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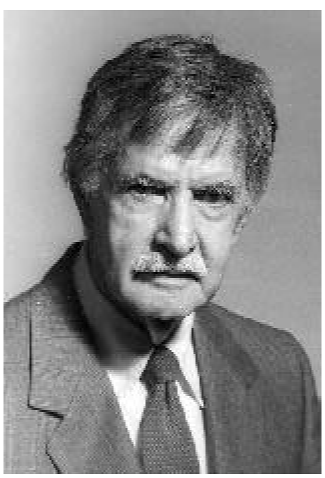
The John A. Blume Earthquake Engineering Center

Department 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*
Administrative Associate: *Racquel Hagen*

DR. JOHN A. BLUME CELEBRATES 90TH BIRTHDAY

Dr. John A. Blume, often called "the father of earthquake engineering", celebrated his 90th birthday on April 8, 1999.

Born in 1909 in Gonzales, California, a few miles south of Salinas, Dr. Blume and his family moved to San Francisco three weeks later. Dr. Blume's rescue work in Santa Barbara following the 1925 earthquake helped pave his interest in earthquake engineering. Recalling the work he did in Santa Barbara, Dr. Blume "resolved then and there to try -- some day -- to do something about the earthquake problem. The fact that my parents and grandparents barely survived the 1906 earthquake gave me added incentive."



In 1929, Dr. Blume enrolled at Stanford University in structural engineering. He received the A.B. degree with distinction in 1933, and his Engineer Degree in January of 1935, also from Stanford. His company, John A. Blume and Associates, founded in 1945, became the preeminent consulting firm in structural and earthquake engineering. In 1964, Dr. Blume decided that he needed to update his education in such modern areas as matrix and computer analysis of structures, statistical methods, stochastic processes and decision-making in civil engineering, and returned to Stanford University to earn his Ph.D. He was awarded the degree on January 6, 1967, exactly 34 years to the day after receiving his A.B. degree. His concept for an earthquake engineering center at Stanford University was realized in 1974, and the University fittingly recognized his vision and generosity by naming the center after him. The John A. Blume Earthquake Engineering Center is appropriate evidence of his conviction that engineering practice derives its substance from education and research.

Everyone at the The Blume Center wishes Dr. Blume a very happy birthday!

BLUME CENTER NEWS

During the Winter Quarter, The Blume Center hosted visitors from the **Earthquake Disaster Mitigation Research Center in Japan**, **Nanyang Technical University in Singapore**, **Kajima** and **Tepco Corp. of Japan**, and the **National Defense Academy of Japan**.

Prof. Ronnie Borja presented a paper entitled "Modeling Strain Localization and Faulting in Soft Rock" at the Plasticity '99 Symposium in Cancun, Mexico on January 5-13, 1999.

On January 7-8 in New York, **Dr. Stephanie King** presented a paper at a workshop on loss estimation methodologies as part of the New York City-area Consortium for Earthquake-Loss Mitigation (NYCEM), a FEMA-funded project for which she is a technical advisor.

Dr. Yoshifumi Nariyuki, Associate Prof., Dept. of Ecosystem Engineering at the University of Tokushima in Japan is a visiting scholar at the Blume Center until September 1999.

Dr. Stephanie King participated in a 2-day workshop on "Geographic Information Science and Geospatial Activities at NSF", held in Washington D.C. on January 14-15.

Several students and faculty spent the weekend of January 29-31 in Lake Tahoe for the **Annual Blume Center Ski Trip**.

Prof. Manabu Yoshimura from Tokyo Metropolitan University is at the Blume Center as a visiting scholar until August 1999.

Prof. Allin Cornell gave the EERI Distinguished Lecture at several locations around the country, including University of Michigan, University of Illinois, Cornell University, and Washington University.

On February 9, **Prof. Helmut Krawinkler**, **Prof. Laura Lowes**, and **Prof. Greg Deierlein** attended the monthly meeting of SEAONC with over 20 graduate students from the Blume Center. Prior to the meeting, the group visited the office of **Forell/Elsesser Engineers** to learn about consulting structural engineering practices.

On February 12, **Prof. Greg Deierlein** participated in a meeting of the BSSC Code Resource Support Committee in San Francisco to discuss proposed changes to the seismic provision of the International Building Code 2000.

