COST ACTION TU0601
Robustness of Structures

Minutes of the 3rd Meeting of Working Group 1

University of Coimbra
Dept. of Civil Engineering
March 2nd and 3rd 2009

Place and date:
The meeting took place in a room of the Dept. of Civil Engineering of the University of Coimbra on March 2nd 2009 between 16.30 and 18.00 and went on in the following day between 8.30 and 10.30.

Participants:
Krzysztof Cichocki, PL
Michael H Faber, CH (only March 3rd)
Enrico Rizzuto, IT
John D Sørensen, DK

Mandate for WG1
The chairman of the WG recalls the mandate for the Group, as it is described in the MoU of the Action.

- WG1 is in charge of Activity 3 'Developing a theoretical/methodical framework for assessing robustness and acceptance criteria'.
- The expected output of the activity is a Report whose completion is foreseen in about 1 year from now.
- It is recalled that the framework to be developed should provide input and support for the other activities of the Action.

Situation of the Report
A preliminary draft of a glossary containing the key terms was circulated at the meeting in Timisoara.

A draft for the first chapters of the report was circulated just before the present meeting (annex 1), following the decisions of the last meeting in Timisoara and the outline prepared at that time.

The Group reviews the present content of the Report.

Chapter 1 Review of documents on Robustness

The first chapter contains a review of the main sources that have been considered. The objective is to review the present applications of the concept of robustness and to outline similarities, differences and possible improvements. Such sources include, at the moment:

Eurocodes:
- EN1990:2002
  - Section 2.1 (Basic requirements), clause (4)P
  - Section 2.2 (Reliability Management), clause (5) e)
  - Denmark – Robustness requirements in national annex to EN1990
- EN1991-1-7:2005 (General actions - Accidental actions)
  - Section 1.5 (Terms and definitions) .14
  - Section 3.2 (Accidental Design situations- identified accidental actions)
  - Section 3.3 (ADS-strategies for limiting extent of localised failure [unspecified cause])

ASCE standards
- standard 7-05
- section 1.4: (General structural integrity)

IMO (International Maritime Organisation, a United Nation Agency),
- Goal-Based New Ship Construction Standards (see MSC81, 2006)
  - functional requirement II.7 (Structural redundancy)

Joint Committee of Structural Safety
- Probabilistic Model Code (JCSS-PMC)
  - Section 2.1 (basic requirements) III item
  - Annex A (robustness)
- Risk Assessment in Engineering - Principles, System Representation & Risk Criteria (June 2008) – (JCSS-RA)

Literature (In particular):
- Ellingwood B.R. & Dunesberry D.O. (2005) Building Design for Abnormal Loads and Progressive Collapse, Computer-Aided Civil and Infrastructure Engineering , 20 (2005) 194-205
- Baker J. W., Schubert M., Faber M.H. (2008) On the assessment of robustness, Structural Safety 30 (2008) 253–267
- ……

For most of the sources listed above the definitions are reported in annexes of the report.

A critical review of the definitions shows that

- The most general definitions are very similar to each others (particularly those taken from codes: Eurocodes, ASCE and from JCSS PMC), despite the use of different terms (robustness, structural integrity, but also progressive collapse prevention). These definitions are focussed on the prevention from an escalation of damage within the structure, given a certain initial (localised) failure / damage.

- In codes of practice, robustness is a quality required for design, construction and operation of structures, but is not completely clear if it is intended as a functional requirement [i.e. a means] to achieve a different goal, (which could be safety) or as a goal in itself. The 'notional removal of column' procedure suggests this second interpretation, as it is not proved that making the structure compliant with this provision reduces efficiently the total risk. The notional removal is actually considered as a way of enforcing a 'minimum robustness' in the structure (a requirement that has its own justification, not related to safety).
- The only document that gives a quantification of robustness is JCSS-RA, which however gives a definition of robustness quite different from the other documents (but in line with Baker et al., 2008).

Chapter 2 Definition of Robustness

At this point the discussion of the WG concentrates on the definition given in Baker et al., 2008, which has been recalled several times in the previous meetings in Zurich and Timisoara and seems to collect many preferences within the participants to the Action.

The main characteristics of this definition are once more recalled:

- it considers robustness as a characteristics of the structure and its environment (both exposures and consequences).
- it provides a quantification of the concept (robustness index), based on the distinction between direct and indirect risks.
- previous discussions have outlined that the robustness index in this version should not be regarded as a goal in itself for design, but just a 'guide' to improve the risk performance of the design.

Later, the discussion moves on the drawbacks of the definition, in particular:

- the fact that the robustness of the same structure changes in different environments seems to be not intuitive for practical applications.
- if an evaluation of robustness is possible only after a complete risk analysis, providing the total risk, what is the added value of computing the Robustness Index? The total risk in itself is the only 'true' goal for design and its value can provide directly indications for the design (or also a 'ranking').
- establishing a difference between direct and indirect risk can be misleading in itself, because the risk is equally important and a reduction in either component is equally valuable in rational decision making.

The discussion proceeds on the second day, when MH Faber outlines an evolution of the robustness definition by Baker et al. This interpretation stands on the assumption that direct risks are covered by code formats (i.e. the basic structural checks contained in codes), while indirect risks are not. A requirement on total risk corresponds to a requirement on the ratio between the risk already covered by checks and the total risk (the ratio being the robustness index).

Objections to this interpretation are

- that it is not easy to say what type of risks are included in Rules and
- that the total risk is anyway the real way of assessing a design: once it is evaluated, what is the need of elaborating other quantities?.

Another aspect touched upon during the discussion is the irrationality of compulsory provisions like the 'column removal' criterion, that could not be justified from a cost-benefit analysis.
The subject is however strictly related to the actual possibility of performing an omni-comprehensive risk analysis, including all risks. This types of provisions are meant to be against 'unforeseeable' risks.

The same level of irrationality is contained in analogous provisions for 'unacceptable' levels of risk in Risk Analysis theory.

After a long discussion, it is decided to propose the same type of arguments within the JCSS at its next meeting in April. This will allow the WG to obtain further elements / arguments useful for a better definition of the framework for robustness.

The meeting of WG1 closes at 10.30 of March 3rd.

Annex 1: **Draft content of 'Theoretical Framework Robustness of Structures'**

Prepared at Timisoara meeting

	Chapter	Responsible
1	Introduction - Purpose of this 'publication' - literature review of definitions and assessment of structural robustness o EN1990 o ISO … o JCSS PMC o JCSS 'Risk assessment … (more in section 2) …	JDS
2	Definition of structural robustness To be based on JCSS: 'Risk assessment in engineering', June 2008 - Hazards - Consequences (direct and indirect) - Definition of robustness	Enrico
3	Quantification of robustness and methods of assessing robustness of structures - System modelling of structures - modelling by series / parallel systems - modelling by ductile / brittle elements - stochastic modelling - estimation of system reliability - … - Quantification of robustness	Turk
4	Acceptance criteria - based on cost-benefit analysis - based on LQI - …	Cichocki
5	Effect of quality control?	
6	Summary & Recommendations - for further R&D - for other activities in TU601	
Annex A	…	
Annex B	…	