. However, experience shows that there is a significance difference between these fixed design parameters and their actual values during operations. The reason behind this phenomenon is that the design parameters are not deterministic, but random in nature. The uncertainties behind this phenomenon are classified into Cognitive and Non-cognitive based on their sources and nature. While the present lecture series aims to systematically address on how to incorporate the first kind of uncertainty by quantifying the parameters in the above mentioned equation for design, the discussion on the second kind of uncertainty (like human error etc.) is beyond the scope of this lecture series. Therefore, the Reliability or Risk assessment in structure design may be described as the procedure to incorporate the uncertainty in a systematic manner to ensure safety and economy. In this context, let us review the factor of safety based design often referred in different codes. The factor of safety (*fos*) is the ratio of the *C* and *D*. Although this remains fixed in a deterministic framework using conventional design procedures, there is an anomaly in uncertain environment –

- Two different structures having same *fos* can have different failure probability.
- Two different structures having same failure probability can have different *fos*.

With this in view, structural reliability provides a framework for –

- More precise and consistent design methodology in random environment
- Achieving a given level of structural reliability (i.e. failure probability)

- Decision making for non-routine cases which are difficult in conventional design framework

In this context, the safety checking and risk assessment are classified into three different levels –

- Level 1: Partial safety factor based approach of basic design variables
- Level 2: Checking safety and economy at some selected locations on the failure boundaries (i.e. limit states) considering uncertainties.
- Level 3: Exact assessment of safety based on detailed probabilistic analysis of the structural systems as a whole.

Organization of the Lectures

The present lecture series is divided in 9 modules. These modules describe following topics –

- Mod 1: General overview of the structural reliability and its role in civil engineering design.

- Mod 2: This module provides an overview of the necessary concepts of Statistics and Theory of probability so that the reader can follow its applications in future lectures. Those having background in Statistics and Theory of Probability may directly move over to next module.

- Mod 3: The fundamentals of Level-2 structural reliability analysis are described in this module. It describes different levels of reliability and their sequential developments. The idea of structural reliability is presented with the help of practical examples and their implementation in MATLAB.

- Mod 4: The readers are then introduced to the intricacies of different simulation techniques like Monte-Carlo simulation, Latin Hypercube Simulations and the advance techniques like variance reduction (e.g. Importance Sampling & Adaptive Sampling) and subset simulation.

- Mod 5: The treatment of implicit limit states using Meta models like Response Surface Method, Adaptive Response Surface Method and the recently developed Stochastic Response Surface Method techniques are explained with examples.

- Mod 6: With this knowledge of reliability analysis in hand, this module aims to explain the applications of these methods for code calibrations and reliability analysis under multiple failure modes (i.e. system reliability).

- Mod 7: In this module, the readers are introduced to structural reliability analysis under fatigue loading first. The discussion ended with further analysis and examples of time dependent reliability analysis.

- Mod 8: The application of reliability methods for structural design optimization is explained in this module with examples. The different methods of reliability based design optimization are explained in brief. Finally a brief introduction to Stochastic FEM and their role in reliability analysis is presented.

- Mod 9: Finally, the lecture series end with example cases for reliability analysis of complex real life structures using MATLAB and commercially available software for finite element analysis like ANSYS in batch mode.

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