Fourth NEES Annual Meeting

Broadening Participation Throughout NEES

Meeting Proceedings

June 21-23, 2006 - Arlington, VA

NEES Consortium, Inc.

George E. Brown, Jr. Network for Earthquake Engineering Simulation

Cooperative Agreement
CMS-0402490

NEES

NEES Consortium, Inc.

George E. Brown, Jr. Network for Earthquake Engineering Simulation

June 14, 2006

Dear Members and Friends of NEES:

On behalf of the Board of Directors I wish to extend to you a very warm welcome to the Fourth Annual Meeting of the NEES Consortium. This meeting is a unique opportunity for all members of the NEES community to come together and share experiences in collaborative research, facility management, education and outreach, and new developments in IT and experimental methods. It follows the successful format of previous meetings held in Park City, San Diego, and Minneapolis, and again provides a forum for exchange of ideas, experiences and information. This year's healthy attendance is indicative of strong community interest in the work and mission of NEES and I encourage you to take every opportunity to network at both the technical and social levels to assure your voice is heard.

As your outgoing President I would like to take this opportunity to thank all those who have supported me and the work of the Board over the last three years. It has been a very rewarding experience to me personally to be part of the start-up period for NEES and see it grow to the point where we have 20-30 research projects underway in our 15 research facilities supported by cutting edge cyberinfrastructure tools. The reasons for our success are many but include the unwavering support of the National Science Foundation, the total dedication of our staff at NEES headquarters in Davis, and the almost 100 volunteers who serve on the Board, its committees and ad hoc task groups. On your behalf, I thank every one of them most sincerely.

I look forward to seeing NEES flourish in the years ahead. And with your continuing support, I have no doubt this will be so.

Again, welcome to the 2006 Annual Meeting and do not forget to take time to enjoy the many attractions of this wonderful city.

Sincerely,

Ian Buckle
President

400 F Street, Davis, CA 95616 tel.: 530.757.6337 fax: 530.757.6340 web: www.nees.org email: info@nees.org

NEES Consortium, Inc.

George E. Brown, Jr. Network for Earthquake Engineering Simulation

June 12, 2006

Dear Members and Friends of NEES:

On behalf of NEESinc governance, management and staff, it is my distinct pleasure to welcome you to the 4th NEES Annual Meeting in the nation's capitol. The past year has been an exciting one for NEES. NEESinc Headquarters is staffed up with prototype administrative processes deployed; NEES' community-based committees have been restructured and re-energized for operations; all fifteen NEES Experimental Sites are up and running; there are nearly 50 shared-use projects on the network with more to be announced soon; the NEES cyberinfrastructure capabilities continue to grow; a pilot NEES Research Experience for Undergraduate (NEESreu) program has been initiated; and there is strong interest from the international community in extending collaboration worldwide. The program assembled for this event has been designed to provide excellent opportunities for you to network with your colleagues, explore the many activities now underway within NEES, and participate in deliberation of current issues affecting the Consortium and its future vision.

The theme of this year's Annual Meeting is "Broadening Participation throughout NEES". Late in 2005, NEESinc conducted a demographic survey provide a glimpse of the initial composition of the NEES community. The responses reflect a relatively tight-knit community consisting largely of senior researchers and facility staff. Nearly two-thirds of the community comes from the academic sector, and over half of those are tenured faculty. Only 5% of respondents identified themselves as practitioners or earthquake risk stakeholders. No respondents identified themselves as coming from the construction industry, emergency preparedness, or public policy. As NEES is just now getting underway in earnest, this outcome is not surprising. Nevertheless, these results point to the need to broaden participation as we move into the future. NEESinc is pleased that initial steps in this direction are being made. Attendance at the 4th Annual meeting has more than doubled that of last year. Nearly 50 young researchers and 15 REU students are in attendance to represent a new and vibrant future generation. International participation is up and is expected to grow in the coming year as NEES forges new partnerships. A summary of EOT activities conducted over the network showed that NEES has directly touched nearly 10,000 individuals nationwide. Though much remains to be accomplished, early signs are very encouraging, and NEESinc governance, management, staff and resources are fully committed to long-term success.

I'd like to thank the members of the 4th Annual Meeting Organizing Committee for their hard work in structuring a program that should prove both enlightening and entertaining. I look forward to hearing about developments in the many shared-use earthquake engineering research projects now underway, as well as learning of advances in both experimental techniques and cyberinfrastructure. The "Issue Forums" will provide for stimulating community interaction on a range of topics. The "Blind Prediction" session should prove to be of interest to all, and the International Collaboration session will provide a glimpse of NEES' future. On behalf of the attendees, I wish to extend appreciation to the many presenters, staff, and volunteers who are contributing to these sessions.

Again, welcome to Washington … and enjoy the meeting!

Sincerely,

Clifford J. Roblee, Ph.D., P.E.
Executive Director

400 F Street, Davis, CA 95616 tel.: 530.757.6337 fax: 530.757.6340 web: www.nees.org email: info@nees.org

Acknowledgments

The following individuals and organizations were generous contributors and volunteers whose efforts were instrumental in organizing the Fourth NEES Annual Meeting. NEES Consortium, Inc. (NEESinc) would like to recognize their contributions:

Annual Meeting Working Group Members: for their involvement and assistance since late 2005 in organizing and planning the technical program and session structure for the Annual Meeting.

