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The John A. Blume Earthquake Engineering Center

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PROFESSOR GREG DEIERLEIN JOINS STANFORD FACULTY

The Blume Center is pleased to announce that Professor Greg Deierlein will be joining the Stanford faculty in the Department of Civil and Environmental Engineering as an Associate Professor starting on September 1, 1998. Prof. Deierlein will join the Structural Engineering and Geomechanics Group and be an integral part of the research and teaching activities at the Blume Center.

Prior to coming to Stanford, Prof. Deierlein was an Associate Professor in the Civil Engineering Department at Cornell University, where he recently received the 1997 Cornell College of Engineering James and Mary Tien Excellence in Teaching Award. His research and teaching focus on structural engineering with emphasis in linear and nonlinear analysis methods and the design and behavior of steel and composite steel-concrete structures under seismic and wind loads.

Prof. Deierlein has published more than 75 refereed journal papers, conference proceedings papers, book chapters, and technical reports. He is active on several professional committees including the AISC Load and Resistance Factor Design Specification Committee, BSSC Technical Subcommittee on Composite Structures, and the ASCE Committee on Composite Construction.

Prof. Deierlein is not a stranger to Stanford's Department of Civil and Environmental Engineering. While on sabbatical leave from Cornell in 1995-1996, he held the UPS Visiting Professorship at Stanford. During his 9-month stay, he developed and taught a new graduate course on nonlinear structural analysis.

VISITING PROFESSOR LASZLO KOLLAR RETURNS TO BUDAPEST

At the conclusion of the Spring Quarter, the Blume Center bid farewell to Professor Laszlo Kollar, who was a Visiting Professor in the Department of Civil and Environmental Engineering for the 1997-98 academic year. While at Stanford, Prof. Kollar taught graduate structural engineering courses on finite element analysis and composite materials. He returns to the faculty of Civil Engineering in the Department of Reinforced Concrete Structures at the Technical University of Budapest.

BLUME CENTER NEWS

On April 14, **Prof. Helmut Krawinkler** organized a CUREe-Kajima workshop at the Blume Center. The topic was near-field ground motion effects on long-period structures.

On April 29, **Prof. Anne Kiremidjian** participated on a USGS-organized panel on earthquakes and their effects on the San Francisco Bay area that was shown on Cable Channel 6 in Palo Alto.

Prof. Helmut Krawinkler attended the 3rd US-Japan Workshop on Steel Fracture Issues held April 19-22 in Tokyo, Japan. The workshop focused on the progress made in the two countries on solving the problems caused by the weld fractures observed in many steel moment resisting frame structures in recent earthquakes.

The Technical Council on Lifeline Earthquake Engineering held its semi-annual Executive Committee Meeting at the Blume Center on April 16-17.

On April 23, **Prof. Helmut Krawinkler** gave a presentation at the first CUREe-SEAOC Seminar on Structural Engineering at U.C. Berkeley. The same seminar was given at the Blume Center on May 6. The purpose of this seminar series was to present practitioner and academic viewpoints on structural engineering to graduate students.

On May 18 and June 26, the Blume Center hosted groups of students and faculty from Reykjavik University in Iceland and the University of Weimar in Germany, respectively.

Several students and faculty from the Blume Center participated in the 6th U.S. National Conference on Earthquake Engineering held May 31 - June 4 in Seattle, including **Prof. Anne Kiremidjian**, **Prof. Allin Cornell**, **Prof. Helmut Krawinkler**, **Dr. Stephanie King**, **Dr. Rachel Davidson**, **Dr. Anju Gupta**, and Ph.D. students **Luciana Barroso**, **Paolo Bazzurro**, **Scott Breneman**, **Jorge Carballo**, **Akshay Gupta**, **Abhijit Kakhandiki**, **Nicolas Luco**, **Nilesh Shome**, and **Hjortur Thrainsson**. The Blume Center organized a reunion for alumni who were attending the conference, which was hosted by Robert Bigler [B.S./M.S., 1996] and his wife Merideth at their Seattle waterfront apartment.

