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The John A. Blume Earthquake Engineering Center

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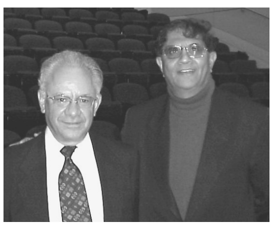
PROFESSOR LUIS ESTEVA SPEAKS AT 2ND SHAH FAMILY LECTURE

Professor Luis Esteva, Director of the Institute of Engineering, National University of Mexico, presented the 2nd Annual Shah Family Lecture on April 6, 2001.

The lecture, "*Towards Optimum Risk and Reliability Levels for Performance-Based Seismic Design*", followed a day of meetings with Civil Engineering students and faculty.



Luis Esteva and Haresh Shah

Professor Esteva is the recipient of numerous national and international awards. He has participated in the formulation of building codes and seismic regulations for Mexico and other countries, and has authored numerous publications.

The Shah Family Fund was established in 1995 to provide annual fellowships for students in Civil Engineering, an annual prize for an outstanding staff member in the School of Engineering and an annual distinguished lecture on catastrophic risk management and related areas.

PROFESSOR TO RECEIVE MEDAL

Professor C. Allin Cornell will receive the 2001 Medal of the Seismological Society of America in Victoria BC, at the SSA annual meeting next year.

The Medal of the Seismological Society of America is awarded annually for outstanding contributions in seismology and earthquake engineering. Past recipients include **George Housner** and **John A. Blume**.

STANFORD CLASS OF 2023

Congratulations to **Professor Chuck Menun** and his wife, **Barbara**, on the birth of their son, **Alexander Joseph**, March 30, 2001. Alexander weighed in at 7lb., 15oz. and was 19" long. Big brother, **Jacob**, was very excited.

BLUME CENTER NEWS

Professor Ronaldo Borja presented a paper entitled *"Propagation of Strong Discontinuity in Elastoplastic Solids"* at the Tenth International Conference on Computer Methods and Advances in Geomechanics held in Tucson, January 7-12.

Profesor Gregory Deierlein gave a presentation on *"Role of Performance-Based Engineering in Risk Assessment"* at the 2001 EERI Annual Meeting in Monterey on February 8.

Professor Ronaldo Borja gave a seminar for the Solid Mechanics and Aero-Astro groups at Stanford University on March 8 entitled *"Finite Strain Continuous and Discontinuous Shear Band Mode Bifurcation of Elastoplastic Solids"*.

On March 9, **Professors Anne Kiremidjian** and **Gregory Deierlein** and several graduate students participated in a PEER-Caltrans workshop to discuss research on seismic performance and risk assessment of highway networks.

STANFORD PARTICIPATES IN PEER ANNUAL MEETING

Faculty and students from the Structural Engineering and Geomechanics Program participated in the PEER Annual Meeting in January in Oakland. About one dozen students participated in the poster session. Technical presentations were given by **Professor Helmut Krawinkler** ("*Seismic Demands and their Dependence on Ground Motions"*); **Professor Allin Cornell** (*"Seismic Performance Assessment Analysis and its Uses"*); and Blume Center Affiliate **William Holmes** of Rutherford and Chekene (*"Performance-Based Earthquake Engineering Needs"*).

OBITUARY: William Joyner

Bill Joyner, a USGS research partner with the Blume Center, passed away on March 24 at home from thyroid cancer. He is survived by his wife, **Mary Lou.** Bill will be greatly missed by his friends and colleagues at Stanford.

RESEARCH SPOTLIGHT

SEISMIC DEMANDS FOR PERFORMANCE-BASED DESIGN

By Ricardo A. Medina and Helmut Krawinkler

Motivation and Objectives

Implementation of the evolving concepts of PBEE (Performance-Based Earthquake Engineering) necessitates the evaluation of seismic demands as a function of ground motion intensity, frequency content, and duration. Demand parameters include all structural response quantities that affect the extent and distribution of structural and nonstructural damage at performance levels ranging from functional limit states to the limit state of collapse. Therefore, the global objective of this project is to understand and quantify, with statistical measures, the force, deformation, and energy demands imposed by ground motions of various characteristics, magnitudes, and distances on building structures of various types, configurations, and structural properties.

