Robustness of Infrastructures Subject to Rare Events

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Overview

- **Introduction**
- **Concept of Robustness**
- **Risk assessment using Influence Diagrams**
- **Results**
- **Conclusions**
Introduction

- Robustness is generally accepted as a characteristic of a good system design

- Objective quantification of robustness is needed

- Robustness is interpreted here as damage tolerance:

  The consequences of structural failure should not be disproportional to the effect causing the failure
Concept for the quantification of robustness

\[ I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk} \]
The Index of Robustness

\[ I_{Rob} = \frac{Direct\ Risk}{Direct\ Risk + Indirect\ Risk} \]

- Assumes values between zero and one
- Measures relative risk only
- Dependent upon the probability of damage occurrence
- Dependent upon consequences
- Is more than a characteristic of the structure
Risk Assessment

- This concept is applied to a V-column overpass consisting of:
  - pre-stressed box girder
  - columns
  - tension elements

- The risk due to vehicle impact is calculated by using influence diagrams
Overview

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**Overpass**

![Diagram of an overpass structure with labeled components]

**Highway**

- velocity
- AADT
- distance column
- faction HGV

- loosing track
- impact
- impact force / yr

- failure column

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Overpass

Highway

Highway

Overpass

\[ P_f \]

\[ N = 0.4 \text{ MN} \]

\[ N = 0.8 \text{ MN} \]

\[ N = 1.2 \text{ MN} \]

Impact load

[ MN ]

0.0

0.2

0.4

0.6

0.8

1.0

1.2

1.4

0.0

0.2

0.4

0.6

0.8

1.0

1.2

1.4

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Direct Consequences

- fatalities / LQI
- repair costs
- property damage
- clean up costs
Indirect Consequences

- fatalities / LQI
- clean up costs
- rebuild costs
- property damage
- user costs
Indirect Consequences

- fatalities / LQI
- clean up costs
- rebuild costs
- property damage
- user costs
Measures to increase the robustness – Structural performance

- Increase reliability of components – vulnerability of one member is reduced
- Expected value of the indirect consequences decreases faster than direct consequences
Measures to increase the robustness – Structural performance

- Increase reliability of components – increase of the damage tolerance.

- The index is converging to an upper limit.
Measures to increase the robustness – System performance

- Reduction of consequences
- Indirect risk increases disproportional to the average daily traffic
Measures to increase the robustness
– System performance

• Increase the redundancy of the roadway network

• Affects mainly the risk due to user costs

• User costs have a large influence on the decision making in roadway networks
Conclusions

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

- It accounts consistently for different robustness related aspects.

- It is shown that influence diagrams have a large potential for the risk assessment of rare events.

- The site and object specific character of rare events can be accounted for by implementing specific information in the network.

- Further work is necessary to set criteria's for acceptable values of the index of robustness.
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Thank you for your attention