Prof. Anne Kiremidjian presented a paper at the Third International Conference on Computational Stochastic Mechanics held in Santorini, Greece on June 14-17.

Dr. Renate Fruchter has established the "Computing in Action" Student Competition, which will be sponsored by Autodesk and held at ASCE's 1998 Annual Convention and Exposition in October in Boston.

RESEARCH SPOTLIGHT

Dynamic Control Strategies for Seismic Resistance of Buildings and Performance-Based Engineering

By Scott E. Breneman and Luciana R. Barroso, Ph.D. Candidates
Research Advisor: H. Allison Smith, Associate Professor

Introduction

In recent years, research in the development of control systems has made significant progress in the reduction of the overall response of civil structures subjected to seismic excitations. While some dynamic controls systems, such as base-isolation systems, have matured to the point of practical applications, many other proposed methods of decreasing the seismic vulnerability of civil structures have yet to progress beyond their conception. Part of what is keeping some of these methods from maturing into realistic alternatives available to earthquake engineers during structural design is the difficulty in incorporating the new dynamic control systems into traditional prescriptive building codes and design methods. This difficulty, however, is being removed through the growth of performance-based design.

Given the current discussions on multi-level performance based design, the benefits of control systems can easily be directly included in the design and vulnerability assessment of structures, without having to form new code standards for each proposed control system. For example, the performance evaluation method we are employing defines the structural seismic performance in terms of the annual probability of exceeding certain demand levels (e.g. inter-story drift ratio or base shear). These probabilities of exceeding certain demand levels arise from combining the results of a site specific probabilistic seismic hazard analysis with the structural behavior ascertained from non-linear dynamic simulation of the structure with any additional dynamic control system. The design process in completed by finding a structural system and dynamic control system combination that yields demand probabilities less than pre-specified design requirements. This method is outlined in a recent publication by Nicolas Luco and C. A. Cornell of Stanford University (Luco and Cornell 1998).

The goals of this research are to delineate how dynamic control system design can be incorporated into performance based design methods and to use these methods to evaluate the benefits of many of the proposed control systems (active and passive). These goals are accomplished by designing several alternative dynamic control systems for example buildings and comparing how efficient the control systems are at increasing the performance of the buildings. An additional goal is to use this comparison to better understand and improve the control system design process. The dynamic control systems considered in the scope of this research include base-isolation systems; viscous, visco-elastic and friction damping devices; active and tuned mass dampers; and active tendon braces.

Performance Evaluation

As accurate determination of structural demands is an important component of the performance evaluation process, much of the work done to date has focused on developing the analytical tools to evaluate the performance of a structure with applied control systems. The evaluation tool for this study is a robust non-linear dynamic structural analysis platform that can easily incorporate a variety of control system models including a model of the digital control algorithms in active control systems (Barroso et al. 1998). Preliminary investigations have shown that simple linear models can lead to inaccurate demand requirements for actively controlled systems. This result is largely attributed to the complex interaction between the nonlinear behavior of control systems (friction, saturation) and structural nonlinearities (primarily yielding). Because of the complexity in adding the control system modeling requirements into a commercial structural dynamics package, we have chosen to implement our own structural dynamics analysis platform, including control systems modeling, in MATLAB. While the MATLAB analysis platform is not as numerically efficient as most commercial structural analysis software, it is much more flexible and can be readily modified and augmented for our research needs. The basic structural modeling is based on 2D lumped plasticity frame elements, including P-M (axial-flexural) capacity interaction in the column hinges. A schematic of the components of a typical beam model is shown in Figure 1. The non-linear behavior of the plastic hinges is defined using the Buc-Wen non-linear hysteretic model including 3% strain hardening (Wen 1976). For structures where large deformations cause significant additional forces, first order P-Delta stiffness reduction is also included in the analysis.

