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THE JOHN A. BLUME EARTHQUAKE ENGINEERING CENTER

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Cornell Receives Housner Medal

Prof. C. Allin Cornell is this year's recipient of EERI's highest honor, the George W. Housner Medal. The medal was awarded for Cornell's distinguished career in advancing understanding of earthquake hazards and reduction of earthquake risk. His seminal paper in 1968, entitled "Engineering Seismic Risk Analysis," was the first to quantify seismic hazard and risk. His publications on probabilistic modeling of earthquake processes form the basis for statistical earthquake forecasting that have been widely applied around the world and are now incorporated in modern building codes. Cornell has made fundamental contributions to structural engineering by integrating seismic hazard analysis, building vulnerability, and failure probability into the design process. He was elected to the National Academy of Engineering in 1981 and is a fellow of the American Geophysical Union. He has received many other honors for his contributions to the field, including the ASCE Walter L. Huber Research Prize, the Norman Medal for the best paper among all ASCE journals, the ASCE Freudenthal Medal for distinguished achievement in safety and reliability studies, and the Medal of the Seismological Society of America (SSA).

Winter 2003 Graduates

Geoff Bomba (Forell/Elsesser), **Sara Casciati**, **Sung-Won Kim**, **Renee Lee**, **Iris Leoncio**, **Amy Padovani** (Rutherford Chekene), **Mehmet Burak Tuncer** graduated with Master's Degrees in Structural Engineering and Geomechanics. Tuncer is continuing at Stanford for an Engineer Degree and Lee will be in the PhD program.

EERI/FEMA Fellowship Recipient at Stanford

Dr. Joseph R. Maffei, Rutherford & Chekene, has been selected as the 2003 NEHRP Professional Fellow in Earthquake Hazard Reduction, awarded by EERI. Maffei is carrying out his research on facilitating the transfer of knowledge between researchers and practicing structural engineers on issues relating to seismic hazard, ground motion, and probabilistic analysis, under the direction of **Prof. Allin Cornell**.

Maffei has been a senior technical consultant at Rutherford & Chekene since 1995. He has written numerous technical reports and papers in which he explored ways to improve the design and performance evaluation of concrete structures and masonry wall buildings, and reviewed the seismic performance of bridge retrofit technology.

Kanvinde Wins EERI Paper Competition

Graduate student Amit Kanvinde won the top prize in EERI's student paper competition for "Methods to Evaluate the Dynamic Stability of Structures: Shake-Table Tests and Nonlinear Dynamic Analysis." Kanvinde received a travel grant to present his paper at the Annual Meeting in Portland in February.

Blume Center News

The Engineering Informatics Laboratory, under the direction of Prof. Kincho Law, received an equipment grant from Intel Corporation. The Engineering Informatics Group conducts research on Computational Engineering and Mathematics, Engineering and Regulatory Information Management, Parallel and Distributed Computing, and Infrastructure for Internet-based Engineering Web Services.

Prof. Anne Kiremidjian participated in the US-Japan Workshop on Lifeline Earthquake Engineering, January 6, in Long Beach, CA. She presented a joint paper with Jim Moore, Nesrin Basoz, Yue-yue Fan, Meredith Williams and Ozgur Yazlali on "Evaluation of traffic delay times in trapoortation networks from earthquakes".

Prof. Kincho Law participated in an E-rulemaking workshop sponsored by NSF and Harvard's School of Government, Harvard University, January 21-22.

Prof. Anne Kiremidjian gave the Distinguished Lecture for the Department of Civil Engineering at the University of Texas, Austin on January 22, "Earthquake Hazard and Risk - A Regional Approach".

In late February, Prof. Helmut Krawinkler went to Beijing for two days to give a presentation on performance-based earthquake engineering at the China-U.S. Workshop on Protection of Urban Infrastructure and Public Buildings Against Earthquakes and Man-made Disasters. The stay in Beijing was rewarding, technically and personally, since it permitted attendance of an interesting workshop plus a re-visit of the Great Wall in Badaling, which he last visited in 1980.

On February 4, Profs. Helmut Krawinkler and Greg Deierlein chaperoned 25 MS students to the SEAONC Stanford Student Night. The SEAONC meeting at the San Francisco City Club was preceded by a tour of the offices of Forell/Elsesser Engineers. The office tour and the SEAONC meeting gave our students a flavor of the positive and collaborative atmosphere that exists in the Northern California structural engineering community.

Profs. Greg Deierlein, Helmut Krawinkler, Eduardo Miranda, Allin Cornell, Chuck Menun and Sarah Billington and several of their graduate students participated an d presented posters at the PEER Annual Meeting in Palm Springs, Feb. 7-8. Profs. Deierlein and Krawinkler chaired breakout sessions and Prof. Miranda made a presentation on seismic performance of nonstructural components.

