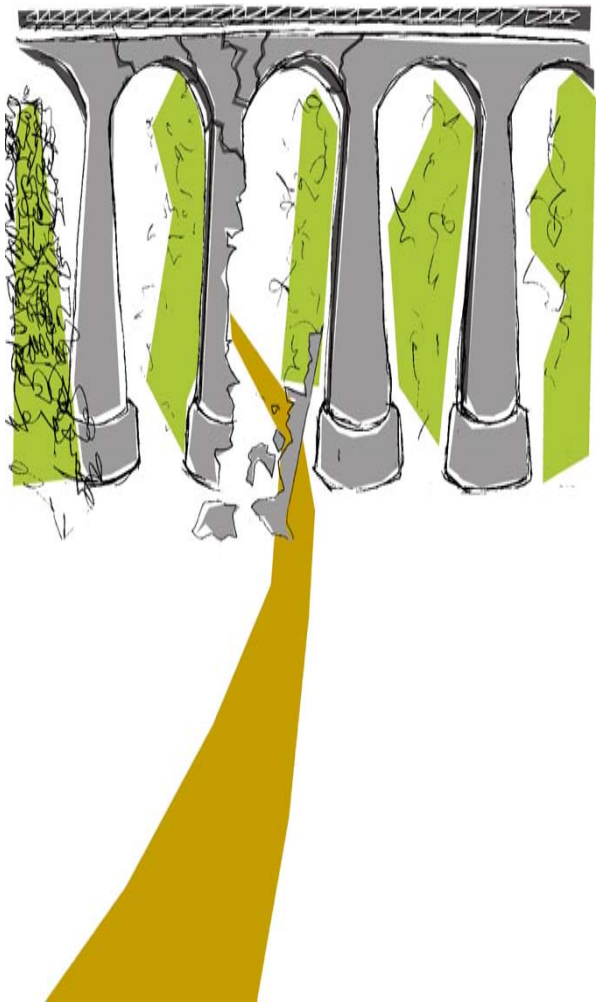
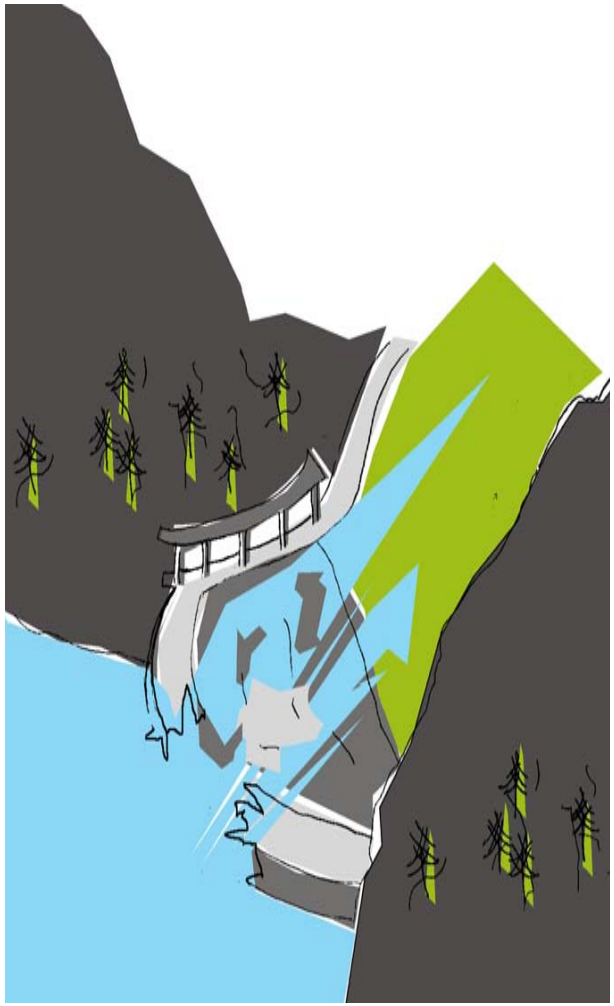