Prof. Greg Deierlein made presentations describing his research work on fracture toughness requirements for welded steel structures at the SAC meetings in San Francisco on January 8-9, and in San Diego on February 16.

Dr. Stephanie King served as Program Chair for the Fifth Annual California GIS Conference, held February 17-19 in Oakland.

On March 17, **Prof. Anne Kiremidjian** gave an invited presentation at Notre Dame University as part of the IBM Seminar Series in Science and Engineering within the Dept. of Civil Engineering.

RESEARCH SPOTLIGHT

Seismic Performance of Composite Steel-Concrete Moment Frame Buildings

Sameh S.F. Mehanny, Ph.D. Candidate
Gregory G. Deierlein, Associate Professor (ggd@stanford.edu)

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Introduction

Over the past twenty years, composite moment frame building systems, or so-called RCS frames consisting of reinforced concrete (RC) columns and steel beams, have been used in the US and Japan as a cost-effective alternative to traditional structural steel or RC construction (Griffis 1992). Compared to high-rise steel buildings, RCS systems offer more efficient use of materials, a reduction in total construction time, and the elimination of field welding at beam-column connections. The latter helps avoid fracture problems experienced with welded steel connections that were observed after the Northridge earthquake. In spite of the advantages of RCS systems, their use in high seismic regions has been constrained by the lack of design information on composite component behavior and inelastic system performance.

As a sequel to previous investigations on composite steel-concrete structures by Professor Deierlein's research group, the objectives of this project are to (1) develop efficient and accurate analytical models for analyzing RCS moment frames, (2) develop damage indices and performance criteria to assess seismic performance of RCS frames under multi-level earthquake hazards, and (3) evaluate the performance implied by building code requirements for RCS frames in the 1997 AISC-Seismic Provisions and the forthcoming International Building Code (IBC) 2000. The ultimate goal is to achieve broader acceptance and utilization of RCS frames in high seismic regions.

Analytical and Modeling Tools

DYNAMIX – a program for the DYNamic Analysis of MIXed (steel-concrete) structures has been developed through this and previous research with capabilities to perform inelastic static and dynamic analyses of two- and three-dimensional steel and RCS frames (El-Tawil et al. 1996). DYNAMIX employs a bounding surface stress-resultant plasticity model that accounts for the interaction of axial loads and biaxial bending moments in steel, RC, and composite beam-columns. Included are the effects of spread-of-plasticity, geometric nonlinearities (P-Δ and P-δ), and cyclic stiffness degradation. Integration points along the element length relate inelastic section behavior (i.e., moment-curvature response captured through the bounding surface model) to overall member response. DYNAMIX also includes models for composite connections between RC columns and steel beams, taking into account finite joint size and inelastic panel shear and bearing deformations with cyclic stiffness/strength degradation. An interactive graphical user-interface facilitates ease of use and interpretation of the computed response with DYNAMIX.

Seismic Damage Indices

Damage indices provide criteria to quantify the performance of structural elements, sub-assemblages, and overall system response under a given loading event. Aside from their role in relating numerical response quantities to physical damage descriptions, damage indices are necessary to establish structural acceptance criteria at near collapse levels, since even the best analytical models alone still cannot faithfully simulate structural collapse under earthquake induced dynamic effects.

A new ductility damage index is introduced, whose chief characteristics are to (1) account for *cumulative* damage, (2) reflect the *temporal* effects of loading sequence, and (3) readily accommodate the response of structural components with *unsymmetrical* behavior, e.g., composite beams. The index is described by the following expression:

$$D_+^\theta = \frac{\left(\left|\theta_+^p\right|_{\text{Current PHC}}\right)^{\alpha} + \left(\sum_{i=1}^{n}\left|\theta_{+,i}^p\right|_{\text{FHC's}}\right)^{\beta}}{\left((\theta^u - \theta^y)_+\right)^{\alpha} + \left(\sum_{i=1}^{n}\left|\theta_{+,i}^p\right|_{\text{FHC's}}\right)^{\beta}}$$

where inelastic component deformations (expressed symbolically as θ) are distinguished between primary and follower cycles and accumulated over the loading history. An example relating the computed damage index to corresponding structural damage in an RCS beam-column joint specimen is shown in Figure 1. The test data shown in this figure are from previous tests of composite RCS connection subassemblies by Kanno and Deierlein (1993).

