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THE JOHN A. BLUME EARTHQUAKE ENGINEERING CENTER

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING, STANFORD UNIVERSITY

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BLUME CENTER TO SPONSOR QUAKE '06 CENTENNIAL ALLIANCE LECTURE SERIES

Professor Greg Deierlein and Blume Center Admin **Racquel Hagen** are serving on the Steering Committee for Stanford University's Quake '06 Centennial Alliance. Commemorating the 1906 San Francisco Earthquake with several events, including an exhibit in Meyer Library, a walking tour of the campus with informational displays, and a lecture series co-sponsored with UC Berkeley, Stanford, as a member of the 1906 Earthquake Centennial Alliance (http://06centennial.org) aims to increase community awareness of the effect of the earthquake on the university campus, and broaden understanding of the way this event has contributed to technological advances in seismic hazard and earthquake preparedness and mitigation.

The Blume Center, together with UC Berkeley, is hosting a series of lectures that will examine various aspects of the 1906 Earthquake. Running from September 2005 through April 2006, each lecture will be given both at Stanford and at Berkeley, in order to reach both communities. The series will be in two parts. Part 1 will feature the Historical and Social Perspectives in three lectures by Kevin Starr, Malcolm Barker and Stephen Tobriner. Part 2 with focus on the Earth Science, Earthquake Engineering, Preparedness and Disaster Response with Mary Lou Zoback, Eric Elsesser Chris Poland and Kathleen Tierney.

For more information including dates and information on the speakers, please see the Quake '06 website at http://quake06.stanford.edu.

PUBLISHED PAPERS

Ruiz-Garcia, J. and **Miranda, E.** "Inelastic Displacement Ratios for Structures Built on Soft Soil Sites," *J. of Struct. Eng.*, Vol. 130, No. 12, December 2004, pp. 2051-2061

Akkar, S. and **Miranda, E.** "Statistical Evaluation of Approximate Methods for Estimating Maximum Deformation Demands on Existing Structures," *J. Struct. Eng.,* 131(1), January 2005, pp. 160-172.

Miranda, E. and **Taghavi, S.** "Approximate Floor Acceleration Demands in Multi-Story Buildings. I: Formulation," *J. Struct. Eng.,* 131(2), February 2005, 203211.

Taghavi, S. and Miranda, E. "Approximate Floor Acceleration Demands in Multi-Story Buildings. II: Applications," *J. Struct. Eng.,* 131(2), February 2005, 212220.

Aslani, H., and Miranda, E. "Probability-based structural response analysis." Engineering Structures, 2005, 27(8), pp. 1151-1163.

BLUME CENTER NEWS

Profs. Allin Cornell and **Eduardo Miranda** participated in the International Symposium on Earthquake Engineering Commemorating Tenth Anniversary of the 1995 Kobe Earthquake (ISEE Kobe 2005) organized by the Japan Association for Earthquake Engineering. The symposium was held on Awaji Island on January 13 - 16, 2005. Prof. Miranda also attended the E-defense Inauguration Symposium on January 16th which included a full-scale testing of a Japanese two-story wood house subjected to full scale 1995 Japan Meteorological Agency (JMA) Kobe record (PGV=160 cm/cm2) in the new E-Defense shake table.

Prof. Allin Cornell was the co-winner of the 2003 Earthquake Spectra Outstanding Paper Award for "Translating Research to Practice: FEMA/SAC Performance-Based Design Procedures." The award was presented at the 2005 EERI Annual Meeting held in Ixtapa, Mexico, Feb. 2-6.

Ph.D. Candidate **Paul Cordova** presented his paper, "“Full-Scale Test of a Composite Moment-Frame System" at the 2005 EERI Annual Meeting. Paul was the 2003-2004 NEHRP Graduate Fellow in Earthquake Hazard Reduction.

Prof. Helmut Krawinkler gave a keynote lecture on "Design for Collapse Safety" at the Second International Conference on Urban Earthquake Engineering, held at the Tokyo Institute for Technology on March 7-8.

Prof. Ronnie Borja participated in an International Workshop on Micro-Geomechanics Across Multiple Strain Scales held in Cambridge, England, on March 20-23, 2005. The workshop was sponsored by NSF.