On the Assessment of Robustness II

Numerical Investigations

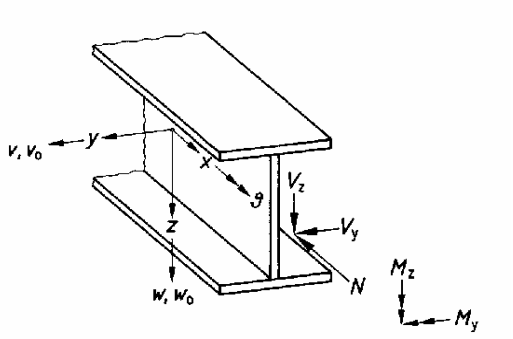
Matthias Schubert,
Daniel Straub,
Jack W. Baker,
Michael H. Faber

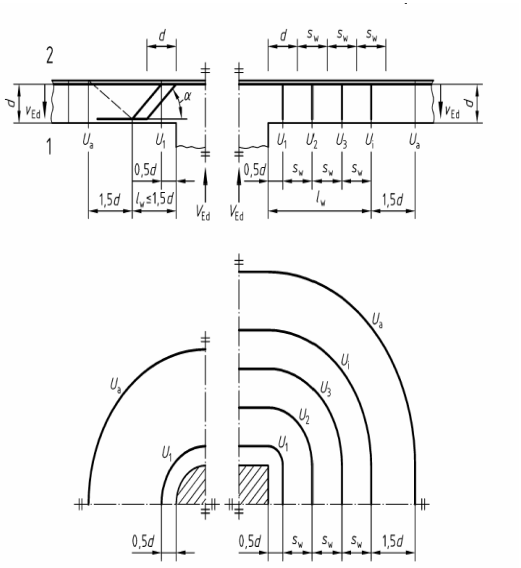
Institute of Structural Engineering IBK
Chair of Risk and Safety
ETH - Zürich



Overview

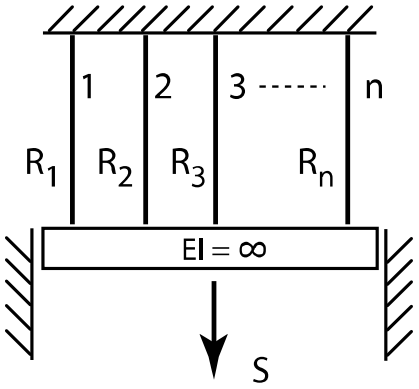
- Introduction
- Structural systems & exposures
- Effect on robustness of
    - Number of elements / load variability
    - Failure consequences
    - Load redistribution
    - Extraordinary loads / repair
- Conditional robustness
- Discussion
- Conclusion





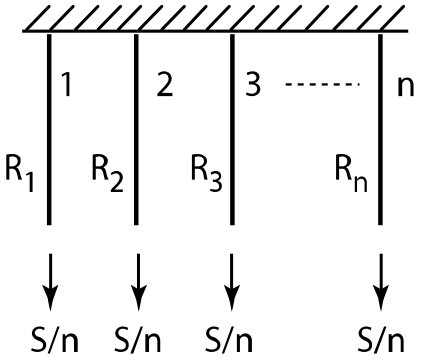
Introduction

- Codes provide instructions for design of the components
- Robustness is recommended by the codes
- Robustness is related to
  - redundancy
  - ductility
  - reliability
  - behavior after damage

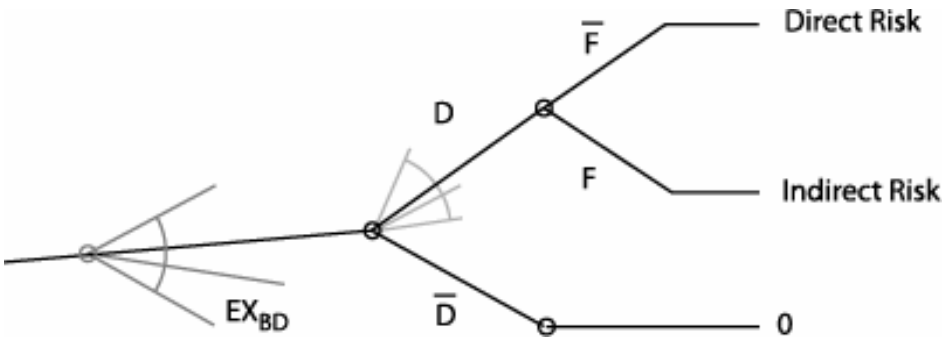


Structural Systems

- Parallel system with *n* elements
- Subjected to different types of exposures
- Perfect ductile / brittle
- Load distribution after component failure
- Element damage / system failure
- The one element case represents series systems



