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On The Modeling and Analysis Of Robustness of Systems

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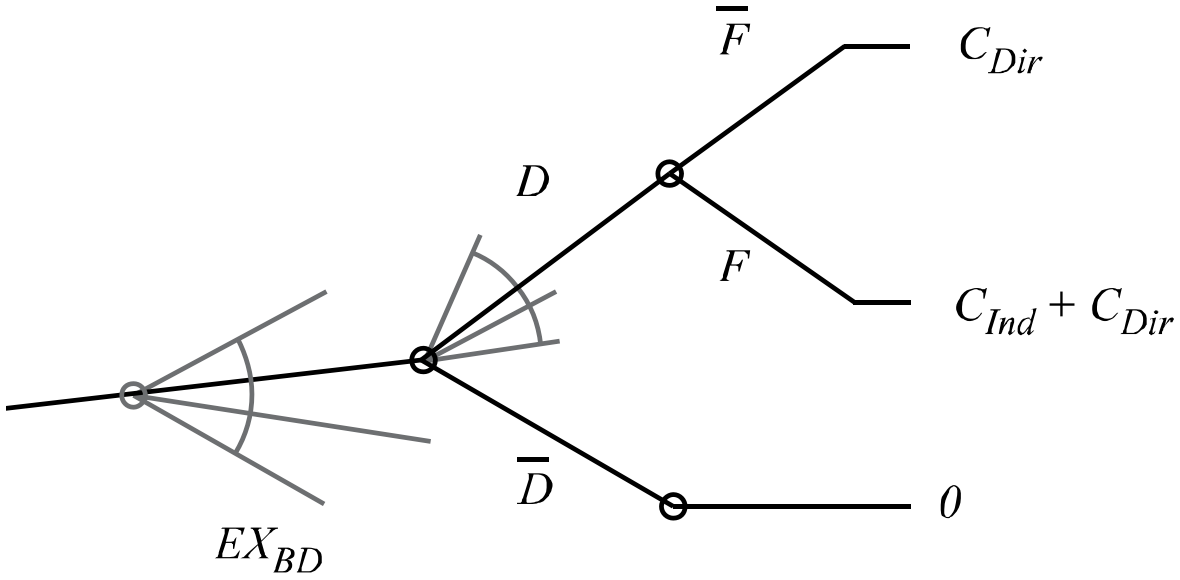
Overview

- *Introduction*
- *Concept of Robustness*
- *Why Robustness ?*
- *Robustness vs. Reliability and system interpretation*
- *Conclusions*

Introduction

- Consequences of collapse may exceed the renewal costs by a order of magnitude.
- Initiated by an event a complex series of mechanisms may lead to large damage or failure.
- The extend to which consequences are generated depends not only on structural characteristics.
- A risk based approach can help to identify events and scenarios, critical components and measures to improve the robustness of systems.

Concept for the quantification of robustness



$$I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk}$$

The Index of Robustness

- This risk based approach allows for
  - consideration of any available information.
  - facilitates for assessing the robustness conditional on different scenarios.

- The Robustness index takes into account the
  - structural performance
  - functionality and
  - significance of the structure.

Why robustness?

Why is the notation “robustness” needed ?

Why robustness?

- Engineered facilities are designed by combining single components to fulfill a desired functionality.

- Each single member has an acceptable performance.

- Every structure is unique - the assembly of the components can be done in several ways which lead to the same functionality but to a different performance.

Why robustness?

The actual design use the following descriptors to characterize the system:

- functionality of the structure
- performance of the constituents (members, joints, etc.)
- the load and the load distribution
- design, execution and assembly

But: structural systems are complex system

Why robustness?

We have to model the system by describing each part of the system.

– and each part of the system has to be described in relation to the behavior of all other parts.

Complexity of systems can be characterized by the amount of information needed to describe the system.

Any simplification in the modeling will therefore lead to a loss of information.

Why robustness?

The established model may not reflect the real performance of the system.

- Code based design focuses on individual components.
- Omits influence of dependencies between component performance and failure modes.

These are the short comings of the system representation

- Decisions on this basis might be sub-optimal.

Why robustness?

Robustness is needed to transfer additional information from the system to the components.

A probabilistic risk based approach taking into account all consequences and system characteristics would lead to optimal decisions.

→ Robustness is required to ensure an adequately low risk for progressive failure in a component based design.

Robustness vs. Reliability of systems

- Component reliability vs. direct risk

- System reliability vs. Robustness

→ Careful system interpretation and characterization is needed in both considerations.

→ The efforts are the same in both considerations.

→ Robustness considerations contain more information of the system than pure system reliability considerations.

