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The John A. Blume Earthquake Engineering Center

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LETTER FROM THE DIRECTOR

Greetings! 1997 was a very exciting year highlighted with our official rededication, the Shah Symposium, a record number of Blume Center reports published by our graduating doctoral students, outstanding job opportunities for our Master of Science students, and extensive participation by our faculty and students at conferences and workshops.

An important event that will have a significant impact on our research in the next five years is the formation of the Pacific Earthquake Engineering Research (PEER) Center with funding from the National Science Foundation (NSF), the State of California, and private industry. As one of the core institutions of PEER, we are actively involved in the center activities. Helmut Krawinkler is our representative on the Governing Board, I serve on the Research Committee, and Ronnie Borja and Stephanie King are active on the Education Committee. PEER will focus on the development of technologies to reduce the risk of urban earthquake losses. Since many of the research topics addressed by PEER are in the mainstream of our research, we expect to actively participate in these projects. An advantage of PEER over individual research projects is that it provides a more focused approach to solving key problems and brings together leading researchers with complementary expertise.

We also look forward to the addition of two new members to our faculty. Our search is progressing well and we hope that the new faculty will join us in early fall.

Once again we have an outstanding Master of Science student class. Among them are nine students holding graduate fellowships from NSF, the Hertz Foundation, and the Stanford Graduate Fellowship program. In addition, we expect that at least four of our doctoral students will be graduating this year.

In the coming year we are planning to hold at least two workshops - one in relation to the PEER center transportation demonstration project and one or more on the fundamentals of reliability leading to performance based engineering. Watch for the announcements in the next few months.

Finally, everyone at the Blume Center joins me in thanking our affiliates and donors for their continued support.

Anne Kiremidjian

BLUME CENTER NEWS

Prof. Anne Kiremidjian participated in the FEMA-sponsored NEHRP Strategic Planning Workshop on Using Knowledge to Reduce Earthquake Losses held September 11-12 in Reno, Nevada.

Prof. Ronnie Borja attended the Fourth International Workshop on Localization and Bifurcation Theory for Soils and Rocks held September 29 - October 2 in Gifu, Japan, where he presented a paper on micromechanics of granular materials, and the International Symposium on Deformation and Progressive Failure in Geomechanics held October 4-7 in Nagoya, Japan, where he presented a paper on strain localization in excavations by finite elements.

Prof. Anne Kiremidjian was invited to give a presentation at the NSF/CERF Research and Development Collaboration Workshop on October 20 in Washington DC.

On October 20, **Prof. Allin Cornell** travelled across the Bay to give a lecture at U.C. Berkeley on the evolution of the interface between earth scientists and structural engineers in seismic design criteria both for building codes and for site-specific and special projects.

Prof. Ronnie Borja and **Dr. Stephanie King** are members of the newly formed Pacific Earthquake Engineering Research (PEER) Center Educational Committee.

In November, **Prof. Anne Kiremidjian** presented two papers at the International Conference on Structural Safety and Reliability (ICOSSAR) held in Kyoto, Japan.

Dr. Renate Fruchter was recently invited to act as an associate editor of the American Society of Civil Engineering Journal on Computing in Civil Engineering.

Prof. Anne Kiremidjian gave a keynote lecture at the International Workshop on Structural Health Monitoring held at Stanford University on September 18-20.

On October 24 and 25, the Blume Center hosted a meeting of the Executive Committee of the Technical Council on Lifeline Earthquake Engineering.

On December 3, **Prof. H. Allison Smith** and her husband John Gordon welcomed the birth of their third child, a daughter Leah Harriet. Prof. Smith is spending the 1997-1998 academic year as a Visiting Scholar at Columbia University's Department of Civil Engineering and Engineering Mechanics.

