CUREe

CUREe News

Winter 1999

In this issue:

CUREe is a nonprofit organization devoted to the advancement of earthquake engineering research, education, and implementation whose university members are listed below:

Caltech · Stanford · Berkeley · Davis · Irvine · Los Angeles · San Diego · USC

CUREe Annual Meeting
Friday November 12th, 1999

12:00pm	Meeting Begins
12:00-1:15pm	Lunch
12:30-1:15pm	President's Business Report
1:15-2:45pm	Discussion of CUREe Business Issues (CUREe Possibly Going National)
2:45-3:00pm	Break
3:00-5:00pm	Project Presentations (Kajima, SAC, Woodframe, future research)

The following articles accompany the above presentations:

FEMA's Steel Frame Structures Program Nears Completion
The CUREe-Caltech Woodframe Project
CUREe-Kajima Project on Effects of Near-Field Ground Motion on Long-Period Structures

FEMA's Steel Frame Structures Program Nears Completion

by Stephen Mahin, UC Berkeley

One of the major overall technical surprises of the 1994 Northridge earthquake was the widespread damage to welded steel moment-resisting frame systems. The economy, versatility and presupposed high plastic deformation capacity of welded steel moment-resisting frame (WSMF) buildings has led to their common usage in Los Angeles and elsewhere in the U.S. While no loss of life resulted and none of the shaken WSMF structures collapsed during the Northridge earthquake, a wide spectrum of brittle connection damage did occur. This damage ranged from minor cracking to completely severed beams and columns.

Understanding the causes of this unanticipated damage, and identifying suitable remedies, requires consideration of many complex technical, professional and economic issues. These issues include metallurgy, welding, fracture mechanics, connection behavior, sys-

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tem performance, and practices related to design, fabrication, erection and inspection.

Because knowledge in many of these areas was judged inadequate and a systematic approach to finding a solution was deemed necessary, the U.S. Federal Emergency Management Agency (FEMA) initiated a 5-year program to develop and verify reliable and cost-effective methods for the inspection, evaluation, repair, rehabilitation and construction of steel moment-frame structures. This coordinated, problem-focused program of investigation, guideline development and professional training is managed by the SAC Joint Venture. The joint venture consists of three not-for-profit professional and educational organizations: the Structural Engineers Association of California (SEAOC), Applied Technology Council (ATC) and California Universities for Research in Earthquake Engineering (CUREe).

Current Activities

Based on a preliminary program of research and investigation, Interim Guidelines, known as FEMA 267, were developed by the fall of 1995. These guidelines focused on welded steel moment frames and covered topics related to welding, metallurgy, quality control and assurance; inspection procedures, damage classification, and the evaluation, repair and modification of damaged buildings following an earthquake; as well as the design of new WSMF structures. Since the introduction of the Interim Guidelines, two major revisions have been released, and systematic efforts have been initiated to develop more reliable, practical and cost-effective design criteria for steel moment-resisting frame buildings related to:

(a) identification, inspection and rehabilitation of existing buildings prior to a damaging earthquake,
(b) identification, inspection, and repair or upgrading of damaged buildings following an earthquake, and
(c) design and construction of new buildings.

In addition to welded steel moment-resisting frames, the current program addresses issues related to partially restrained, bolted and energy dissipative connections. Innovative, yet practical performance-based engineering procedures are incorporated as an integral feature of the overall effort.

The project's work plan was developed by the Project Management Committee in conjunction with FEMA and a nationally-representative Project Oversight Committee comprised of representatives from the design profession, regulatory agencies, and the construction and steel industry as well as experts in public policy and various technical fields. The Project Management Committee consists of the Program Manager (Stephen Mahin), the Project Director for Topical Investigations (James Malley), the Project Director for Guideline Development (Ronald Hamburger), and representatives from the three Joint Venture partners (William Holmes, Chris Rojahn and Robin Shepherd). FEMA's Program Manager is Michael Mahoney, and its Technical Advisor for the project is Robert Hanson.

Teams of researchers, technical specialists, and design and construction professionals have been assembled from throughout the U.S. to work on the various investigations, assess social, economic and political impacts, and to develop design guidelines. Additional information on the make-up of the various project teams and results obtained may be found on the SAC World Wide Web site (http://quiver.eerc.berkeley.edu:8080).

New Guidelines Near Completion

By the first quarter of 2000, a new set of Seismic Design Criteria will be developed applicable to buildings in the U.S. located in areas of low, medium and high seismicity. Completion of these documents involves a series of focused workshops and solicited written reviews. The guideline documents are being prepared by a team of experts and design professionals, including John Hooper, Larry Reaveley, Tom Sabol, Mark Saunders, Robert Shaw and Ray Tide. Four separate guideline documents are in preparation:

- *Seismic Design Criteria for New Moment-Resisting Steel Frame Structures;*
- *Evaluation and Upgrade Criteria for Existing Welded Moment-Resisting Steel Frame Structures;*
- *Post-Earthquake Evaluation and Upgrade Criteria for Welded Moment-Resisting Steel Frame Structures; and*
- *Quality Assurance Guidelines for Steel Frame Construction.*

The technical background underlying these documents is summarized in a series of State of the Art Reports on the following topics: (a) Materials and Fracture; (b) Joining and Inspection; (c) Connection Performance; (d) System Performance; (e) Performance Prediction and Evaluation; and (f) Performance of Steel Buildings in Past Earthquakes. The economic, social and political costs and ramifications of implementing the Seismic Design Criteria, and specific means to ameliorate adverse impacts have been assessed and are described in a report to be released in early 2000.

Performance-Based Approach Utilized

An explicit reliability-based design, analysis and evaluation framework has been adopted in the development of the guidelines. Two specific performance levels are being addressed – an incipient structural damage state and a collapse prevention state. In order to estimate the probability that a structure will exceed the damage limits of desired performance levels within defined levels of confidence, the framework directly accounts for uncertainty and randomness inherent in construction, estimation of ground shaking hazards and prediction of structural response to ground shaking.

The reliability-based analysis and evaluation framework developed builds upon a conventional Load and Resistance Factor Design (LRFD) format. The resulting Demand and Capacity Factor Design (DCFD) framework differs from the usual LRFD specifications currently incorporated in building codes in that it is based on a probabilistic assessment of the dynamic performance of the entire structural system, rather than on the performance of individual building elements.

For new construction, the DCFD procedures are simplified into a conventional code format and produce designs consistent with the intent of current building code provisions; i.e., to provide a high level of confidence that designs will be capable of resisting Maximum Considered Earthquake demands with a low probability of collapse. A number of "prequalified" welded and bolted connections are identified that can be used in many situations to streamline the application of these new procedures.

