Basis of Assessment of Structural Robustness

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Introduction

• Developments of high-performance materials, construction technologies and methods of structural analysis - design of ***complex*** and ***slender structures vulnerable*** to extreme events

• ***Robust*** structures - significantly ***reduced consequences***

• Requirements and methods for assessment of robustness in ***codes*** - ***vague*** and ***insufficient*** for practical use

• The ***contribution*** attempts to:
- present achievements of the ***COST Action TU0601*** Robustness of Structures (2006-2011)
- provide an ***illustrative example*** on decision making about robustness measures

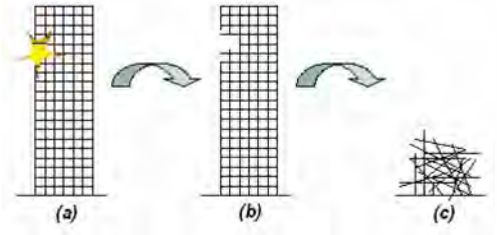
Definitions of robustness

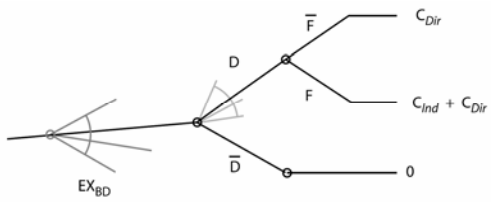
• ***EN 1990*** - sufficient structural reliability can be achieved by suitable measures such as ensuring an appropriate degree of ***robustness*** (structural ***integrity***)

• ***EN 1991-1-7*** - ability of a structure to withstand extreme events without being damaged to an extent ***disproportionate*** to the original cause

• Useful definitions - indicator of the ***ability of***:
- ***structure*** to perform adequately under accidental situation
- ***system containing*** a ***structure*** to perform adequately under accidental situation of the structure

Assessment of robustness





a) ***Exposures***

• Models of exposures *EX*

b) Local damage (***direct consequence***)

• Damage *D*, or undamaged state $\tilde{D}$

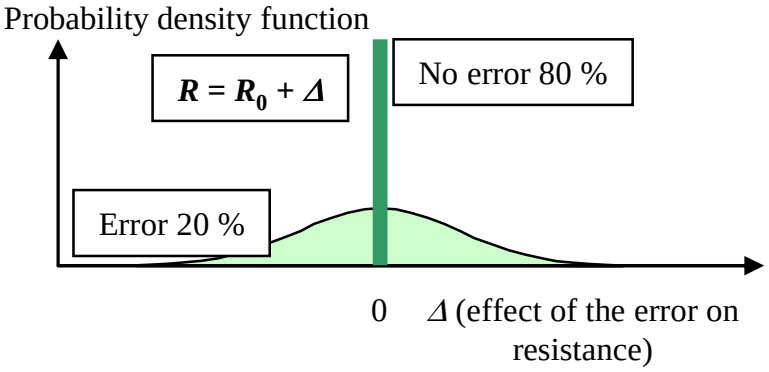
c) Collapse (***indirect consequence***)

• Collapse *F* or structural survival $\tilde{F}$

• An example of ***indicator***: $I_{\text{rob}} = \dfrac{R_{\text{Dir}}}{R_{\text{Dir}} + R_{\text{Ind}}}$

Exposures

- ***Probabilistic characteristics*** of exposures:
  - ***Known*** and dealt with (normal loads, some accidental actions)
  - Known in principle, but ***unrecognized*** or ignored (accidental actions, human errors)
  - ***Unknown*** (lack of knowledge of the profession) or unforeseeable (some human errors)

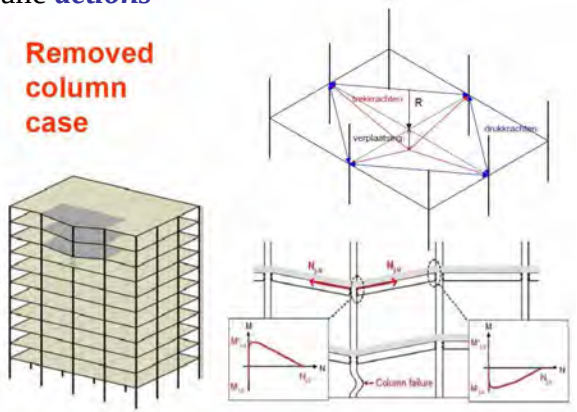


Structural models

- Structural models – analysis of various damage scenarios, estimation of the ***probability*** of the ***collapse***:
  - partly ***damaged*** structure
  - large cracks and/or plastic ***deformations***
  - ***catenary*** or membrane ***actions***
  - high temperatures
  - ***dynamic*** effects