- **Jill Andrews** (University of Michigan)
- **Rigoberto Burgueño** (Michigan State University)
- **Gregory Fenves** (University of California, Berkeley)
- **Jerome Hajjar** (University of Illinois)
- **Jon Heintz** (Applied Technology Council)
- **Bruce Kutter** (University of California, Davis)
- **Ronald Mayes** (Simpson, Gumpertz, Heger)
- **Harry Yeh** (Oregon State University)

Portland Cement Association (PCA): For their generous co-sponsorship of the UCSD/PCA/NEES Blind Prediction Contest, as well as their contribution towards co-hosting the Wednesday evening Reception.

NEES Technical Committee Chairs: for their involvement and assistance in organizing and hosting the Issue Forum sessions at the Annual Meeting.

- **Jacobo Bielak** (Carnegie Mellon University)
- **Shirley Dyke** (Washington University of St. Louis)
- **Marc Eberhard** (University of Washington)

NEESinc is supported by the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Program of the National Science Foundation under Award Number CMS-0402490.

NEES

TAB 1

Program

Fourth NEES Annual Meeting
June 21–23, 2006 • Arlington, Virginia

Program
Day One: Wednesday, June 21, 2006

7:00 – 8:00 am

Registration and Continental Breakfast *(Salon C + D+ E)*

8:00 – 8:30 am

Opening and Welcome Session *(Salon A+B)*

Session Chair: **Clifford Roblee**, NEES Consortium, Inc.

Welcome Address

Bruce Kutter, University of California, Davis

Welcome Address

Joy Pauschke, National Science Foundation

8:30 – 9:30 am

Broadening the Domestic NEES Community Session *(Salon A+B)*

Session Chair: **Clifford Roblee**, NEES Consortium, Inc.

NEES and Earthquake Engineering Practice: Getting the Rubber to Meet the Road

Craig Comartin, CD Comartin

Opportunities for NEES Research Utilization

Robert Hanson, University of Michigan (Emeritus)

Opportunities to Diversify the Future Engineering Workforce

Cathy Fore, Oak Ridge Associated Universities

9:30 – 10:30 am

NEESit Plenary Session *(Salon A+B)*

Session Chair: **Jon Lea**, NEES Consortium, Inc.

Overview of the Year for NEESit

Anke Kamrath, NEESit/San Diego Supercomputer Center

Demonstration of New Data and Telepresence Capabilities

Lelli Van Den Einde and Shannon Whitmore, NEESit/San Diego Supercomputer Center

Future Directions for NEES Cyberinfrastructure

Ahmed Elgamal, University of California, San Diego

NEES

Day One (con't): Wednesday, June 21, 2006

10:30 – 11:00 am

Break *(Salon C + D+ E)*

11:00 am – 12:30 pm

Advanced Tools Plenary Session *(Salon A+B)*

***Session Chair:* Sharon Wood**, University of Texas, Austin

Centrifuge Modeling for Soil-Pile-Bridge Interaction
Bruce Kutter, University of California, Davis

Model Development for a Reinforced Concrete Bridge Using Shake Table and Centrifuge Data
Marc Eberhard, University of Washington

Making Waves: Ground Response, Liquefaction, and Soil-Foundation-Structure Interaction at the NEES Permanent Experimental Field Sites
Jamison Steidl, University of California, Santa Barbara

High Performance, Parallel Simulation Platform for NEES
Boris Jeremic, University of California, Davis

Real-Time Hybrid Testing With Rate-Dependent Seismic Hazard Mitigation Devices
James Ricles, Lehigh University

12:30 – 2:00 pm (presentations begin at 1:30)

Luncheon EOT Presentations *(Washington Ballroom)*

***Session Chair:* John van de Lindt**, Colorado State University

The EOT Execution Plan
Shirley Dyke, Washington University of St. Louis

Report on NEESreu Program and Efforts to Enhance NEES Community Diversity
Melanie Brown, NEES Consortium, Inc.

2:00 – 3:00 pm

UCSD/PCA/NEES Blind Prediction Contest Plenary Session *(Salon A+B)*

***Session Chair:* Robert Bachman**, RE Bachman Consulting Structural Engineers

The Seven-Story Test Structure
José Restrepo, University of California, San Diego

The UCSD/PCA/NEES Blind Prediction Contest
Robert Bachman, RE Bachman Consulting Structural Engineers

Presentation by Contest Winner—Academic/Researcher Division
Presentation by Contest Winner—Practitioner Division
Presentation by Contest Winner—Undergraduate Division

NEES

Day One (con't): Wednesday, June 21, 2006

3:00 – 4:00 pm

Issue Forums Plenary Session *(Salon A+B)*

***Session Chair:* Jill Andrews**, University of Michigan

IT Strategy Committee (ITSC) Issue Forum Introduction
Jacobo Bielak, Carnegie-Mellon University (*ITSC Chair*)
Jerome Hajjar, University of Illinois Urbana-Champaign
Andrei Reinhorn, University of Buffalo
Gregory Fenves, University of California, Berkeley
Stephanie Couch, CENIC/University of California, Davis