- The systems are kept generalized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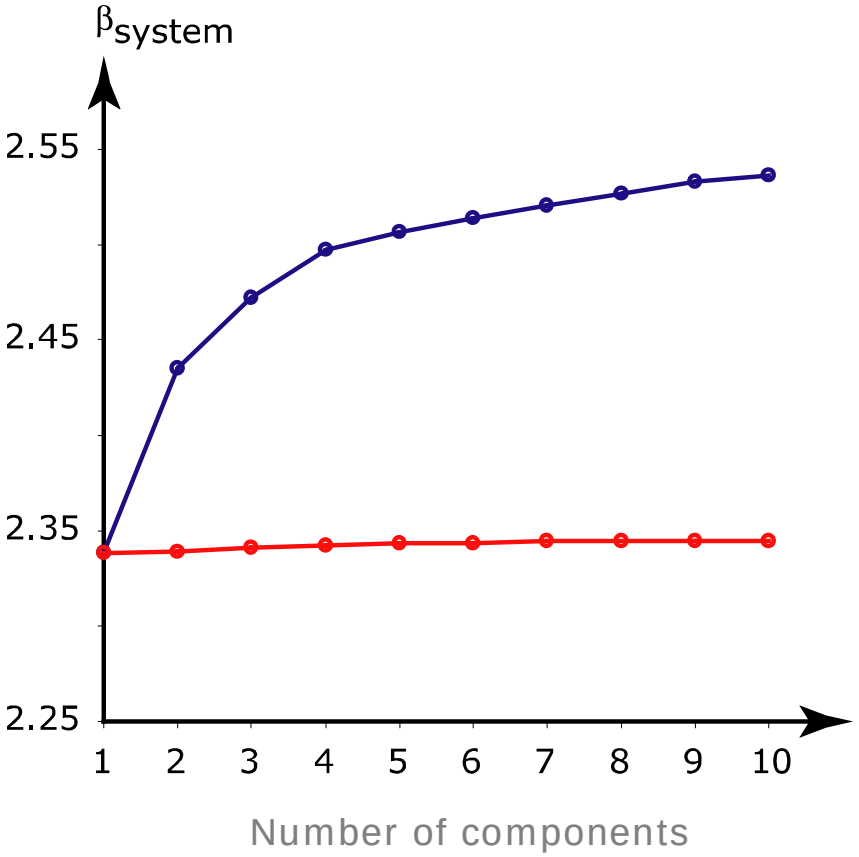
Exposures