RESEARCH SPOTLIGHT

Effects of Vertical Irregularities on Seismic Behavior of Building Structures

by Ali Al-Ali, Ph.D. Candidate

Research Advisor: Professor Helmut Krawinkler

Sponsored by The National Science Foundation Project:
"Research in Support of a Transparent Design Methodology" (Grant CMS-9322524)

Introduction

Urban development in seismically active regions has increased significantly all over the world. This development is accompanied by an increased demand for aesthetic buildings that often have irregular shapes. Even buildings with regular shapes can have an irregular distribution in their masses, stiffnesses, or strengths. Our research study focuses on improving the understanding of the behavior of irregular structures under earthquake loading and on implementing the acquired knowledge in a practical design methodology.

This research study quantifies how the seismic demands for structures with vertical irregularities are different from those for regular structures. It also investigates several analysis and design procedures and provides information on their appropriateness for irregular structures.

Design Methodology

The current study is a continuation of research studies that started at the Blume Center at Stanford University in the 1980's. The general objective of those studies is the development of a transparent seismic design methodology that accounts for demands and capacities explicitly in the design process. Figure (1) shows a schematic of this design methodology.

Previous studies at the Blume Center have investigated the inelastic demands of structures modeled as Single Degree of Freedom (SDOF) systems, the effects of soft soils on the behavior of structures, and the inelastic demands of structures modeled as "regular" Multi Degree of Freedom (MDOF) systems. Our study extends the investigation of MDOF systems to account for mass, stiffness, and strength irregularities.

Scope

The research summarized here focuses on the behavior of building structures with vertical irregularities. Irregularities in a building structure can be due to an irregular distribution of one or more of these basic parameters: masses, stiffnesses, and strengths. In order to have a better understanding of the behavior of irregular structures, the effects of each one of these parameters need to be separated. This is done in this study by performing extensive parametric analyses to assess the effects of each one of the parameters separately. Realistic cases of combinations of irregularities are also investigated and analyzed.

The behavior of irregular structures is assessed by evaluating the results of elastic and inelastic, static and dynamic analyses. The analyses are computer simulations in which the building structure is represented by a mathematical model and subjected to a ground motion record or an incremental static load. Building structures are modeled in the study by single bay, 10-story generic frames.

