Structural robustness as an innovative design concept

M. Sykora, M. Holicky
Czech Technical University in Prague, Klokner Institute, Prague, Czech Republic

1 INTRODUCTION

Developments of high-performance materials, construction technologies and methods of structural analysis within last decades facilitate design of increasingly complex and slender structures. These structures may be vulnerable to unfavourable effects of extreme events including accidental impacts, explosions, fire, flooding, terrorism etc. In most cases failures of structures exposed to such events may hardly be completely prevented. For sufficiently robust structures, consequences can, however, be significantly reduced. Despite many significant theoretical, methodical and technological advances over the recent years, structural robustness is still an issue of intensive research. Requirements and methods for assessment of robustness specified in present codes are vague and seem to be insufficient for the use in practice. The COST Action TU0601 Robustness of Structures has thus been established to improve the robustness assessment methods. The submitted paper, based on working materials of the Action, attempts to promote discussion on structural robustness between architects and structural engineers.

2 DEFINITIONS

In EN 1991-1-7 (2006) robustness is defined as the ability of a structure to withstand events like fire, explosions, impact or the consequences of human error, without being damaged to an extent disproportionate to the original cause. Recent discussions have indicated that robustness is a complicated concept, which is not understood uniformly within an engineering society. Robustness may be perceived as an 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.

Figure 1 accepted from EN 1991-1-7 (2006) illustrates the basic concept in robustness:

a) Exposures,
b) Local damage due to exposure,
c) Total (or extensive) collapse of the structure following the local damage.

Quantification of robustness by deterministic, reliability-based and risk-based robustness index has been proposed by several researchers.

3 EXPOSURE CONDITIONS AND STRUCTURAL MODELS

Modelling of the relevant exposures includes the assessment of probabilistic characteristics of extreme events as well as information on normal loads. Potential hazards may be split up into unforeseeable; known, but unrecognized or ignored; and known and dealt with.

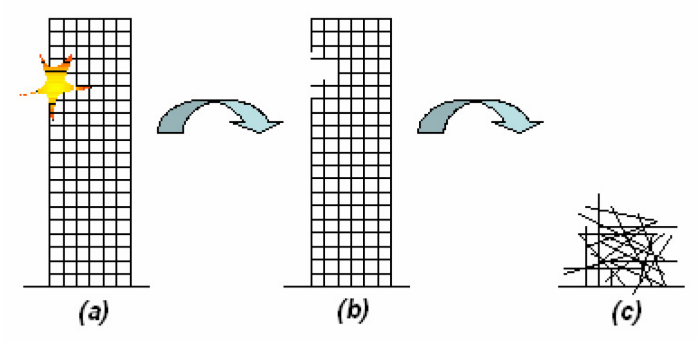

Figure 1. Illustration of the basic concept in robustness, EN 1991-1-7 (2006).

In the assessment of structural robustness appropriate models for structural behaviour are needed to analyse various damage scenarios resulting from the exposures and estimate the probability of total collapse, given an extreme load. Such models should be able to deal with partly damaged structure, plastic deformations, large deflections and catenary or membrane actions, high temperatures, and dynamic effects.

4 DESIGN PRINCIPLES

Ellingwood et al. (2007) indicated that no universal approach for evaluating the potential for progressive collapse exists due to many means by which a local collapse in a specific structure may propagate. For reduction of the probability of progressive collapse in the event of loss of structural elements, structural measures including alternative load paths, ductility, higher reliability of key elements, and an integrated system of ties were proposed. The numerical study is provided to show decision making concerning robustness measures.

5 CONCLUDING REMARKS

Structural robustness can become a key concept in design of new modern structures. However, presently robustness seems not to be understood uniformly within an engineering society. Some experts perceive the robustness as an indicator of the ability of a structure to perform adequately under accidental situation while the other as an indicator of the ability of a system containing a structure to perform adequately under accidental situation of the structure. Despite its significance, quantification of robustness and methods of assessment are not sufficiently developed and further improvements are urgently needed. The numerical example indicates that decisions concerning structural robustness can be based on methods of risk assessment and optimisation.

ACKNOWLEDGEMENT

This study has been conducted at the Klokner Institute, Czech Technical University in Prague, within framework of the research project COST OC08059 Assessment of structural robustness. Achievements of the COST Action TU0601 Robustness of structures have been utilized.

REFERENCES

Ellingwood, B.R. et al. 2007. *Best Practices for Reducing the Potential for Progressive Collapse in Buildings,* NISTIR 7396. USA: National Institute of Standards and Technology.

EN 1991-1-7 2006. *Eurocode 1: Actions on structures - Part 1-7: General actions - Accidental actions*.