- Dead load and live load
  - Weibull distribution

- Applied load is the yearly maximum

- Also unforeseen extraordinary loads are applied

- Each component has the same probability of failure

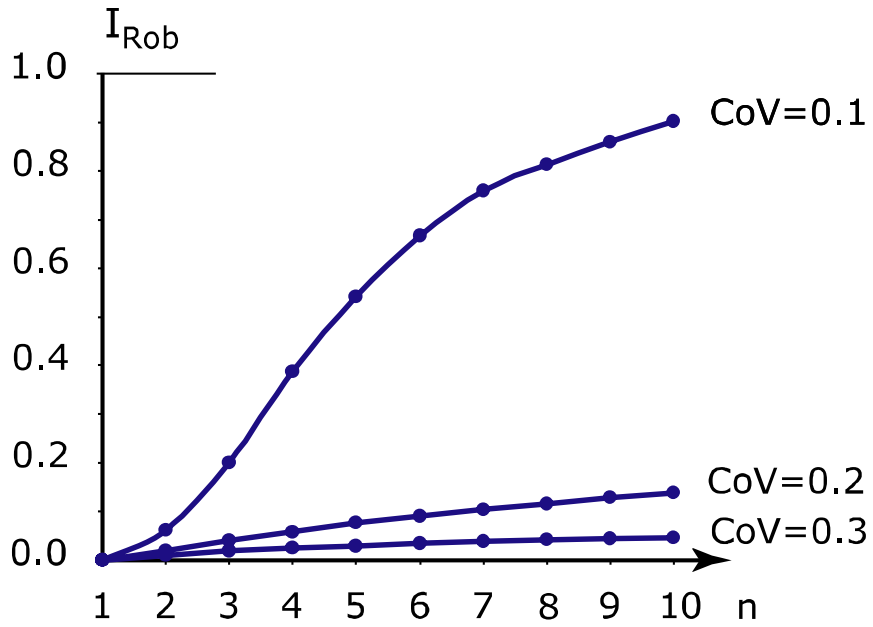


Number of components – ductile material

- The greater the number of components, the more robust

- One component – No robustness

- One component – Series system

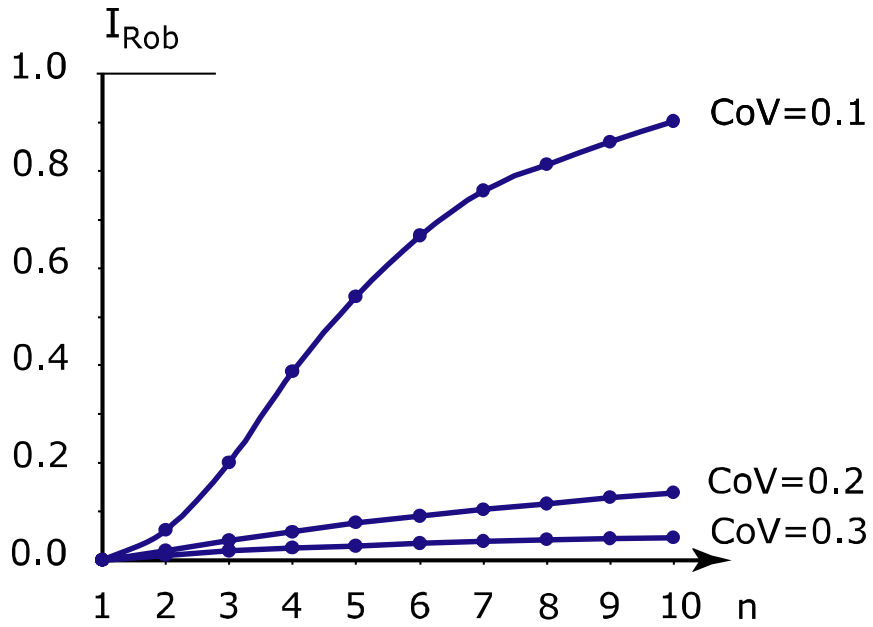


Load variability – ductile material

- Higher CoV leads to less robustness

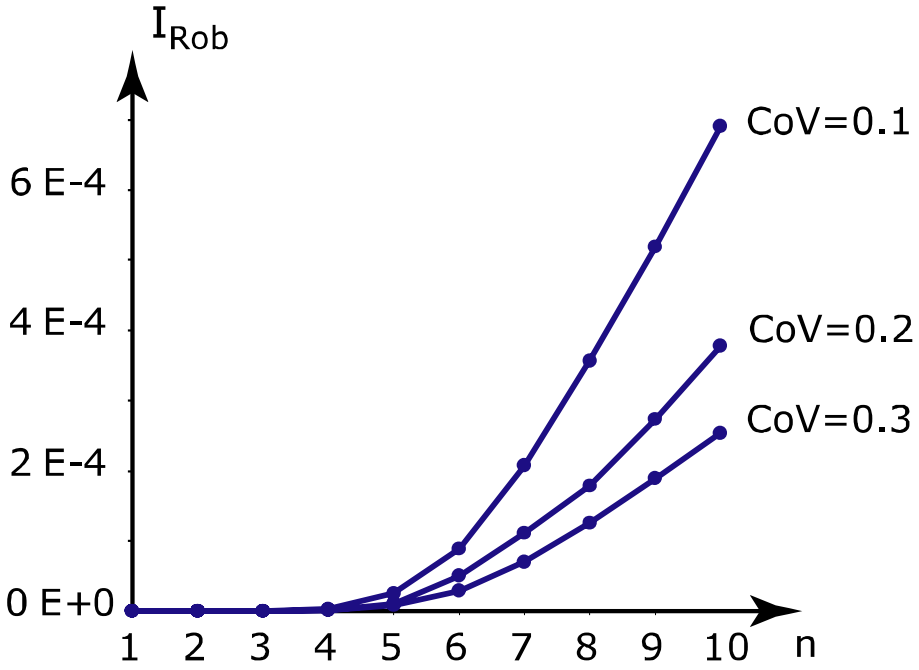
- Higher Cov increases the probability that the system fails if one component is damaged