Performance Assessment and Case Studies

Two RCS framed buildings, 6- and 12-stories tall, have been designed for a *theme* structure study as part of the US-Japan cooperative research on composite and hybrid structures. The buildings are designed according to the 2000 IBC for a high seismic region with mapped spectral accelerations of S_s=1.5g and S_1=0.72g. Seismic performance is assessed using two sets of acceleration records – one comprised of eight *general* records and the other of eight *near-fault* records with forward directivity. For multi-hazard analyses, it is assumed that the accelera

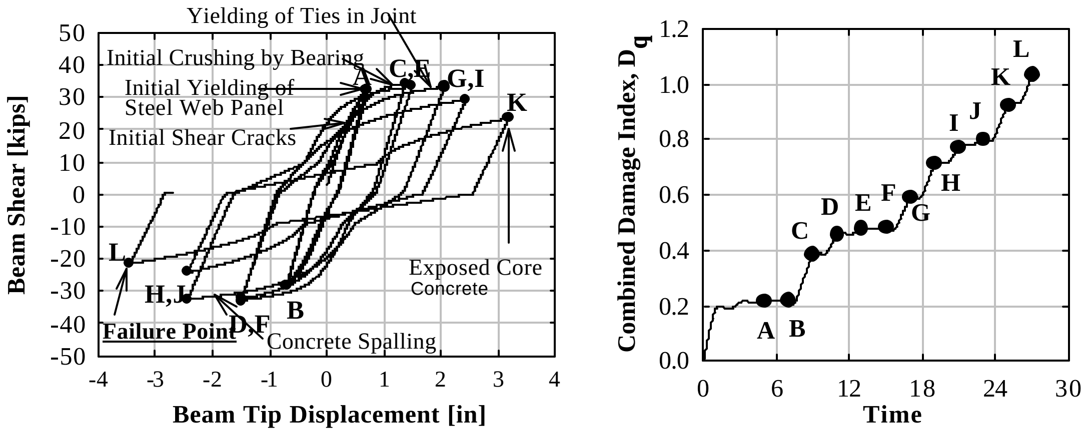

Figure 1. Evolution of damage and damage index in composite beam-column connection.

tion component of the records can be linearly scaled to represent various earthquake intensities.

An example set of results for the 6-story building subjected to the near-fault records is shown in Figure 2. Here the spectral accelerations of the scaled earthquake records, measured at the fundamental period of the structure, are related to the peak inter-story drift ratio from corresponding time-history analyses. Thus, each point in Figure 2 corresponds to the peak response

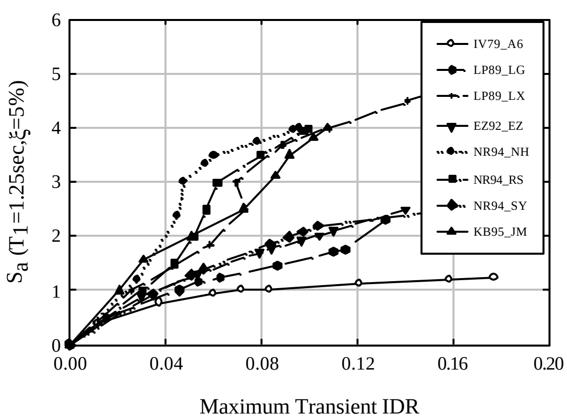

Figure 2. S_a-IDR relationship for near-fault records.

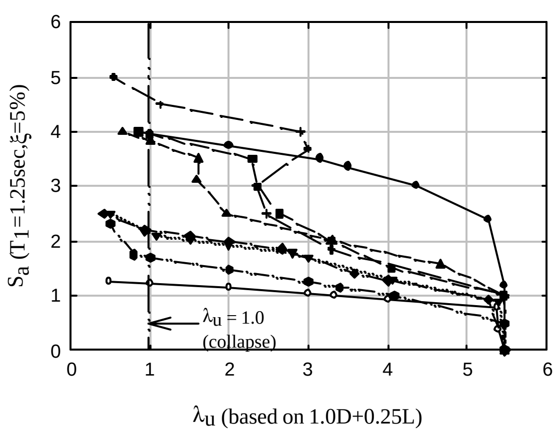

Figure 3. S_a-λ_u relationship for near-fault records.

from a single time history, and the eight plots joining the points for each ground record represent so-called Dynamic Pushover Curves. Owing to the limitations of the analysis to fully capture strength/stiffness degradation, these curves in and of themselves do not reveal a clear stability limit.

