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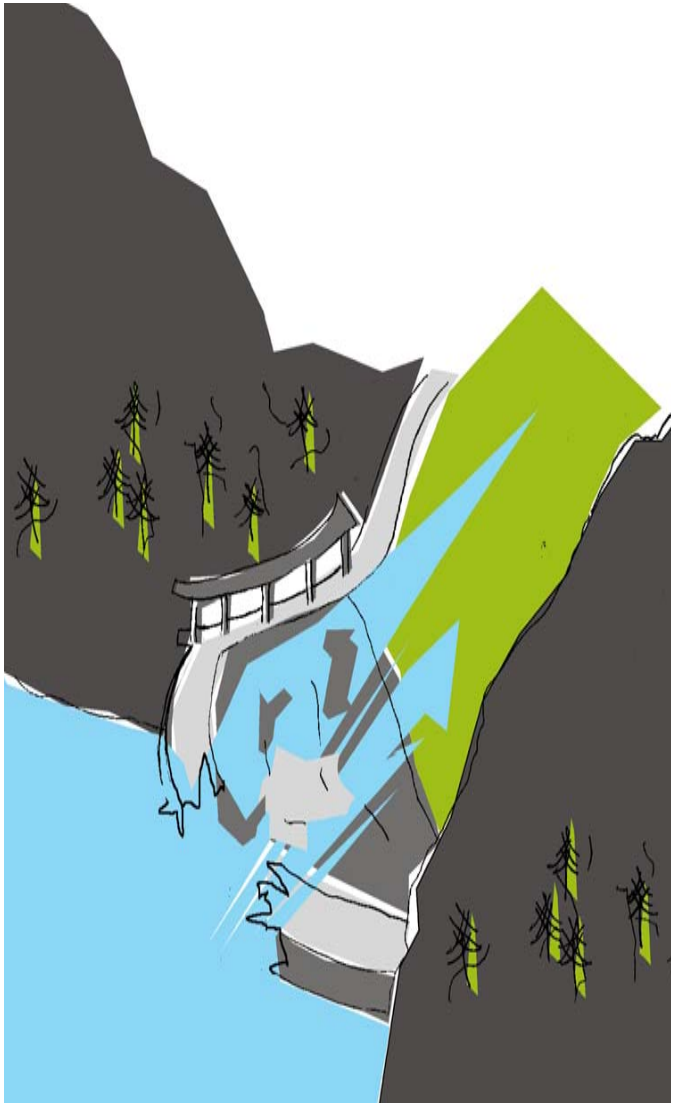

Probabilistic Assessment of the Robustness of Structural Systems

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Introduction

- Robustness is generally accepted as a characteristic of a good system design
- Objective quantification of robustness is needed
- A risk-based method for measuring robustness is proposed here
- Robustness is interpreted here as damage tolerance:

  "the consequences of structural failure should not be disproportional to the effect causing the failure"