Education, Outreach, and Training (EOT) Committee Issue Forum Introduction
Shirley Dyke, Washington University of St. Louis (*EOTC Chair*)

Site Operations Committee (SOC) Issue Forum Introduction
Marc Eberhard, University of Washington (*SOC Chair*)

4:00 – 4:30 pm

Break *(Salon C + D+ E)*

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session I: Pushing Experimental Boundaries & Hybrid Simulation *(Salon A)*

***Session Chair:* Jerome Hajjar**, University of Illinois Urbana-Champaign

Hybrid Simulation of Structural Collapse
Bozidar Stojadinovic, University of California, Berkeley

The UB-NEES Site: Pushing Experimental Boundaries in Full and Large Scale Structural and Nonstructural Testing
Thomas Albrechinski, University of Buffalo

We've Only Just Begun -- A Dynamic New Use for NEES Capabilities
Andrew Budek, Texas Tech University of Washington

NetSLab Based Remote Hybrid Testing in a Hierarchical Network Environment
Yurong Guo, CIPRES-Hunan University

A High Performance Desktop Fast Hybrid Test Platform
Gary Haussmann, University of Colorado, Boulder

Day One (con't): Wednesday, June 21, 2006

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 2: Sensors and Instrumentation *(Salon B)*

***Session Chair:* Bruce Kutter**, University of California, Davis

High Strain Measurement in Concrete Structures Using POF Sensors
Omid Abdi, North Carolina State University

State-of-the-art Development of Distributed Coaxial Cable Sensors for Crack Detection with ETDR Measurements
Genda Chen, University of Missouri-Rolla

The NEES@University of California, Davis High-Speed Wireless Data Acquisition System
Daniel Wilson, University of California, Davis

Instrumentation for the NEESR Sand Aging Field Experiment
David Saftner, University of Michigan

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 3: Numerical Simulations *(Van Buren Room)*

***Session Chair:* Gregory Fenves**, University of California, Berkeley

VEES -- An XML-Driven Visualization and Development Environment
Alisa Neeman, University of California, Santa Cruz

Hybrid Simulation Evaluation of the Suspended Zipper Braced Frame
Tony Yang, University of California, Berkeley

Fiber Based Simulation of Rectangular Concrete Walls
Jonathan Waugh, Iowa State University

GrdVis: A Visualization and Data Analysis System
Daniel Kuchma, University of Illinois Urbana-Champaign

OpenSees Design Environment (ODEn)
Alisa Neeman, University of California, Santa Cruz

Day One (con't): Wednesday, June 21, 2006

6:00 – 7:30 pm

NEESR PI Awardees Meeting *(Commonwealth Room)*

Meeting Chair: **Joy Pauschke**, National Science Foundation

Open to all meeting attendees.

6:00 – 9:00 pm (awards ceremony begins at 8:00)

Poster Session and Reception *(Lincoln Hall)*

Reception co-hosted by **Portland Cement Association** (PCA) of Skokie, IL

Including awards ceremony for UCSD/PCA/NEES Blind Prediction Contest

Day Two: Thursday, June 22, 2006

7:00 – 8:00 am

Registration and Continental Breakfast *(Salon C + D+ E)*

8:00 – 9:00 am

NEES Overview Session *(Salon A+B)*

Session Chair: **Ian Buckle**, University of Nevada, Reno *(NEESinc President)*

A National Science Foundation Perspective on NEES
Joy Pauschke, National Science Foundation

A Consortium-Level Perspective on NEES
Clifford Roblee, NEES Consortium, Inc.

A Research Site Perspective on NEES
Kenneth Stokoe, II, University of Texas, Austin

9:00 – 10:30 am

NEESR Active Projects Spotlight Session I *(Salon A+B)*

Session Chair: **Joy Pauschke**, National Science Foundation

Large-Scale Tests of Structural Braces and the Validation of Micromechanical Ultra Low Cycle Fatigue Models
Amit Kanvinde, University of California, Davis

Self-Centering Steel Frame Systems
Richard Sause, Lehigh University

Tests of Zipper Frames
Roberto Leon, Georgia Institute of Technology

Earthquake Studies of a Two-Span Reinforced Concrete Bridge System with Varied Column Heights
Mehdi 'Said' Saiidi, University of Nevada, Reno

10:30 – 11:00 am

Break *(Salon C + D+ E)*

NEES

Day Two (con't): Thursday, June 22, 2006

11:00 am – 12:30 pm

NEESR Active Projects Spotlight Session 2 *(Salon A+B)*

***Session Chair:* Helmut Krawinkler**, Stanford University

Highly Damage-Tolerant and Intelligent Slab-Column Frame Systems Through Combination of Advanced Materials and Embedded Wireless Sensing
Gustavo Parra-Montesinos, University of Michigan

Dynamic Passive Procedures for Backfill Based on Full-Scale Pile Cap Testing (A NEESR Project)
Travis Gerber, Brigham Young University

Multi-Site Soil-Structure-Foundation Interaction Test (MISST)
Bill Spencer, University of Illinois Urbana-Champaign