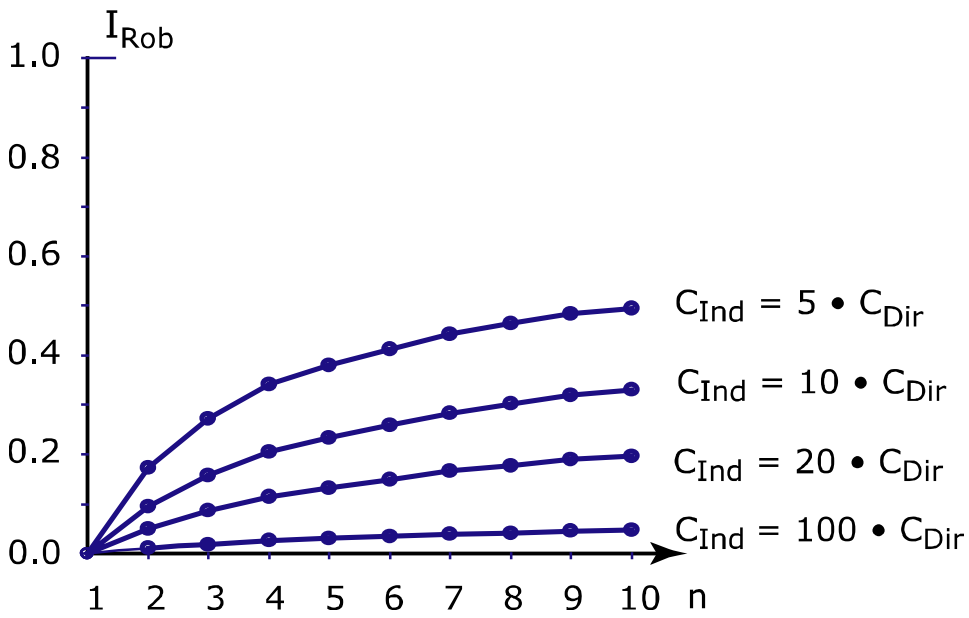
- Here uncorrelated resistance is assumed – Correlation has the same effect as reducing the number of components



Load variability – brittle material

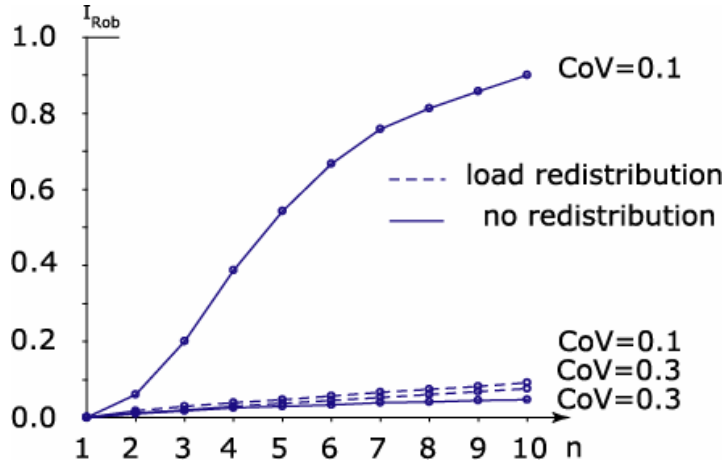
- No residual carrying capacity
- Cascading system failure
- The robustness is close to zero
- Indirect risks are dominating
- Probabilities for damage states are low – or failure consequences high

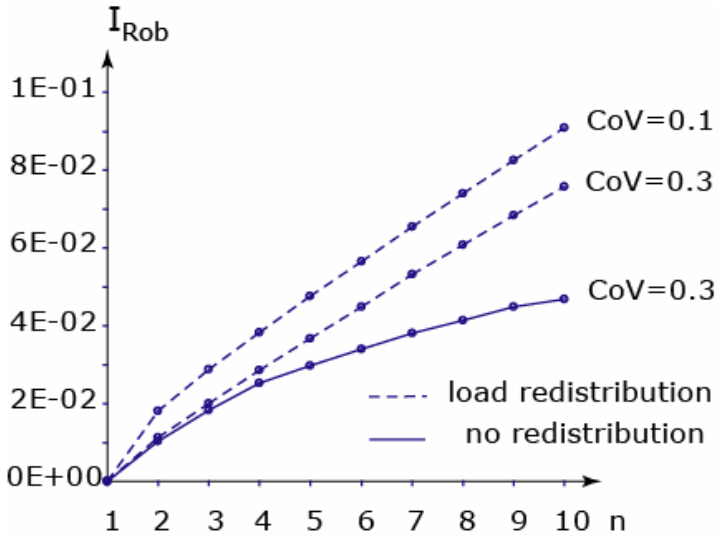




Failure Consequences

- The higher the indirect consequences, the lower the robustness
- Increase the robustness with
  - effective egress routes
  - decisions in rescue action
  - effective warning systems
- Effect of increasing the damage consequences
  - The robustness is related to reliability