Dr. Renate Fruchter organized and chaired the 4th International Social Intelligence Design Workshop (SID2005), March 24-26, Stanford. University. She presented three papers together with her students - **Zhen Yin**, **Pratik Biswas**, and **Subashri Swaminathan**.

Prof. Sarah Billington attended the ACI Convention in New York City (April 17-19).

Prof. Ronnie Borja presented a paper on the theoretical formulation for partially saturated porous media at the Third Biot Conference on Poromechanics held in Norma, Oklahoma on May 24-27, 2005.

Prof. Helmut Krawinkler was on sabbatical leave during Spring Quarter, spending about half of the time at Stanford catching up with research commitments and the other half visiting the following universities: April 19-May 11: Universidad Politecnica de Valencia in Spain (host: Prof. Pellicer (MS '92)), June 13-20: U. of Patras, Greece (host: Prof. Beskos), June 26-28: U. of Ljubljana, Slovenia (Host: Prof. Fajfar), June 29-July 2: Technical U. Vienna, Austria (hosts: Profs. Ziegler and Adam, and July 3-7: Technical U. Budapest, Hungary (host: Prof. Kollar. During these visits he participated in research discussions and gave seminars on prediction of collapse and other research at the Blume Center. In between, from June 20 to 23, he attended the ICOSSAR conference where he gave a presentation on collapse prediction.

Ph.D. Candidate **Jiro Takagi** and his wife **Ritsuko** welcomed their first child, a daughter, **Mei**, on May 3.

stets were observed in the tests was observed to be relatively high when developing fragility functions only as a function of peak interstory drift ratio. Therefore, in order to obtain improved estimates of the probability of experiencing or exceeding these damage states, fragility surfaces were developed for the third and fourth damage states, in which the probability of experiencing each damage state was computed not only as a function of the peak interstory drift ratio but also as a function of the vertical shear ratio, V_g/V_0, where V_g is the vertical shear that acts on the slab critical section defined at a distance d/2 from the column face in which d is the average slab effective depth, and the normalizing shear force V_0 is the nominal punching shear strength in the absence of moment transfer in the connection. For the case of punching shear failure damage state, in the proposed fragility surface, the probability of experiencing punching shear failure is computed using Eq. (1), but the median interstory drift capacity varies as a function of the level of gravity load present in the slab at the time of earthquake as follows

$$\widehat{IDR}_{DS3} = 0.014 + 0.03\exp\left[-4440\left(\frac{V_g}{V_0}\right)^{1}\right] \quad (2)$$

and the logarithmic standard deviation of the interstory drift capacity also varies as a function of the vertical shear ratio as follows

$$\sigma_{\ln IDR_{DS3}} = 0.62 - 0.4\exp\left[-11.6\left(\frac{V_g}{V_0}\right)^{2.9}\right] \quad (3)$$

Figure 2 shows the fragility surface resulting from the use of Eqs. (1), (2) and (3). Comparison of Figures 2 and 3 shows that computing the two parameters of the lognormal distribution as a function of the gravity shear ratio using Eqs. (2) and (3) leads to much better estimations of the probability of experiencing or exceeding a damage corresponding to a punching shear failure. For example, in a slab-column connection with a vertical shear ratio of 0.1 subjected to an interstory drift ratio of 0.02, the probability of experiencing or exceeding a punching shear failure is essentially zero as can be seen in Figure 2, while if the effect of the gravity load ratio is neglected, (e.g., using Figure 1), this probability would be estimated as 46%, hence, significantly overestimating damage in the connection.

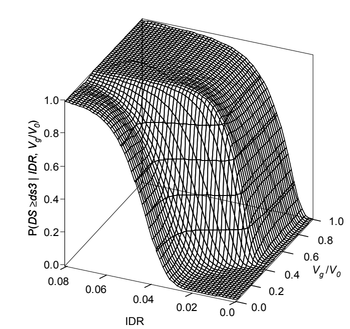

Figure 2. Fragility surface proposed to account for high levels of specimen-to-specimen variability for the third damage state in slab-column connections.