Profs. Greg Deierlein and Eduardo Miranda participated in the 2003 Pacific Conference on Earthquake Engineering held in Christchurch New Zealand on February 12-15. They presented work being conducted in the Pacific Earthquake Engineering Research (PEER) Center. Other participants from PEER included Profs. Mary Comerio, Peter May and Jack Moehle.

Prof. Kincho Law presented a seminar entitled "Interenet-Enabled Software Framework for Finite Element Structural Analysis," at UCSD, February 19.

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RESEARCH SPOTLIGHT

Global Collapse Safety of Deteriorating Systems

By Luis Ibarra and Helmut Krawinkler

Introduction

In this study global collapse is associated with dynamic instability in a sidesway mode, usually triggered by large story drifts that are amplified by P-Δ effects and material deterioration. Therefore, replication of collapse necessitates modeling of deterioration characteristics of structural components subjected to cyclic loading.

Traditionally global collapse is evaluated by using "happy" (nondeteriorating) systems to predict Engineering Demand Parameters (EDPs) and assigning judgmental limits to these parameters. However, relevant EDPs, like story drift and ductility, become unstable in systems close to collapse and small perturbations produce large variations on EDPs. For this reason,

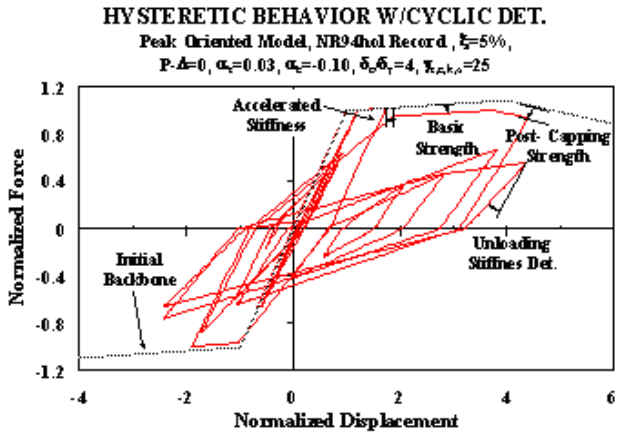

Figure 1 Deteriorating Peak Oriented Model

in the proposed methodology global collapse is described not by an EDP but by a relative intensity measure, defined as the ratio of ground motion intensity to a structure strength parameter. The relative intensity at which collapse occurs is called "collapse capacity". The use of deteriorating models permits a redistribution of damage and takes into account the ability of the system to sustain significantly larger deformations than those associated with reaching the ductility "capacity" in one component. A final product could be the mean annual frequency of collapse, which is obtained by developing fragility curves from collapse capacities and combining them with the hazard information at a given site.

Description of Deteriorating Models

Deterioration models have been developed for bilinear, peak-oriented and pinching hysteretic models. The monotonic backbone curve of these systems is trilinear, consisting of an elastic stiffness K_e, a strain hardening range that is capped at a maximum strength F_c associated with the deformation δ_c, and is followed by a negative tangent stiffness $\alpha_c K_e$. In addition, the following four cyclic deterioration modes are considered (using energy dissipation as a deterioration criterion, Ref. 1): basic strength, post-capping strength, unloading stiffness, and reloading (accelerated) stiffness deterioration. Figure 1 shows the response of an SDOF peak oriented system with rapid cyclic deterioration. Basic strength and post-capping deterioration effects move the strain hardening and post-capping branch toward the origin, unloading stiffness deterioration decreases the unloading stiffness, and reloading stiffness deterioration increases the target maximum displacement.

Collapse Capacity

To obtain the collapse capacity, inelastic time history analysis are carried out in which the relative intensity $(S_a/g)/\eta$ is increased until dynamic instability occurs. For SDOF systems, S_a/g, which is used as a measure of the ground motion intensity, IM, is the spectral acceleration at the natural period of the system and, $\eta = F_y/W$ is the normalized base shear yield strength. If S_a/g is increased and η is kept constant, the resulting graphs are called Incremental Dynamic Analysis (IDA) curves. If η is decreased and S_a/g is kept constant, the graphs may be called Strength Variation (SV) curves, and $(S_a/g)/\eta$ is then equivalent to the conventional strength reduction factor, R.