For new structures, guidance is also provided on using the complete DCFD format, so that a designer can consistently and rationally consider other performance objectives, including lower probabilities of collapse, specific probabilities of incurring damage, as well as higher levels of confidence for achieving the target performance levels. For existing structures, the DCFD approach provides the basis for assessing likely performance or the confidence that a performance level will be achieved.

Broad Range of Supporting Technical Studies Conducted

To support the development of this performance-based design, analysis and evaluation approach, nearly 100

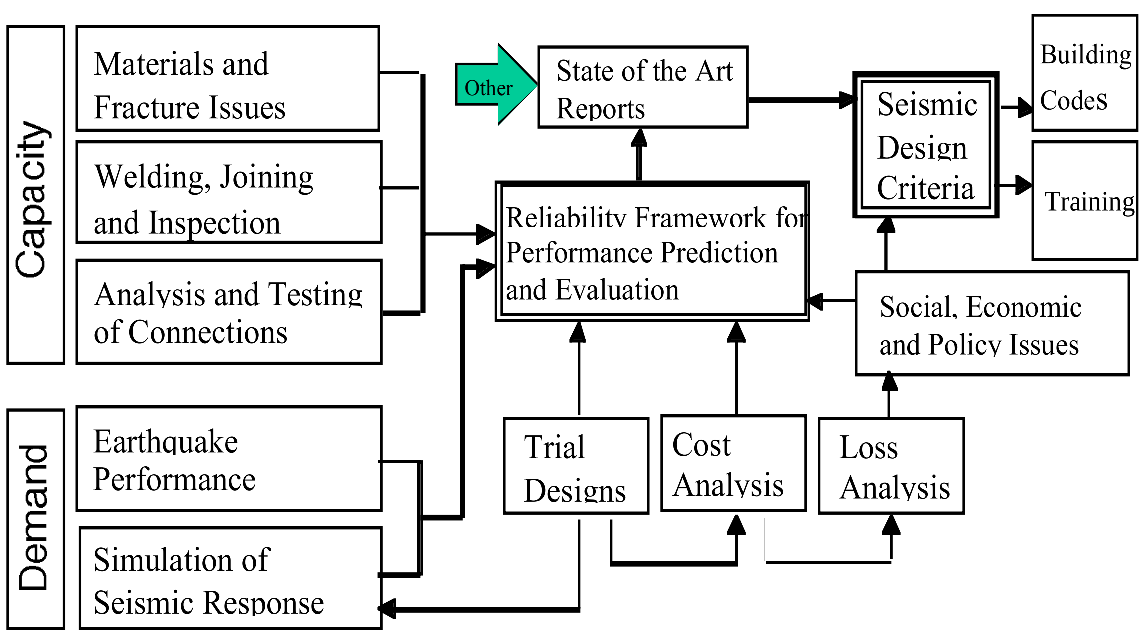

Figure 1

carefully coordinated, problem-focused investigations were undertaken. The basic inter-relation of these investigation areas is shown diagrammatically in Figure 1.

Integrative Studies for Performance Prediction and Evaluation

A team of investigators lead by Doug Foutch is synthesizing information from the other investigation teams to develop a set of consistent demand and capacity factors. Analysis method adjustment factors have also been introduced to account for differences among response predictions based on various conventional and refined analysis methods (e.g., the equivalent static lateral force approach, dynamic linear analysis, and nonlinear static and dynamic analyses) and modeling assumptions. To compute the default demand and capacity factors contained in the guidelines, Foutch's team evaluated the dynamic capacities and demands of building systems having different heights, configurations and types of connections, and subjected to ensembles of ground motions representing different seismic hazard conditions. Three, nine and twenty story 'model' buildings were considered in these studies. The model buildings were located at three sites across the U.S. representative of regions of high, moderate and low seismicity and designed using various criteria (including several pre-Northridge and contemporary codes). A new Incremental Dynamic Analysis (IDA) approach was introduced to characterize and quantify the dynamic capacity of the complete structural system. This approach incorporates information about the hysteretic characteristics and deformation capacity of members and connections. Demand statistics were computed for the model buildings considering ensembles of ground motion time histories corresponding to current NEHPR seismic hazard maps for various return

