Risk-Based Structural Evaluation Methods

Best Practices and Development of Standards

Edited by Michel Ghosn, Graziano Fiorillo, Ming Liu, and Bruce R. Ellingwood

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Preface

The structural engineering community has recently implemented methodologies that incorporate explicit risk assessment principles and performance-based criteria to design new structures with improved and predictable performance, assess the safety of existing structures, and manage our deteriorating civil infrastructure systems. Particular attention has been paid to extending the design and safety evaluation processes from their original focus on individual structural components to a more complex approach that considers the performance of an entire structural system, such as a building or a bridge, and, on an even larger scale, a portfolio of multiple structures. The interest in risk analysis techniques has intensified following recent extraordinarily destructive events, including Hurricane Katrina and Superstorm Sandy in the United States, the Fukushima Earthquake in Japan, and other extreme natural hazard events that have severely affected communities for many years.

This report summarizes the findings from a survey of attitudes of researchers, structural engineers, and government agencies to risk-informed structural engineering practices and a follow-up workshop held in September 2014 which were completed under the auspices and financial support of the Structural Engineering Institute of the American Society of Civil Engineers. The survey and workshop objectives were to examine the progress made on the implementation of risk-based structural evaluation methods (RBsEM), review best practices, and investigate the possibility of developing risk-based standards.

In the broadest terms, *risk* in structural engineering can be defined as the integration of the probability of structural failure and the associated consequences. The responses to the survey and the discussions at the workshop demonstrated that risk analysis principles are well established from a theoretical point of view. However, a number of barriers have hampered a wide-scale implementation of risk-based methods in decision-making processes. These barriers include (a) the difficulty of applying probabilistic analysis techniques when evaluating the performance of complex structures and networks; (b) limited statistical data to model the intensity of extreme hazards and their effects on structural systems; (c) the lack of calibrated criteria that relate analysis results to physical damage of different types of structural systems; (d) the difficulty of enumerating the consequences of failure and assigning quantifiable measures for these consequences; and (e) the paucity of guidelines and standards.

Some industries, such as the nuclear power industry, have overcome many of these challenges through long-term research. Furthermore, in seismic engineering, the use of probabilistic performance-based design methods, combined with consideration of the consequences of damage, has become widely accepted, and the process is on track for routine application. Concepts of performance-based design, with objective or subjective evaluations of risk, have also been introduced in ASCE 7 and other standards for the design and safety evaluation of buildings and other structures. Other industries, such as those concerned with the state of dams and transportation infrastructure systems, have recently initiated ambitious research programs to improve their risk analysis methodologies and have, in the interim, resorted to implementing empirical approaches based on the experience of industry leaders and the review of historical data and the archival literature.

Despite the progress made in the field, implementation of RBsEM is still in its infancy, and additional work remains before risk-based methods evolve as the standard approach for decision-making processes in structural and infrastructure engineering. All the Participants in the survey and workshop, who included members of government and regulatory agencies, practicing engineers, and academic researchers, have expressed great interest in advancing RBsEM, which in their opinion presents the best approach for addressing issues related to the management of aging structural and civil infrastructure systems susceptible to increased environmental and climate-related hazards, as well as increased security threats.

The survey respondents and workshop participants made a number of recommendations to encourage and support the application of RBsEM in structural and infrastructure engineering practice and advance the field. The implementation of these recommendations will require the involvement of professional societies such as the American Society of Civil Engineers, regulatory agencies, research organizations, and educational institutions. These recommendations can be summarized as

- Developing guidelines and training programs for risk assessment;
- Facilitating the implementation of technical innovations and providing technical support, including the development of appropriate computer software;
- Enhancing data gathering and developing advanced statistical analysis techniques for the probabilistic modeling of hazards, projection of expected extreme natural and human-made events, assessing the resulting physical damage to structures and infrastructure, and estimating associated direct and indirect losses;
- Investigating approaches for establishing optimum risk acceptance criteria that take into consideration public attitudes toward risk for different levels of hazards and multiple hazards; and
- Exploring effective means of communicating risk to different stakeholders including the general public.

Because of the nature of the problem it addresses, structural and infrastructure risk assessment is a multidisciplinary process that requires diverse technical expertise, including engineers, system analysts, social scientists, economists, and actuaries. The risk analysis team would also include experts in specific topics depending on the issues and hazards of concern. For example, materials scientists would help identify structural degradation mechanisms, climate scientists would provide projections of future changes in climatic hazards, and geoscientists would help in modeling of seismic hazards. Furthermore, civil infrastructure risk-based decision making involves multiple stakeholders, including owners, regulators, policymakers, and the affected community, with a great impact on the well-being of the general public. Hence, there is great incentive for all concerned to promote the field and encourage the implementation of RBsEM as the basis for managing our structural and infrastructure systems.