Workshop of the Belgian *fib* member group

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Design for Structural Robustness

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OUTLINE

1. Introduction
2. MC2020 developments related to robustness
3. Future activities

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1 - Introduction

Dr. Wouter Botte

→ **Postdoctoral researcher** at the
Department of Structural Engineering and Building Materials (UGent)

→ PhD in Civil Engineering (2017)
"*Quantification of Structural Reliability and* ***Robustness of New and Existing Concrete Structures*** *Considering Membrane Action*"

Supervisors: Robby Caspeele – Luc Taerwe

→ Convenor AG10 Action Group: Robustness

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1 - Introduction

MC2020 Action Groups established to focus on specific technical topics,
e.g. bond, durability and service life design, non-linear finite element modelling…

➔ **AG10 Action Group: Robustness**

➔ Start: January 2018

➔ 25 members – 11 countries

➔ Several members are also part of:
CEN/TC250/WG6 and JRC report writing

➔ 6 meetings

Country	Delegates
Italy	9
Belgium	**3**
Portugal	3
UK	3
Spain	2
Germany	1
France	1
Denmark	1
Austria	1
Sweden	1
China	1

➔ **Primary goal**: revise/update MC2010 sections related to robustness

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2 - MC2020 developments related to robustness

Where to find structural robustness in MC2020?

PART II Basic principles

Chapter 5 – Performance-based approach

5.2 – Performance evaluation framework

5.2.1 – Structural performance

5.2.1.2 – Principles of limit state design

5.2.1.2.4.1 – Special considerations: robustness → Brief & general section

PART VI Design and assessment procedures

Chapter 27 – Evaluation of structural performance

27.9 – Design for robustness → Main section on structural robustness

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Current status?

First draft of the chapter finalized and discussed in Action Group

➔ Will be distributed to wider group for commenting end of January

➔ Content subjected to changes

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27.9.7 Robustness considerations for existing structures
(27.9.8 Robustness criteria)

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27.9.1 General

→ **Definition:** **no accidental** and/or **exceptional events or damage** to structural components would result in **disproportional consequences** for the structural system or even **total collapse** of the whole structure during its **lifetime**.

→ **Design for robustness** can involve identification of:

- Hazards
- Direct damage
- Comprehensive damage
- Direct and indirect consequences

→ Several **strategies** can be adopted

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27.9.2 Design considerations

→ **When to do what?** Based on Consequence Class of the structure

→ **Design considerations:**

- Low risk group: no additional measures
- Medium-low risk group: indirect design methods (e.g. prescriptive rules/key element method)
- Medium-high risk group: medium-low + combination of indirect and direct design methods
- High risk group: direct design methods based on a systematic risk assessment
- Direct and indirect consequences

→ General **design recommendations**

- Shape of structure (simple/regular)
- Detailing rules
- Ductility
- Etc.

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27.9.3 Design scenarios for robustness

→ Design for robustness should involve the **identification and assessment of design scenarios**, i.e. each design scenario relating to a **set of events/conditions occurring during the construction or lifetime of the structure** leading to a state of the system for which the **effect of disproportionate consequences** should be assessed.

→ Such design scenarios can be **identified based on**

- specified accidental actions ⟹ Design for identified hazards
- notional damage
- notional actions

⟹ Design for threats that cannot be specified

To be discussed with the relevant stakeholders.

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27.9.4.1 Design for accidental actions

Threat-specific design requires the **identification and quantification** of all abnormal events that could possibly affect the structure and the resulting actions on it.

➔In general cases, such input data is incomplete and/or imprecise […] Therefore, the application of a direct design method […] may [...] be **complemented by elements of threat-unspecific design** […].

When structures are checked for specific accidental actions and/or to resist local damage, load **combination rules** should reflect the low probability of concurrence of the accidental action and the design live loads, i.e. **partial factors which are lower than for the case of ULS verifications**.

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27.9.4.2 Design for notional actions

27.9.4.2.1 - Notional damage scenarios:

- Notional removal scenarios

  […] structural elements will be notionally removed and the structure will be checked for disproportionate consequences.

- Notional deterioration scenarios

  […] geometrical and/or material properties […] will be notionally reduced and the structure will be checked for disproportionate consequences.

27.9.4.2.2 - Notional loads

Notional loads are **generally specified as a uniformly distributed equivalent static load**.

A value often referred to in standards for a notional load for buildings is 34 kN/m² […] should be treated with caution in case the design scenario considered is considerably different, […].

→ Consideration of load combination rules

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27.9.5 Design strategies

The method to be applied depends on the design considerations […]

→ Generally, design strategies for robustness can be divided into two types:

1) Indirect design methods

➔Focus not explicitly on the ability to sustain abnormal load effects

➔Prescriptive rules (e.g. horizontal/vertical ties)

2) Direct design methods

[…] aim to limit the effect of local failure. These design methods can start from one or more of the following design strategies:

- ➔ Alternative load path strategy
- ➔ Consequence reduction strategy

In case these do not lead to an adequate level of robustness:

- ➔ Event control strategy
- ➔ Key element design

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27.9.6 Robustness quantification

Robustness quantification should be based on the **comparison of**:

- The amount and extent of **initial damage**
- The corresponding **follow-up consequences**

Robustness metrics can be divided into the following levels with decreasing complexity:

- **Risk-based quantification** based on a complete risk analysis […];
- **Reliability-based quantification** based on e.g. probabilities of failure […];
- **Deterministic quantification** based on structural measures […]

→ Can be considered **in case of**:

- Comparison of design alternatives
- Follow-up of robustness during lifetime of the structure

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27.9.7 Robustness considerations for existing structures

→ Constraints may affect the level of robustness

→ Two **design situations** are identified:

- Change of use results in a significantly higher risk ➔ adopt higher consequence class
- Alterations/extensions should not reduce the level of robustness

→ **Large unknowns** on structural properties ➔ adopt high risk group

→ **Some design strategies might be unfeasible** in some cases

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3 – Future activities

→ Reviewing chapters MC2020 based on comments by other groups

→ Development of *fib* Bulletin on structural robustness

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