A Database for Modeling Deterioration in Beams and Columns Subjected to Cyclic Bending Moments
Dimitrios Lignos, Stanford University

Full-Scale Testing of Polyethylene Pipelines at Fault Rupture
Michael O'Rourke and Thomas O'Rourke, Cornell University

12:30 – 2:00 pm (presentation at 1:30)

Luncheon with Presentation *(Washington Ballroom)*

Tsunami Reconnaissance Data Repository
Harry Yeh, Oregon State University

2:00 – 3:30 pm

NEESR New Projects Spotlight Session 1 *(Salon A+B)*

***Session Chair:* Robert Nigbor**, University of California, Los Angeles

Collaborative Study of Biaxial Seismic Response of Bridge Systems
Mehdi 'Said' Saiidi, University of Nevada, Reno

Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls
P. Benson Shing, University of California, San Diego

Seismic Simulation and Design of Bridge Columns Under Combined Actions, and Implications on System Response
Abdeldjelil "D.J." Belabi, University of Missouri-Rolla

NEESR-Grand Challenge: Seismic Risk Mitigation for Ports
Glenn Rix, Georgia Institute of Technology

Inelastic Web Crushing Performance Limits of High-Strength-Concrete Structural Walls
Rigoberto Burgueño, Michigan State University

NEES

Day Two (con't): Thursday, June 22, 2006

3:30 – 4:00 pm

Break *(Salon C + D+ E)*

4:00 – 6:00 pm

EOT Committee Issue Forum Breakout Session *(Salon A)*

Session Chair: **Shirley Dyke**, Washington University of St. Louis (*EOTC Chair*)

4:00 – 6:00 pm

IT Strategy Committee Issue Forum Breakout Session *(Salon B)*

Session Facilitators: **Jacobo Bielak**, Carnegie-Mellon University (*ITSC Chair*)
Jerome Hajjar, University of Illinois Urbana-Champaign
Andrei Reinhorn, University of Buffalo
Gregory Fenves, University of California, Berkeley
Stephanie Couch, CENIC/University of California, Davis

4:00 – 6:00 pm

SOC Issue Forum Breakout Session *(Van Buren Room)*

Session Facilitator: **Marc Eberhard**, University of Washington (*SOC Chair*)

6:00 – 7:00 pm

Pre-Banquet Reception with Poster Session *(Lincoln Hall)*

7:00 – 9:00 pm

NEES Banquet
Including the 2006 NEESinc Business Meeting,
Awards Ceremony, and Audience Polling *(Washington Ballroom)*

Day Three: Friday, June 23, 2006

7:00 – 8:00 am

Continental Breakfast *(Salon C + D+ E)*

8:00 – 9:30 pm

NEESR New Projects Spotlight Session 2 *(Salon A+B)*

Session Chair: **Harry Yeh**, Oregon State University

Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses
Gregory Deierlein, Stanford University

NEESWood: Full-Scale 3-D Testing, Numerical Modeling, and Other Progress
John van de Lindt, Colorado State University

NEESR II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands
Russell Green, University of Michigan

Development of Performance-Based Tsunami Engineering -- PBTE
H. Ronald Riggs, University of Hawaii at Manoa

Experimental Verification of Semiactive Control of Nonlinear Structures Using Magnetorheological Fluid Dampers
Richard Christenson, University of Connecticut

High-Performance Fiber Reinforced Cement Composites for New Coupled Wall Systems and Retrofit of Existing Framed Structures
James Wight, University of Michigan

Day Three (con't): Friday, June 23, 2006

9:30 – 11:00 am

Broadening Participation: International Collaboration and World Forum Report *(Salon A+B)*

***Session Chair:* Roberto Leon**, Georgia Institute of Technology

Report on the World Forum on Collaborative Research in Earthquake Engineering
Bill Spencer, University of Illinois Urbana-Champaign

World Forum Report: Cyberenvironments
Jerome Hajjar, University of Illinois Urbana-Champaign

World Forum Report: Data Infrastructure
Gregory Fenves, University of California, Berkeley

World Forum Report: Simulations
Ahmed Elgamal, University of California at San Diego

Report on International Collaboration Interest Survey
Clifford Roblee, NEES Consortium, Inc.

Progresses of Large-Scale Tests at E-Defense, NIED, Japan
Masayoshi Nakashima, E-Defense, NIED, and Kyoto University

Research on Networked Structural Laboratories in China
Yan Xiao, University of Southern California/CIPRES-Hunan University

11:00 am – 12:00 pm

Issue Forums Report-Back Plenary Session *(Salon A+B)*

***Session Chair:* Rigoberto Burgueño**, Michigan State University

IT Strategy Committee (ITSC) Issue Forum Report
Jacobo Bielak, Carnegie-Mellon University (*ITSC Chair*)

Education, Outreach, and Training (EOT) Committee Issue Forum Report
Shirley Dyke, Washington University of St. Louis (*EOTC Chair*)

