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LETTER FROM THE DIRECTORS

As we write this column, many of us in the earthquake engineering community are still trying to comprehend the impact of the Hanshin Earthquake which struck on January 17 at 5:48am Japan time. As rescuers were sifting through the rubble, searching for survivors, and firefighters were attempting to extinguish widespread fees, (but mostly watching in despair, overwhelmed by the magnitude of the disaster and by the lack of water), we watched with amazement and a feeling of horror. The earthquake appears to have tested all aspects of earthquake engineering from seismic zoning to basic design concepts, to disaster response, and social and economic preparedness. As information has trickled in, the picture has been slowly clarified, although it may be several months if not a year before we have an understanding of the causes of the widespread damage to all engineered structures. Estimated at a moment magnitude of 6.8, the earthquake appeared to spare nothing. Single and multi-family dwellings collapsed, were extensively damaged, or were burned in the ensuing fires. All types of commercial and industrial buildings, including many critical facilities, were hit hard. Currently, it is estimated that 74,442 buildings were damaged or collapsed. Lifelines were interrupted over large areas: 900,000 households without electricity, 850,000 households without gas, and 2.5 million people without water (INCEDE, 1995). Damage to transportation systems is extensive with numerous bridges, several elevated highway and railway structures collapsing. The Hanshin death toll is 5,079, with an additional 100 persons missing and more than 26,000 injured.

Coming on the first anniversary of the Northridge Earthquake, it is the second time in a year that a significant earthquake has struck right in the heart of a major modern metropolitan area. With the Hanshin Earthquake, Kobe's emergency response capabilities were truly tested for the first time, only to prove that our resources and training are never quite adequate. These two earthquakes have raised issues that can no longer be ignored. In particular, we need to face up to the questions: What do we do with the large stock of buildings recognized to be unsafe or potentially hazardous? Are modern seismically designed structures susceptible to failures? Where do we find the resources needed to prepare ourselves for the next quake? Once again, another disaster re-emphasizes the extraordinary challenges that face the earthquake engineering community.

Anne Kiremidjian and Helmut Krawinkler

CENTER NEWS

During the upcoming Spring Quarter, **Professor Helmut Krawinkler** will be taking a much deserved (and desired) sabbatical leave at the Technical University Vienna, Austria.

In January, the Shah Family Endowment Fund was established, honoring **Professor Haresh Shah,** his wife, Joan, and his sons, Mihir and Hemant. This fund, totaling approximately $1 million when complete, comes from a personal gift from the family plus equity from the sale of Risk Management Solutions, Inc., a company based on work that Haresh and Weimin Dong did here and later licensed through the University's Office of Technology Licensing. The majority of the endowment will fund fellowships, with preference given to Civil Engineering students interested in risk management. Additional funding will goes towards a visiting scholar and the establishment of a $1000 prize to be awarded to a School of Engineering staff member.

The Blume Center welcomes two visiting scholars sponsored through the Shimizu Visiting Professorship. **Professor Peter Fajfar** is from the Faculty of Civil Engineering and Geodesy at the University of Ljubljana, Slovenia. His fields of interest include earthquake engineering, seismic codes, and seismic hazard analysis. **Professor Jun Kanda** is from the Department of Architecture at the University of Tokyo. His research interests include earthquake and wind engineering, reliability theory, and structural design.

On January 24, the Blume Center sponsored a special seminar by **Stephanie King** and **Christopher Rojahn** entitled "The Hyogoken-Nanbu Earthquake: Kobe, Japan, January 17, 1995."

The Blume Center co-convened the Workshop on Seismic Damage Quantification and Performance of Structures held February 7-8 in San Francisco. **Professor Helmut Krawinkler, Professor Anne Kiremidjian,** and Visiting Shimizu Professors **Peter Fajfar** and **Jun Kanda** were active participants in the workshop. Professor Kiremidjian gave a state-of-the-art presentation on "Use of Damage Models in Structural Evaluations."

Professor Allison Smith was elected to serve as Interim Treasurer of the California Universities for Research in Earthquake Engineering (CUREe) while Treasurer Helmut Krawinkler is on sabbatical leave.

RESEARCH SPOTLIGHT

Consolidation and Restoration Interventions on the Tower of Pisa: Interpretation and Geotechnical Analysis

Project Sponsor: Consorzio Progetto Torre di Pisa, Italy **Project Duration:** September 1992 - March 1995

Investigators: Ronaldo I. Borja (Stanford University); Giovanni Calabresi (University of Rome); James K. Mitchell (VPI & State University); Robert L. Schiffman (University of Colorado, Boulder)
Stanford Research Assistants: Richard Regueiro, Claudio Tamagnini

Few monuments have been studied as much by the engineers as the Leaning Tower of Pisa. Constructed over a period of roughly two hundred years (1173-1370), the tower was already tilting even before it was fully built. In 1990, with a total southward tilt already in the order of about 5.5 degrees (or a deviation close to 5.5 meters at the top), the tower was declared dangerous and closed to the public. No fewer than 17 committees have been formed since the construction of the tower, and the latest one is still at work to try to find the best way to correct this dangerous tilt.