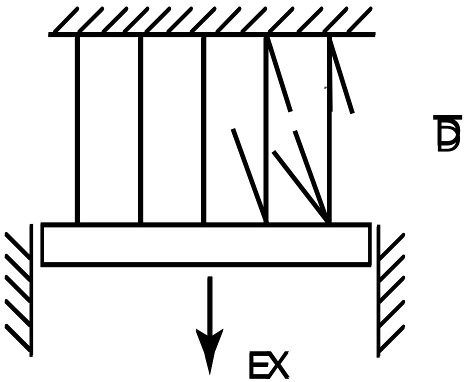
Introduction

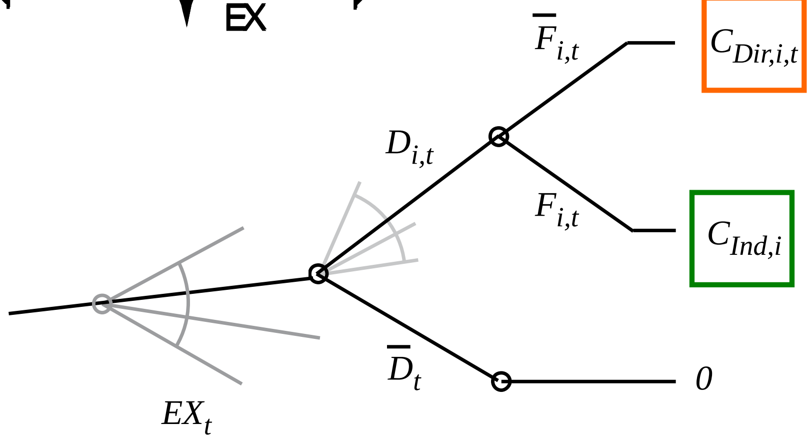
Desirable properties for a measure of robustness:

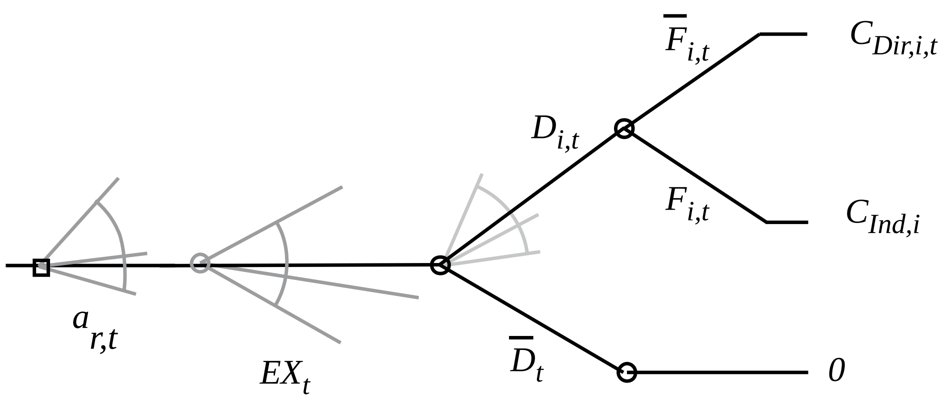
- General applicable to systems
- Allows for ranking of alternative systems
- Provides a criterion for identifying acceptable robustness

Framework

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







Robustness is related to:

- Redundancy
- Ductility
- Reliability
- Behavior after damage
- Consequences

The Index of Robustness

- Dependent upon the probability of damage occurrence
- Dependent upon consequences
- Depend upon the exposure
- Dependent upon post damage actions
- Is more than a characteristic of the structure

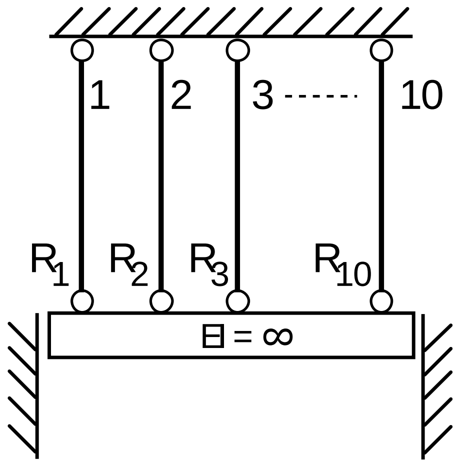
Effect of deterioration on the robustness

- Endogenous or exogenous effects might reduce the resistance over time
- The probability of failure and the probability of damage changes in time
- Intuitively, the robustness decreases over time

Effect of deterioration on the robustness

Structural System

- Parallel system with ten members
- Structural components are perfectly ductile
- Uniform redistribution of the load
- Marginal component failure probability 10^{-3}
- Initial resistance ~ LN(1.715,CoV=0.07)
- Time dependent degradation function (Faber and Melchers, 2001)