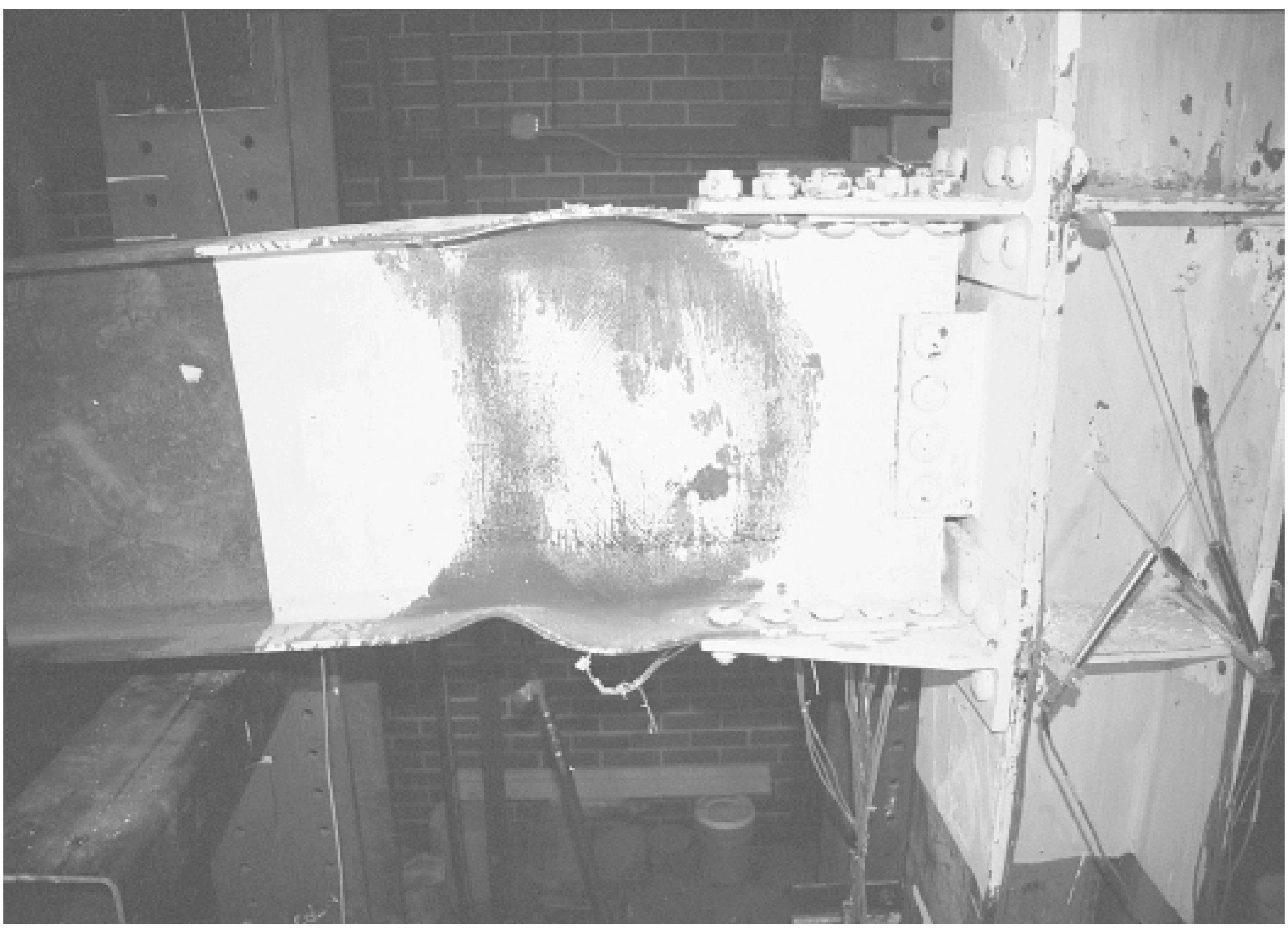

Figure 2: Tee-stub bolted connection detail tested at the Georgia Institute of Technology

periods (approximately 2500, 475, 72 and 42 years) and representative of firm (as well as of soft) soil conditions.

Capacity-Related Studies

A series of studies was undertaken to better characterize the capacity of a steel moment-resisting frame building. These investigated the influence on capacity of materials, joining conditions and connection details as well as of loading history and rates.

Materials and Fracture – The Materials and Fracture Team under the guidance of Karl Frank examined strength and toughness properties of materials in commercially available structural steel shapes, including new materials just coming on the market. Special T-stub connection specimens were also fabricated and tested to assess through-thickness properties of steel in column flanges. Various factors were considered in these tests, including loading rate, the strength and notch toughness of base materials, restraint provided by the finite size of the joint, and local welding details. Such studies have helped understand local behavior and the loads that can be developed in welded and bolted joints.

Welding and Nondestructive Testing – To better understand the behavior of welded joints and to develop reliable criteria for the design and acceptance of welds, a variety of investigations were undertaken by a team under the leadership of Matt Johnson. Tests were conducted on a variety of welded connections, including standard metallurgical and fracture specimens, wide pull plates joined by complete penetration welds, T-stub joints and full-sized beam-to-column connections. Studies included evaluation of the sensitivity of welded joints to the strength and toughness of the base and weld metals, the process, procedure and condition used in welding, test temperature and loading rates. Studies have been made to examine mechanical, fracture, metallurgical and chemical properties of deposited weld metal and of actual and simulated heat-affected zones, and the susceptibility of various weld consumables to hydrogen-assisted cracking. In addition, a number of field, laboratory and analytical studies have been carried out to assess ultrasonic testing procedures as well as newer inspection technologies. Weld acceptance criteria have been established based on strength and toughness of the materials, conditions of use (degree of inelastic action expected), joint geometry, criticality of the weld to the integrity of the structural system, and presence of discontinuities. Toughness-based criteria for specifying and accepting weld materials are being incorporated in the new guidelines.

Connection Performance – This research area is coordinated by Charles Roeder. Detailed finite element and statistical analyses have been utilized to identify and assess factors influencing behavior of welded and bolted beam to column connections, devise simplified methods for predicting their deformation and strength capacities, and to develop simplified analytical methods suitable for design practice. More than 150 full size beam to column connections have been tested as part of this program, supplementing hundreds more conducted or sponsored by industry, the National Science Foundation, National Institute of Standards and Technology, and the American Institute of Steel Construction. For welded connections, three general approaches have been considered in developing connection details: (1) improving conventional unreinforced connections through changes in weld materials, local details, shear tab connections and weld access holes, (2) locally strengthening the connection of the beam to column by adding cover plates, ribs or haunches, and (3) locally weakening the beam away from the column face by reducing the width of the beam flanges. Interior and exterior beam to column connections have been examined, with and without slabs. The effect on behavior of panel zone yielding, strain rates, loading histories as well as local and lateral torsional buckling is being carefully assessed. Bolted connections have also been considered, including connections utilizing various bolted T-stub, flange plate, end plate, and clip angle details. Special attention was placed on conducting tests to identify the actual strength and deformation characteristics of simple connections intended in design to carry gravity loads only.

A database of more than 500 connection tests is being used to devise and evaluate design methods for estimating connection strength and deformation capacities (along with appropriate capacity reduction factors). Based on an assessment of these and other data, a series of pre-qualified connection design procedures have been identified that permit design and detailing of connections for routine frame applications without requiring project-specific qualification testing. Each pre-qualification includes applicable design, detailing, joining and inspection information as well as a statement of the stringent conditions under which the pre-qualification applies. For those applications in which one of the standard connections is not pre-qualified, a project-specific connection qualification procedure is stipulated.

Demand-Related Studies

A number of basic studies on the seismic demands on systems and connections have been made as a counterpoint to the studies of capacities. These investigations include a review of damages to WSMF buildings during the Northridge, Loma Prieta and other recent earthquakes, and the predicted demands for the three, nine and 20 story 'model' buildings.

Performance of Steel Frame Buildings during Past Earthquakes – Various investigations have been conducted to assess the performance of WSMF buildings in past earthquakes. In addition to the Northridge earthquake, information has been gathered related to the Hyogo-ken Nanbu (Kobe), Landers/Big Bear, Loma Prieta, Whittier Narrows, and other earthquakes. Results have been interpreted to help understand factors contributing to the damage observed in actual structures, assess recommended preliminary screening criteria used to identify potentially damaged buildings, evaluate procedures for selecting connections within a building to be inspected, identify details and other structural features associated with damage, evaluate the accuracy of analytical methods, and assess the economic, social and other impacts of damage. Two types of simplified evaluation models have been extracted from this data: one for estimating structural performance and one for estimating economic losses.

System Performance – Focused investigations were conducted to assess the effect of various structural and ground motion parameters on global and local demands. Model buildings having three, nine and 20 stories, located in regions of high, moderate and low seismicity, are used as the basis of these studies. Research in this area is coordinated by Helmut Krawinkler. Investigations have assessed the sensitivity of seismic response to (a) structural configuration, proportioning and modeling, (b) deterioration of hysteretic characteristics due to factors like local buckling, brittle fracture, and bolt slip; and (c) ground motion intensity and dynamic characteristics, including consideration of multi-component excitations and excitations representative of soft soil and near-fault sites. Focussed studies were also made to identify potential benefits in regions of low and moderate seismicity of alternative framing systems utilizing partially restrained and bolted connections.