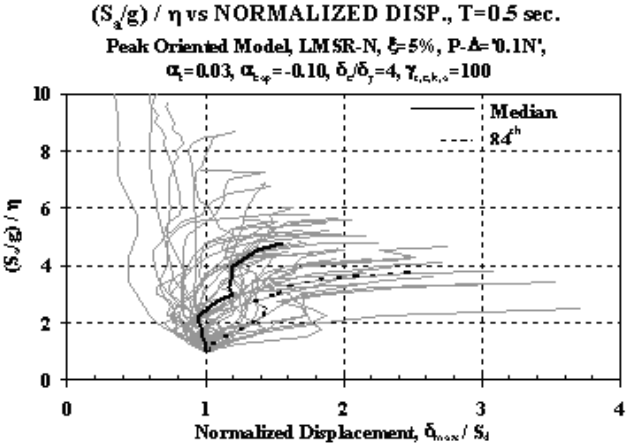

Figure 2 (Sa/g)/η -EDP curves for SDOF Systems

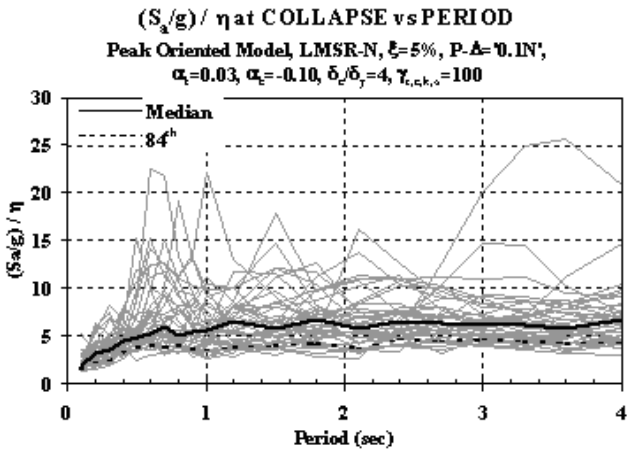

Figure 3 Collapse Capacity Curves for SDOF Systems

Global collapse occurs when the $(S_a/g)/\eta$-EDP curve becomes flat because the relative intensity can no longer be increased. In SDOF systems, this implies that the loading path is on the back-bone curve and intersects the horizontal (zero resistance) axis. Thus, a condition for collapse is the presence of a negative slope in the backbone curve, which can be caused by P-Δ effects, post-capping slope, or a combination of these two.

Figure 2 shows $(S_a/g)/\eta$-EDP curves for an SDOF system

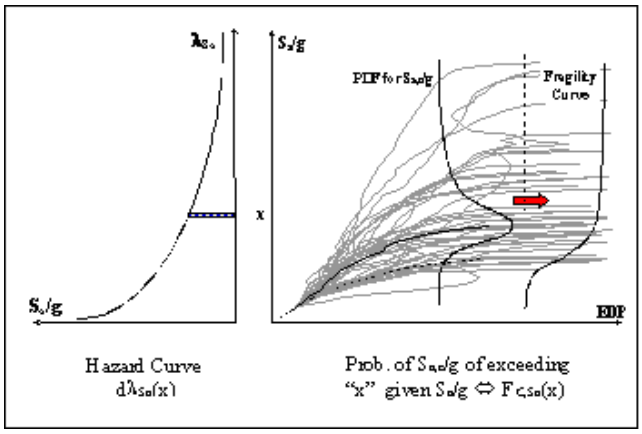

Figure 4 Assessment of Mean Annual Frequency of Collapse

with T=0.5 sec and specific deterioration parameters. This plot is part of a parametric study carried out with a set of 40 "ordinary" ground motions over a period range from 0.1 to 4.0 seconds. A large dispersion of results caused by differences in the frequency content of the ground motions is observed. Curves of this type can be produced for different deterioration parameters, which permits an evaluation of the parameters that most influence collapse. Collapse capacities are the $(S_a/g)/\eta$ values associated with the last point on the curves. If these points are computed over a period interval of interest, results of the type shown in Figure 3 are obtained.

Mean Annual Frequency of Collapse

The mean annual frequency of collapse can be computed as,

$$\lambda_f = \int F_{C_{Sa}}(x)\,|\,d\lambda_{S_a}(x)\,| \qquad (1)$$

where $F_{C_{Sa}}(x)$ represents the probability of the S_a capacity, $S_{a,c}$, exceeding x, and $\lambda_{Sa}(x)$ is the mean annual frequency of Sa exceeding x (ground motion hazard). $F_{C_{Sa}}(x)$ corresponds to the fragility curve obtained from individual collapse capacities, see Figure 4. In this context, the structure strength parameter η is kept constant, i.e., the individual curves represent IDAs.

Figure 5 shows mean annual frequencies of collapse for a specific site, for selected η values. These results are obtained by numerical integration of collapse fragility curves of the type shown in Figure 4 over hazard curves for selected periods pertaining to the specific site.