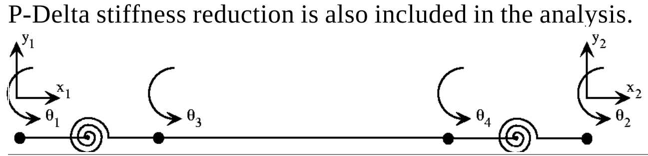

Figure 1 : Lumped Plasticity Beam Model

Example Problem

The performance of a three-story, steel moment resisting structure is evaluated to illustrate the preceding concepts. The design of the unaugmented structure was developed for case studies in the SAC Phase 2 Steel Project under 1994 Uniform Building Code requirements (Krawinkler and Gupta 1998). The design represents a "real" structure, professionally designed according to typical engineering practice for the region. A 2D finite element model of one SMRF frame of the structure was developed using the lumped plasticity model with nonlinear hinges placed at the bases of the columns and the ends of each moment resisting girder. The resulting model has 38 degrees of freedom with an elastic period of 1 sec.

For this structural system, we have designed several dynamic control systems including passive and active systems. We will show a comparison of the results of three passive systems and one active system. The first passive system is a Friction Pendulum System (FPS) with an isolation period of 3 sec. The other two passive damping systems are fluid viscous damper systems, each increasing the damping of the first mode of the structure to 30% of critical damping by adding viscous elements acting as braces across each of the 3 stories. The passive damping system D1 has an equal distribution of damping in all 3 stories, while the system D2 distributes the damping proportional to story stiffness. The active system included in this example is a active tendon brace (ATB) system with braces spanning the center bay of each story of the building. The active braces saturate at a force of 325 kips (~5% building weight). For sensor configuration of the active system, the building is also equipped with accelerometers to measure the horizontal acceleration of each floor and the deflection across the actuator. While this active control system would not considered viable alternative for a three story SMRF building, it is included to provide an understanding of the scope of our work. Given this active control architecture, H_∞ control theory was used to design a control algorithm to command the actuators in response to the sensor measurements where the controller design objectives were to minimize a combination of the inter-story drifts, the absolute acceleration of the stories and the control forces required.

The four controlled systems and the original uncontrolled structure were then simulated using 20 ground motion records. The ground motion records selected for the analyses are the 20 included in the 10% probability of exceedence in 50 years set developed by Paul Sommerville et al. for the SAC Phase 2 Steel Project and the Los Angeles site (Sommerville, Anderson et al. 1998). The acceleration time histories have each been uniformly scaled so the spectral accelerations conform to the 1996 USGS probabilistic ground motion maps at the structural periods of 0.3, 1, 2 and 4 sec.

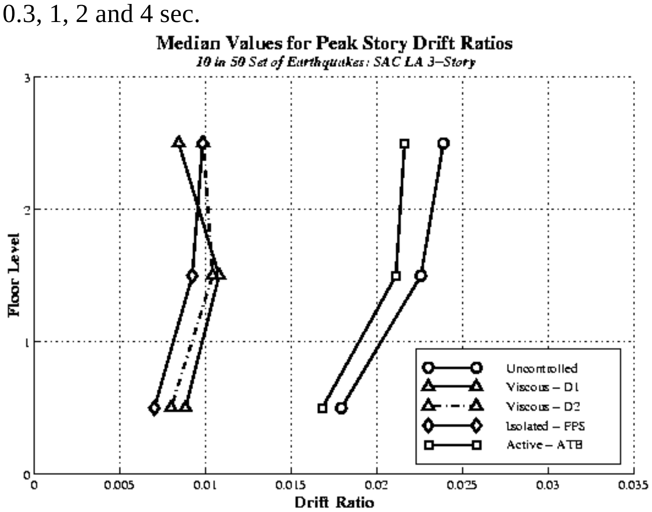

Figure 2 : Median Peak Story Drift Angles

Figure 1 shows a comparison of the median peak drift ratio in each story over the suite of earthquakes. What is readily apparent in this figure is that the active brace system reduces the peak drift ratio only by small amounts (5-9%) while all of the passive systems reduce the peak drift values to around 0.01 (roughly 50%). Each of these passive systems were designed to keep the structure elastic under this medium level of earthquake excitation. The resulting passive viscous dampers have maximum axial forces of over 1,000 kips, whereas the active system only has 325 kips forces available while working from the identical locations.

