Issue No. 31 Summer 2002

THE JOHN A. BLUME EARTHQUAKE ENGINEERING CENTER

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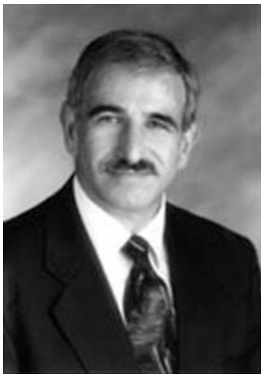
Special Spring Seminars

The Blume Center was pleased to host two outstanding seminars this past spring quarter by Leslie E. Robertson, LERA, and Ronald Hamburger, Simpson Gumpertz and Heger, Inc.

On April 9, Leslie Robertson presented an examination of the World Trade Center, from its inception in 1962 through the tragic events of September, 11, 2001. As Structural Engineer of Record for the World Trade Center, Robertson shared his unique insights into the original planning, design and construction of the project and the many innovations embodied in its design and construction. He also discussed the damage and repair of the tower complex following the 1993 truck bombing and his thoughts on its ultimate destruction from the attack of Sept. 11, 2001. Apart from the technical challenges faced in the project, Robertson recounted personal stories of the engineers, architects, and contractors who designed and built the World Trade Center. These included recollections of the project architect, Minoru Yamazaki, Robertson's partners, John Skilling and Jack Christiansen, and wind engineer, Alan Davenport. Once described by Yamasaki as "a monument to world peace" and "representation of man's belief in humanity", memories of the World Trade Center live on as testament to the triumph of those who designed and built the towers and a memory to those who perished on September 11.



On May 31, Ronald Hamburger presented a seminar entitled, "Dealing with uncertainty in performance-based earthquake engineering (PBEE)". This seminar was a culmination of a guest lectures he presented in the graduate earthquake engineering course this past spring. Hamburger described the evolution of seismic design methods from traditional prescriptive approaches through the latest PBEE concepts, such as those incorporated in the reliability-based FEMA/SAC methodology for steel moment-resisting frame structures, which he helped develop. Hamburger concluded by reflecting on future directions in performance-based engineering, including those being explored in the new ATC-58 project to develop performance-based seismic design guidelines.

Blume Center News

Prof. Ronaldo Borja and Ph.D. Candidate **Medji Sama**, attended the **Sixth International Workshop on Bifurcation and Instabilities in Geomechanics** held at St. John's University in Minnesota on June 2-6, sponsored by NSF. Prof. Borja gave a presentation entitled *"Strain Localization with Large Deformation."*

From May 13-15, **Prof. C. Allin Cornell** attended a meeting of a committee advising the USGS National Seismic Hazard Mapping Project.

On May 9-10, Profs. Luis Esteva(Shimizu Visiting Professor), Chuck Menun, and Eduardo Miranda attended the **UC Berkeley-CUREE Symposium in Honor of Ray Clough and Joseph Penzien.** PhD Candidates **Ricardo Medina**, **Luis Ibarra**, **Jorge Ruiz-Garcia**, and Post-Doc **Christoph Adam** all received a NSF grant to attend the symposium.

Profs. Gregory Deierlein and Jerry Hajjar (2001 UPS Visiting Professor) gave a presentation at the **2002 National Steel Construction Conference**, entitled, *"Proposed New Provisions for Frame Stability using Second-Order Analysis,"* in Seattle, on April 24.

Several Blume Center research students and faculty presented papers at the **2002 ASCE Structures Congress** in Denver, April 3-6: Prof. Gregory Deierlein presented a paper co-authored with **Rohit Kaul**, *"Generalized-Hinge Concepts for Beam-Columns in OpenSees"*; **Paul Cordova** (PhD Candidate) presented a paper co-authored with Prof. Deierlein, *"Seismic Design and Performance Assessment of Composite Steel-Concrete Moment Frames"*; **Amit Kanvinde** (PhD Candidate) presented a paper co-authored with Prof. Deierlein and **W.M. Chi**, *"Micromechanical Models for Predicting Ductile Crack Initiatiion in Metals"*; **Jun Peng** (PhD Candidate) presented a paper co-authored with **Prof. Kincho Law**, *"An Internet-Enabled Software Framework for Collaborative Development of Structural Analysis Program"*.

Prof. Anne Kiremidjian gave the Keynote Lecture, *"Structural Damage Detection and Health Monitoring: A Myth or Reality"* at the **SPIE Conference** in San Diego, March 17-21.