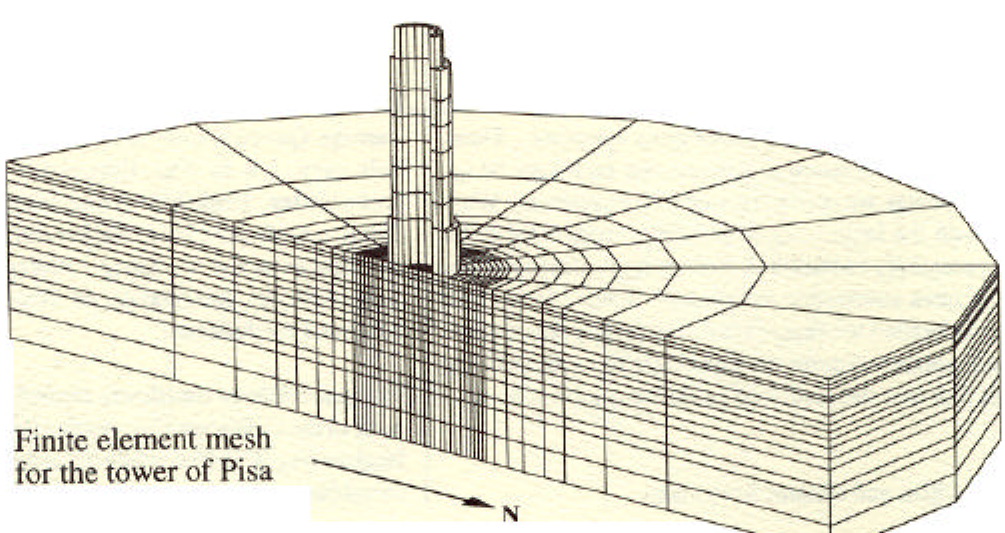
This project involving four geotechnical investigators has produced the first three-dimensional finite element model ever constructed for the tower of Pisa. Previous numerical models have utilized either plane strain or axisymmetric assumptions, which unavoidably introduced unknown geometrical errors into the analyses. The goal of this project is to use the three-dimensional model to study the time-dependent behavior of the foundation subsoil. Among the factors included in the investigation are hydrodynamic lag due to fluid flow (or consolidation), and creep effects arising from the viscous behavior of an underlying soft clay deposit known locally as Pancone clay.

The modeling procedure involves a process of sequential construction using the finite element method. With this procedure, the finite elements representing the tower body are placed sequentially using the element birth option of a nonlinear finite element code called SPIN. The accompanying figure shows the finite element mesh for the tower of Pisa at the end of construction.

The tilting of the tower is triggered by a soft silty layer located directly below the tower foundation block, which increases in thickness in the southward direction. This perilously geological feature has been well documented from extensive geotechnical investigations, and serves as the "imperfection" required by the numerical model to make the tower tilt.

The numerical modeling requires consideration of both material and geometric nonlinearities. The foundation subsoils are modeled using critical state soil mechanics and theory of plasticity, in which the yield surface is represented by the ellipsoid of modified Cam-Clay theory. The parameters for this model were obtained from high-quality laboratory tests conducted in Rome. The geometric nonlinearity is included in the analysis using a methodology known in continuum mechanics literature as the multiplicative decomposition of the deformation gradient.

In July 1993, about 600 tons of lead ingots were laid on the base of the tower as a temporary stabilization measure. The present committee is now studying other remedial measures that have longer-term impact, such as electro-osmosis to alter the compactness of the soil, and subsoil earth removal which has been used on a tilting cathedral in Mexico city. The goal is not to straighten the tower completely, but just bring it to a stable tilt. Once properly calibrated, the numerical model developed in this research may be used as a tool to study the consequences of such proposed remedial measures.



Finite element mesh for the tower of Pisa

RESEARCH SPOTLIGHT

Development of Transparent Seismic Design Methodology

Project Sponsor: National Science Foundation (2 projects) **Duration:** May 1994 - September 1997

Principal Investigator: Helmut Krawinkler

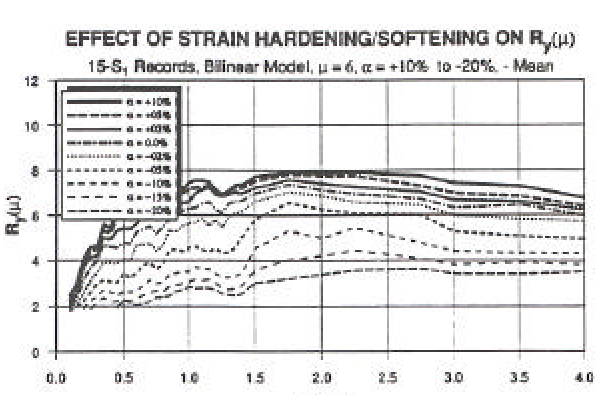
Research Assistants: Pasan Seneviratna, Scott Lawson, Ali Al Ali