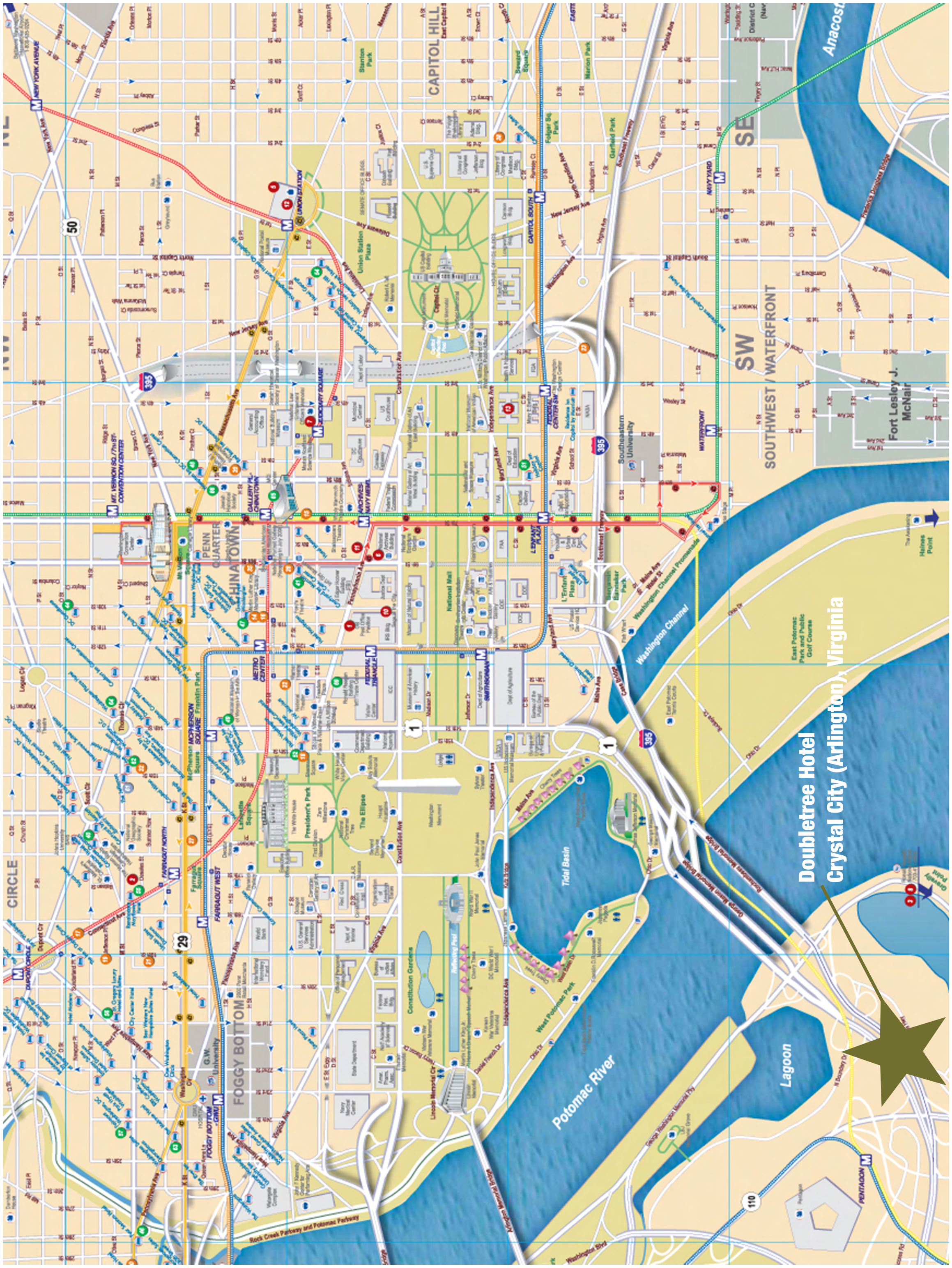
Site Operations Committee (SOC) Issue Forum Report
Marc Eberhard, University of Washington (*SOC Chair*)

Annual Meeting Adjourns at Noon

For those who are attending the Workshops (Site Operations Managers, IT Managers, and NEESit) or the Board of Directors' Meeting, please visit the registration table for a schedule of these events.

NEES

Washington, D.C Area



NEES

metro System Map

Legend

- Red Line • Glenmont to Shady Grove
- Orange Line • New Carrollton to Vienna/Fairfax-GMU
- Blue Line • Franconia-Springfield to Largo Town Center
- Green Line • Branch Avenue to Greenbelt
- Yellow Line • Huntington to Mt Vernon Sq/7th St-Convention Center

Station in Service
Planned Station
Transfer Station
Virginia Railway Express
Commuter Rail
Parking

REV 012/04

No Smoking

No Eating or Drinking

No Animals (except service animals)

No Audio or Video Devices (without earphones)