Economic, Social and Political Impacts Considered

Numerous activities were conducted to assess the practicability of the new Seismic Design Criteria and to assess its economic, social and political impacts. Related activities in this area include trial applications, estimates of costs and other losses associated with implementing or not implementing the new criteria, and a series of workshops including participation by building owners and managers, government officials, representatives from financial and insurance institutions, and experts in social science, law and public policy. A panel of experts, lead by Thomas Tobin is providing input in this area.

Future Activities

The Seismic Design Criteria will be the subject of a Review Workshop held in December 1999. Based on comments from the workshop, and additional written comments, the criteria will be finalized during the first quarter of 2000. During the remainder of 2000, information will be disseminated to various groups. A number of seminars are planned around the US to describe the guidelines to engineers and building officials.

Concluding Remarks

New lessons are learned from every major earthquake. The potential for brittle failures in welded steel connections was one of the major unanticipated lessons of the 1994 Northridge earthquake. The FEMA-sponsored program to Reduce Earthquake Hazards in Steel Moment Frame Structures has developed considerable new

Continued on page 15

The CUREe-Caltech Woodframe Project

by John Hall, California Institute of Technology

This effort seeks to improve the seismic performance of woodframe construction through development of cost-effective retrofit strategies and changes in design and construction procedures and building codes. CUREe performs the work under subcontract to Caltech; funding is received by Caltech from FEMA through the California OES. Total budget is $5.2 million with a 25% matching fund requirement, bringing the total to $6.9 million. Work on the project started in September 1998. Listed below in Table 1 are the project elements, budgets (including matching fund contribution), and management personnel.

Task 1.1.1 Shake Table Tests of a Two-Story House. Budget: $400,000. P.I.: André Filiatrault (UCSD). The main objectives are to quantify woodframe building seismic response for various construction configurations, and to establish relations between ground motion intensity, structural system response and repair cost. The specimen is a simplified but full-scale two-story house of engineered design. The footprint is 16 feet by 20 feet, and this is accommodated by a steel frame extension mounted on the UCSD shaking table. There are 13 test phases planned to examine a variety of conditions: level of ground motion, presence of openings, amount of sheathing, presence of finishing materials, presence of hold-downs and straps, degree of symmetry, and direction of ground motion. See Figures 4 and 5.

Element	Budget	Management
1. Testing and Analysis	$3,445,000	Frieder Seible, Andre Filiatrault, Chia Ming Uang
2. Field Investigations	$995,000	Goetz Schierle
3. Codes and Standards	$647,000	John Coil, Kelly Cobeen, James Russell
4. Economic Applications	$405,000	Thomas Tobin
5. Education and Outreach	$818,000	Jill Andrews
6. Project Management	$571,000	John Hall, Robert Reitherman

Table 1: Woodframe project budget

Most of the following discussion deals with Element 1, Testing and Analysis, since that is where most of the progress has been made to date. Briefly, the other four elements are advancing along the following lines. Element 2: statistical studies of Northridge damage; Element 3: identification of code issues, involvement in planning the Element 1 testing agenda, code input to the testing program; Element 4: refinement of the proposed tasks; Element 5: newsletters, videotaping. In the near future, additional work getting underway includes case studies of earthquake damage (Element 2), economic analysis of retrofit and code changes (Element 4), and preparation of an educational exhibit featuring wood building construction aspects and retrofit techniques (Element 5).

Figure 3 gives an overview of the tasks under Element 1, Testing and Analysis. Listed below are brief descriptions of these tasks together with budget amounts (25% match included) and principal investigators.

Task 1.1.2 Shake Table Test of a Multi-Story Apartment Building. Budget: $400,000. P.I.: to be determined. This task is in the planning stage and may be combined with Task 1.4.5 (Soft/Weak Stories). Of interest are design code provisions for multi-story apartment buildings as well as retrofit strategies for older, deficient construction, especially soft and unsymmetrical first stories created by tuck-under parking garages. The initial part of this task will deal with component testing; additional funds will be needed before the desired shake table tests can be performed.

Task 1.1.3 Program Development and Experimental Study of the Seismic Response of Woodframe Construction. This task originated at the University of Brit-

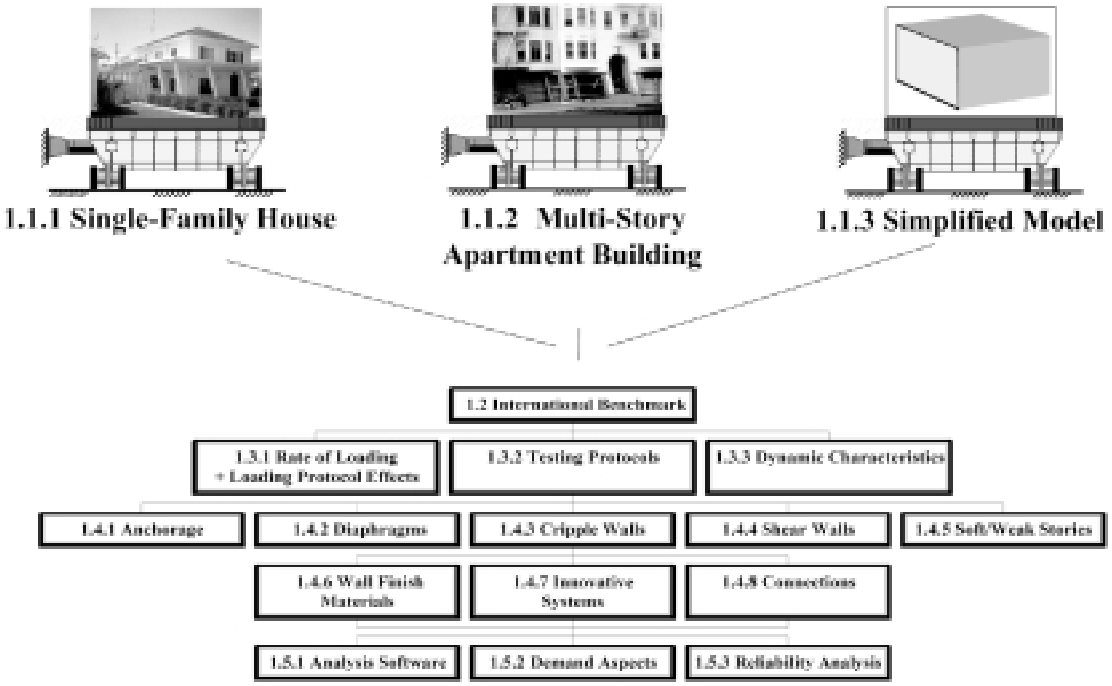

Figure 3: Woodframe project testing and analysis plan

ish Columbia and is funded outside our Project; it is being coordinated with the CUREe/Caltech Woodframe Project. The test specimen is a sheathed box-type structure with 3-dimensional aspects. Data from static and dynamic loading will be used to calibrate a finite element computer program containing plate, beam and nonlinear spring elements to model panels, framing members and nails.