Prof. Anne Kiremidjian presented a paper with **Jerry Lynch, Prof. Kincho Law**, **Tom Kenny** and **Ed Carryer** on *"Issues in Wireless Structural Damage Monitoring Technologies",* at the 3rd World Conference on Structural Control, April 7-12 in Como, Italy.

RESEARCH SPOTLIGHT

Structural Performance Assessment at Near-Fault Sites

By Nicolas Luco and C. Allin Cornell

Motivation and Objectives

At the core of two recent performance-based seismic guidelines, namely the FEMA 350-353 (2000) recommendations for steel moment-resisting frame buildings and the draft ISO Offshore Structures Standard (Younan et al. 2001), is a procedure called Probabilistic Seismic Demand Analysis (PSDA) that is used to compute the mean annual frequency (or annual probability) of exceeding a specified seismic demand for a given structure at a designated site (Cornell 1996). PSDA has also recently been adopted by the Pacific Earthquake Engineering Research (PEER) center as a "foundation on which performance assessment can be based" (http://peer.berkeley.edu/news/2000spring/).

As expressed mathematically in the equation below, PSDA convolves (i) IM, the ground motion hazard at the designated site expressed in terms of the intensity measure IM, and (ii) GDM|IM, the conditional probability of exceeding a specified value of the structural demand measure DM for a given ground motion level.

In principle, the conditional probability GDM|IM is based on DM results from nonlinear dynamic analyses (NDA's) of the given structure for a limited suite of earthquake records - it may also be estimated via more practical methods (e.g., FEMA 350).

When applying PSDA, the ground motion intensity measure (i.e., IM) adopted is customarily the spectral acceleration at or near the fundamental period of the structure (with a damping ratio of 5%), denoted here as Sa(T1). In part, this IM choice is driven by convenience, as seismic hazard curves in terms of Sa(T1) are either readily available (e.g., from USGS) or commonly computed. Moreover, several studies (e.g., Shome et al. 1998) have demonstrated that Sa(T1) is more closely related than PGA, for example, to inelastic demands (e.g., drift) for moderate-period structures (e.g., T1˜1sec). Consequently, the conditional distribution of DM given Sa(T1) can be estimated with relatively few NDA's of the given structure. More recent studies, however, (e.g., Shome & Cornell 1999) have demonstrated that for tall, long period buildings for which higher modes contribute significantly to the seismic response (at least in the elastic range), the results of PSDA may not be accurate when Sa(T1) is employed as the IM. Similarly, for sites susceptible to near-source "pulse-like" ground motions, the use of Sa(T1) can also lead to inaccurate PSDA results, as demonstrated in the PSDA example below.

Ensuring the Accuracy of PSDA

In order to ensure the accuracy (i.e., lack of bias) and precision (i.e., small uncertainty) of PSDA with relatively few NDA's, the IM employed should be "sufficient" and "efficient." An efficient IM is defined simply (from the perspective of a structural engineer) as one that results in a relatively small variability of DM given IM, thereby reducing the number of NDA's and earthquake records necessary to estimate GDM|IM with adequate precision (Shome & Cornell 1999). A sufficient IM, on the other hand, is defined as one that renders DM conditionally independent, given IM, of earthquake magnitude (M) and source-to-site distance (R), thereby ensuring an accurate estimate of GDM|IM regardless of the M's and R's of the earthquake records used for the NDA's. As detailed in (Luco 2002) and illustrated in the PSDA example below, both the efficiency and the sufficiency of an IM can be quantified using (i) the same NDA results used to compute GDM|IM, and (ii) linear regression analysis.

Alternative Ground Motion Intensity Measures

Motivated by the fact that Sa(T1) has been observed to be relatively inefficient and insufficient in relation to drift demands for near-source ground motions and for tall, long period buildings, several new structure-specific scalar IM's are introduced in (Luco 2002). Keeping in mind that the ground motion hazard, IM, must be computed in order to apply PSDA, the space of alternative IM's is intentionally limited to measures that can be computed from only (i) modal vibration properties of the given model structure (e.g., T1 and T2), (ii) a nonlinear static-pushover curve for the model structure, and (iii) elastic or inelastic spectral displacements for the ground motion - all three are routinely attainable pieces of information about a given structure and ground motions at a designated site.

In the PSDA example to follow, only two of the aforementioned IM's are considered. Regarded as a basis for comparison, the ground motion intensity measure IM1E, which is roughly proportional to Sa(T1), is simply the first-mode estimate of the structural demand measure of interest (i.e., DM) computed according to elastic modal analysis. In an attempt to reflect the contributions of higher modes and the effects of inelasticity, the ground motion intensity measure IM1I&2E is considered as well. As detailed in (Luco 2002), IM1I&2E is equal to the first-two-mode elastic SRSS estimate of DM multiplied by a ratio of inelastic to elastic first-mode spectral displacements.

