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The John A. Blume Earthquake Engineering Center

Dept. of Civil & Environmental Engineering, Stanford University, Stanford, California, USA, 94305-4020

Telephone: (650) 723-4150

Fax: (650) 725-9755

E-mail: earthquake@ce.stanford.edu

WWW: http://blume.stanford.edu

Director: Professor Anne S. Kiremidjian

Associate Director: Dr. Stephanie A. King

ERIC ELSESSER IS 1998/99 SHIMUZU VISITING PROFESSOR AT STANFORD UNIVERSITY

Eric, a Stanford graduate and long time friend of many of us, has been appointed to this prestigious Visiting Professorship. Eric is co-founder and President of Forell/Elsesser Engineers, one of the leading structural engineering companies in the country. He will help our department in developing a new educational program in engineering/construction integration. Eric will participate in our teaching program, organize a seminar series, and be an invaluable resource to all of us. We are looking forward to having Eric join us for this academic year and hope that this one-year visiting appointment will be the beginning of a long lasting and close relationship with our faculty and students.

PROF. ANNE KIREMIDJIAN RECEIVES AWARD FROM ATC

Prof. Anne Kiremidjian received an ATC Award for Excellence at the First Applied Technology Council (ATC) Awards Dinner held July 18, 1998 in San Francisco. The awards were conceived to honor certain ATC project participants for extraordinary service on completed ATC projects. Prof. Kiremidjian was honored for Extraordinary Achievement in Earthquake Damage and Loss Estimation, primarily for her work as a consultant on statistics and probability in the development of earthquake damage evaluation data for California (the ATC-13 project).

FACULTY POSITION IN CEE DEPT.

Stanford University's Department of Civil and Environmental Engineering invites applications for a faculty position in the area of Reliability and Risk Engineering. The individual must have strong research interests in the probabilistic aspects of structural and/or geotechnical engineering systems affected by natural or man-made hazards. Candidates with interests in emerging technologies (such as health monitoring, control, and advanced materials) are encouraged to apply. The position is tenure-track, and the appointment will be made at the Assistant Professor level. Applicants should send a resume, transcripts, and a list of references to: Prof. Kincho Law, Chair of Faculty Search Committee, Dept. of Civil and Environmental Engineering, Stanford University, Stanford, CA, 94305-4020. Further information can be found at the Dept. of Civil and Environmental Engineering World Wide Web site at http://www-cive.stanford.edu.

BLUME CENTER NEWS

Prof. Anne Kiremidjian moderated a session at the Western United States Earthquake Insurance Summit, held June 24-26, 1998 in Sacramento, California.

Prof. Greg Deierlein, **Prof. Allin Cornell**, and **Prof. Helmut Krawinkler** participated in the EERI Workshop on Performance Based Seismic Design held in San Diego, California on July 17-18, 1998. Prof. Deierlein presented a paper entitled “Structural Acceptance Criteria for Performance Based Seismic Design.”

Prof. Anne Kiremidjian gave a keynote lecture at the 50th International Conference on Short and Medium Span Bridges, held July 13-16, 1998 in Calgary, Canada.

Prof. Anne Kiremidjian presented a paper at the Third China-Japan-US Trilateral Symposium on Lifeline Earthquake Engineering, held in Kunming, China on August 4-7, 1998.

Prof. Helmut Krawinkler, **Prof. Anne Kiremidjian**, **Dr. Stephanie King**, and **Dr. Akshay Gupta** presented papers at the 11th European Conference on Earthquake Engineering held in Paris, France on Sept. 5-11, 1998.

Prof. Ronnie Borja attended the Biot Conference in Poromechanics held in Louvain-la-Neuve, Belgium on Sept. 14-16, 1998. He presented a position paper entitled “Issues in Mathematical Modeling of Solid-Fluid Interaction with Application to Liquefaction of Soils” as a member of a 10-person NSF-sponsored US delegation to the conference.

Prof. Helmut Krawinkler, **Prof. Greg Deierlein**, and Ph.D. candidate **Nicolas Luco** presented a summary of their work for the SAC Joint Venture at the SAC Workshop held in Los Angeles, California on Sept. 16-17, 1998.

Prof. Ronnie Borja was invited to participate in a UJNR Workshop on Soil-Structure Interaction held Sept. 22-23, 1998 in Menlo Park, California. The workshop involved US and Japanese investigators who are actively engaged in soil-structure interaction research. Prof. Borja’s presentation was entitled “Nonlinear Soil-Structure Interaction.”