- ***Validation*** with available experimental data

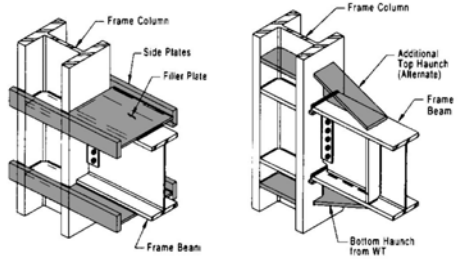
- For selected cases ***simplified design rules***

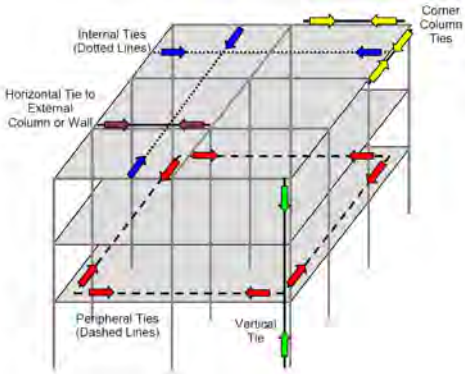


Design principles

- ***No universal approach***

- ***Reduction*** of the probability of ***collapse***:
- ***Redundant load paths***
- An integrated system of ***ties***
- ***Ductility*** of structural members and connections
- ***Resistance*** to ***brittle failure***
- Exterior ***columns*** and walls capable to ***bridge over*** several ***stories***
- Increased ***reliability*** of ***key*** structural ***elements***
- ***Maintenance***





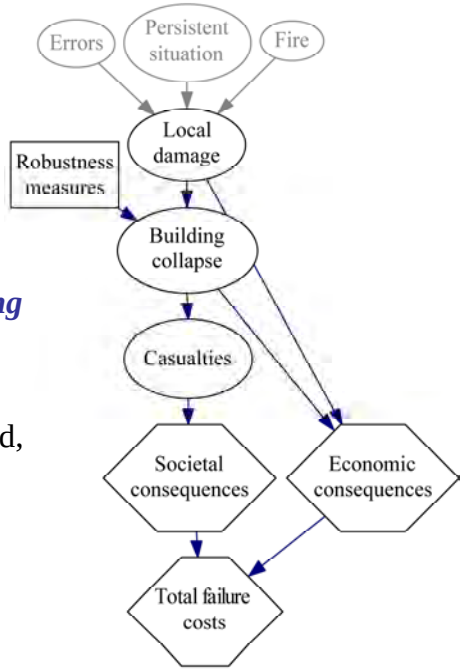
Numerical example

- Decisions concerning robustness - ***optimisation*** of ***costs*** and ***consequences***

- Robustness measures – level of ***tying*** for an office building

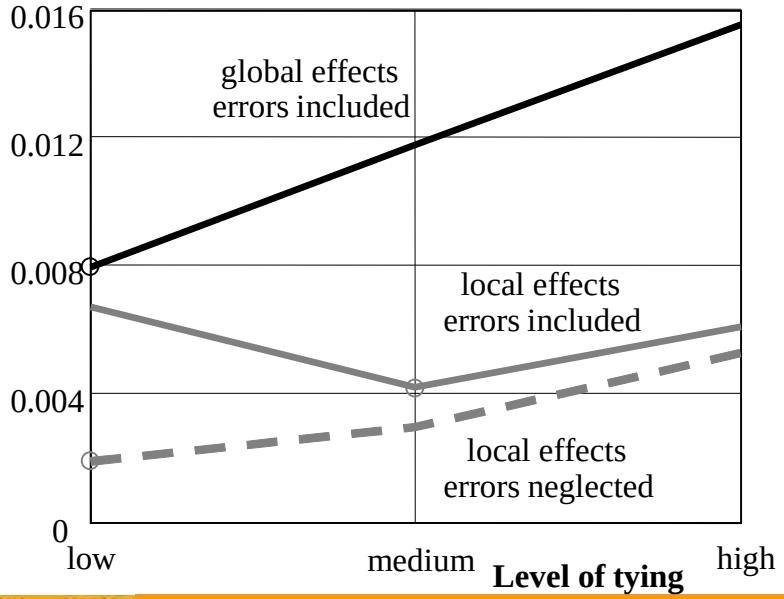
- ***Local*** effects: few members affected, alternative load paths, ***tying positive***

- ***Global*** effects: most structural members affected, ***tying*** may lead to ***propagation*** of ***collapse***



Cost optimisation

Standardised total costs $(C_{tot} - C_0) / C_0$ (low level of tying)



Conclusions

• ***Robustness*** is a key property of new ***modern structures***.

• Robustness is ***not understood uniformly***.

• Quantification of robustness and methods of assessment are ***insufficiently developed***.

• A crucial issue is the ***definition of robustness*** and consequences that should be included in the assessment.

• The ***risk-based approach*** provides a useful tool for decision making concerning robustness measures.

• The numerical example indicates that it may be important to distinguish between ***local and global effects*** of exposures.

•***Assessment*** of direct and indirect ***consequences*** of failure/collapse is essential for practical applications.

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Thank you for your attention.