Specific objectives of this study include the following:

- Evaluate demand patterns as a function of the properties of structures and ground motions.
- Identify the most relevant ground motion and structural response parameters and establish relationships between these parameters.
- Evaluate sensitivity of demands to properties of structures, ground motions, and analysis models and methods.
- Evaluate sensitivity of demands to structure-foundation-soil interface conditions.
- Evaluate seismic demands of particular concern for nonstructural and content systems (e.g., floor accelerations and velocities, story drifts).
- Organize the acquired knowledge into a format that can be used as foundation for approximate performance assessment and for a conceptual seismic design procedure that incorporates multiple performance objectives.

The focus of the study is on frame structures, for which story shear strength is the controlling strength parameter, and story drift is the most relevant deformation parameter. Wall structures also will receive attention. For the latter type, the relative values of story shear strength and bending strength control behavior, and wall plastic hinge rotation or shear deformation is the most relevant structural deformation parameter.

Demand Evaluation Process

In order to achieve the global objective of this study, a database is being developed that contains comprehensive information on relevant ground motion parameters and demand parameters for SDOF and MDOF systems. On the input side, ordinary and special ground motions (near-fault and soft soil) are considered, and on the response side the focus is on all structural response parameters that may significantly affect the performance of structural, nonstructural, and content systems (e.g., forces, drifts, rotations, floor accelerations).

Specific tasks for the seismic demand evaluation include:

- Design a family of generic structures that cover the range of structural parameters of interest.
- Select and document sets of ground motions that cover the range of ground motion parameters of interest.
- Develop a database for storage and retrieval of all the ground motion input and structure response data of interest for performance assessment.
- Develop an evaluation system through which relationships between ground motion parameters and seismic demand parameters can be established.
- Perform extensive analytical parameter studies on elastic and inelastic SDOF and MDOF systems.
- Synthesize data and arrive at a comprehensive evaluation of seismic demands.

Representative Results for MDOF Systems

The results of simulations with various structural systems are documented in a database and representative diagrams. Typical sample diagrams used to evaluate the response of a frame system are presented next. The presented results are obtained by subjecting a two-dimensional, 9-story frame to a set of 20 ordinary ground motions and varying the base shear yield strength (defined by $\gamma = V_y/W$).

The 9-story frame used in these graphs has a fundamental period of 0.9 seconds; 5% modal damping is assumed at the first and fourth mode. Plastic hinging is confined to beam ends and column bases. The hysteretic behavior at plastic hinge locations is modeled by a non-deteriorating, peak-oriented (Clough) model with 3% strain hardening. Global P-Delta is also modeled and it translates into a stability coefficient of 1.5% at the first story level. Since this example deals with a non-deteriorating system, the dynamic response of the model is not intended to be representative of the seismic demands when the system is close to the limit state of incipient collapse; and the results are not reliable for large levels of inelasticity at which cyclic deterioration will affect the response. Thus, the following example is relevant for performance objectives related to damage control and loss of functionality (downtime), and not to collapse prevention. Issues related to the limit state of incipient collapse, in which modeling of deteriorating hysteretic behavior becomes a critical aspect, are investigated in a separate research study.

The set of 20 ground motions represents seismic excitations from California earthquakes (moment magnitude between 6.5 and 7.0, closest distance to fault rupture between 13 and 30 km), recorded in NEHRP soil profile type D. Figure 1 shows spectra of the 20 ground motions normalized by the their spectral acceleration at the fundamental period of the frame, $S_a(T_1{=}0.9s)$. This normalization is equivalent to scaling all records to the same spectral acceleration at 0.9 seconds. The scatter in the elastic spectral demands is large, both to the right and to the left of T = 0.9 s. The scatter to the left of T = 0.9 seconds is important for higher mode effects, while the scatter to the right of T=0.9 seconds influences the behavior of the system once the system enters the inelastic range (period elongation effect).