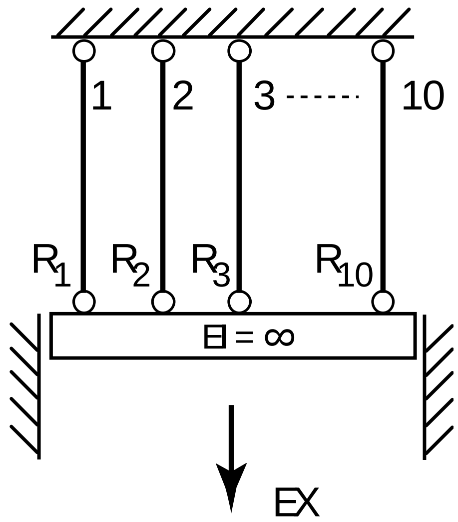


$$R(t) = R_0 \cdot \psi(t_a)$$

Effect of deterioration on the robustness

Exposure

- Dead load ~ N(0.3,Cov=0.1)
- Live load ~ W(0.7,Cov=0.3)

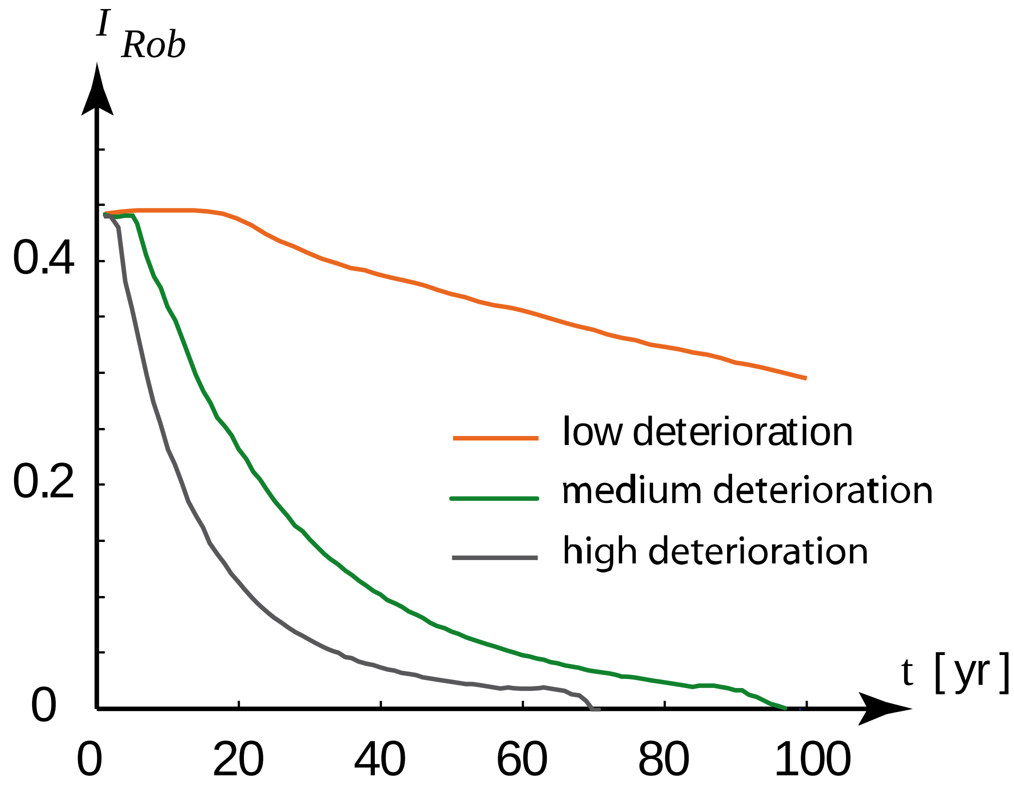


Consequences

- Damage consequences for a single component is equal to one
- Failure consequences are 100 times the damage consequences

