

Structural Reliability
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Lecture –86
History Definition and Scope (Part - 04)

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Structural reliability – a brief history

Structural Reliability
Lecture 10
History
definition
and scope

- 1947: Freudenthal published “Safety of Structures”
 - Measurement uncertainty
 - Randomness vs. ignorance
 - Statistical variations in load and strength
 - Probabilistic basis of factor of safety
- “The laws of structural design must be considered a combination of **functional** and **statistical** relationships “
- Functional = obeying the **laws of the theory of structures**
- Statistical = **real physical properties appear as parameters** of the functional relations.
- There are cases in which apparently functional relations are **intrinsically statistic.**”

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As the electronics industry was investigating the reliability of its products in the 50's, 60's and beyond. The structural engineering community was also playing the pioneering role in formulating the safety of structures on a probabilistic platform. And the effort was led by Professor M. Freudenthal with the publication of his famous paper the safety of structures in 1947. What I have done here is taken out one or two sentences from that paper which identifies the key concepts of measurement uncertainty the difference of randomness and ignorance acknowledges statistical variations in load and strength and calls for a probabilistic basis of the factor of safety.

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Structural reliability – a brief history

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1947: Freudenthal "Safety of Structures" (contd.)

"[The safety margin] must provide for (1) The imperfection of human observations and actions (**uncertainty**); (2) the imperfections of intellectual concepts devised to reproduce physical phenomena (**ignorance**)"

"With increasing perfection of design methods ... "ignorance" can be largely eliminated; but ... "uncertainty" ...can never be removed. Hence **the safety factor** is a measure of uncertainty rather than of ignorance."

Note: These days, we refer Freudenthal's "uncertainty" as *statistical randomness*. The term **uncertainty** is loosely used as a generic catch-all word for *randomness, chance & ignorance*.

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If we continue reading that paper then professor Freudenthal clearly makes a distinction between uncertainty which we now understand as statistical variations versus ignorance which we now understand as epistemic uncertainty modeling uncertainty etcetera.

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Structural reliability – a brief history

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- 1956: Freudenthal publishes "Safety and the Probability of Structural Failure"
 - Probability based design standards
 - Direct / Indirect enforcement of target reliability
 - Risk based calibration
- Target reliability = "numerical values for the probabilities with which both failure and unserviceability are to be avoided"
- Minimize the "sum of the cost of the structure and the probable cost of failure or of unserviceability"
- "It is evident that the probability of failure of an important structure or of a structure the failure of which would endanger human life should be practically zero"
- comparison of the risk of failure or unserviceability with other risks of similar consequences may provide a first rough rule for the specification of an acceptable probability of failure or of unserviceability."

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A few years later Freudenthal published in 1956 his paper safety and the probability of structural failure in which he developed these concepts in far greater detail and we see the concepts of probability based design standards the seed of that idea and particularly his understanding on target reliability. How to enforce that target reliability in design and how to calibrate that target

reliability based on risks.

And in fact he clearly points out the relation between acceptable safety, safety standards and the consequences of failure.

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Structural reliability – a brief history

- 1960s
 - Natural hazard data and modeling
 - Load capacity formulation
 - Reliability bounds
 - Limit state design
- 1970s
 - Progressive collapse
 - First generation reliability based design standards
 - First order reliability methods
 - Acceptable safety
- 1980s
 - System reliability
 - Variance reduction techniques
 - Modeling uncertainty
 - Time dependent reliability
- 1990s
 - Second generation reliability based design standards
 - Performance based design
 - High dimension problems

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The subject of structural reliability grew in the 60's and beyond we see an emphasis on limited design natural hazards, data collection and modeling and the load capacity formulation that we do today. In the 1970s there was emphasis on development of reliability-based codes which we now call the first generation design standards a focus on progressive collapse led by the Ronan point disaster

The development of the first order reliability methods or form which we will study later in this course and continued investigation on acceptable safety or target reliability. There were emphasis on systems reliability variance reduction and development of time-dependent reliability concepts from a capacitive demand point of view which again we will look later in this course that was in the 1980s.

The 1990s saw refinement of the design standards the introduction of the concepts of performance-based design and a look at high dimension problems in reliability.

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Structural reliability – a brief history

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- 2000s
 - Nonlinear analyses
 - Robustness
 - Resilience
 - Interaction with other disciplines
like economics, sociology

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In this century we see the subject evolving into non-linear analysis the concepts of robustness, resilience and we see more and more interdisciplinary work taking place between structural safety and economics and sociology.