Over the summer, several Ph.D. candidates at the Blume Center successfully defended their Ph.D. dissertations. They are **Ali Al-Ali**, **Paolo Bazzurro**, and **Akshay Gupta**.

In September, **Carol Strovers** accepted a position as Facilities Administrator for the Stanford Center for Research in Disease Prevention and the Division of Immunology and Rheumatology. Carol served as an Administrative Associate at the Blume Center for almost three years, and we wish her the best of luck in her new position.

RESEARCH SPOTLIGHT

Earthquake Ground Motions and Nonlinear Dynamic Analysis

By Professor Allin Cornell and
Ph.D. Candidates Nilesh Shome, Jorge E. Carballo, and Nicolas Luco

Sponsored by the National Science Foundation, Mineral Management Services,
the Nuclear Regulatory Commission, and the SAC Phase II SMRF Project

Introduction

Recent examples of the growing use of nonlinear time-history analysis include offshore platform and major bridge designs and reassessments, as well as SEAOC, FEMA and SAC building guidelines and research. The number, selection, and possible modification of the records used, as well as the interpretation of the results, are issues that should include seismological as well as engineering input. Yet there is little universal and systematic guidance on just what should be done or even what the relevant issues are. Much of the recent effort in our group can be interpreted as addressing this problem. The following material illustrates simple elements of these studies. References follow.

The Generic Problem

Although real sites are more complicated, suppose for clarity of exposition that the threat to a 5-story steel moment resisting frame (SMRF) building is just a single fault at distance R = 15 km that produces only magnitude M = 5.5 events. What can be said about the expected nonlinear response in such a structure when the event occurs? We shall characterize the critical response by the maximum interstory drift angle (ductility). For a particular design of the structure, Fig. 1a shows a simple histogram of the maximum story drift ductility results of nonlinear analyses of a simplified model of a 2D representation of the frame subjected to 20 randomly chosen accelerograms from a "bin" of firm soil recordings observed between 5 and 25 kilometers from earthquakes of moment magnitude 5.25 to 5.75. The records are unaltered (beyond standard seismological filtering). As is so often the case with seismic problems, the primary impression left is one of wide dispersion; the ratio of the largest to smallest observation is a factor of more than ten! The median value is 2.8 and the coefficient of variation about 0.8; more precisely, d, the standard deviation of the natural log of the results is 0.62. This last measure is useful because it is a direct measure of the effort that is required to obtain a confident estimate of the anticipated behavior. A rule of thumb is that to estimate the (median) response "with 10% accuracy" (i.e., to be about 65% "confident" that the estimate is within 10% of the true value, or 95% confident that it is within 20%) we must use a sample of records with size $n = (d/0.1)^2$, or 39 in this case. These are hardly stringent accuracy requirements yet the number of nonlinear runs ("sample size") implied is much larger than common practice or than desirable. Taller, longer period structures have still larger values of d and hence even larger computational demands.

Anything one might do to try reduce this demanding requirement must be justified. One suggestion we make is to first "normalize" the records by an appropriate scaling parameter. One that suggests itself is the spectral acceleration at roughly the first mode frequency of the structure, S_a. (This would be the perfect choice if the structure were a single degree of freedom (SDOF) system and remained elastic during all records.) That this is a useful parameter even for this multi degree of freedom (MDOF) nonlinear system is suggested by Fig. 2, which shows that there is a general trend of drift ductility (μ) with respect to S_a for 1.0 seconds. The deviations away from this trend have d of only about 0.3. The median value of S_a for all 20 records is 0.12g. If first we normalize the records such that they all have this common S_a value, and then conduct the nonlinear analyses we obtain the results shown in Fig. 1b. Importantly, the median ductility is virtually identical to (i.e., formally, not statistically significantly different from) the "right" value, that found by the direct analysis of all 20 original records. But further, the dispersion, d, is only about 0.3, half of the direct value. These two pieces of information suggest that this normalization procedure (1) introduces no bias in estimating the anticipated (median) response and (2) reduces the dispersion by about a factor of 2, implying a reduction of 2^2 or 4 in the necessary number of records. Study of other choices for this scaling parameter has found none consistently better for moderate period structures.

