Robustness of Structures

Discussion and Examples

Matthias Schubert
ETH Zürich, Institute for Structural Engineering, Group Risk & Safety

Michael H. Faber
ETH Zürich, Institute for Structural Engineering, Group Risk & Safety
Concept for the quantification of robustness

\[ I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk} \]
Aim of the presentation

- Discuss the concept of the distinction between direct and indirect consequences

- Discuss system effects on the robustness
Direct and indirect consequences

Overpass

Highway

Highway
Direct and indirect consequences

System 1: „Column“

Exposure:
- Vehicle impact
- Splash water
- Salt
...

Robustness

Vulnerability

Failure of the column

direct consequences

Corrosion of the reinforcement

indirect consequences
Direct and indirect consequences

System 2: „Bridge“
Exposure:
- Axle load
...

System 1: „Column“
Exposure:
- Vehicle impact
- Splash water
- Salt
...

Robustness
Vulnerability

indirect consequences
Bridge failure

direct consequences
Failure of the column

Failure of the column
Corrosion of the reinforcement
Direct and indirect consequences

System 1: "Column"
- Vehicle impact
- Splash water
- Salt

System 2: "Bridge"
- Axle load

System 3: "Highway network"
- Traffic
- Axle load
- HGV traffic

Exposure:
- Network failure
- Bridge failure
- Failure of the column
- Corrosion of the reinforcement

Types of consequences
- Direct consequences
- Indirect consequences

Risk assessment

Results

Conclusion
Example: Vehicle impact on a V-column bridge

- fatalities / LQI
- clean up costs
- rebuilding costs
- property damage
- user costs

System „V-column bridge“

Exposure:
- Vehicle impact on the column

- fatalities / LQI
- repairing costs
- property damage
- clean up costs
Introduction

Concept of robustness

Aim

Types of consequences

Risk assessment

Results

Conclusion

Highway

velocity

AADT

distance column

faction HGV

loosing track

impact

impact force / yr

prob dying

repair costs

SVSL

user costs

repair / clean up

Highway

Overpass

velocity

AADT

HGV

cars

normal force

failure bridge

failure column

damage column

highway damage

detour length

persons car

prob dying strike

strike car

bridge closure

detour length

velocity detour

SVSL

rebuild

user costs

SVSL
Contributions to the total risk

- Disportionality between the two types of the risk.

- Indirect risk dominates the total risk.

- User costs play major role.

- Can the index of robustness be increased by increasing the reliability?
Influence of the reliability on the robustness

- Increasing the reliability lead to increase of the robustness.
- The total risk can be reduced.
- Index (and the total risk) converge to an upper limit.
- Reliability is not the only characteristic which leads to robustness.
Contributions to the total risk

- High reliability – indirect risk still dominate the total risk.

- User costs contribute significantly to the total risk.

- Robustness is influenced by the location in the system - Redundancy

\[ R_{\text{tot}} = 4152 \text{ [CHF yr}^{-1}] \]
\[ \beta_{\text{sys}} = 4.45 \text{ [yr}^{-1}] \]
Influence of the redundancy on the system

- Redundancy leads to a reduction of the indirect consequences.

- Robustness can be increased by introducing redundancy into the system.

- Bridge (structure) change its characteristics (reliability, redundancy, etc.) with its location and significance in the network (system).
Conclusions

• Distinction between direct and indirect consequences is related to the problem settings, the decision maker and the definition of the considered system.

• The proposed index of robustness is applicable to complex and realistic systems.

• It accounts consistently for different robustness related aspects such as reliability and redundancy.

• Robustness (and reliability) are not just characteristics of the static system.
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Thank you for your attention