PSDA Example at a Near-Fault Site

To demonstrate the precision and accuracy of PSDA when employing IM1I&2E versus IM1IE at a site susceptible to near-source "pulse-like" ground motions, a 9-story SMRF building (T1=2.23sec) hypothetically located at a U.C. Berkeley site that is 3.6km from the Hayward-Rogers Creek (HRC) Fault system is considered. The structural demand measure (DM) of interest is the maximum (over all stories) peak (over time) interstory drift angle (i.e., normalized by story height), denoted max. Note that, unlike for IM1IE, the ground motion hazard at the site expressed in terms of IM1I&2E cannot be calculated via Probabilistic Seismic Hazard Analysis (PSHA) because an attenuation relation for IM1I&2E does not exist. Hence, as detailed in (Luco 2002), an alternate approach using earthquake records simulated by Mai (2002) is taken. Via this simulation-based approach, it is also possible, with hundreds of NDA's, to compute the DM hazard (i.e., DM) "exactly."

The figures on the left below illustrate the log-log linear regressions of the DM results from NDA on IM1E (top row) and on IM1I&2E (bottom row) for a set of 30 earthquake records (in this case all simulated for a full rupture of the HRC Fault system). The results of these regressions are used in computing GDM|IM and also to demonstrate the enhanced efficiency (i.e., smaller dispersion about the regression fit, quantified by) of IM1I&2E relative to IM1IE. The middle two figures, on the other hand, illustrate log-linear regressions of the DM residuals from the left-most figures on the associated earthquake magnitudes, which are used to assess the sufficiency of IM1E and IM1I&2E. Note that the enhanced sufficiency of IM1I&2E relative to IM1IE is quantified by the "p-value" that is small when the conditional dependence of DM, given IM, is significant. Finally, the figures on the right display the results of PSDA, using IM1E or IM1I&2E, for a range of specified DM values (i.e., DM hazard curves). Shown in each figure are six different PSDA estimates of the DM hazard, each computed using a different set of 30 simulated earthquake records (one of which is the same set considered in the other four figures). Also shown is the "exact" solution computed via the simulation-based approach mentioned above. Note that when IM1I&2E is employed in lieu of IM1IE, all but one of the DM hazard curves computed via PSDA coincides with the "exact" result.

As demonstrated in this example, the use of an efficient and sufficient ground motion intensity measure like IM1I&2E is important for ensuring the accuracy of PSDA at near-fault sites. Unlike Sa(T1) (or IM1E), however, computing the ground motion hazard at a site in terms of IM1I&2E remains a major challenge.

Acknowledgements

The authors gratefully acknowledge the financial support of the U.S.-Japan Cooperative Research in Urban Earthquake Disaster Mitigation Project (NSF 98-36) under grant number CMS-9821096, and the PEER Center (also sponsored by NSF) under project number 3051999.