No Litter or Spitting

No Dangerous or Flammable Items

TAB 2

Day 1: June 21

Annual Meeting Day One
Wednesday June 21, 2006

NEES

Day One Program At-A-Glance
Wednesday June 21, 2006

7:00 – 8:00 a.m.	**Registration & Continental Breakfast** *(Salons C, D, & E)*
8:00 – 8:30 a.m.	**Opening and Welcome Session** *(Salons A & B)*
8:30 – 9:30 a.m.	**Broadening the Domestic NEES Community Plenary Session** *(Salons A & B)*
9:30 – 10:30 a.m.	**NEESit Plenary Session** *(Salons A & B)*
10:30 – 11:00 a.m.	**Break**
11:00 – 12:30 p.m.	**Advanced Tools Plenary Session** *(Salons A & B)*
12:30 – 2:00 p.m.	**Luncheon** *(Washington Ballroom)*
2:00 – 3:00 p.m.	**NEES/UCSD Blind Prediction Competition Plenary Session** *(Salons A & B)*
3:00 – 4:00 p.m.	**Issue Forums Plenary Session** *(Salons A & B)* Brief presentations to frame Issue Forum Breakout Sessions, hosted by NEESinc's committees: ***Education, Outreach, and Training Committee*** ***IT Strategy Committee*** ***Site Operations Committee***
4:00 – 4:30 p.m.	**Break**
4:30 – 6:00 p.m.	**Advanced Tools Concurrent Breakout Sessions** Three (3) concurrent breakout sessions featuring technical presentations on the following topics: ***Pushing Experimental Boundaries & Hybrid Simulation Breakout Session*** *(Salon A)* ***Sensors and Instrumentation Breakout Session*** *(Salon B)* ***Numerical Simulations Breakout Session*** *(Van Buren Room)*
6:00 – 7:00 p.m.	**NEESR Program Awardees Meeting** Open to public. *(Commonwealth Room)*
6:00 – 8:00 p.m.	**Poster Session & Reception** *(Lincoln Room)* Co-hosted by the Portland Cement Corporation of Skokie, IL
8:00 – 9:00 p.m.	**Presentation of Blind Prediction Competition Awards** *(Lincoln Ballroom)*

Session Descriptions

Broadening the Domestic NEES Community Plenary Session

Presentations demonstrating synergistic collaboration among domestic earthquake engineering organizations having common objectives, leading to advances in the earthquake engineering community.

NEESit Plenary Session

During this plenary session, presentations will be made about activities underway at NEESit, including demonstration of end-to-end data flow processes and remote participation in research experimentation.

Advanced Tools Plenary and Breakout Sessions

This group of one plenary and three concurrent breakout sessions feature presentations in three technical topical areas:

Pushing Experimental Boundaries: New or enhanced capabilities at the NEES experimental sites. Example topics include advances in hybrid testing methodologies, improved centrifuge model containers and robotics, and field and portable equipment enhancements.

Sensors and Instrumentation Technology: Successful use of new instrumentation and sensor technology available at NEES equipment sites and other laboratories. Examples include wireless technology, MEMS sensors, lasers, fiberoptics, miniature sensors, dense sensor arrays, cameras, tomography, close range photogrammetry, etc.

Numerical Simulations of NEES Results/Data: Development of new numerical and computational algorithms/models, computational modeling/simulation in support of NEESR projects, results and/or data repositories, integration of simulation and experimentation, simulation/visualization of dynamic data, web-based platforms for data simulation/visualization, data reduction methods, algorithms and platforms, and methods/procedures for experimental measurements that better support numerical and computational simulation.

UCSD/NEES 7-Story Building Blind Prediction Plenary Session

The The School of Engineering at the University of California at San Diego (UCSD), the Portland Cement Association (PCA) of Skokie, IL., and the NEES Consortium Inc. (NEESinc) are pleased to announce a blind prediction contest. The contest is open to teams from the practicing structural engineering community, the academic and research community (including graduate students), and the undergraduate engineering student community (with graduate student or faculty advisors). Between October of 2005 and January 2006, a full-scale vertical slice of a seven-story reinforced concrete wall building was subjected to increasing intensity of uniaxial earthquake ground motions on the new NEES Large High-Performance Outdoor Shake Table located at UCSD's Engelkirk Structural Engineering Center.

Responses were measured using an extensive instrumentation array, and all results have been archived for future release. The largest input motion was the Sylmar Medical Facility free-field record obtained in the 1994 Northridge Earthquake, which is one of the strongest recorded motions from that event and includes some near-fault ground-motion characteristics. The building slice was designed using a displacement-based and capacity approach for a site in Los Angeles that resulted in design lateral forces that are significantly smaller than those currently specified in building codes used in the United States. The prediction contest will be "blind" and compare analytical response "predictions" with those measured during experimental testing.

Issue Forums Plenary Session

The Issue Forums sessions will feature group discussions on three separate topics selected by each of NEESinc's technical committees (the *EOT*, *IT Strategy*, and *Site Operations Committees*). The topics will be introduced in a plenary session, followed by group discussion during three concurrent breakout sessions. Each Issue Forum breakout group will be asked to provide a report on their discussions during a plenary session on the final day of the Annual Meeting.

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***Session Chair:* Clifford Roblee**, NEES Consortium, Inc.