Effect of deterioration on the robustness

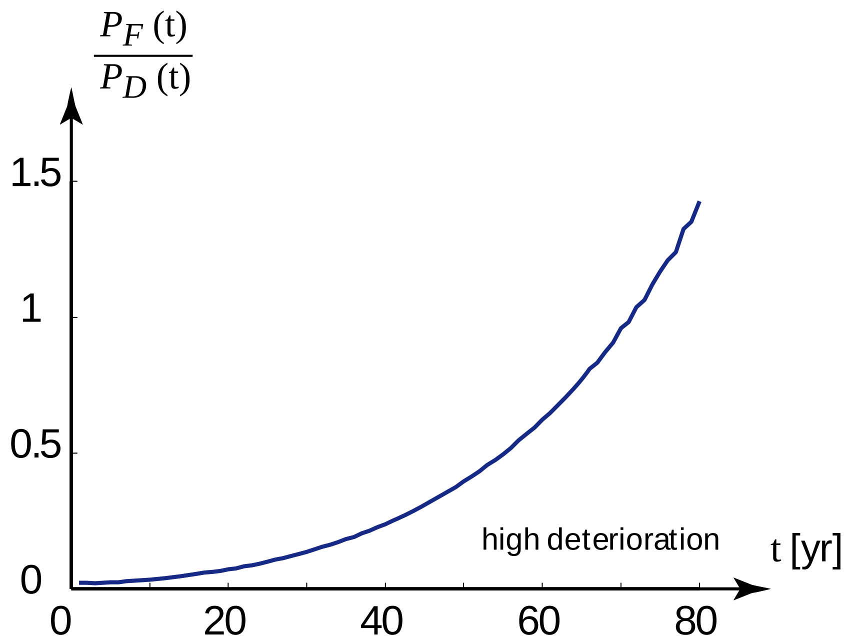
- Initial system is highly redundant
- The system seems to be robust
- The robustness decreases rapidly over time
- High robustness of the initial system compared to deteriorated system



Effect of deterioration on the robustness

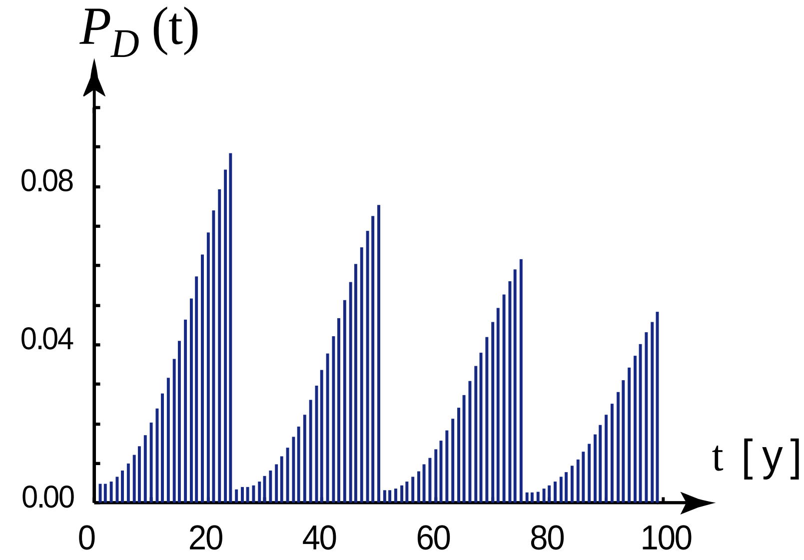
$$I_{Rob}(t) = \frac{\sum_i P_{D,i}(t)\cdot C_{Dir}}{\sum_i P_{D,i}(t)\cdot C_{Dir} + P_F(t)\cdot C_{Ind}} \approx \frac{P_{D,1}(t)\cdot C_{Dir}}{P_{D,1}(t)\cdot C_{Dir} + P_F(t)\cdot C_{Ind}} = \frac{C_{Dir}}{C_{Dir} + \frac{P_F(t)}{P_{D,1}(t)}\cdot C_{Ind}}$$