We conclude then that, at least for the case of a unique scenario or design event (specific M and R), the simple expedient of normalizing the representative records by the median S_a (given M and R) can reduce the computation required without biasing nonlinear response estimates. It may still be difficult to justify sample sizes much less than about 10, however. Further, this scaling is structure-specific; it works because after the normalization the records have comparable intensity in the frequency range most critical to the structure.

More Realistic Sites

Few sites have such a simple seismic threat. Typically, a multitude of faults, each capable of a spectrum of magnitudes and epicenters, surround the site. Most frequently the site will be characterized by a probabilistic seismic hazard analysis (PSHA) that integrates the contributions of all potential magnitudes and distances to the likelihood of experiencing a record exceeding a specific spectral acceleration (or linear SDOF response) level. The question is how to select records to represent this complicated mixture of M and R threats?

In the authors' view recent studies suggest that, near-source directivity effects aside, this problem is simply not as difficult as it might appear. A single M and R pair may be quite enough, or it may be quite sufficient to select records from a rather casually representative set of M and R pairs. Why? Because it appears that, given the S_a intensity, the nonlinear displacement response of many structures is virtually independent of magnitude and distance.

The practical implication is that one need not be overly concerned where records have come from, as long as they are of the right intensity in the frequency range of primary importance. These results suggest implicitly that given a "representative" spectrum (perhaps a uniform hazard spectrum) for the site, the engineer is advised to scale the records to the corresponding spectral acceleration level at the first mode frequency of the structure. This will yield unbiased (conditional) median response results with relatively low dispersion.

These general conclusions are not without limits. They may not apply to duration-sensitive cumulative response measures. For taller structures with longer first periods, the normalizing and/or scaling to the first mode spectral acceleration may not bring major dispersion reduction benefits, and there may well be magnitude sensitivity for smaller magnitudes. However, it is possible for such structures to introduce procedures that do reduce the dispersion and hence reduce the number of records and nonlinear analyses (Shome, 1998).

Probabilistic Seismic Demand Analysis (PSDA)

The ultimate objective of efforts to combine the PSHA and efficient nonlinear dynamic analysis is to estimate the annual probability of exceeding any specified level of some chosen "demand" measure, such as maximum interstory drift. In general, as, for example, in modern performance based engineering, we may want to consider several different levels of several different response measures. We call this PS<u>D</u>A (probabilistic seismic demand analysis). The general scheme we use follows from the elements discussed above. It makes use of the commonly available PSHA for a representative S_a, and the results of nonlinear dynamic analyses conducted by scaling records from events with "not unreasonable" M and R pairs to several appropriate levels of this S_a. Making use of the elementary total probability theorem will produce results like those shown in Fig. 3 for the maximum interstory drift for a typical central Los Angeles design of a 5-story SMRF.

We are currently working to help introduce a Load and Resistance Factor Design (LRFD)-like, probability-based, nonlinear-displacement-based, seismic analysis and design scheme. Other work is aimed at near-source record characterization, at "spectrum-compatible" records, and establishing system-level capacities to match these predicted demands.

References

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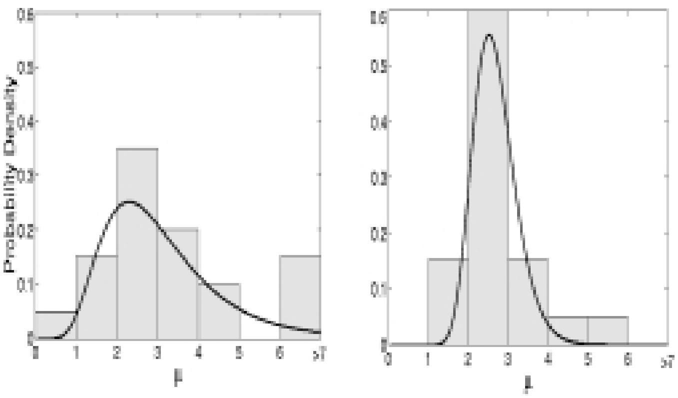

(a) (b)

Fig 1. Fitted distributions and histograms of a) unaltered records; b) normalized records