Task 1.2 International Benchmark. Budget $70,000. This task invites parties to predict certain responses of the shake-table tests on the single-family house (Task 1.1.1). Predictions will be blind, and comparisons of the computed and experimental results will be made at a workshop.

Task 1.3.1 Loading Protocol and Rate of Loading Effects. Budget: $150,000. P.I.: Chia Ming Uang (UC San Diego). This work evaluates differences in behavior (strength, back-bone curve, deformation capacity) which result from differences in loading protocol. The primary test specimens will be shear panels of plywood, OSB or gypsum wallboard. The list of loading protocols to be examined includes sequential phased displacement (SEAOSC), ISO, and CUREe/Caltech (both ordinary and near-fault earthquake characteristics...see following task). In addition, this task examines the effect of loading rate on behavior: slow test vs. load applied at a period of 0.5 seconds.

Task 1.3.2 Testing Protocols. Budget: $80,000. P.I.: Helmut Krawinkler (Stanford). Under this task, appropriate loading protocols will be developed for use by the testing program: cyclic displacement histories for component tests and time history motions for shake table tests. Force-controlled protocols are also needed for de-

Figure 4: Expanded shake table

Figure 5: Two-story house

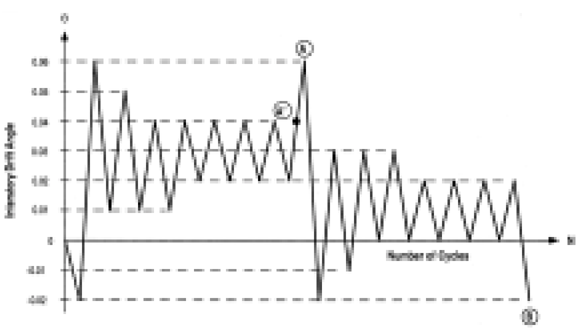

Figure 6: SAC near-fault loading history

vices such as hold-downs. Separate protocols will be established to represent ordinary ground shaking and to include near-source effects. Attention must be paid to the return period of the loading. Experience from the SAC Steel Project is being taken into consideration.

Task 1.3.3 Dynamic Characteristics of Woodframe Buildings. Budget: $90,000. P.I.: James Beck (Caltech). The goal of this task is to assess periods of vibrations and amounts of damping for woodframe buildings. Sets of CDMG records from up to five wood buildings will be examined by system identification methods. This effort also includes vibration data from the shaking table test on the single-family house (Task 1.1.1). Another phase of the dynamic characteristics task is to conduct ambient and forced vibration field tests on representative wood buildings.

Task 1.4.1A Anchorage of Woodframe buildings. Budget: $150,000. P.I.: James Mahaney (Wiss Janney Elstner Assoc.). This testing program focuses on the sill plate to foundation connection. Test variables include anchor bolt size and spacing, washer characteristics, sill plate dimensions, amount of dead load, and direction of applied load (amount of the uplift component). A reusable shear wall as part of the test setup is employed to apply the proper distribution of load to the sill plate.

Task 1.4.1B Hillside Connection Tests. Budget: $50,000. P.I.: Yan Xiao (USC). The diaphragm to foundation connection along the upslope edge is of interest here. Four specimens will be tested: one representing typical older construction; two retrofit strategies for older construction; and a new design. A reusable diaphragm in the test setup ensures that the proper combination of moment and shear is imparted to the connection.

Task 1.4.2 Diaphragm Behavior. Budget: $90,000. P.I.: Dan Dolan (Virginia Polytechnic University). This project has yet to be defined in detail but will deal with cyclic strength and stiffness characteristics of typical diaphragms found in residential wood construction.

Task 1.4.3 Seismic Behavior of Constant Height and Stepped Cripple Walls. Budget: $150,000. P.I.: Rob Chai (UC Davis). Current design and retrofit provisions for cripple walls are examined in this testing program on at least twenty 12-foot-long specimens. Variables include height of wall, type of sheathing (plywood, OSB, stucco), braced length/total length, vertical load and foundation type. Stepped cripple walls, intended to

Date of Earthquake	Magnitude (M_L)	Epicentral Distance (km)	Maximum Acceleration (g)	
			Ground	Structure
Parkfield – Elementary School				
04/04/93	4.2	7	7.5% H	12.3% H
12/20/94	4.7	4	8.9% H	20.1% H
Bishop – Fire Station				
05/17/93	6.0	61	1.8% H	4.4% H
Eureka – 2-story Office Building				
02/08/95	3.9	13	3.7% H, 0.8% V	6.2% H
San Bernardino – 2-story Motel				
06/28/97	4.2	1	6.4% H, 3.5% V	9.2% H
07/26/97	3.7	0	3.8% H, 2.7% V	7.8% H
03/11/98	4.5	18	2.3% H, 1.1% V	7.1% H
Indio – 1-story Hospital				
07/26/97	4.9	33	2.4% H	8.3% H

Table 2: Selected CDMG strong motion records

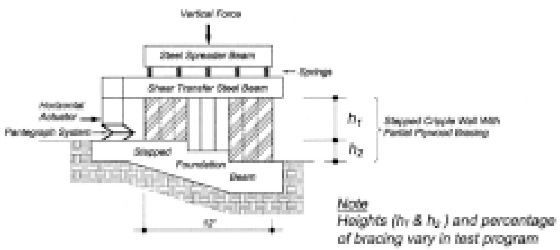

Figure 7: Stepped cripple wall tests

represent hillside construction, are to be constructed at slopes of 27˚ and 45˚.

Task 1.4.4 Behavior of Shear Walls. Budget: $290,000. P.I.: Gerry Pardoen (UC Irvine). Objectives of this test program are to improve the understanding of the cyclic behavior of full-scale shear walls with attention given to the following test variables: gravity load, nail types, grade of framing lumber, staples, hold-downs, and aspect ratio. More than 20 test groups (>50 specimens) are planned, including many with door and window openings and two multi-story 16-foot by 16-foot walls. See Figure 8. Several specimens will duplicate shear walls from the house of Task 1.1.1 so that load-deflection curves will be available for subsequent analyses of this house. The testing program is designed to expand on and complement another shear wall testing project for the City of Los Angeles that is nearing completion.

Task 1.4.5 Issues with Soft/Weak Stories. Budget: $100,000. P.I.: to be determined. This task is still being planned and may be combined with Task 1.1.2 on multi-story apartment buildings. The likely focus is retrofit schemes for apartment buildings with tuck-under parking.