Epistemic Uncertainty on Fragility Functions

In addition to specimen-to-specimen variability, another source of uncertainty that need to be considered in estimating the level of damage in slab-column connections is epistemic uncertainty. Two sources of epistemic uncertainty were incorporated in this study. The first source is the uncertainty caused by using fragility functions whose parameters have been obtained from a limited number of specimens. This source of epistemic uncertainty is referred here as finite-sample uncertainty. The second source is the uncertainty produced by the fact that damage observations in the specimen are typically only collected at peak values of each cycle of the loading protocol. Therefore, the drifts reported at a certain damage state in a specimen will typically correspond to the peak drift that was imposed to the loading cycle in which the damage state was observed.

Figure 3 presents an example on the effects of epistemic uncertainty on the fragility curve for the third damage state in a slab-column connection with a gravity shear ratio of 0.2. The black line in the figure corresponds to the fragility curve in the absence of epistemic uncertainty, while the gray bands correspond to a 90% confidence band on the fragility curves when both sources of epistemic uncertainty have been considered. It is worth noting that the second source of uncertainty in addition to increasing the confidence band on the median drift also decreases the drift capacity (i.e., introduces a bias by shifting the fragility curve to the left) This means that even the parameters used in Eq. (1) are uncertain. As shown in the figure, this uncertainty may be significant and needs to be accounted for when performing propagation of uncertainty in loss estimation [2]. For example, as shown in Figure 3, a 50% probability of experiencing or exceeding a punching shear failure damage state (median capacity) can occur at interstory drifts ranging from 0.035 to 0.05.

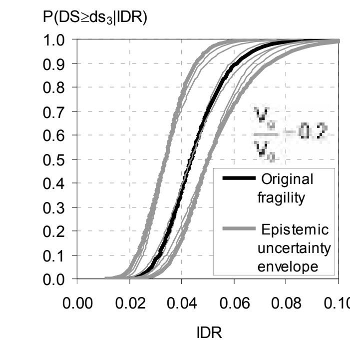

Figure. 3. Incorporation of epistemic uncertainty to the fragility function corresponding to the punching shear failure damage state of a slab-column connection.

Conclusions

Fragility functions that provide a probabilistic estimation of the level of damage experienced in slab-column connections of non-ductile reinforced concrete buildings have been presented. In these fragility functions the damage is estimated as a function of the peak interstory drift imposed on the connection. The new fragility information can be used in estimating damage at the component level and with damage states associated to specific repair actions. Furthermore, by using results from experimental studies, the study has identified and quantified the uncertainties associated with estimating damage in slab-column connections.

Two sources of uncertainty were incorporated in the fragility functions: specimen-to-specimen variability and epistemic uncertainty. Specimen-to-specimen variability corresponds to the fact that different specimens experience the various damage states at levels of deformation that in general are different for each specimen. The specimen-to-specimen variability was incorporated by developing drift-based fragility functions at each damage state. Two kinds of epistemic uncertainty were considered. The first one is associated to the fact that the parameters of the fragility functions have been obtained from a limited number of specimens, and the second is associated to the fact that damage observations in the various specimen were typically collected only at the end of each loading cycle and therefore the resulting fragility functions are influenced by the drift increment used in the loading protocol that was employed to test each specimen. Quantitative measures for each of these two kinds of epistemic uncertainty were developed using statistical procedures. Results indicate that in some cases the effects of epistemic uncertainty on the probability of experiencing each damage state are significant and should be incorporated.

References

1. PEER Center, (2005). PEER Testbed Study on a Hotel Building – Exercising Seismic Performance Prediction.", Editor: Krawinkler, H., Pacific Earthquake Engineering Research (PEER) Center, Richmond, CA. In press.
2. H. Aslani, E. Miranda (2005). Fragility Assessment of Slab-Column Connections in Existing Non-Ductile Reinforced Concrete Buildings. Journal of Earthquake Engineering. In press.
3. H. Aslani, (2005). Probabilistic Earthquake Loss Estimation and Loss Disaggregation in Buildings." *Ph.D. Thesis*, John A. Blume Earthquake Engineering Center, Dept. of Civil and Environmental Engineering, Stanford University, Stanford, CA. 382 pages.