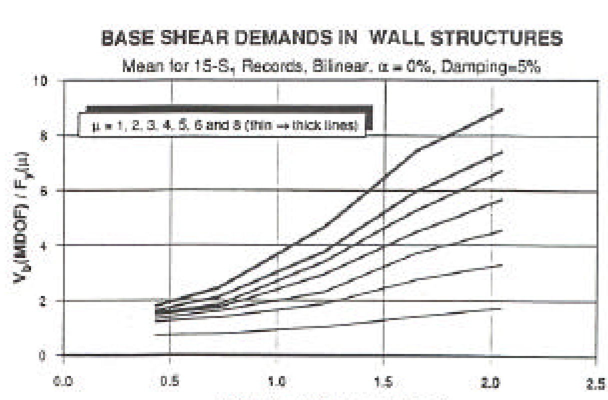
For many years standard seismic design has been based on elastic concepts, even though it is recognized that most structures will go far in the inelastic range when subjected to major earthquakes. By now it is widely recognized that such an equivalent elastic approach cannot be based on sound physical principles and, therefore, will result in designs with inconsistent levels of protection. This recognition is reflected in many recently initiated efforts by national and State organizations (BSSC, ATC, SEAOC), in which attempts are being made to develop guidelines and codes that are based on inelastic design principles. The research performed at Stanford focuses on the development of fundamental concepts that provide in- put to these efforts. Two research projects are in progress. One is concerned with the development of "A Deformation Based Methodology for the Evaluation and Upgrading of Existing Structures" (NSF Project CMS-9319434), and the other focuses on "Research in Support of a Transparent Seismic Design Methodology" (NSF Project CMS-9322524).

The research in the first project is concerned with the development of basic concepts and fundamental information needed to formalize a deformation based methodology for the evaluation and strengthening of existing structures. This methodology is intended to (1) permit an assessment of the expected seismic performance of existing structures and the identification of basic strengthening needs, (2) facilitate the development of an effective strengthening scheme and provide target values for the required strength and deformation capacities of the components of the strengthening scheme, (3) permit a verification of the seismic performance of the strengthened structure and provide information for fine-tuning of the elements of the strengthening scheme, and (4) provide information on the deformation demands that will govern requirements for detailing of the elements of the strengthening scheme.

The research in the second project focuses on the refinement of basic concepts and the development of fundamental knowledge needed to formalize and implement a demand/capacity based seismic design methodology that explicitly considers the inelastic response characteristics of structures. The overriding consideration in this approach is that every step is based on fundamental physical concepts that make the design process transparent and equally applicable to the seismic evaluation of existing structures and seismic designs of new structures, using conventional structural systems as well as new structural systems, materials, and innovative energy dissipation or base isolation systems. The design objective is to provide a structure with sufficient strength, stiffness, and ductility such that the deformation demands imposed by design earthquakes do not exceed the deformation capacities associated with design limit states (e.g., life safety, collapse prevention).

Much has been accomplished already in both projects. Inelastic strength, displacement, and energy demand spectra have been developed for different soil types, and statistical studies on the dynamic inelastic response of frame and wall structures have led to the development of criteria that permit the incorporation of higher mode effects in the design process. Criteria have been developed for the execution of a pushover analysis for performance evaluation, a simplified nonlinear analysis technique that is being implemented in the ATC-33 project on "Guidelines for the Seismic Rehabilitation of Buildings."





NEWLY PUBLISHED TECHNICAL REPORTS

No. 114 - *Prioritization of Bridges for Seismic Retrofitting* by Nesrin Basoz and Prof. Anne S. Kiremidjian. January, 1995.

No. 115 – *Method for Developing Motion Damage Relationships for Reinforced Concrete Frames* by Ajay Singhal and Prof. Anne S. Kiremidjian. January, 1995.

NEWLY SPONSORED RESEARCH PROJECTS

Stochastic Analysis of Ship Response and Fatigue Reliability, sponsored by the Office of Naval Research. Principal Investigators: Research Associate Steven Winterstein and Prof. C. Allin Cornell. 1/95 - 1/96

Seismic Building Assessment Procedures, sponsored by the National Science Foundation. Principal Investigators: Prof. C. Allin Cornell and Research Associate Steven Winterstein. 3/1/95 - 2/29/98

ALUMNI NEWS

On January 28, **Stephanie King** [Ph.D.,'941 and **Christopher Rojahn** [M.S., '67; Engineer's Degree, '681 were married in Palo Alto. Stephanie currently is a half-time post-doctoral fellow working here in the Blume Center. Chris is Executive Director of Applied Technology Council in Redwood City.

Jon R. Wren [Ph.D.,'94] is now working at Failure Analysis Associates and is teaching part-time at San Jose State Univer- sity.

Hiroyuki Fuyama [Ph.D., '931, a senior research engineer at the Vibration and Noise Control Laboratory at the Takasago Research and Development Center of Mitsuibishi Heavy Industries, Inc., and his wife, Hiromi, recently welcomed their third child and second daughter, Ikue.

Both **Guy Harris** [M.S., '91] and **Scott Hamilton** [M.S., '93] are on faculty in the Department of Civil Engineering at the U.S. Military Academy in West Point, New York.

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