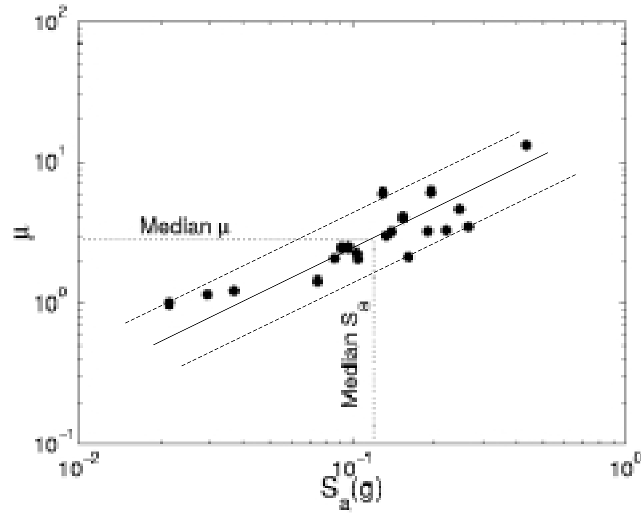

Fig. 2. Variation of drift ductility (μ) given S_a

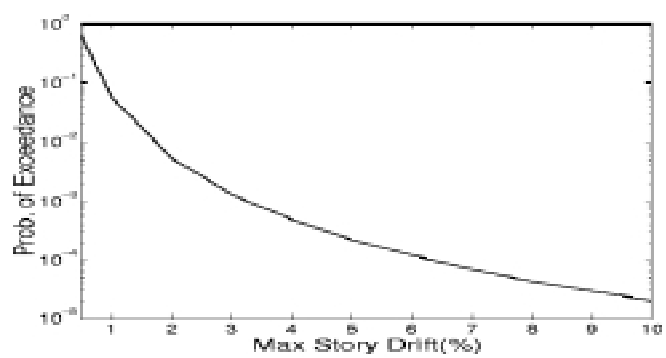

Fig. 3. PSDA curve for maximum interstory drift

CEE EMERITUS PROFESSOR JACK R. BENJAMIN DIES

Jack Benjamin, a long-time faculty member in structural engineering, died on August 26 at the age of 81. Jack came to Stanford in 1948 and retired in 1973. He was well known as a pioneer in the application of statistical and probabilistic methods to civil and structural engineering.

Professor Benjamin was born in 1917 in Olympia, Washington. He was educated at the University of Washington (B.S. and M.S. degrees) and Massachusetts Institute of Technology (Doctor of Science degree, 1942). He then served four years in the U.S. Army during World War II. After the war, he joined the faculty of Rensselaer Polytechnic Institute in 1946, where he taught structural engineering for two years. He then came to Stanford where he stayed for the remainder of his academic career. Professor Benjamin conducted research on probabilistic methods and taught courses in structural design. He was active in the American Concrete Institute (ACI), and was a member of the American Society of Civil Engineers (ASCE) and the Earthquake Engineering Research Institute (EERI).

After retiring from Stanford, Jack and a group of Stanford graduates formed a consulting firm, Jack R. Benjamin and Associates, Inc., currently headquartered in Menlo Park. As a Professor Emeritus, Jack was called upon on several occasions to teach classes in structural engineering and probabilistic methods.

A Memorial Fund in honor of Professor Benjamin has been established in the Department of Civil and Environmental Engineering. Memorial contributions may be sent to the Department at the address given on the heading of this newsletter.

WORKSHOP ON RISK ANALYSIS OF TRANSPORTATION SYSTEMS

On July 10-11,1998, the Blume Center hosted a PEER Center Workshop on Earthquake Risk to Transportation Systems. The workshop was organized by **Prof. Anne Kiremidjian**, **Prof. Samuel Chiu**, and **Dr. Stephanie King** of Stanford University, and **Prof. James Moore** of the University of Southern California. There were 45 participants from PEER Center universities, key transportation engineering and management organizations, emergency response personnel, and business risk managers. The workshop started with presentations on the state-of-the-art in transportation risk analysis and presentations from various transportation provider and user organizations on current needs.

Following the presentations, the participants were divided into three working groups. Group I focused on reviewing the state-of-the-art in transportation system risk modeling and identify gaps in knowledge, analysis, tools, and data. Group II was charged with the task of identifying the needs for emergency response and disaster planning. Group III focused on issues related to regional economic impact of transportation system failure, including approaches for quantifying the losses from business interruption due to loss of transportation corridors. In addition to making recommendations pertaining to specific issues, each group was also asked to identify an application region and a business sector that should be targeted for the demonstration project.

The workshop was held in part to launch the PEER Center Demonstration Project led by Prof. Anne Kiremidjian. Please contact her at the Blume Center for more information on the outcome of the workshop or the plan for the demonstration project.

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(mailing label)