MODELING UNCERTAINTIES IN SEISMIC VULNERABILITY AND RISK ASSESSMENT

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Synopsis

Buildings, bridges and other civil infrastructure must be designed and constructed to withstand the effects of man-made and natural hazards so as to ensure public safety and to support the goals and needs of society. The earthquake hazard is paramount among the natural hazards impacting civil infrastructure. In the United States, the impacts of three major earthquakes in recent times – San Fernando in 1971, Loma Prieta in 1989, and Northridge in 1994 – have highlighted the limitations in scientific and engineering knowledge concerning earthquakes and their socioeconomic impact on urban populations and have provided the impetus for significant advances in engineering practices for earthquake-resistant design of buildings, bridges, lifelines and other civil infrastructure. Notwithstanding these advances, the uncertainties remaining in seismicity and in the response of buildings, bridges, transportation networks and lifelines are among the largest of the natural phenomena hazards confronting engineers and managers of civil infrastructure. The inevitable consequence of these uncertainties is risk that civil infrastructure will fail to perform as intended or as expected by the owner, occupant or user, or society as a whole. It is not feasible to eliminate risk entirely; rather, the risk must be managed in the public interest by engineers, code-writers and other regulatory authorities. Risk management requires a trade-off between investment and reduction in consequences. Confronted with the need to manage the uncertainties associated with earthquake prediction and infrastructure response, the structural engineering and regulatory communities are embracing the notions of reliability and risk analysis as tools to support decision in the face of uncertainty and for management of risk in the public interest.

Much of the research to date on the performance of civil infrastructure during and after earthquakes has concentrated on areas of the United States with high seismic hazard. Research in the past three decades has revealed that the earthquake hazard in areas of the Central and Eastern United States (CEUS) is non-negligible, when viewed on a competing risk basis with other extreme natural phenomena hazards. Building design, regulatory practices, and social attitudes toward earthquake risk may differ in these areas, where civil infrastructure generally is not designed to withstand ground motions of the magnitude that modern seismology indicates are possible or probable. As a result, the risk to affected communities in the CEUS (measured in terms of economic or social consequences) may be far more severe than has been commonly believed.

The state of the art in uncertainty modeling and risk analysis now has advanced to the point where integrated approaches to earthquake hazard analysis, performance evaluation for civil infrastructure, and seismic risk management are feasible. Consequence-based engineering (CBE) is a new paradigm for seismic risk assessment and reduction across regions or interconnected systems, enabling the effects of uncertainties and benefits of alternate seismic risk mitigation strategies to be assessed in terms of their impact on the performance of the built environment during a spectrum of earthquake hazards and on the affected population. CBE is the unifying principle for research conducted by the Mid-America Earthquake Center at the University of Illinois at Urbana-Champaign, one of the three NSF-sponsored university earthquake research centers. Some recent advances in uncertainty modeling and risk-based decision tools that are accessible to a spectrum of stakeholders with different skills and talents – architects, engineers, urban planners, insurance underwriters, and local governmental agencies and regulatory authorities - are briefly reviewed in this presentation. An integrated approach to risk-informed decision-making provides stakeholders with a structured framework for thinking about uncertainty and how public safety and economic well-being may be threatened by the failure of civil infrastructure to perform under a spectrum of seismic events. The benefits of such an approach are an improved ability to assess the effectiveness of various risk mitigation strategies in terms of risk reduction per dollar invested, and thus a better allocation of public and private resources for managing risk.

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