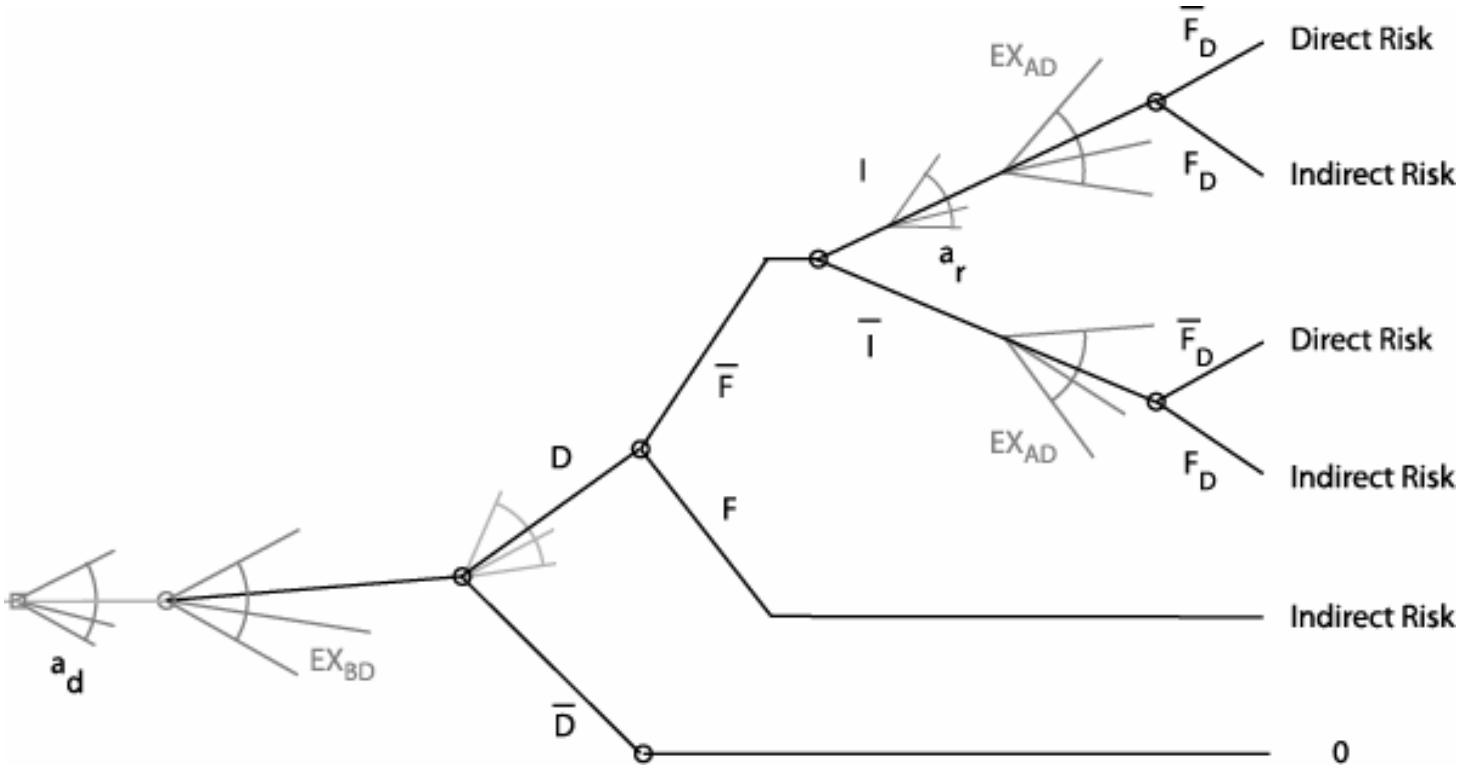




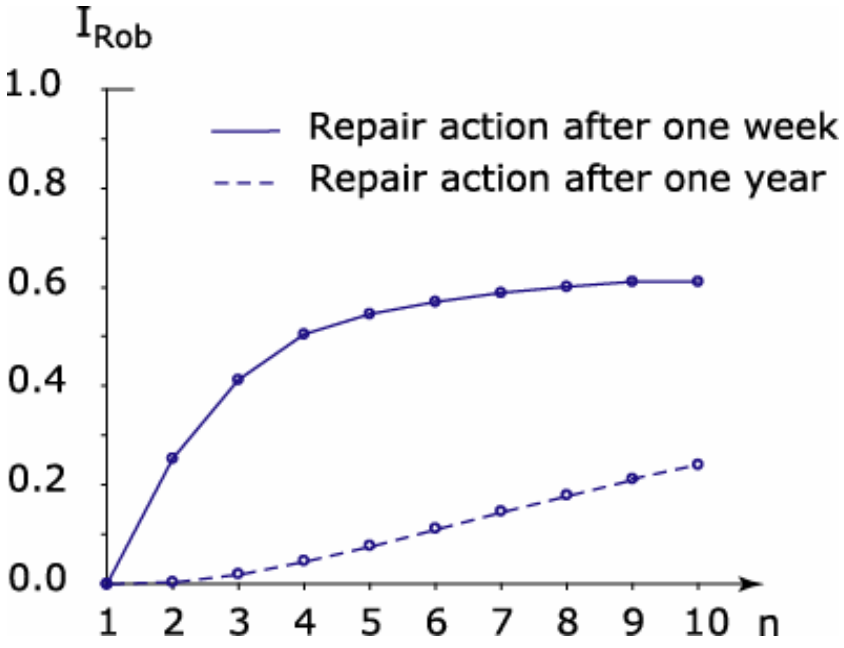
Load redistribution

- How is the load carried by the structure? Tie together or accept local failure?
- Load redistribution might increase system failure
- Indirect consequences occur in the case of local failure
- In some cases it is better to tie the structure together – but not in all cases.
- This robustness assessment can help to identify the proper strategy

Extraordinary loads / repair actions



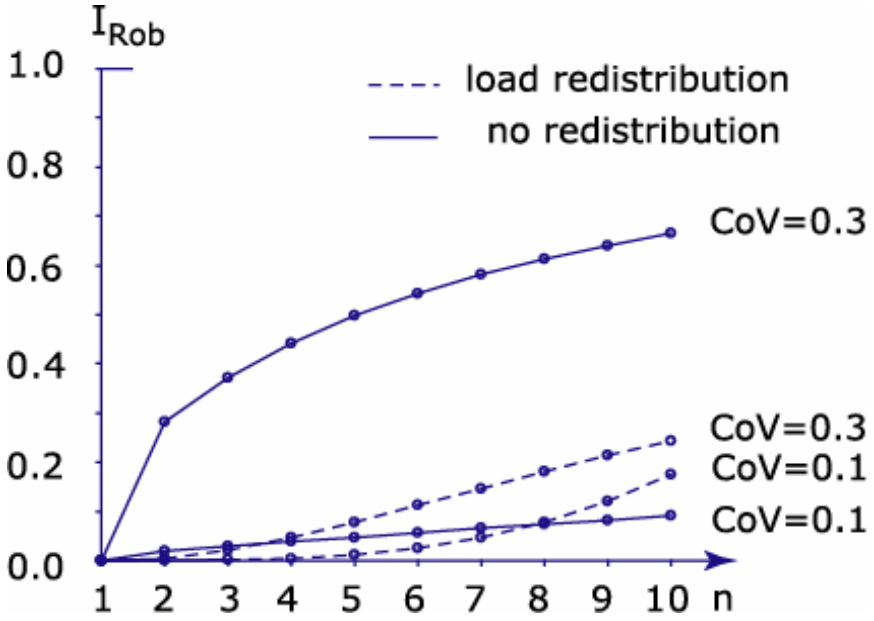
Extraordinary loads / repair actions



- Random load in time + accidental loss of one component
- The structure is more robust when damage can be detected
- The robustness is also affected by actions such as monitoring and repair
- Imperfect damage detection or partial repairs can easily be included

Conditional robustness

- Loss of one component is assumed
- Information about structural performance
- Other damage states can be investigated
- Useful if the triggering event or the probability is unknown
- Different CoV and system properties are investigated
- Different strategies can be investigated to identify highest robustness