Concluding Remarks

The use of deterioration models allows the evaluation of collapse capacity in terms of the relative intensity $(S_a/g)/\eta$. The mean annual frequency of collapse can be obtained by integrating the collapse fragility curve for a given η value over an S_a hazard curve pertaining to a specific site. The results presented here are for SDOF systems and a few selected deterioration parameters. Parametric studies for multi-story frame structures are nearing completion.

Ref. 1: Ibarra, L., Medina, R., and Krawinkler, H., "Collapse Assessment of Deteriorating SDOF Systems," Proceedings of the 12th European Conference on Earthquake Engineering, London, Sept. 2002.

Acknowledgements:

The research summarized here is supported by the Pacific Earthquake Engineering Research (PEER) Center as part of a multi-year effort to develop basic concepts for performance-based earthquake engineering. This support is much appreciated.

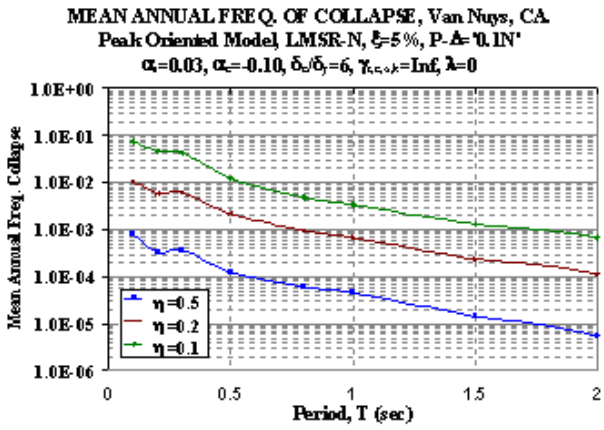

Figure 5 Mean Annual Frequency of Collapse for SDOF systems

Published Papers

Lai, T.Y., Borja, R., Duvernay, B., and **Meehan, R.,** *"Capturing strain localization behind a geosynthetic-reinforced soil wall,"* International Journal for Numerical and Analytical Methods in Geomechanics, 2003; 27: 425-451.

Alumni News

Eugenio Pellicer (MS '93) received tenure and was promoted to Associate Professor at the Universidad Politecnica de Valencia (Spain).

Hoon Sohn (PhD '98) won the Best Paper Award (first place) at SPIE's NDE for Health Monitoring and Diagnostics Symposium for "Utilizing the Sequential Probability Ratio Test for Building Joint Monitoring", co-authored with David W. Allen, Keith Wordon and Charles R. Ferrer.

2003 Stanford Visitation Day

The Department of Civil and Environmental Engineering hosted prospective graduate students who have been offered admission to a Visitation Day on Saturday, March 22, 2003. The event began with a general orientation given by **Chairman Bob Tatum**, followed by individual program orientations. The Structural Engineering and Geomechanics Program hosted over 35 prospective students at their program orientation. Faculty speakers included **Profs. Chuck Menun**, **Greg Deierlein**, **Eduardo Miranda**, and **Ronnie Borja**. The event also featured a luncheon with the faculty and current graduate students, and concluded with a campus tour.

Blume Center News

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Prof. Greg Deierlein gave an invited presentation on PEER Research at an ATC 58 workshop on performance-based seismic design in San Francisco on Feb. 24-25. Profs. Helmut Krawinkler, Allin Cornell, Anne Kiremidjian, and Eduardo Miranda participated in the workshop.

Prof. Kincho Law participated and presented a paper entitled "Design of Wireless Sensor Units with Embedded Time-Series Damage Detection Algorithms for Structural Health Monitoring," co-authored with **Jerry Lynch**, **Arvind Sundararajan**, **Anne Kiremidjian** and **Ed Carryer**, at a Caltrans/UCSD workshop on Structural Monitoring and Diagnostics of Bridge Infrastructure, UCSD, March 7-8, 2003.

Three papers were presented by graduate students at the SPIE (the International Society for Optical Engineering) conference on Smart Systems and NDE for Civil Infrastructures, March 2-6, 2003 in San Diego. **Jerry Lynch** (MS ' , PhD '02) presented a joint paper with **Profs. Anne Kiremidjian**, **Kincho Law** and **Ed Carryer** from Stanford and **Hoon Sohn** (PhD ') and **Charles Farrar** of Los Alamos National Labs on "Wireless structural monitoring field validation using the Alamosa Canyon Bridge". Postdoctoral fellow **Dr. Ying Lei** presented a joint paper with **Prof. Kiremidjian**, **Jerry Lynch** and graduate student **Krishnan Kesavan** on "Time synchronization algorithm for system Identification". Graduate student **Anil Kottapalli** presented papers at the conference co-authored with **Jerry Lynch**, **Profs. Kiremidjian**, **Law**,

Alumni, Affiliates and Friends are encouraged to send news items about yourselves to earthquake@ce.stanford.edu for inclusion in the next newsletter.

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