StrGeo & DCI Seminars

During the Winter and Spring we were honored to have a number of seminars given by both practitioners and faculty of other Universities. The seminars are a wonderful opportunity for our students to hear about current research and innovations at other institutions and in the private sector.

Dr. Jeremy Isenberg of Weidlinger Assoc. gave the John A. Blume Distinguished Lecture on April 7, "A Rational Defense Against Irrational Acts: Civil Engineering Aspects of Homeland Security."

Special seminars were given by **Bret Lizundia** of Rutherford & Chekene, "Design and Construction of The New de Young Museum;" **Youssef M.A. Hashash** of the Univ. of Illinois, "A Novel Approach to the Extraction of Complex Soil Behavior;" **Leslie E. Robertson** of LERA, "Recent and Current Work: Hong Kong to Shanghai;" **Theodosios Tassios** from NTU, Athens, "Build, Operate and Transfer: Public Works in Ancient Greece;" **Victor Li** of the Univ. of Michigan, "Next Generation Structural Concrete - Development and Applications;" **John Ochsendorf** of MIT, "Static and Dynamic Analysis of Masonry Structures: From Arch Bridges to Gothic Cathedrals;" and **Reginald DesRoches** of Georgia Tech, "Appilications of Shape Memory Alloys in Seismic Resistant Design and Retrofit."

PEER Annual Meeting

The Blume Center was well represented at the PEER 2005 Annual Meeting in Walnut Creek, April 29-30. **Profs. Greg Deierlein**, **Sarah Billington**, and **Allin Cornell** made plenary session presentations on “Benchmarking Performance Implied by Design Codes,” “Improved Bridge Performance through Self-Centering Technologies,” and “Guidelines for Selection and Scaling of Ground Motions for PBEE.” Eight graduate students presented posters on a variety of topics related to performance assessment and design of bridges, buildings, and transportation systems.

Winter/Spring 2005 Graduates

The following students graduated with a Masters Degree in Structural Engineering and Geomechanics or Design Construction Integration in Winter Quarter: **Adam Burkett** (Rutherford & Chekene), **Giselle Chanona** (KPFF-LA), **Rupa Garai** (SOM), **Sabrina Macedo-Moran** (Robert Silman Assoc.), **Symoane Mizell** (Camp Dresser & Mckee), **Serge Rizk** (Wall Street Analytics) and **Rajkiran Vojjala** (RMS).

Receiving a Masters Degree in Structural Engineering and Geomechanics or Design Construction Integration in Spring Quarter were **Liz Agnew** (Hinman Consulting)**, Rex Arashi** (Buehler & Buehler), **Richie Armstrong** (UC Davis-PhD), **Noor Atari** (SOM), **Justin Bocian** (Severud and Associates), **Will Boenig, Yu-Ning Chen** (Dasse Design), **Carlos Fernandez, Kenneth Fung** (LERA), **Josh Guerard, Jason Holland, Cameron Hufford** (Magnusson Klemencic Assoc.), **Pardeep Jhutti** (Ficcadenti Waggoner and Castle), **Hyung Kim** (John A. Martin & Assoc.), **Jennifer Kimura** (SOM), **Carl Kloos, Erik Kneer** (Degenkolb), **Dimitrios Kolios, Nick Kuffel, Satoshi Matsuki, Julian Nahan** (Beck Group), **Steve Patton** (Nabih Youssef Eng), **Meredith Resnick** (Lockheed Martin), **Neal Turbow** (Pruitt, Eberly & Stone), **Zixiao Zhang, Molly Ziergiebel** (Sensametrics, Inc.). **Hesaam Aslani** received his Ph.D. in Structural Engineering and is now working at RMS.

Student Awards

Graduate Student **Cole Olsen** received the 2005-2006 W.R. Grace Scholarship Award from the American Concrete Institute.

Ph.D. Candidate **Qiang Fu** won the top prize in the EERI graduate student paper category, "The Application of Incremental Dynamic Analyses to Fault-Normal Near-Field Ground Motion."

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