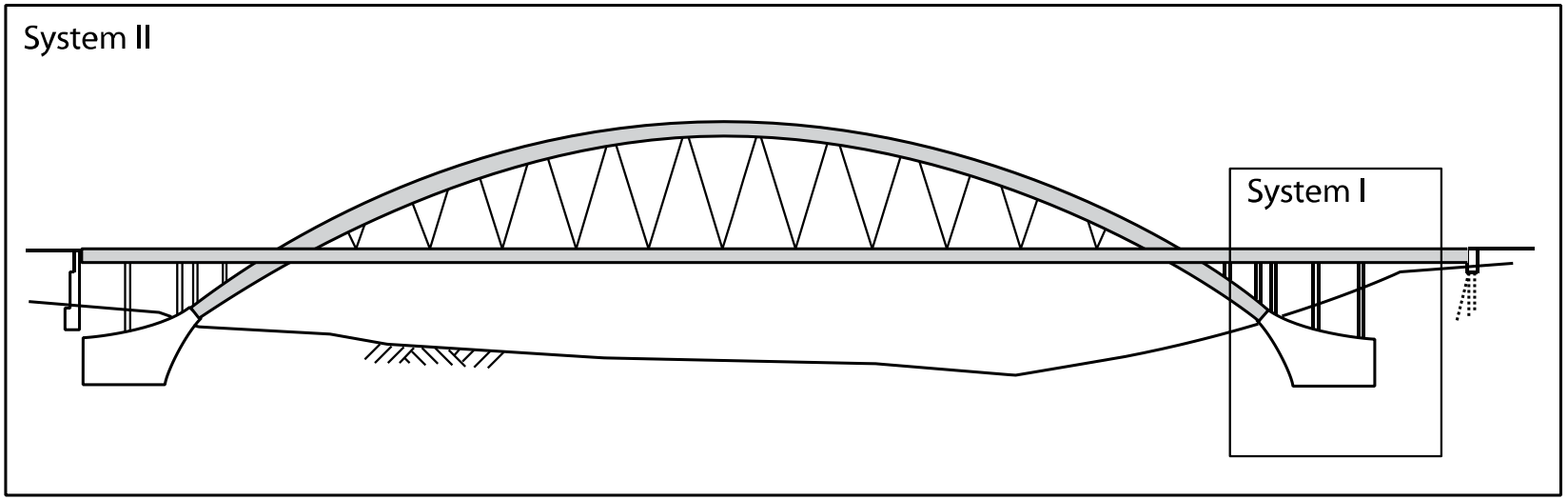
Robustness vs. Reliability of systems

- System reliability depends on:
  - Exposures (type, space and time).
  - Structure (interaction, complexity, representation).
  - Definition of the damage and failure.

Robustness vs. Reliability of systems

- System robustness depends on:
  - Exposures (type, space and time).
  - Structure (interaction, complexity, representation).
  - Definition of the damage and failure.
  - Types of consequences: direct and indirect.

System interpretation



- Both systems have fixed boundary conditions.

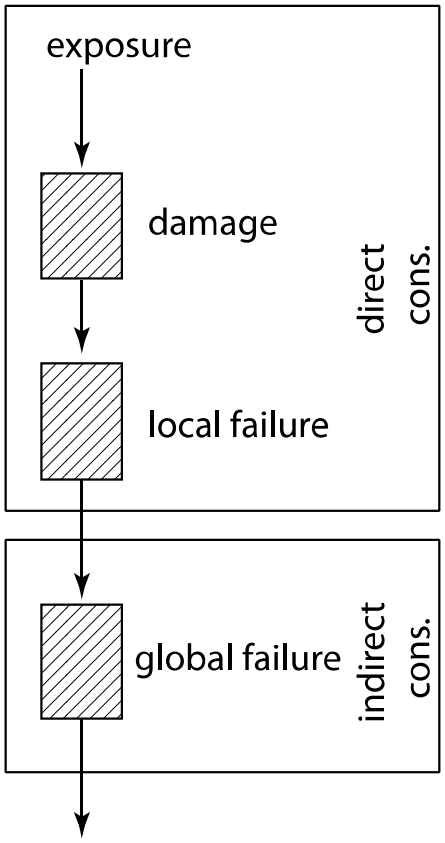
- Changes in the system results in changes of the types of consequences.

- For fixed systems the types of consequences are fixed
  - robustness for different configurations can be compared.

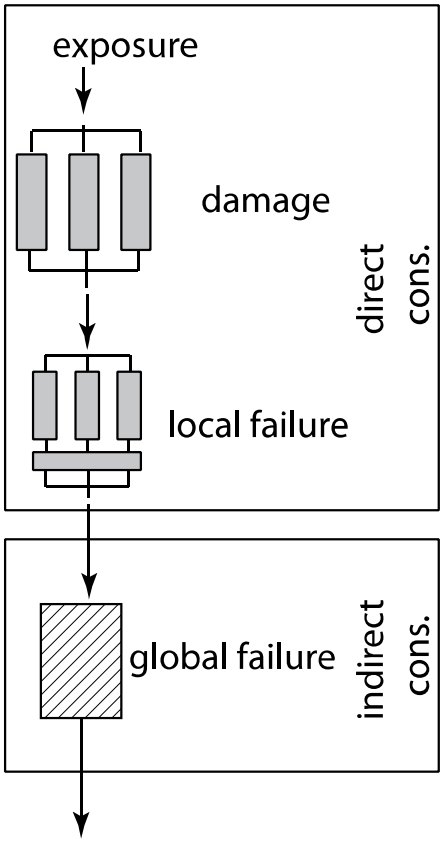
System interpretation

– Level of detail might differ – the risk remains the same.

System definition II



System definition II



Conclusions

- Robust requirements to structures are relevant due to the emergent properties of complex systems.
- There is a need to transfer information from the system level to the component level.
- A quantitative measure of robustness which contains this information could be utilized in a component based design.
- A standardization of the definition of the boundary conditions, a common idealization of the system and a characterization of the system performance is needed.

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Thank you for your attention