To complete the performance based evaluation of these systems, this structure and control systems are also simulated at other levels of earthquake excitation (Sommervile's SAC-LA 2% in 50 years, and 50% in 50 years ground motion suites). The results of these analyses are then combined with the site spectral acceleration hazard analysis to estimate the annual exceedance probabilities of drift demands. These drift demand curves can be used to determine whether the structure and control system meet the design objectives or compare the effectiveness of alternative control schemes across multiple hazard levels.

Summary and Future Work

This comparison only provides an example of the structural dynamic evaluation of a few alternatives available to earthquake engineering. The authors are working with a variety of control system architectures on the 3, 9 and 20 story SAC structures. Also significant work has been completed on more accurate system models used in the design of active controllers (Breneman and Smith 1998). Parties interested in more information on this research are welcome to contact the authors directly. In addition, detailed reports on this work will be available in Ph.D. dissertations and Blume Center reports next spring

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ALUMI NEWS

Erik Straser [Ph.D., 1998] received his doctorate in June and has joined the venture capital firm DVM Ventures in Menlo Park.

Abhijit Kakhandiki [Ph.D., 1998] received his doctorate in June and has joined the Palo Alto office of SAP, an international enterprise application software company. He was also married on July 4 in Pune, India.

Rachel Davidson [Ph.D., 1997] recently joined the faculty in the Department of Civil Engineering at the University of North Carolina at Charlotte.

On June 2, **Ajay Singhal [Ph.D., 1996]** and his wife Anju welcomed the birth of their first child, a daughter Arpita.

Greg Chiu [Ph.D., 1995] left his position at the Institute for Business and Home Safety (IBHS) and is currently a Research Assistant Professor in the Department of Building and Construction at the City University of Hong Kong.

Eduardo De Santiago [Ph.D., 1996] is an Assistant Professor in the Department of Civil and Architectural Engineering at the Illinois Institute of Technology.

Natasha Shekdar [M.S., 1998] is working for the Boeing Company in Seattle.

Cynthia Cardona [M.S., 1997] is working as a project manager for GeoHazards International (GHI). Although GHI is still affiliated with Stanford, they have moved their headquarters from the Blume Center to Palo Alto.

Anju Gupta [Ph.D., 1997] is working for Risk Management Solutions in Menlo Park in the Government Services Division.

STUDENTS TO RECEIVE STANFORD GRADUATE FELLOWSHIPS

Three incoming graduate students pursuing M.S./Ph.D. degrees in Structural Engineering and Geomechanics have received Stanford Graduate Fellowships beginning in the Fall Quarter of 1998. The recipients are Shawn Kerrigan, Chao Li, and Gwynn Masada. The Department of Civil and Environmental Engineering was able to offer the new Stanford Graduate Fellowships to seven of its top prospective doctoral students. The fellowship program offers full support to more than 100 science, engineering, and social science students across the University, and hopes to increase that number to 300. Fellowships provide three years of tuition plus an annual stipend of about $16,000. The grants are intended to aid not only the fellows but also the professors and research groups with whom they work.

Over $125 million has been raised of the $200 million goal that Stanford President Gerhard Casper set when he announced the graduate fellowship program in 1996. The program was started to tackle the problem of uncertain government support for research, especially inventive and interdisciplinary work, such as the earthquake engineering research conducted at the Blume Center. The fellowship program is also being considered as a recruitment tool. It was very successful in its first year, as 56% of students who were offered the fellowships selected Stanford over MIT, Caltech, Berkeley, Carnegie Mellon, and other top science and engineering universities.

For more information on the Stanford Graduate Fellowships see http://www-leland.stanford.edu/dept/DoR/Fellows/.

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