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The John A. Blume Earthquake Engineering Center

Department of Civil Engineering Stanford University Stanford, California 94305-4020

Telephone: (415) 723-4150 1 FAX: (415) 725-9755 E-mail: earthquake@ce.stanford.edu

Director: Professor Anne S. Kiremidjian

Editor: Professor H. Allison Smith Administrative Associate: Jeannette Cosby

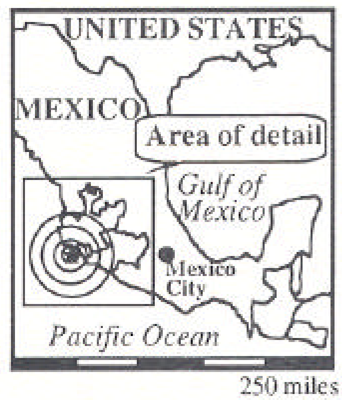
Editor's Note: In October Professor Ronnie Borja, Erik Straser, a Ph.D. student working with Professor.Kiremidjian, and Alex Barron, a M.S. student, visited the Manzanillo Earthquake site and provided the following article for the Newsletter. On November 1, the team gave a special seminar on the earthquake to the graduate students, professors, and earthquake engineers affiliated with the Blume Center. CENTER NEWS, which normally occupies this space, is on the back cover of the Newsletter

MANZANILLO EARTHQUAKE STUDY

Two structural engineering graduate students and one geotechnical faculty flew to the port city of Manzanillo, about 130 miles SW of Puerto Vallarta on the Pacific Coast of Mexico, following a Richter magnitude 7.6 earthquake that rocked this city and its neighboring towns on October 9, 1995, killing scores of people. Graduate student Erik Straser arrived at the site 72 hours after the main shock, together with three structural engineers from Degenkolb and Associates, a Blume Center affiliate. The team investigated the towns of Manzanillo, Cihuatlán, Melaque, and Barra de Navidad. Meanwhile, at the invitation of CUREe, graduate student Alex Barron and Professor Ronnie Borja went to the site on the weekend of October 21 and focused their field investigation on central Manzanillo, Chavarín, and the damaged areas on the shores of Manzanillo and Santiago Bays.

Among the numerous sites visited by the investigating teams was the 12-story Hotel Costa Real located in Manzanillo, which collapsed following the main shock, killing about forty people. The Casa Grande Hotel in Barra de Navidad also suffered extensive damage from collapsed water tanks atop the stairway. Many other hotels near the shores of this major tourist center have been damaged by the earthquake, and a house was washed away from the shore by a 2-meter tsunami generated by the main shock in Manzanillo. Evidence of liquefaction was also noted by the investigating teams in central Manzanillo, as well as in the residential areas near the Laguna de Cuyutlán. A one-kilometer stretch of Highway 200 near the Playa Azul area suffered significant subsidence, and the north-bound lanes of the highway were still impassable at the time of the field study.

The investigating teams noted that the collapses of non-engineered structures were most likely due to inadequate reinforcements. In addition, the roof of most of these structures is very heavy. Essential and engineered facilities, especially schools, were only slightly damaged, and there was evidence of seismic upgrades of these structures since the 1985 earthquake.



The regional hospital had damage to its mechanical room and infill walls, but was otherwise intact. In general, engineered facilities constructed of cast-in-place concrete frames with masonry infill performed well.

The main shock occurred officially on October 9, 1995 at 9:37 a.m. local time (8:37 a.m. PDT). The epicenter was 20 km SE of Manzanillo; the source was at a 33-km depth subduction zone where the North American, Cocos, and the Riviera plates intersect. A 6. 1 -magnitude aftershock was recorded on October 12, 1995 at 10: 52 a.m. local time (9:52 a.m. PDT), which lasted about 20 seconds. The quake was the second powerful tremor to hit Mexico in a month. On September l4, an earthquake of Mw = 7.3 killed five people in southern Mexico near the town of Copala.

RESEARCH SPOTLIGHT

EFFECTS OF ARCHITECTURAL WALLS ON BUILDING RESPONSE AND PERFORMANCE

by Vicki L. Vance, Ph.D. Candidate
Research Advisor. Professor H. Allison Smith

Introduction
A building is a complex assemblage of components, often classified as either *structural or non-structural.* While many non-structural elements - including architectural walls - are connected directly to the structural system, their effects are largely ignored in conventional analyses. Engineers may have a qualitative understanding of how non-structural components alter building behavior, but little research has been conducted to *quantify* their impact. Non-structural components potentially contribute to overall building stiffness, strength and damping and may have a significant impact on building performance, expected level of damage.

The objective of this research is to assess the amount by which architectural walls affect building response and performance. The results of this research will be particularly beneficial to engineers using system identification and damage detection techniques, by enabling them to develop analytical models which more accurately approximate measured response data and better predict behavior. In addition, as performance-based design becomes more widely practiced, evaluation of expected levels of damage to non-structural, as well as structural, components will be important.

