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Decision-Theoretic Methodology for Performance-based Structural Engineering
FINAL REPORT (12/21/00 – 07/01/04)

Research goals and objectives:

The research goals were to facilitate utilization of high-performance innovative materials and products in complex civil infrastructure systems subjected to natural and man-made hazards by providing computationally efficient and integrated analysis and simulation tools for the analysis of uncertainties and management of risk. The research was a collaborative effort involving investigators at Georgia Tech and Johns Hopkins University, who worked collaboratively on six tasks under joint SNL-NSF sponsorship. The Georgia Tech investigators had responsibility for two of these six tasks:

(1) Task (1): Time-dependent structural reliability assessment tools that provide interfaces between physical models of the structural system, models of uncertainty and performance requirements.
(2) Task (6): Fragility modeling of building structural systems subjected to deterioration and second-order nonlinear actions resulting from earthquake ground motion.

Technical accomplishments during reporting period:

A major part of the GT effort was aimed at fragility modeling issues (Task 6), with specific reference to the performance of steel moment frames subjected to a spectrum of intensities of earthquake ground motion. The (conditional) limit state probabilities of steel frames were evaluated using several computational finite element platforms with capabilities for dynamic analysis of structural systems modeled with material and geometric nonlinearities. The vast majority of the analyses were performed using OpenSees, an open-source code developed at the University of California/Berkeley. Although the earthquake ground motion was found to be the major source of uncertainty, the epistemic uncertainties in the selection and modeling of structural systems were found to be non-negligible. Since the structural system fragilities are based on numerical simulation and the damage state probabilities relevant for engineering decision analysis are small, efficient simulation schemes based on stratified sampling were investigated. The time-dependent deterioration in structural behavior due to connection damage (Task 6) was investigated in a later state of the project, and structural systems were subjected to a sequence of earthquakes to determine the extent to which previous damage and the resulting period shifts would impact subsequent behavior under a second earthquake. Simplified approximate methods for estimating fragilities were found suitable for assessing performance under moderate ground motions, but were less useful for intensities sufficient to cause a non-negligible probability of collapse.

Publications

Preparation of the following papers was made possible, in part, by the support from this research project:

Igusa, T. Buonopane, S.G. and B.R. Ellingwood (2002), "Bayesian analysis of uncertainty for structural engineering applications," *Struct. Safety* 24(2):165-186.

Sakurai, S., B. R. Ellingwood and S. Kushiyama (2002). "Reliability of a multistory steel frame with partially restrained connections." *Proceedings. ICOSSAR'01 Int. Conf. on Struct. Safety and Reliability* (R.B. Corotis, G.I. Schueller & M. Shinozuka, eds.), Paper No. FCO009, A. A. Balkema (CD-ROM).

Igusa, T., S.G. Buonopane and B.R. Ellingwood (2002). "Reliability-based simulation for performance-based design," *Proceedings, ICOSSAR'01 Int. Conf. on Struct. Safety and*

Reliability (R.B. Corotis, G.I. Schueller & M. Shinozuka, eds.), Paper No. FCO372, A. A. Balkema (CD-ROM).

Schafer, B.W., Igusa, T., Buonopane, S.G., Ellingwood, B.R. (2002), "Decision-theoretic view of building design codes," *2002 NSF Design, Service and Manufacturing Grantees and Research Conference*, San Juan, PR, January.

Nie. J. and B.R. Ellingwood (2003), "New developments in directional methods for system reliability assessment," *Proceedings, Int. Conf. on Applications of Statistics and Probability in Civil Engrg.* (ICASP 9), Millpress, Rotterdam, pp. 85-90 (also CD-ROM paper 152).

Taftali, B., B.R. Ellingwood and R. DesRoches (2004), "Fragility of steel moment frames with novel beam-to-column connections utilizing shape memory alloys," *Proceedings*, PMC 2004 Albuquerque, NM

Ellingwood, B.R. (2004), "Risk-informed condition assessment of aging civil infrastructure: research issues," *Proceedings*, PMC 2004, Albuquerque, NM.

Nie, J. and B. R. Ellingwood (2005), "FE-based structural reliability assessment using efficient directional simulation," *J. Engrg. Mech. ASCE* 131(4):

Ellingwood, B.R. (2005), "Strategies for mitigating risk to buildings from abnormal load events," *Int. J. fo Risk Assessment and Mgt.* (in press).

Graduate Education

The following graduate students have been supported, in part, by this research project:

Mehmet Yorulmaz, "Model-based simulation for performance-based design," (M.S., August, 2002)

Jinsuo Nie, "A new directional method to assess structural system reliability in the context of performance'based design," (Ph.D., December, 2002)

Quanwang Li, "Assessment of seismic vulnerability of damaged buildings," (Ph.D., expected completion August 2005)

Berk Taftali, "Seismic reliability evaluation of steel frames with shape memory alloy connections" (Ph.D., expected completion April 2005)

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