Task 1.4.6 Seismic Performance of Gypsum and Stucco Walls. Budget: $120,000. P.I.: Kurt McMullin (San Jose State University) and Gregory Deierlein (Stanford). This task, with both testing and analytical components, seeks to establish a seismic performance-damage-repair relationship for wall finish materials and to investigate new fastening methods which will reduce damageability of the finishes. Cyclic and monotonic tests are planned on a variety of 8-foot by 8-foot solid panels and 16-foot by 8-foot panels with door and window openings. The analytical effort will employ a 2-dimensional, elastic finite element method, with possible extensions to nonlinearity and fracture mechanics.

Task 1.4.7 Fluid Dampers for Seismic Energy Dissipation of Woodframe Structures. Budget: $50,000. P.I.: Michael Symans (Washington State University). This study employs nonlinear finite element analysis to investigate the effectiveness of fluid dampers for seismic protection of wood buildings, including multi-story structures. Issues to be addressed include number and location of dampers, properties of dampers, installation strategies, amount of response improvement, and cost impact.

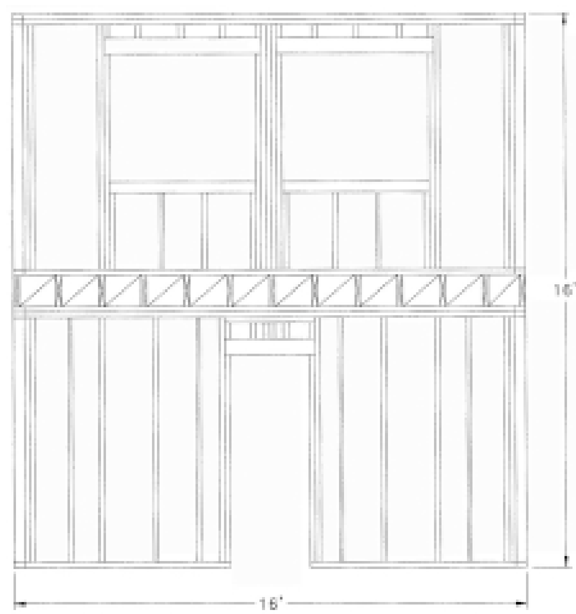

Figure 8: 16' X 16' shear wall with openings

Task 1.4.8A Effect of Fastener Penetration on Sheathing-to-Wood Connections. Budget: $40,000. P.I.: Fernando Fonseca (Brigham Young University). The purpose of this task is to establish a database on the cyclic behavior of dowel-type connections under shear loading with special attention given to the overdriven condition. Tests will be conducted on individual nails, bolts, wood screws, lag screws and staples connecting wood to wood, sheathing to wood, sheet metal to wood, and sheathing to metal stud. The data will be placed on a CD-ROM with a search capability.

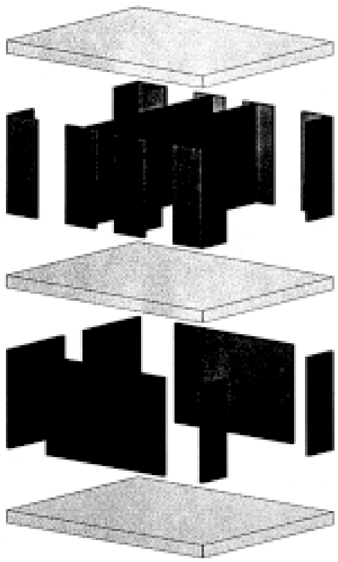

Figure 9: Analytical modeling of two-story shear wall building

Task 1.4.8B Diaphragm to Wall Connections. Budget: $60,000. P.I.: Gerry Pardoen (UC Irvine). Several specimens will be tested to examine load transfer and deformation characteristics of typical diaphragm-to-wall connections. Appropriate pieces of the diaphragm and wall framing are included in the test setup.

Task 1.4.8C Other Connection Tests. Budget: $60,000. P.I.: to be determined. This task is in the planning stage of identifying high priority connection systems between wood building components which merit investigation through testing. One example under consideration is a multi-story shear wall configuration that is offset at floor level.

Task 1.5.1A Analysis Software. Budget $130,000. P.I.: Andre Filiatrault (UC San Diego). The goal of this task is to improve the current software available for seismic analysis of wood buildings. The work is being carried out in conjunction with the house shake test (Task 1.1.1). The initial focus is on modeling nonlinear shear walls in a 3-dimensional arrangement; additional features will be added. See Figure 9.

Task 1.5.2 Demand Aspects. Budget: $50,000. P.I.: Helmut Krawinkler (Stanford). This study, not yet funded, performs analyses to evaluate demands on wood buildings from a variety of earthquake ground motions (ordinary and near-fault) at different return periods.

Task 1.5.3 Reliability Analysis. Budget $50,000. P.I.: to be determined. This task is in the planning stage.

The CUREe/Caltech Woodframe Project is actively seeking sources of matching funds, donations of materials and services, and new money to expand and add projects. SEAONC is considering a donation of $7500 to investigate the differences between two types of nails. A current $1.55 million proposal to the California Earthquake Authority and the Department of Insurance aims to develop a guide for use by appraisers and engineers in the field to assess damage and repair costs following an earthquake. The guide will draw on experience from previous earthquakes plus results of new tests on soil, foundations and walls. CUREe is also cooperating with PEER in an effort led by the Seismic Safety Commission to draft legislation that would appropriate money to undertake mitigation projects in the State. Should this effort be successful, additional money will be available for investigating the seismic resistance of wood construction. Some preliminary contacts have also been made with the Division of the State Architect regarding applications to school buildings.

Serious study of the earthquake behavior of wood construction is long overdue, with most previous structural research being devoted to steel, concrete and masonry. Data from the Northridge earthquake pertaining to wood — $20 billion property loss, 50,000 residents displaced long-term, 24 of the 25 fatalities that occurred in buildings — show that the need for action is great. However, real solutions, which will involve not only engineering advances but other aspects such as training to improve construction quality, will take time. The CUREe/Caltech project will address many aspects of the problem, but perhaps its greatest achievement will be to spark a long-term involvement of California researchers who, together with their newly established cooperation with other researchers and the industry, will put seismic behavior of wood buildings on a sound engineering basis. Since wood construction is complicated structurally, it will be necessary to do quite a lot of multi-component testing and shake table tests on full-scale structures. Although shaking tests on actual size buildings are usually considered not to be feasible, the light weight of wood buildings makes them an exception. The only obstacle is that

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CUREe-Kajima Project on Effects of Near-Field Ground Motion on Long-Period Structures

by Helmut Krawinkler, Stanford University

Near-field ground motions include large pulses that may greatly amplify the dynamic response of structures, particularly if structures are called upon to respond inelastically to earthquake ground motion. Pulses will amplify the maximum interstory drift for elastic structures, and more so for inelastic structures. The amplified interstory drifts may impose excessive deformation demands on elements, which in turn may lead to incremental (P-delta) collapse.