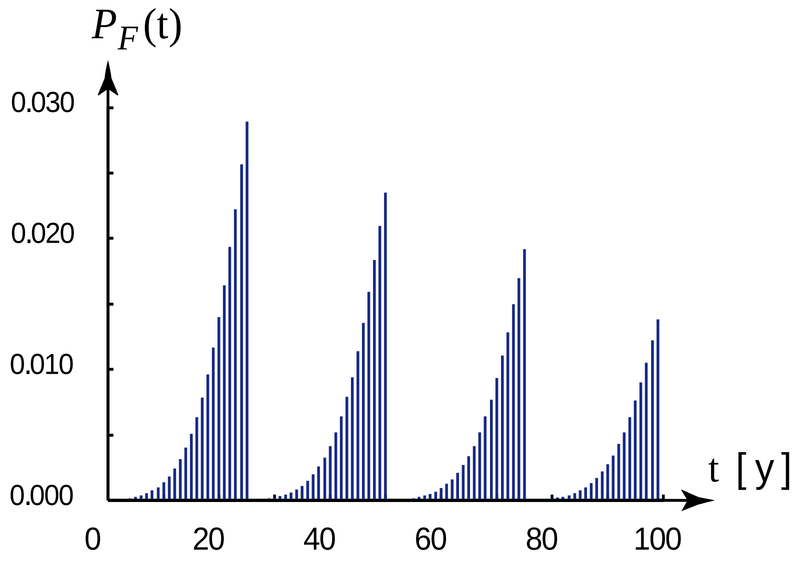
- Deterioration leads to a disproportional increase of the failure probability



Effect of inspections and repair actions

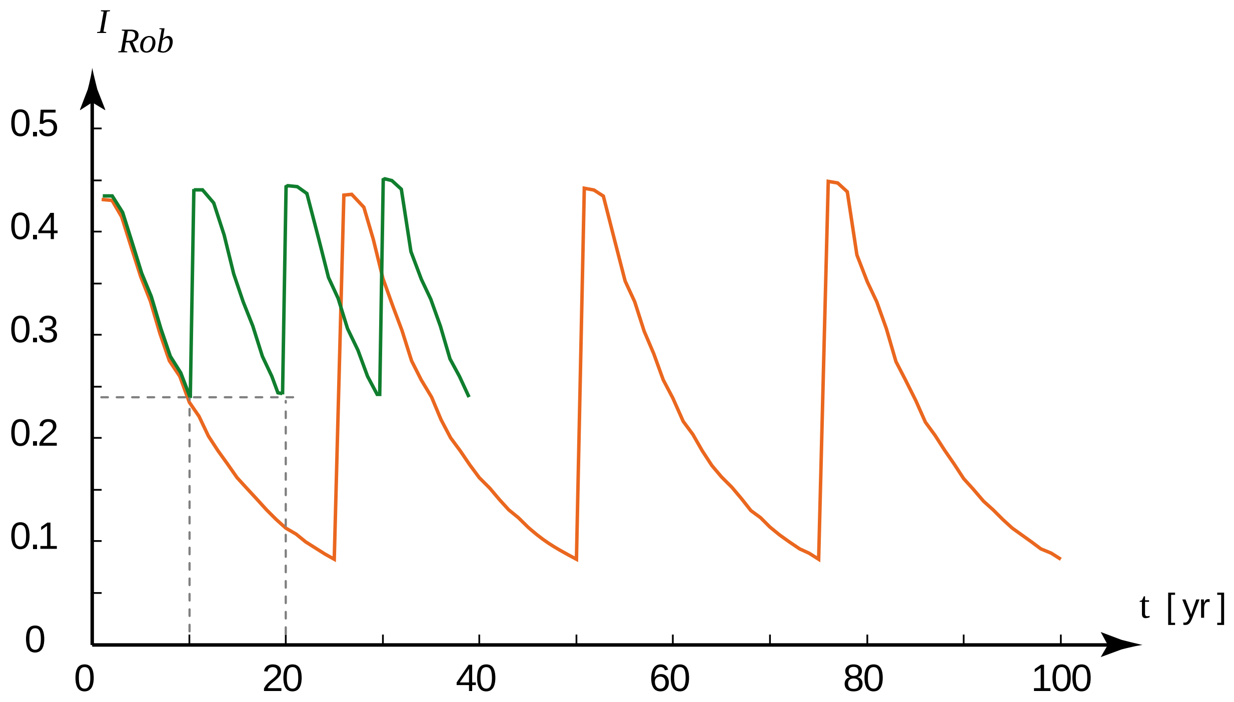
- High deterioration is assumed
- Inspection every 25 years
- Perfect repair actions are assumed