Research.Description
The first step of this research involved developing an analytical model to represent architectural walls in structural analyses [Smith and Vance, 19961. The finite element formulation of this theoretical model is based on a quadrilateral, plane element with four nodes and eight degrees-of-freedom, the load-deformation characteristics of the wall are defined a pinched hysteresis model. The theoretical model is utilized parametric study designed to assess the effects of architectural walls. The parametric study involves analyzing of frames with various types and distributions of architectural walls included. In conjunction with the parametric study, simplified methods of accounting for the effects of architectural walls on building responses are being investigated. In particular, the feasibility of representing the effects of the walls by an equivalent viscous damping is being considered. In addition, results of the parametric study will be used to establish performance criteria for architectural walls as a function of the level of input ground motion. The results of this research will be verified by studying the effects of architectural walls on an actual building. Currently, this research is focused on the parametric study.

Parametric Study
Variables of the parametric study include frame height, wall configuration and distribution, and ground motion record and scaling. Six frames, with periods ranging from 0.59 *to 2.36* seconds, were 'designed' such that under the appropriate 1994 UBC equivalent static lateral load pattern, the drift in each story is a specified value with a straight line deflected shape. Structural members were 'designed' to remain elastic, so that all of the nonlinear effects may be attributed to the architectural walls. Three different wall configurations are included in this inquiry; the parameters which define the load-defornnation characteristics of these walls are based on experimental research conducted by Freeman t 19771, Rihal f 1 9931 and Adham *et aL [* 1990). A range of distributions of partition walls per unit floor area are or considered. Fifteen different ground motions from the 1989 Loma Prieta, 1992 Landers, and 1994 Northridge Earthquakes are utilized in this study; each of the ground motion records. is scaled such that the maximum interstory drift in the bare frame corresponds to a set of prescribed values related to the yield displacement of the walls. Time-history analyses are performed using a modified version of DRAIN-2DX; an additional element has been incorporated into DRAIN-2DX.-to represent the architectural walls [Smith and Vance, 19961.

Preliminary Results
While the parametric study is still in progress, some preliminary results are available. Of particular interest is the amount by which the architectural walls shift the natural period of the structures. The percent change in the fundamental period of the bare frame (frame with no walls included) when the stiffness of the architectural walls are included in the modal analysis of the frames is presented in Table 1. The values associated stress with each of the wall configurations, denoted *Common, Diagonal Strap, and Friction* and distributions, *lft* of partition by walls per *12.5ft², 25f², and 50ft²* of floor area are presented. in a The percent change in period ranges from approximately 2% to 60%, with larger shifts in natural period associated with a set shorter period structures.

The results depicted in Figures I and 2 are based on a single wall type with *3-5/8*" steel studs spaced at *16*" on center and *1/2* " gypsum wallboard facing panels. The results plotted in Fig ures I and 2 represent average frame responses to the suite of ground motions; each of the ground motions is scaled to *level 2* which corresponds to an interstory drift of 0.0045 times the story height in the bare frame. The maximum average interstory drift of the frames with architectural walls included, normalized by the maximum average interstory drift of the bare frames (no walls included), are plotted in Figure 1 versus period. Each line in Figure 1 represents a different distribution of architectural walls, ranging from 1ft of walls per *50ft²* of floor area to *1ft* per *12.5ft²*. The results indicate that the peak drift in the frames is *85* to *100%* of the peak drift in the bare frames, depending on

Table 1. Percent Change in Initial Fundamental Period

Wall Configuration	Wall Distribution	Percent Change in Period $((T_{bare}-T_{wall})/T_{bare})$					
		1-story	2-story	4-story	6-story	8-story	10-story
Common	12.5ft²	23.21	19.40	16.05	13.56	12.03	11.28
	25.0ft²	13.85	11.30	9.18	7.61	6.67	6.38
	50.0ft²	7.70	6.17	4.95	4.06	3.54	3.56
Diagonal Strap	12.5ft²	58.44	53.55	48.40	44.36	41.53	39.52
	25.0ft²	45.72	40.58	35.44	31.51	28.89	27.17
	50.0ft²	32.54	27.90	23.57	20.32	18.27	17.07
Friction	12.5ft²	11.81	9.58	7.75	6.40	5.59	5.41
	25.0ft²	6.46	5.17	4.14	3.38	2.94	3.03
	50.0ft²	3.40	2.69	2.15	1.74	1.51	1.76

the level of the input ground motion. Drift responses are relatively independent of the period of the frame.

The amount of the energy dissipated by the architectural walls as a percentage of the total amount of energy dissipated by the system is plotted versus period in Figure 2. The structural system is 'designed' to remain elastic, thus the structural sys- tem dissipates energy solely through damping. The walls dissipate energy through hysteretic behavior with no additional viscous damping included. As indicated in Figure 2, as much as 30% of the total amount of energy dissipated by the system is dissipated by the architectural walls, with walls in shorter period structures tending to dissipate a greater proportion of the energy. Note that the results presented here are based on a single wall configuration and level of input ground motion, thus the generalizations that have been made are not necessarily conclusive.