The need exists for focused research to improve our understanding of near-field ground motions and their effects on structures. As part of the CUREe-Kajima research program, three projects are about to be completed, with the focus on the following objectives:

- Identify and quantify characteristics of near-field ground motions,
- achieve an understanding of the effects of large pulses on the response of elastic and inelastic structures,
- quantify the seismic demands imposed by near-field ground motions on building structures and long-span highway overpasses, and
- develop techniques for improving the response of flexible structures to near-field ground motions.

Each project has a US component and a Kajima component. Only the US components are summarized here.

Project #1. Effects on Building Structures and Design Issues, PI Professor Helmut Krawinkler, Stanford. This project focuses on the response of elastic and inelastic SDOF and MDOF structural systems to various pulses and near-field ground motions. The responses are evaluated for story drift demands, global displacement demands, and energy demands. The emphasis is on a quantification of response in terms of parameters that facilitate incorporation of near-fault effects in design and performance evaluation procedures. Recorded near-fault ground motions are represented by equivalent pulses, which are used to predict seismic demands of frame structures for recorded ground motions and to estimate the expected demands in future earthquakes as a function of earthquake magnitude and distance from the ruptured fault.

Project #2. Performance Improvement of Long Period Building Structures, PI Professor James Anderson, USC. This one-year project is concerned with performance prediction for four existing tall frame structures and methods for performance improvement considering conventional and innovative approaches, ranging from the addition of walls or bracing systems to the employment of passive energy dissipation devices. Nonlinear time history analysis of complex structural systems is utilized to evaluate various improvement techniques.

Project #3. Performance of Long-Span Highway Overpasses, PI Professor John Wallace, UCLA. This one-year project is concerned primarily with response evaluation and improvement of long-span continuous rigid frame bridges. Both simplified and more detailed analytical models are developed and analyzed. Parametric studies using the simplified models are performed to address important response characteristics and to identify areas where more detailed models are needed.

The results of these studies were discussed at a recent project meeting at Kajima Corporation in Tokyo. The following accomplishments and conclusions were identified at this meeting:

- A comprehensive study was completed on the effects of near-fault ground motions on the response of building frame structures. The following important conclusions are drawn from this study:
- The fault-normal component of near-fault ground motions with forward directivity is very severe and imposes seismic demands that are significantly larger than considered in present design practice. (See Figure 10, in which the 15-D*

velocity spectrum represents presently used design ground motions.)

- Even if near-fault records are rotated, one of the two rotated components will be comparable in intensity to the fault-normal components, see Figure 11.
- Near-fault ground motions can be represented successfully, but with limitations, by simple equivalent pulses defined by a pulse period and effective velocity. The effective velocity matches well with the PGV of the time history trace.
- The seismic demands depend strongly on the ratio of structure period to pulse period, and are largest for structures whose period is shorter than the pulse period.
- The equivalent pulses were used to achieve a parametric assessment of the global and local response of frame structures to recorded near-fault ground motions.
- The equivalent pulses were used to predict the damage potential of future near-fault ground motions as a function of earthquake magnitude and distance from the fault. Representative scenario strength demand spectra for a magnitude 7 earthquake are shown in Figure 12. This provides a partial answer to the question of the additional risk that near-fault effects pose to the built environment. A detailed near-fault hazard analysis is needed to provide a more complete answer.
- A study was performed on the detailed response of several existing multi-story frame structures subjected to near-fault ground motion records. Several retrofit options were investigated to reduce the very large seismic demands. Retrofits with walls or braced frames were found to be only partially effective. The use of 30% viscous damping in the analysis model led to a significant reduction in seismic demands, which indicates that energy dissipation devices are a potential means for improving the performance of tall buildings to near-fault ground motions.
- A study was performed on the effects of near-fault ground motions on long-span highway overpasses. The global conclusions are similar to those drawn from the building study. Local (curvature) demands for support structures were evaluated using a fiber element for flexural/axial interaction in reinforced concrete piers.

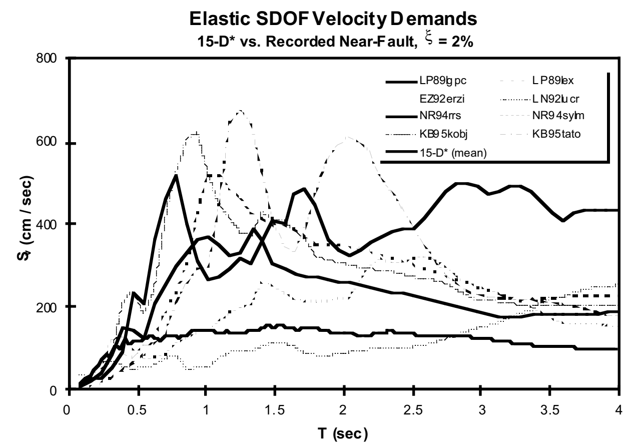

Figure 10: Velocity spectra of near-field ground motions and presently employed design ground motions (15-D)*

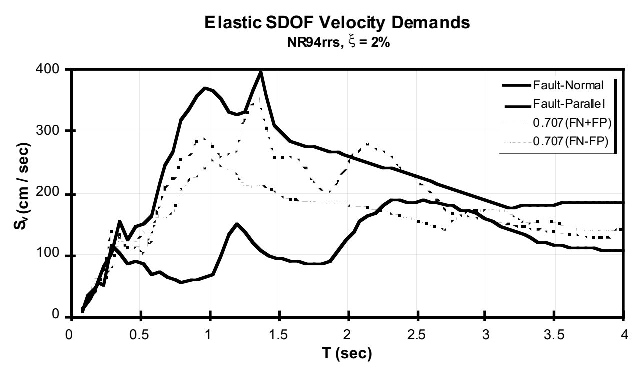

Figure 11: Velocity spectra of fault-normal/parallel components and 45° rotated components

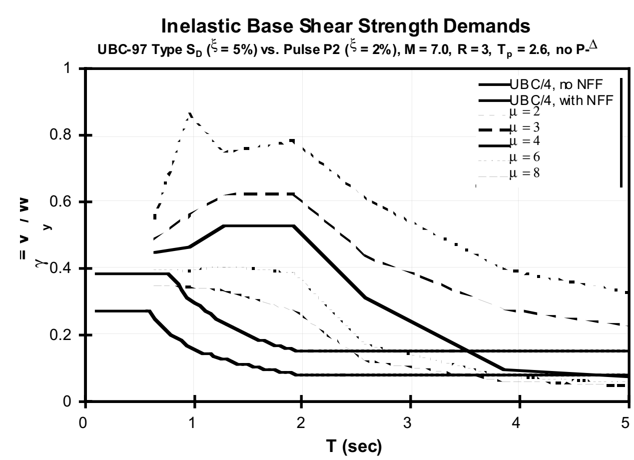

Figure 12: Scenario strength demand spectra for a magnitude 7 earthquake at 3 km from the site (soil type D)

Network for Earthquake Engineering Simulation (NEES)

The National Science Foundation has been developing plans and budget approvals for the National Network for Earthquake Engineering Simulation (NEES). At the time of this printing (early November, 1999), no Requests for Proposals (RFPs) have been issued by NSF, but are expected shortly.