Figures 2 and 3 present story drift demands as a function of the base shear yield strength ($\gamma = V_y/W$) of the structure. The ordinate represents the ratio of spectral acceleration at the first mode period $S_a(T_1)/g$ to base shear coefficient γ, and the abscissa represents an engineering demand parameter (EDP), e.g., maximum story drift angle over the height normalized by a convenient SDOF parameter, in this case the elastic displacement demand at the first mode period $S_d(T_1)$ divided by structure height H. Both $S_a(T_1)/g$ and $S_d(T_1)$ can be viewed as ground motion intensity measures, IMs. This representation serves two purposes. It illustrates the effect of decreasing the structure strength on the EDP (while keeping the IM constant), but it can also be viewed as IDAs (Incremental Dynamic Analyses) illustrating the effect of increasing the IM on the EDP for a structure of constant strength. If $S_a(T_1)$ represents the ordinate of a design spectrum, then the ratio $[S_a(T_1)/g]/\gamma$ can be viewed as a conventional R-factor.

Figure 2 presents the variation of maximum story drift over the height with a decrease in base shear strength γ (or an increase in S_a). The plot shows data points for the individual records, as well as median and 84th percentile values. The maximum story drift over the height is often used as the critical parameter for assessing safety against incremental collapse (global instability). For this specific purpose the presented results may not be very meaningful, because they are obtained from a non-deteriorating hysteresis model, which is believed to be inadequate at large inelastic deformations (large values of $[S_a(T_1)/g]/\gamma$). The presented information may be more relevant for damage control (loss estimation), in which case story drift is an important EDP for structural and nonstructural damage. If damage is caused primarily in the story with maximum drift, then the data presented in Figure 2 is pertinent. If damage is proportional to drift, in general, then the average of the maximum drifts in each story is a better measure of performance. This information is presented in Figure 3.

Figures 2 and 3 show that for this specific structure (9 stories, T = 0.9 sec.) the median values of both the maximum drift over height and the average of the maximum drifts in each story are rather insensitive to $[S_a(T_1)/g]/\gamma$. This implies (in the median) constant drift for structures of variable strength subjected to ground motions of constant IM, or a linear increase in drift for structures of constant strength subjected to ground motions of increasing IM. The normalization to $S_d(T_1)/H$ relates these EDPs to an SDOF parameter that is proportional to the IM of the ground motions. In average, the maximum story drift over the height is about 2.4 times $S_d(T_1)/H$, and the average of the maximum story drifts in each story is about 1.7 times $S_d(T_1)/H$. However, the dispersion of the data is very large, which shows one of the shortcomings of using the first mode spectral acceleration as the primary intensity measure. In this project, statistical data of this type will be generated for various types of structures and for structures of a large range of periods. Attempts will also be made to find intensity measures that lead to a smaller dispersion of the data.

The sample results presented here are a minute fraction of the engineering demand data generated in this project. The challenge will be to communicate the entirety of the results in a manner useful to the research community involved in Performance-Based Earthquake Engineering, and to the professional community that has to implement it.

Acknowledgements

This research is supported by the NSF through PEER (Pacific Earthquake Engineering Research Center) whose mission is to develop, validate, and disseminate performance-based seismic design technologies for buildings and infrastructure to meet the diverse economic and safety needs of owners and society.

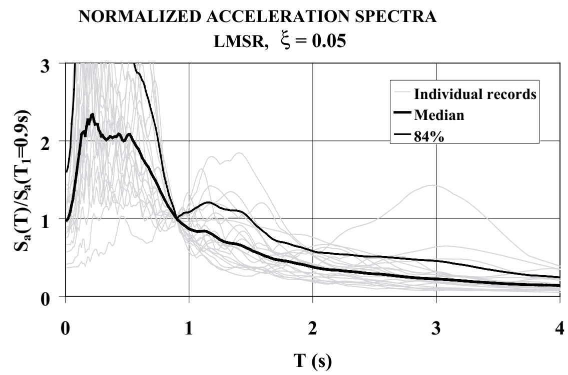


Figure 1. Set of 20 ordinary ground motions normalized to their spectral acceleration at T = 0.9 seconds.