Conclusions

As buildings continue to house more sensitive equipment and clients begin to demand structures designed for reduced levels of damage in earthquakes, it becomes increasingly important to understand the effects of non-structural components. Preliminary results indicate that architectural walls do have an impact on building response and performance. In particular, the partition walls may cause a large variation in the initial fundamental period of the frame; thus, they may significantly alter the behavior of structures under ambient vibrations and moderate seismic motions. The architectural walls also have some impact on the displacements, drifts, and amount of energy dissipated. In general, the effect of the walls decreases as the level of input ground motion increases and walls become damaged. This research will be summarized in a Blume Center Technical Report due out next spring.

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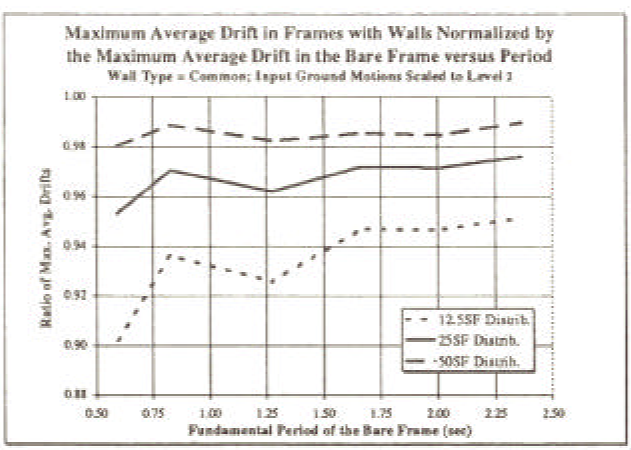

Figure 1. Ratio of Avg. Max. Drifts versus Period

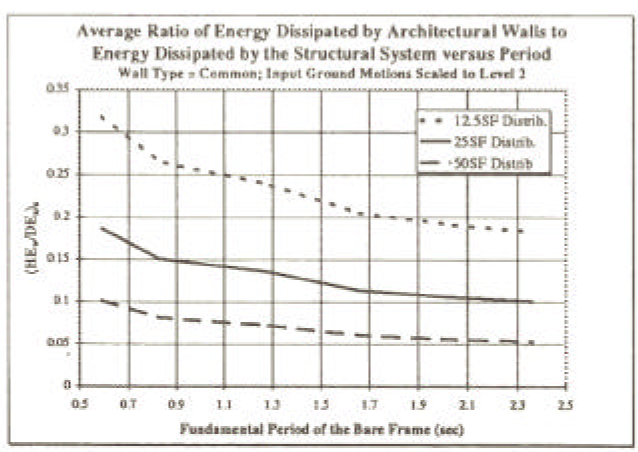

Figure 2. Avg. Ratio of Dissipated Energy versus Period

CENTER NEWS

We welcome back **Professor Haresh C. Shah,** former department chairman, after a one year leave of absence. Professor Shah has resumed his teaching responsibilities in the Structural Engineering Program and is continuing supervision of various research projects through the Blume Center.

Beginning this quarter, **Professor Peter Pinsky** has assumed responsibilities as Associate Chair of the Department of Civil Engineering. **Professor Helmut Krawinkler** will take over Professor Pinsky's duties as Program Coordinator for the Structural Engineering and Geomechanics Program.

Professor H. Allison Smith participated in the International Conference on Developments in Artificial Intelligence for Civil and Structural Engineering held in Cambridge, England in August, where she presented research related to a CUREe/Kajima project co-investigated with Professor Sami Masri at USC and Professor Jim Beck at Caltech.

Professor Anne Kiremidjian testified before the Science Subcommittee of the U. S. House of Representatives Science Committee at the hearings for the National Earthquake Hazards Reduction Program (NEHRP) which will be coming up for re-authorization in 1996.

Several Blume Center researchers, including **Professors Anne Kiremidjian** and **Haresh Shah, Dr. Stephanie King,** Ph.D. student **Nesrin Basoz** and visiting scholar **Sayaka Irie** participated in the 5th International Conference on Seismic Zonation held in Nice, France in October.

Professors Haresh Shah and **Helmut Krawinkler** were invited to give lectures at the CUREe Symposium in Honor of George Housner, held in October at Caltech.

On November 29, **Professor Dr. Sc. Techn. Hugo Bachmann** of the Swiss Federal Institute of Technology Zuerich - Switzerland gave a special seminar, entitled *Structural Dynamics - A Great Challenge,* to the Structural Engineering and Geomechanics Program. The seminar was attended by approximately fifty students, faculty, and professional affiliates of the Blume Center.

NEWLY SPONSORED RESEARCH PROJECTS

An Automated Damage Monitoring System For Civil Structures, sponsored by the National Science Foundation. Principal Investigator: Professor Anne S. Kiremidjian; Co-PI's – Professor Kincho Law and Professor Teresa Meng (Electrical Engineering); Senior Research Fellow - Dr. Eduard Carrier. 9/l/95 - 8/31/98.

The John A. Blume Earthquake Engineering Center c/o
Department of Civil Engineering
Stanford University
Stanford, CA 94305-4020

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