Welcome Address
Bruce Kutter, University of California, Davis

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Joy Pauschke, National Science Foundation

8:30 – 9:30 am

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NEES and Earthquake Engineering Practice: Getting the Rubber to Meet the Road
Craig Comartin, CD Comartin

Opportunities for NEES Research Utilization
Robert Hanson, University of Michigan (Emeritus)

Opportunities to Diversify the Future Engineering Workforce
Cathy Fore, Oak Ridge Associated Universities

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NEESit Plenary Session *(Salon A+B)*

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Overview of the Year for NEESit
Anke Kamrath, NEESit/San Diego Supercomputer Center

Demonstration of New Data and Telepresence Capabilities
Lelli Van Den Einde and Shannon Whitmore, NEESit/San Diego Supercomputer Center

Future Directions for NEES Cyberinfrastructure
Ahmed Elgamal, University of California, San Diego

NEES

Day One (con't): Wednesday, June 21, 2006

10:30 – 11:00 am

Break *(Salon C + D+ E)*

11:00 am – 12:30 pm

Advanced Tools Plenary Session *(Salon A+B)*

Session Chair: **Sharon Wood**, University of Texas, Austin

Centrifuge Modeling for Soil-Pile-Bridge Interaction
Bruce Kutter, University of California, Davis

Model Development for a Reinforced Concrete Bridge Using Shake Table and Centrifuge Data
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Making Waves: Ground Response, Liquefaction, and Soil-Foundation-Structure Interaction at the NEES Permanent Experimental Field Sites
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High Performance, Parallel Simulation Platform for NEES
Boris Jeremic, University of California, Davis

Real-Time Hybrid Testing With Rate-Dependent Seismic Hazard Mitigation Devices
James Ricles, Lehigh University

12:30 – 2:00 pm (presentations begin at 1:30)

Luncheon EOT Presentations *(Washington Ballroom)*

Session Chair: **John van de Lindt**, Colorado State University

The EOT Execution Plan
Shirley Dyke, Washington University of St. Louis

Report on NEESreu Program and Efforts to Enhance NEES Community Diversity
Melanie Brown, NEES Consortium, Inc.

2:00 – 3:00 pm

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Session Chair: **Robert Bachman**, RE Bachman Consulting Structural Engineers

The Seven-Story Test Structure
José Restrepo, University of California, San Diego

The UCSD/PCA/NEES Blind Prediction Contest
Robert Bachman, RE Bachman Consulting Structural Engineers

Presentation by Contest Winner—Academic/Researcher Division
Presentation by Contest Winner—Practitioner Division
Presentation by Contest Winner—Undergraduate Division

NEES

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***Session Chair:* Jill Andrews**, University of Michigan

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Jacobo Bielak, Carnegie-Mellon University (*ITSC Chair*)
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Education, Outreach, and Training (EOT) Committee Issue Forum Introduction
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4:00 – 4:30 pm

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4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session I: Pushing Experimental Boundaries & Hybrid Simulation *(Salon A)*

***Session Chair:* Jerome Hajjar**, University of Illinois Urbana-Champaign

Hybrid Simulation of Structural Collapse
Bozidar Stojadinovic, University of California, Berkeley

The UB-NEES Site: Pushing Experimental Boundaries in Full and Large Scale Structural and Nonstructural Testing
Thomas Albrechinski, University of Buffalo

We've Only Just Begun -- A Dynamic New Use for NEES Capabilities
Andrew Budek, Texas Tech University of Washington

NetSLab Based Remote Hybrid Testing in a Hierarchical Network Environment
Yurong Guo, CIPRES-Hunan University

A High Performance Desktop Fast Hybrid Test Platform
Gary Haussmann, University of Colorado, Boulder

Day One (con't): Wednesday, June 21, 2006

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 2: Sensors and Instrumentation *(Salon B)*

***Session Chair:* Bruce Kutter**, University of California, Davis

High Strain Measurement in Concrete Structures Using POF Sensors
Omid Abdi, North Carolina State University

State-of-the-art Development of Distributed Coaxial Cable Sensors for Crack Detection with ETDR Measurements
Genda Chen, University of Missouri-Rolla

The NEES@University of California, Davis High-Speed Wireless Data Acquisition System
Daniel Wilson, University of California, Davis

Instrumentation for the NEESR Sand Aging Field Experiment
David Saftner, University of Michigan

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 3: Numerical Simulations *(Van Buren Room)*

***Session Chair:* Gregory Fenves**, University of California, Berkeley

VEES -- An XML-Driven Visualization and Development Environment
Alisa Neeman, University of California, Santa Cruz

Hybrid Simulation Evaluation of the Suspended Zipper Braced Frame
Tony Yang, University of California, Berkeley

Fiber Based Simulation of Rectangular Concrete Walls
Jonathan Waugh, Iowa State University

GrdVis: A Visualization and Data Analysis System
Daniel Kuchma, University of Illinois Urbana-Champaign

OpenSees Design Environment (ODEn)
Alisa Neeman, University of California, Santa Cruz

Day One (con't): Wednesday, June 21, 2006

6:00 – 7:30 pm

NEESR PI Awardees Meeting *(Commonwealth Room)*

Meeting Chair: **Joy Pauschke**, National Science Foundation

Open to all meeting attendees.

6:00 – 9:00 pm (awards ceremony begins at 8:00)

Poster Session and Reception *(Lincoln Hall)*

Reception co-hosted by **Portland Cement Association** (PCA) of Skokie, IL

Including awards ceremony for UCSD/PCA/NEES Blind Prediction Contest

Broadening the Domestic NEES Community Session

Wednesday, June 21, 2006

8:30 – 9:30 am

Broadening the Domestic NEES Community Session *(Salon A+B)*

Session Chair: **Clifford Roblee**, NEES Consortium, Inc.