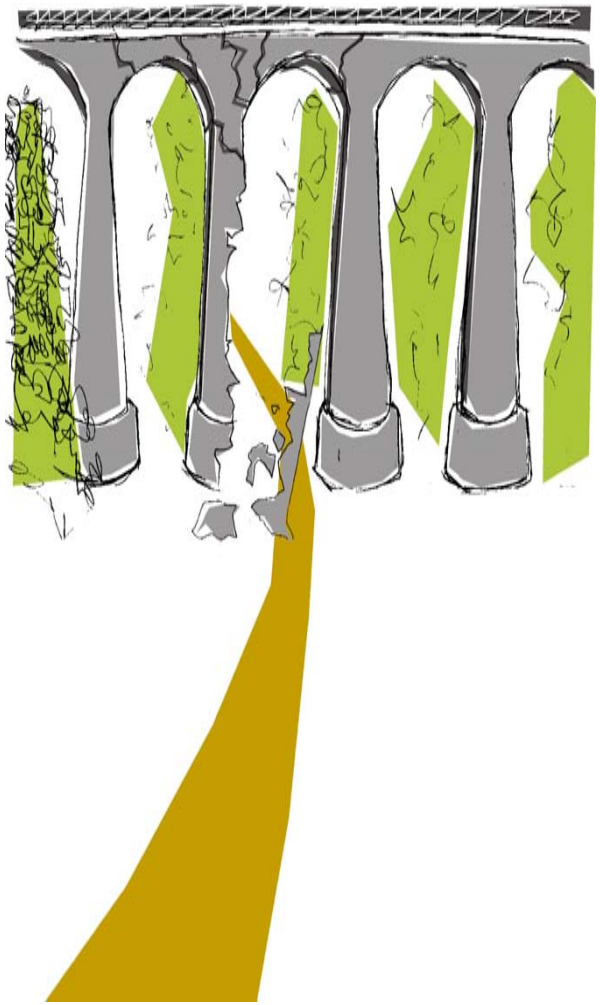


Discussion

- This first study of general systems showed the potentials of the index

- Further work:

  - Identification of index values that indicate acceptable robustness
  - Application for decision making, to identify efficient action
  - Investigation of local failure consequences
  - Identification of simplified design guidelines for codes

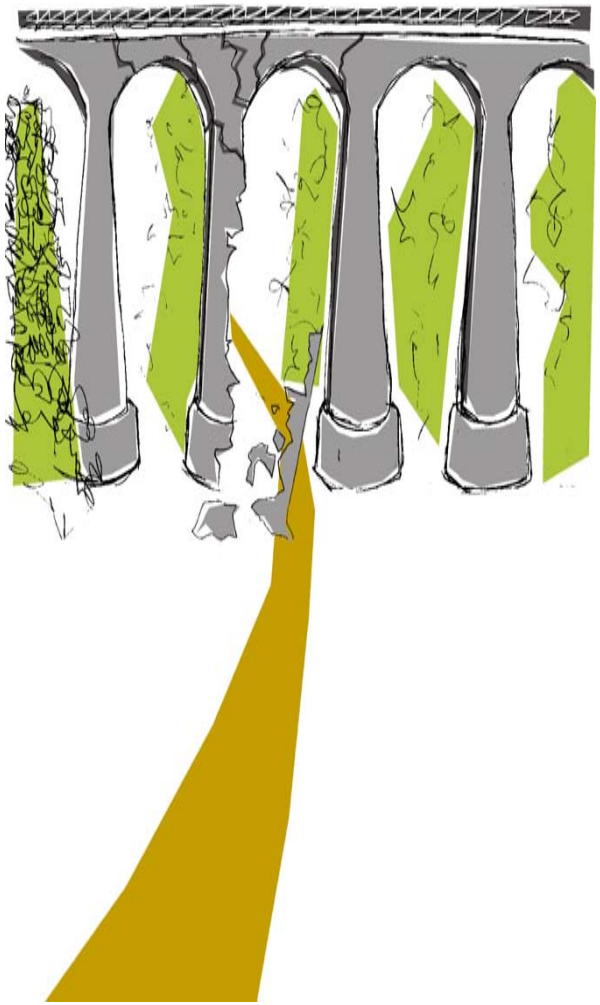


Conclusions

- The index shows that system robustness is increased by
  - Increasing redundancy
  - Lowering variability in the load
  - Increasing ductility
  - Decreasing failure consequences

- The index accounts for actions such as evacuations and repair

- The index accounts for the time when actions are taken



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Thank you for your attention