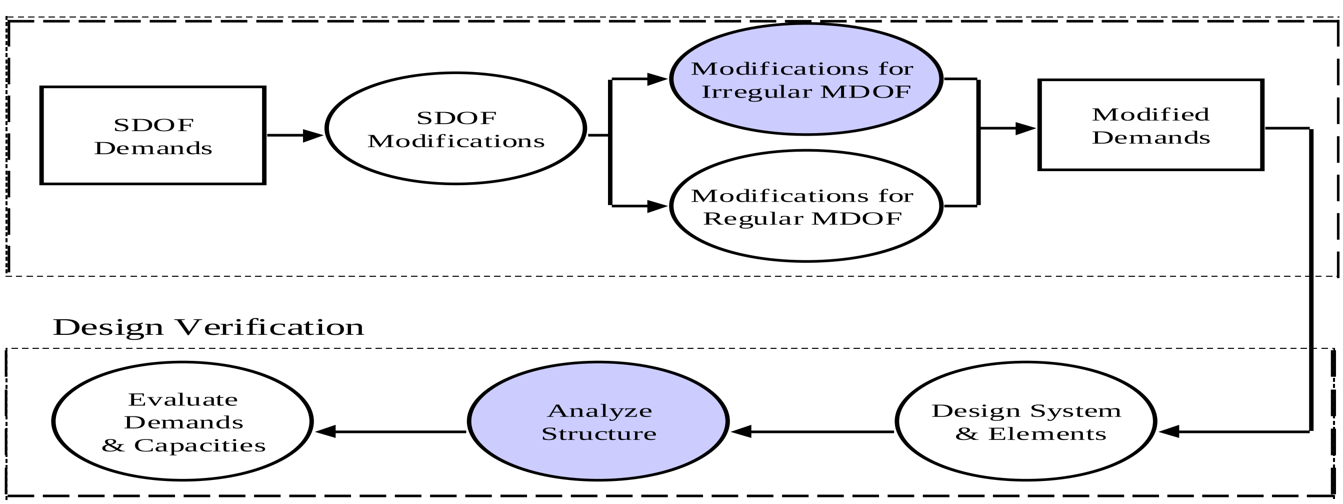

Figure (1) Design Methodology

Ground Motions and Uncertainty

Since earthquakes are random phenomena with great uncertainty, investigating the seismic behavior of structures is done in a statistical manner. Each model that represents a specific irregular case is subjected to a suite of 15 ground motion records, then the relevant response parameters are evaluated by calculating central values and measures of dispersion. The ground motion records used in the study were chosen from real earthquakes which occurred in the western U.S. after 1983. The spectral shapes of these records resemble the NEHRP design spectrum for rock soils (soil type-B).

Mass and Stiffness Irregularities

In order to investigate the behavior of irregular structures, a "regular base case" is defined. The response of irregular cases is compared to that of the base case. The effects of mass or stiffness irregularities on the elastic dynamic properties that control the behavior are assessed. These elastic properties are: initial period, mode shapes, period ratios, modal participation factors, and mass participation factors.

The elastic response of the cases with irregular mass or stiffness distributions is compared to the "regular base case" by performing a series of elastic dynamic analyses. These elastic analyses are: spectral analysis using the smooth NEHRP design spectrum, spectral analyses using the spectra of the 15 ground motion records, and elastic time history analyses using the same records. Comparing the results of each case from these analyses provides an assessment of the appropriateness of these analysis methods for the different irregular cases. As an example, Figure (2) shows a comparison of story shear distributions for case KM(1-5)*10 using different elastic analysis procedures. Case KM(1-5)*10 represents a structure with an irregular stiffness distribution in which the stiffnesses of stories 1 through 5 are ten times the stiffnesses of the same stories for the regular base case.

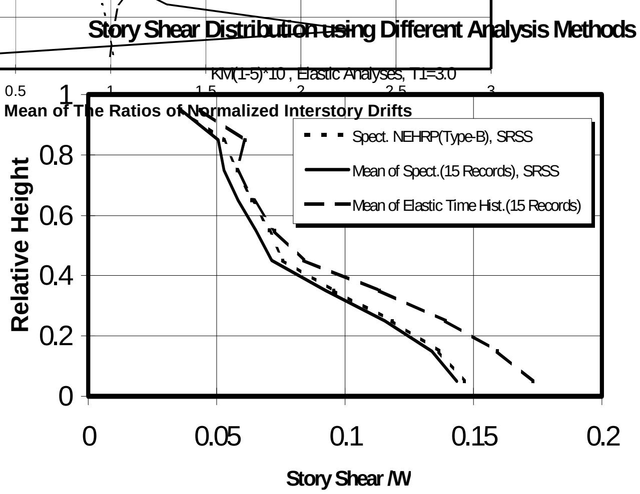

Figure (2) Story Shears due to Different Analysis Methods

Inelastic time history analyses are performed using the 15 records. The inelastic response of each one of the cases is compared to the regular base case, conclusions about the difference in behavior are drawn, and the strength and ductility distributions for the irregular cases are evaluated.

Strength Irregularities

In order to asses the effects of strength irregularities, several cases with vertical strength irregularities are developed. These cases are analyzed through inelastic time history analyses, using the same 15 records, and their response is compared to the regular base case. As an example, Figure (3) shows the effects of increasing the strength of one story by a factor of two and the effects of the location of that story on the ductility demands. SM(1)*2, SM(5)*2, and SM(10)*2 represent cases in which the strength of the 1st, 5th, and 10th story is doubled, respectively.

