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The John A. Blume Earthquake Engineering Center

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LETTER FROM THE DIRECTOR

As SEAOC's Vision 2000 and the new International Building Code (IBC) are being developed with a target issue date for the year 2000, the need for developing a performance based design code has become the hot topic of the structural engineering community. Yet, few have a notion as to what this might entail. While I cannot provide a detailed answer to this question, I will attempt to give it my interpretation and point out the difficulties in this process. I discuss this topic in the hope of increasing awareness of the problems, while pointing out some possible solutions. Thus, with this and the next few issues of the Newsletter, I will share my views on the subject and invite comments from members of the practicing and academic communities.

Current seismic codes were developed on the criteria that life safety should be provided under a catastrophic earthquake and damage should be minimal under a severe earthquake. These criteria were put to the test with the Loma Prieta, CA 1989, and the Northridge, CA 1994 earthquakes. Functionality became an issue with many structures that in fact met the postulated design criteria but raised questions about their adequacy.

Underlying the concept of performance based design is the premise that the owner will have the ability to select from several possible performance levels and that these levels will need to be related to present and future costs that include those arising from construction and maintenance and those resulting from damage and loss of functionality in future catastrophic events. This approach implies that we can develop a quantitative measure of performance. Selection of a performance level can then be logically achieved through a decision process where the decision maker, in this case most likely the owner, can make educated choices with the help of the engineer and architect. In principle, structural reliability theory can provide the foundations for the development of such a quantitative measure. The load and resistance factor design (LRFD) can be viewed as the first attempt towards such a systematic approach. The LRFD, however, lacked the holistic approach that is needed for a performance based design. A holistic approach will necessarily have to include the structural system, its behavior and the resulting economic and possibly social consequences. The first challenge then, is to define a practical approach to this problem.

In subsequent issues, I will attempt to define the components of performance based design in the hope to provide a starting point for a dialog.

CENTER NEWS

We are pleased to welcome two new visiting scholars to the Blume Center. **Dr. Seung Rae Lee**, Associate Professor of Civil Engineering at the Korea Advanced Institute of Science and Technology (KAIST), and **Dr. Francisco Montans**, Structural Engineering from SINEX, Inc. in Madrid, Spain are both working with **Professor Ronnie Borja** in the area of constitutive modeling and its application to dynamic soil-structure interaction analysis.

Professor Anne Kiremidjian was invited to present a seminar on "Advanced Technological Tools for Regional Earthquake Damage and Loss Estimation," in November, 1995 at the University of Geneva in Switzerland.

Professors Helmut Krawinkler and **Anne Kiremidjian** participated in the U.S.-Japan Workshop sponsored by NSF on "Research Needs Emerging from the Kobe and Northridge Earthquakes," held December 13-16 in Hawaii.

On February 2, the Blume Center hosted a Chinese Delegation, headed by **Mr. Na Xiangqian** of the National Science Foundation of China.

Several Blume Center researchers participated in the recent EERI Annual Meeting in Los Angeles held Feb. 7-10, including **Professor Anne Kiremidjian**, **Dr. Stephanie King**, and students, **Nesrin Basoz**, **Vicki Vance**, **Rachel Davidson**, **Anju Gupta**, and **Abhijit Kakhandiki**.

In January, **Jeanne Cosby** accepted a position as an Adminstrative Associate in the Department of Chemical Engineering. Jeanne served as an Administrative Assistant here in the Blume Center for four years, and we wish her the best of luck in her new position.

New Appointment

A most enthusiastic welcome to **Dr. Stephanie King** who became the Associate Director of the Blume Center as of January 1, 1996. Dr. King received her Ph. D. from Stanford in 1994 and has worked as a postdoctoral researcher at the Blume Center since then. She brings with her experience in research, project management and knowledge of the Blume Center's activites. We look forward to working together towards achieving the long-term goals of the Center.

RESEARCH SPOTLIGHT

RISK ASSESSMENT FOR HIGHWAY TRANSPORTATION SYSTEMS

by Nesrin Basoz, Ph.D. Candidate

Research Advisor: Professor Anne S. Kiremidjian

Recent natural disasters, e.g., tornadoes, hurricanes and earthquakes with significant life and property loss have underscored the risks associated with natural hazards. These disasters have demonstrated the vulnerability of lifelines and the need for mitigation strategies as well as emergency response planning and management. Highway transportation systems are vital, in particular, to society's functions under normal and even more so under emergency conditions. In general, it is important to maintain functionality and serviceability of these systems during and after disasters. A key objective in risk reduction is to minimize life and property loss due to a disaster under limited economic constraints. In this research, a risk assessment methodology is developed to serve as a tool in the decision process for: **(***i*) retrofitting of critical components in the system as a means of pre-disaster mitigation, (*ii*) pre-disaster emergency response planning, and (*iii*) emergency response operations immediately after the disaster.

Methodology

The *risk assessment methodology* consists of vulnerability (or damage) and impact (or importance) evaluation for the lifeline system. The vulnerability assessment includes hazard analysis, classification of the critical components of interest such as bridges or tunnels, and fragility analysis. Importance assessment considers the consequences of the damage to life safety and to the socio-economic well-being of a community. Decision analysis methods are used to integrate engineering, economical and social factors that influence decisions for the risk reduction. Network analyses are used to include systems performance information in the decision process.