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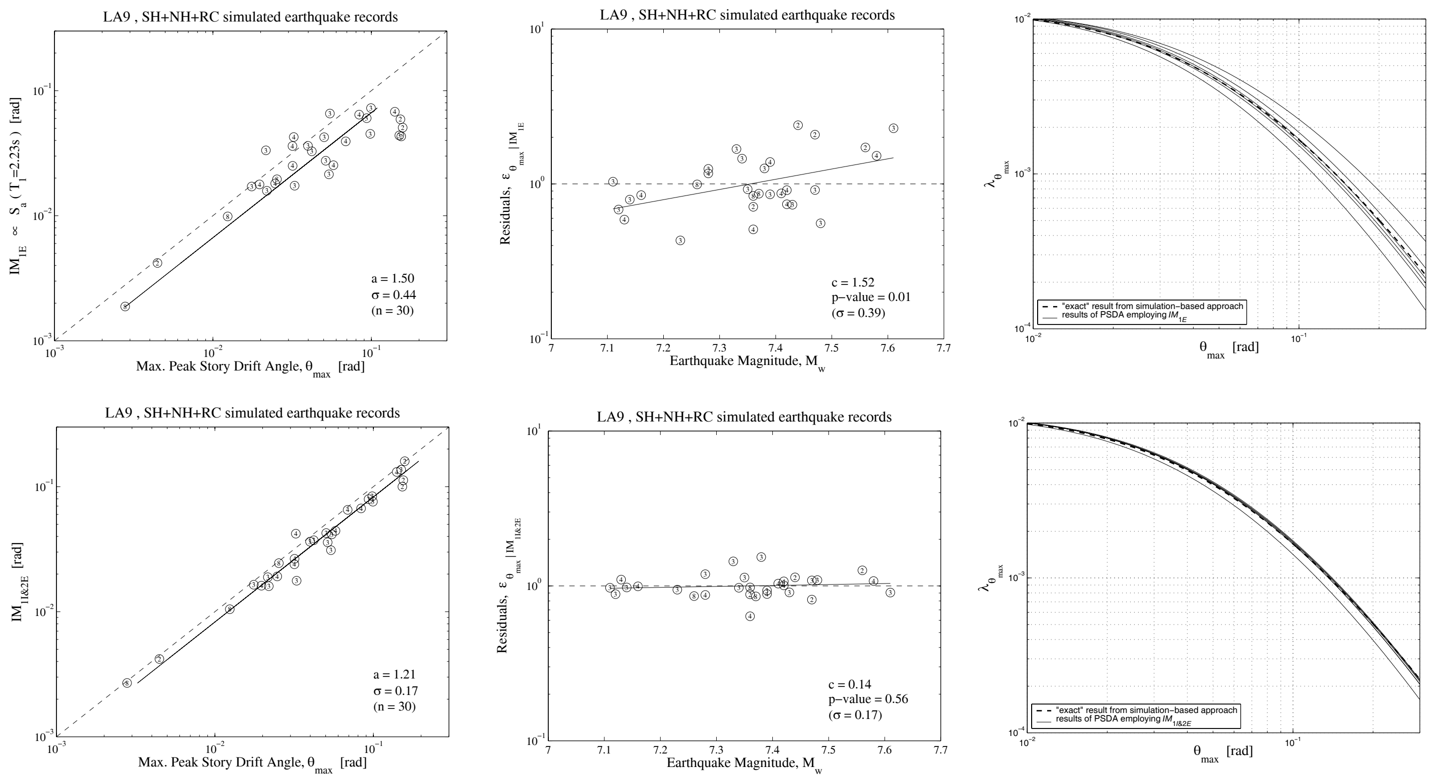

Krawinkler on Sabbatical

Professor Krawinkler, much to the his "regrets" but with joy expressed by the students, took a short sabbatical leave during spring quarter. After spending the month of April on catching up with chores, he succeeded in leaving the country for May, June, and July. He made technical visits, had exciting technical discussions with colleagues and friends from universities and industry,

and was invited to the following great places: University of Patras in Greece (host: Prof. M. Fardis), the Technical University of Istanbul (host: Prof. F. Karadogan); the Middle East Technical University (host: Prof. P. Gulkan), the annual meeting of the French Association of Seismologists and Earthquake Engineers in Paris (host: Prof. W. Jalil, Prague (host: Prof. P. Marek; to attend a conference on Monte Carlo simulation), and the University of Ljubljana in Slovenia to continue his collaborative work with Professor Peter Fajfar. Every place was a true pleasure to eyes, mind, and stomach, and his hosts have been most generous in their efforts to make his visit a delightful experience.

In his visits he found out that excellent work in earthquake engineering is done not just in California, but also in many other places. He also rediscovered the pleasure of supplementing hard work with enjoyable personal, cultural, social, and just plain fun experiences, a practice that is taken for granted in the places he visited.

Spring 2002 Graduates

Structural Engineering and Geomechanics students graduating with a Master of Science degree in Spring Quarter 2002 were **Jack Baker, Sarah Besser, Gek Choo Goh** (Public Service Commission of Singapore), **Richard Hansen** (Washington Group International, Inc.), **Ayse Hortacsu** (Hart Weidlinger), **Jackie Lai** (Volkswagon of America), **Jimmy Lam, Wing Law, Kirsten McKay, Matthew Melrose** (LERA), **Jason Stone** (LERA), **Mehmet Tuncer, Robert Wright, Chia Yeh, and Kwang Yeo.** Receiving their PhD degree were **Nicolas Luco** (AIR Worldwide Corporation), and **Timothy Lai** (Foster Wheeler Environmental Corporation).

Graduating from the Design Construction Integration (DCI) program with a Master of Science Degree were **Pablo Algara**, **Diego Aviles-Amador**, **Brian Baer**, **Kevin Coyne**, **Sharon Kik Yu Eng**, **Robert Farman**, **John Foster**, **Jack Gerwick**, **Florent Janssen**, **Amy Wang**, **Wendy Wang**, **Douglas Whimpey** and **Lawrence Wong**.

Awards and Appointments

Prof. Anne Kiremidjian was named to the National Research Council Committee on the Long-Term Research Agenda for Earthquake Engineering.

Prof. Kiremidjian has also been appointed to the External Advisory Board of the Mid-America Center.

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