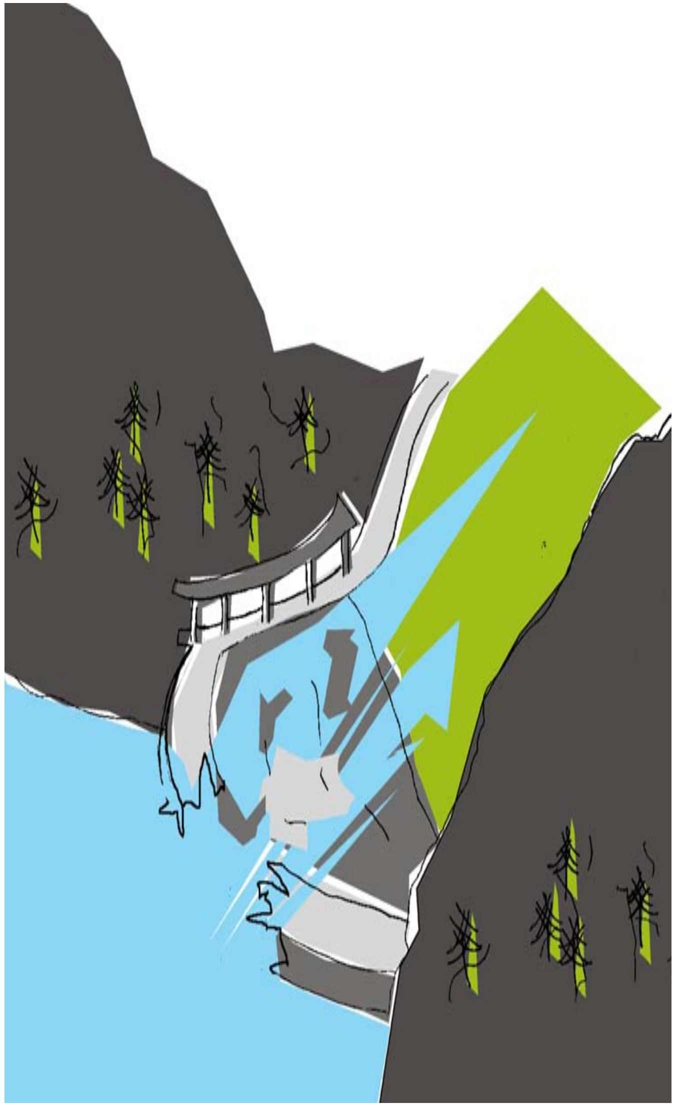
Effect of inspections and repair actions

- Repair and maintenance actions can increase the robustness
- The robustness can be kept above a certain level
- Robustness calculations can help to identify repair and maintenance strategies.



Conclusions

- The framework is based on risk assessment and decision theory
- The index of robustness facilitates the quantification of robustness
- It allows for the implementation of different mitigation measures over the life time of structural systems
- By implementing inspection and repair actions the robustness of a system can be controlled
- Further research is necessary to develop factors for a code based design including direct and indirect consequences.



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Thank you for your attention