In this research, the details of the methodology are developed for highway transportation systems subjected to earthquakes. The developed risk methodology, however, is general since it is applicable to different natural or man-made hazards and can be applied to lifeline systems other than transportation systems. Bridges are selected as the critical components because in an earthquake, damaged bridges are most detrimental to the functionality of the highway system. Figure 1 shows the components of the developed methodology for highway transportation systems.

<u>Prioritization of bridges for seismic retrofitting - pre-disaster mitigation:</u> In order to provide the tools for pre-earthquake mitigation, a methodology is developed for prioritization of bridges for seismic retrofitting (Basöz and Kiremidjian, 1995). In this methodology, the prioritization of bridges is based on vulnerability and importance assessments. The prioritization methodology is designed for screening analysis in which detailed evaluation for each bridge is not conducted. A rank order for bridges is defined as $\{R\} = \{R_1, R_2, \ldots, R_N\}$ such that $R_1 > R_2 > \ldots > R_N$ where N is the total number of bridges to be retrofitted. The bridge assigned to R_1 is identified as the first candidate for seismic retrofitting. Probabilistic seismic hazard analysis is used to obtain the ground motion level at a bridge site for a specified annual probability of occurrence.

The prioritization methodology requires that bridges be grouped according to pre-defined bridge classes such as those given in ATC-13 (ATC, 1985) and NIBS (Risk Management Solutions, 1995). Although bridge class definitions and corresponding ground motion-damage relationships currently exist, new bridge classes are developed in this study in order to better describe the structural characteristics of bridges. An expert system for classification of bridges (ESCOB) is developed. In order to evaluate the damage potential of bridges in

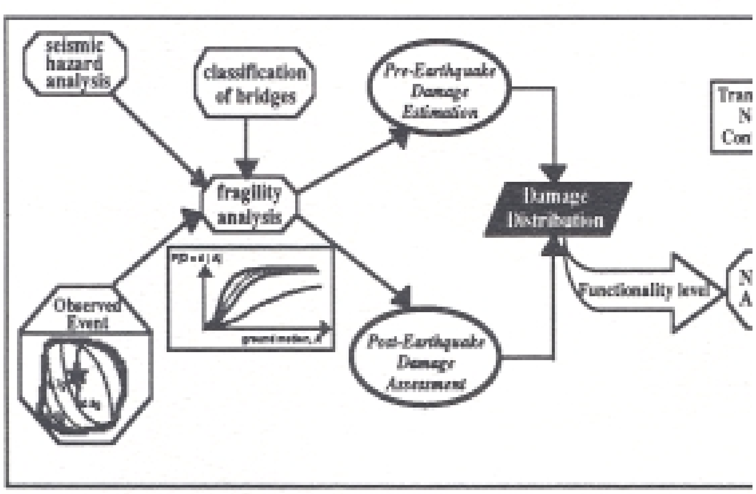

Figure 1. Components of the Risk Assessment Methodology

each class, it is necessary to formulate new fragility (or motion-damage) relationships. To quantify damage, damage states for components of concrete bridges (columns, abutments, and connection joints) are defined. Once a bridge is assigned to a bridge class, the vulnerability of the bridge is assessed by fragility analysis for given damage states. Physical damage states are then translated to functionality levels to link the damage assessment to the importance assessment.

The importance assessment for prioritization purposes is defined as a function of life safety of riders, emergency response, long-term economic impacts, lifeline interaction, and significance of a bridge from historical and defense perspectives. To assess the effect of each factor on the importance criterion, multi-attribute utility theory is used. Network analyses are performed to obtain attribute values necessary for emergency response and long-term economic impact factors. For the emergency response period, the functionality of the system is defined as the accessibility of the disaster areas. An algorithm is developed to perform connectivity analysis for emergency response (CAFER). CAFER identifies all the essential bridges for accessibility of the disaster areas, determines alternate routes and associated time delays, and calculates the relative importance of each bridge for the connectivity of the highway system. For long-term economic impact purposes a conceptual serviceability analysis is developed to estimate user costs. The serviceability analyses considers the functionality level of bridges and solves a dynamic traffic assignment problem to model traffic congestion. The final ranking of bridges is obtained by combining vulnerability and importance criteria through decision analysis methods.

<u>Pre-earthquake emergency planning:</u> CAFER is also used for pre-earthquake emergency response planning purposes. Different bridge failure scenarios are examined to identify all possible fastest paths between different disaster areas and locations of available resources such as hospitals, fire and police stations. Expected time delays are also determined. Based on these results, emergency response planners can identify potential areas that are particularly hard to reach.

<u>Emergency response management:</u> An algorithm is developed to be used in emergency response management applications immediately after an earthquake. This algorithm, a modification of CAFER, identifies the fastest path to reach to a given disaster area from any of the resource locations given the damage inventory for bridges. This application is useful to managers who are in charge of dispatching rescue and/or fire fighting teams from various locations.