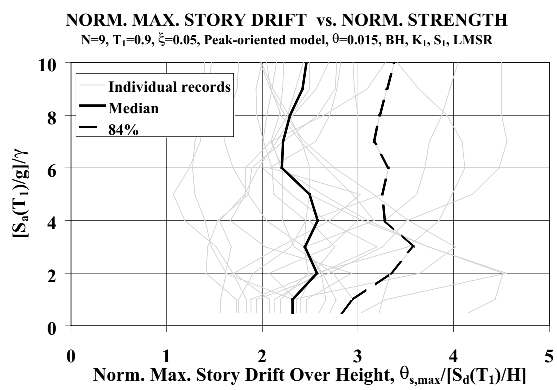


Figure 2. Maximum story drift over the height as a function of structure strength.

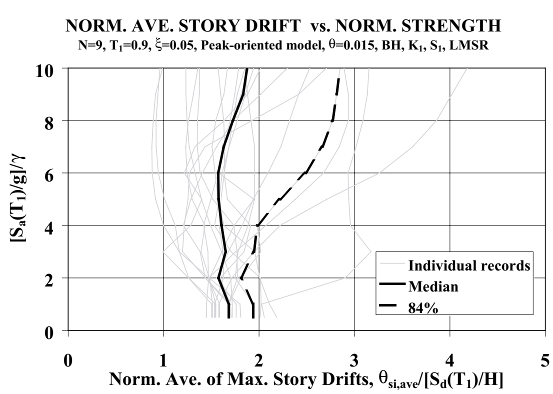


Figure 3. Average of maximum drifts in each story as a function of structure strength.

STANFORD PROFESSOR JOINS INDIA EARTHQUAKE SURVEY

At 8:46 AM on January 26, 2001, a major earthquake measuring 7.6 shook the state of Gujarat in western India. It was felt in most parts of India. The earthquake caused substantial loss of life and property. According to the latest estimates available from government sources, 18,253 people lost their lives and another 166,836 suffered injuries of various degrees. The earthquake affected 7,904 villages in Gujarat, destroying 332,188 homes and damaging another 725,802.

Approximately one month after the earthquake, a reconnaissance survey organized by **Professor Emeritus Haresh Shah** was conducted by a team of 21 professionals that included representatives from the fields of engineering, disaster management, public administration, political science, social geography and seismology. The survey, beginning February 25, 2001 and ending on March 4, 2001, included affected regions of the Districts of Ahmedabad, Kachchh, Rajkot, and Surendranagar. The team visited the cities of Ahmedabad, Anjar, Bhachau, Bhuj, Gandhidham, Kandala, Limbdi, Morvi, Navlakhi, Rajkot, and Surendranagar.

The reconnaissance team represented a number of countries including Bangladesh, Germany, India, Indonesia, Iran, Japan, Kyrgyz Republic, Malaysia, Nepal, The Philippines, Uganda, United Kingdom, and United States. The individuals were sponsored by numerous organizations, including the World Seismic Safety Initiative (WSSI), Earthquakes and Megacities Initiative (EMI), OYO Corporation, and National Science Foundation. **Professor Charles Menun** participated in the reconnaissance survey with support provided by the John A. Blume Earthquake Engineering Center. Among the members of the reconnaissance team were Stanford University alumni **Ravi Mistry**, **Weimin Dong** and **Laura Dwelley Sampat**.

The objective of the reconnaissance survey was to investigate the Gujarat earthquake catastrophe from several perspectives including, but not limited to, engineering, rebuilding and reconstruction, social, economic, political, organizational, and disaster management perspectives, and to identify: (1) factors leading to the catastrophe, and (2) ways to mitigate it. The investigation addressed technical, disaster management, and social issues. A summary of the reconnaissance team's findings will be spotlighted in the next Blume Center Newsletter. A complete account of the reconnaissance survey is documented in the WSSI-EMI report *Interdisciplinary Observations on the January 2001 Gujarat Earthquake*, which can be obtained from the John A. Blume Engineering Center web site http://blume.stanford.edu.

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