Under the direction of Professor Bruce Kutter, Chair of the CUREe Committee on NEES, an e-mail/world wide web discussion group has been established, and an exploratory seminar was held to develop material to post on the website. This is provided as a service to the broad field of earthquake engineering and is not limited to CUREe members.

Purposes of this Discussion Group

1) To allow researchers, network architects, and host facility managers to discuss issues regarding the NSF-NEES program. Official information about this program may be found at http://www.eng.nsf.gov/nees/.

2) To help interdisciplinary researchers to find collaborators with complementary expertise. To this end, everyone is encouraged to submit a brief resume and a statement of their potential contributions to NEES.

3) To provide a forum for debates and discussions of technical and cultural issues associated with NEES.

Sending and Reading Messages to this Group

Anyone can post messages to this list by sending email to curee-nees@ucdavis.edu. To respond to a specific message posted on the web site, copy the subject line of the posted message to your email message subject line. Also copy relevant text from the posted message to your email message. Archived messages at the web site may be sorted by subject to view related messages. Messages sent to this list may be viewed at http://listproc.ucdavis.edu/archives/curee-nees.

CUREe will act as a moderator to eliminate irrelevant and inflammatory postings. The moderator will forward appropriate messages to the web site within one or two business days after they are received.

Disclaimers

The list is not reviewed or condoned by the National Science Foundation. CUREe will attempt to remove junk mail and messages containing inflammatory comments, but will not review the messages for accuracy. UC Davis is serving as a host for this discussion forum but bears no responsibility for the content of the messages posted to this site.

Additional Student to Attend 12WCEE

An eighth CUREe-sponsored student will attend the Twelth World Conference on Earthquake Engineering. Ayhan Irfanoglu, a graduate student at the California Institute of Technology, was granted a student travel award to attend the conference, which will be held January 31st through February 4th in Auckland, New Zealand.

Changes to Board of Directors

CUREe would like to thank outgoing At-Large Directors Professor Karl Romstad and Professor Gregory Fenves and one of our two SEAOC-nominated Directors Gregg Brandow, who will finish their terms at the end of this year. Professors Romstad and Fenves also served as officers for CUREe in the capacity of President and Secretary, respectively. CUREe members have recently elected two new appointees to the Board of Directors. Professors Jean-Pierre Bardet and Anne Kiremidjian will serve two-year terms beginning January 1st, 2000. Thanks also to all who particpated in the election process, and congratulations to our new appointees.

Steel Frame Structures

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knowledge illuminating the various factors that interact to control the seismic behavior of these structures, and is developing cost-effective and practical guidelines for the design, analysis and construction of steel buildings containing welded, bolted and other types of moment-resisting connections. The Program has advanced the state of the art for designing new steel buildings as well as for evaluating and repairing (or upgrading) existing ones. While much has been achieved, many technical problems and social, economic and policy issues have been identified requiring further research, development or implementation activities. None the less, the Program has clearly demonstrated the efficacy of solving large, technically challenging problems in the field of earthquake loss reduction through problem-focused projects that coordinate and integrate research, guideline development and training efforts.

Acknowledgments

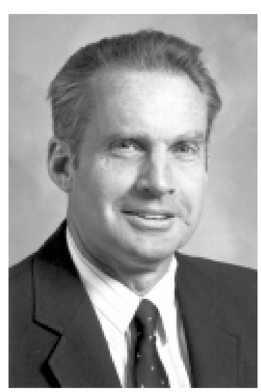
SAC Joint Venture has carried out the Program to Reduce Earthquake Hazards in Steel Moment Frame Structures under FEMA Contract EMW-95-K-4672. The Joint Venture is also indebted to the generous contributions of time, services and material by numerous individuals, companies and organizations. This article is intended for general information and does not represent the policy or recommendations of FEMA or the SAC Joint Venture.

CUREe President Karl Romstad Resigns, Gerard Pardoen Takes Helm

In early October, Professor Karl Romstad resigned from his position as CUREe President (his term was to run through the end of this year). Professor Romstad notified the other Executive Committee members and the CUREe office that he was trying to fulfill too many responsibilities and at this point, in his last year before retirement, he needed to shed some of his loads. He also resigned as the UC Davis member of the PEER Institutional Board to free up some time and ease his pace. He decided to resign now because the UC Davis school year was about to begin, and with a heavy teaching load on top of other responsibilities, he realized that now was the time to make the decision.

The transition has been a smooth one, since Professor Romstad worked hard to "clean off his desk" of pending CUREe matters in recent weeks. CUREe deeply appreciates how hard and effectively he has worked as CUREe's President this year.

Under CUREe's Bylaws, Professor Gerard Pardoen, as Vice-President, took on the duties of President. At its November 6, 1998 meeting held at USC, the Board "approved the slate of officers for 1999 with the understanding that Gerry Pardoen would become President in 2000." Because Professor Pardoen agreed to serve as President for the year 2000 if elected by the board, he feels comfortable taking on the work of serving the additional months as President.



Prof. Karl Romstad

Prof. Gerard Pardoen

Woodframe Project

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the plan areas of existing tables are too small. So, the construction of a large special purpose table, perhaps as part of an existing facility so that the hydraulic machinery could be shared, could serve an important function and should be viewed as an urgent near-term goal. An example of a project which requires such a facility would be proof-testing of a retrofit strategy for an apartment building with tuck-under parking.

CUREe Members to Gather at 12WCEE

A room with a terrific view at the Vertigo restaurant in Auckland, New Zealand has been reserved for February 1st, when CUREe will host a dinner open to all members and spouses who are attending the 12th World Conference on EarthquakeEngineering. The cost of the dinner will be partially subsidized by CUREe.

This will be a nice opportunity for CUREe members to get together and to meet with some of the New Zealand conference organizers, who will also be in attendance.

More information will be forthcoming, but if you are planning on attending the 12WCEE, remember to save February 1st for the CUREe dinner.

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