Application of the Methodology

The spatial data analysis, management and modeling capabilities of a Geographic Information System (GIS) enable its use as a tool for analysis and evaluation of spatially distributed lifeline systems. In this research, GIS is used to: (*i*) estimate seismic hazard at each bridge site, (*ii*) determine damage and functionality level of each bridge, (*iii*) obtain network configuration with respective connectivity and traffic characteristics information; and (*iv*) convey the results.

Case studies representing real world applications are being conducted for the developed methods. The bridge prioritization methodology is being applied to Palo Alto, California area. The pre-earthquake emergency planning and emergency response management methods are applied to the Northridge area. Figure 2 demonstrates an application of the pre-earthquake emergency planning for the I-5/SR-14 intersection in the Los Angeles area. The available routes for all possible bridge failure scenarios are identified when multiple origin points exist.

Conclusions

A risk assessment methodology for highway transportation systems is developed to assist in decisions for seismic retrofitting of bridges, and emergency response planning and management. The methodology considers system performance by means of network analysis and uses decision analysis to address the values and risk preferences of the decision makers. In an application to the Northridge area presented here, available routes subsequent to potential bridge failures are identifed. Other applications of the methodology include ranking of bridges for retrofitting decisions, evaluation of bridge damage, assessment of system performance and economic losses subsequent to bridge damage, identification of critical bridges and estimation of available routes and detours for rescue and fire fighting operations.

References

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Risk Management Solutions, Inc. (1995). *Development of a Standardized Earthquake Loss Estimation Methodology*, Vol. 1, Technical Manual (prepared for National Institute of Building Sciences), Menlo Park, California.

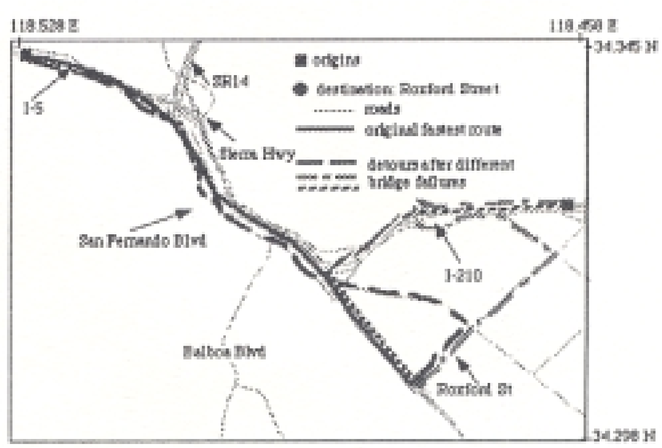

Figure 2. Available Paths Subsequent to Bridge Damage at the I-5/SR14 Interchange

ALUMNI NEWS

Scott M. Anderson (M.S., 1995) is working for Charles Pankow Builders, Ltd. and recently was transferred from the Altadena office to the San Francisco office.

J. Geoffrey Chase (Ph.D., 1995) is continuing his research in the area of structural control as a member of the research staff at Xerox Palo Alto Research Center (PARC).

Olivier Collignon (M.S., 1995), a Ph.D student and research assistant working with Professor Helmut Krawinkler, and his wife, Isabelle, welcomed the birth of their daughter, Quitterie Marie, on January 17.

Rajesh K. Singh (Ph.D., 1993) married Alicia Keller on December 8, 1995 in Palo Alto. Raj is working as a Senior Engineer at Risk Management Solutions (RMS) in Menlo Park.

Yoshitaka Takeuchi (Eng. Deg., 1992) of Obayashi Corporation will be returning to Stanford as a Visiting Scholar during the month of April, 1996 to work with Professor Allison Smith on the Obayashi/Stanford collaborative project on integrated control for intelligent structures.

Wen-Hwa Wu (Ph.D., 1994) and his wife, Shing-Yih, welcomed the birth of a daughter, S-Wei, on September 1, 1995.

NEWLY FUNDED RESEARCH PROJECTS

"Fundamental Studies in the Theory of Finite Element Discretization with Applications in Structural Acoustics," sponsored by Office of Naval Research. Principal Investigators: Professors Peter Pinsky and Tom Hughes. 11/1/95 -10/31/98

Short Course Announcement

SEISMIC HAZARD AND RISK ANALYSIS WITH GIS

The John A. Blume Earthquake Engineering Center at Stanford University announces a Short Course on *Seismic Hazard and Risk Analysis with Geographic Information Systems (GIS)*. The 2-day course will be offered on April 19-20, 1996 on the campus of Stanford University. The course is designed for risk managers, city planners, emergency response officials, members of the insurance industry, earthquake engineers, and others who are interested in learning the background theory, modeling issues, database development, and practical use of GIS for applications in earthquake damage and loss estimation. No prior knowledge of GIS is required. For more information, please contact: Dr. Stephanie King, John A. Blume Earthquake Engineering Center, Dept. of Civil Engineering, Stanford University, Stanford, CA 94305-4020; phone (415)725-0360; fax (415)725-9755; E-mail: sking@ce.stanford.edu.

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