In a subsequent step, damage indices calculated from each time history analysis provide the basis for modifying the structural analysis model to approximate the damaged condition after an earthquake. Primarily, these modifications involve reducing element stiffnesses and strengths based on the accumulated damage and incorporating the residual (permanent) building drift into the structural topology. This modified model is then reanalyzed by a second-order inelastic analysis under gravity loads to determine the resulting gravity load stability index, λ_u, defined as the normalized vertical gravity load capacity. This index provides a failure criterion for each earthquake record and intensity, $S_a(T_1,\xi)$, which can then be related to a specific hazard level. Values of λ_u range from λ_{uo} = 5.5 for the undamaged structure to λ_u = 1.0 for conditions at incipient collapse. λ_u thus serves as a global failure criterion that integrates the effect of local damage on reducing the system stability. Figure 3 shows the evolution of damage from λ_{uo} to λ_u=1.0 for the eight near-fault records. These data infer relationships between the near-collapse limit state λ_u=1.0 and seismic hazard (intensity) levels.

References

Griffis, L.G. (1992), "Composite Frame Construction," *Constructional Steel Design - An International Guide*, Ed. Dowling et al., Elsevier Applied Science, NY, pp. 523-554.

El-Tawil, S.; Deierlein, G.G. (1996), "Inelastic Dynamic Analysis of Mixed Steel-Concrete Space Frames," *Stuct. Engrg. Report 96-5*, Cornell Univ., Ithaca, NY, 235 pgs.

Kanno, R.; Deierlein, G.G. (1996), "Seismic Behavior of Composite (RCS) Beam-Column Joint Subassemblies," *Proc. of Composite Constr. III*, ASCE, NY, pp. 236-249.

NEWLY SPONSORED PROJECTS

NPDP Internet Information Stystem and Dam Performance Evaluation System, sponsored by the Federal Emergency Management Agency. Principal Investigators: **Prof. Ronaldo Borja** and **Consulting Prof. Martin McCann, Jr.**

Several faculty members have received projects funded though the Pacific Earthquake Engineering Research (PEER) Center. They include:

Professor Greg Deierlein
Project Title: *Analytical Models for Reinforced Concrete Frames with Strength and Stiffness Degradation*

Professor Allin Cornell
Project Title: *Technical Foundation for Performance-Based Design Formats*

Professor Anne Kiremidjian
Project Title: *Seismic Risk Model for a Highway System*

Professor Helmut Krawinkler
Project Title: *Seismic Demands for Performance-Based Design*

Professor Kincho Law
Project Title: *A Software Platform for Collaborative Development of Nonlinear Dynamic Analysis Code*

Professor Laura Lowes
Project Title: *Development and Verification of a Bond-Zone Model*

BLUME CENTER VISITING PROFESSOR
KATSUHIKO ISHIDA

The Blume Center welcomes Dr. Katsuhiko Ishida to Stanford University. Dr. Ishida will be at the Blume Center as a visiting professor until April 2001. Currently, he holds the position as Director of Abiko Research Lab, Central Research Institute of the Electric Power Industy in Tokyo, Japan. He holds a Bachelor of Engineering degree from the Musashi Institue of Technology and his Masters and Ph.D. from the University of Tokyo. Stanford was priviledged to host Dr. Ishida as a Visiting Research Scholar at the Blume Center from 1978-80. A member of the Architectural Institute of Japan, the Seismic Society of Japan and the Institute of Social Safety Science, Dr. Ishida has published over 40 papers on earthquake engineering.

His current reseach at the Blume Center focuses on developing the dynamic, 3-dimensional town model to simulate the effects of earthquake disaster mitigation activities. The model considers the development of the dynamic function of the town. He is also looking into risk assessment of the design process under performance based design procedures.

The John A. Blume Earthquake Engineering Center
Stanford University
Department of Civil & Environmental Engineering
Building 540, MC: 4020
Stanford CA 94305-4020

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