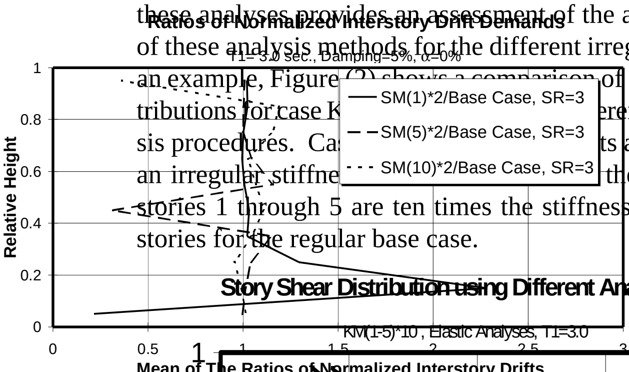

Figure (3) Effects of Strength Irregularity on Interstory Drift

The cases with irregular strength distribution are analyzed also by static pushover analyses. This is done to investigate how well the results of the pushover analysis method compare with the inelastic time history analysis results.

Conclusions

Many real building structures exhibit irregularities in their mass, stiffness, or strength distributions over height. The effects of these irregularities on the seismic behavior of structures are not well understood. This research study separates and quantifies the effects of mass, stiffness, and strength irregularities. The study also assesses the appropriateness of using different elastic and inelastic analysis methods for irregular structures.

By separating the effects of the three types of vertical irregularities, we found that the seismic response is more sensitive to an irregularity in strength distribution than to the same irregularity in mass or stiffness distributions. The effect on the behavior is also dependent on the location of the irregularity, as shown in the example presented in Figure (3). Different demand parameters are affected differently by vertical irregularities. Roof displacement demands are more robust and do not vary from the base case as much as ductility demands for different irregular cases. The findings of this research will improve our understanding of the behavior of irregular structures, and will be implemented in a practical design methodology.

VISITING PROFESSOR LAZSLO KOLLAR

The Department of Civil and Environmental Engineering is pleased to have Professor Laszlo Kollar as a Visiting Professor for the 1997-1998 academic year. Prof. Kollar joins the faculty of the Structural Engineering and Geomechanics Group for the year. This is his second time as a visitor at Stanford, as he was a Visiting Scholar and Visiting Associate Professor in the Dept. of Aeronautics and Astronautics from 1990 to 1993.

Prof. Kollar is on the faculty of Civil Engineering in the Dept. of Reinforced Concrete Structures at the Technical University of Budapest. He received his Ph.D. and Doctor of Sciences from the Hungarian Academy of Sciences and his Doctor Habil from the Technical University of Budapest. Prof. Kollar specializes in the study of composites and shells, and the behavior of reinforced concrete structures. He is the author or co-author of nearly 50 technical papers and serves on the editorial board of the Journal of Reinforced Plastics and Composites.

While visiting at Stanford this year, Prof. Kollar is teaching two graduate structural engineering courses on finite element analysis. He is living in Palo Alto with his wife and daughters.

NOTE! NEW DEPARTMENT NAME AND AREA CODE CHANGE

On September 1, 1997, the Department of Civil Engineering at Stanford University was renamed as the Department of Civil and Environmental Engineering. The faculty chose to do this because environmental engineering has grown as a field to the point where it has a very clear identity. At many other institutions, environmental engineering is not part of civil engineering. However, at Stanford environmental engineering is considered an integral part of civil engineering. By including the environmental engineering descriptor in its name, the department's goal is to enhance the long and rich civil engineering tradition that exists at Stanford.

Another change has taken place that affects the Blume Center. The telephone area code for cities on the southern San Francisco peninsula, including Stanford University, has been changed from 415 to 650. Please update your records to reflect our new department name and telephone area code. All other contact information for the Blume Center remains the same.

NEWLY SPONSORED RESEARCH PROJECTS

Decision Support Tools for Earthquake Recovery of Businesses - sponsored by the California Universities for Research in Earthquake Engineering (CUREe) Phase III Joint Research Program. Principal Investigators: **Prof. Anne S. Kiremidjian**, Prof. James Beck (Cal Tech), and Prof. Simon Wilkie (Cal Tech). 10/20/97 - 10/19/99.

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