NEES and Earthquake Engineering Practice: Getting the Rubber to Meet the Road
Craig Comartin, CD Comartin

Opportunities for NEES Research Utilization
Robert Hanson, University of Michigan (Emeritus)

Opportunities to Diversify the Future Engineering Workforce
Cathy Fore, Oak Ridge Associated Universities

Presentation Summary

Speaker:

Craig Comartin
CD Comartin Inc.

Session:

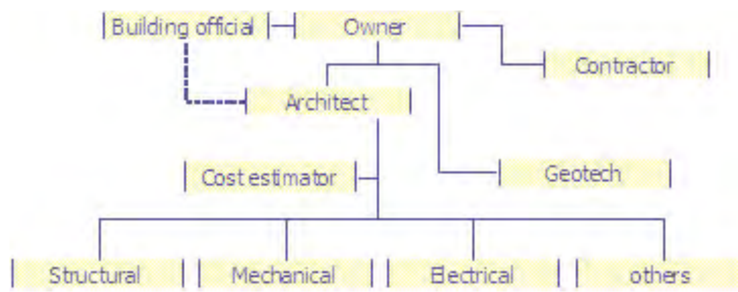
Broadening the Domestic NEES Community Session
Wednesday, June 21, 8:30 – 9:30 am

Presentation title:

NEES and Earthquake Engineering Practice: Getting the rubber to meet the road.

Major points/topics:

- What do practitioners really do?
- What motivates them with respect to research?
- What do they think of NEES?
- How can they get what they could really use?
- What should researchers be doing?



Abstract/Summary

Practitioners are driven by conflicting motivations. They like codes and standards because they are concerned about liability. Standards also level the playing field with respect to their competition. They are sensitive to the marketplace in which they compete in another respect. They want to distinguish themselves from the competition. They want to be known for providing greater value. That means better designs in terms of performance and costs.

Engineering research traditionally takes a very long time to reach practice. There are a number of reasons for this including a lack of communication regarding important needs, the importance of academic career goals, the process for the development of codes and standards, and the lack of tangible benefits to building owners.

NEES is an important undertaking. But, so far, its image within practice is faint at best. Engineers do not understand what cyber-infrastructure, telepresence, and data repositories have to do with their everyday lives. This is not to say these are not good things but hopefully they are not the ultimate end product. How can NEES researchers relate better to practitioners. The traditional advice of serving on code committees and applied research efforts still applies, but there are some unique opportunities on the NEES horizon. First, NEES should be pushing hard for project-related testing programs. There are a number of excellent examples of the use of tests to reduce construction costs for specific projects. This is extremely efficient and effective use of technology. Secondly, visual and numeric simulation techniques can provide new tools for the practitioner to add greater value to their products and relate the benefits more convincingly to clients.

NEES

NEES 4TH ANNUAL MEETING ~ JUNE 21–23, 2006

Presentation Summary

Speaker:

Robert D Hanson
University of Michigan

Session:

Broadening the Domestic NEES Community Session
Wednesday, June 21, 8:30 – 9:30 am

Presentation title:

Opportunities for NEES Research Utilization

Major points/topics:

- NEES researchers are responsible for getting their research results used
- NEES researchers need to recognize relative priorities for their research contributions
- Two example opportunities for NEES research participation: (a) ATC 58 - Performance-based Seismic Design; (b) ATC 63 – Quantification of Building System Performance and Response
- Major contributors to this presentation are: Mike Mahoney, DHS/FEMA; Ron Hamburger, ATC 58 leader; Bob Bachman, ATC 58 NPP leader; Craig Comartin, ATC 58 RMP leader; Andrew Whittaker, ATC 58 SPP leader; Charles Kircher, ATC 63 leader; and Eduardo Miranda and Keith Porter, NPP team.

Abstract/Summary

It is the responsibility of the NEES researcher to assure that their research results are put to use. This can be accomplished by involving code committee members and design professionals in their project design and implementation [as is currently done by the NSF Earthquake Centers], becoming active in code committee and professional activities [such as with ATC projects], and interpreting their research results in light of the results obtained by other researchers [i.e., digest the essence from multiple location research efforts]. NAE, EERI, BSSC, FEMA, NIST and industry groups have identified research needs. The list is long and priorities are not well established. The example opportunities described in this presentation should help provide insight to priorities.

Two ongoing ATC projects are used to illustrate the needed NEES research generated data and provides recommendations for number of specimens, testing protocols [FEMA 461], data collection format, and archiving needs. ATC 58 is a performance-based seismic design project for new and existing buildings that is in its first phase – assessment of seismic performance. In this context seismic performance considers the continuum from no damage to building collapse. The assessment criteria includes (a) life-loss or serious injury, (b) direct economic loss, and (c) indirect and economic loss. The highest priority needs for data are associated with structural and nonstructural element, component, and system performance from initiation of damage, through various levels of damage and their associated repair requirements, to collapse. From an initial assessment for one building it appears that nonstructural components provide the greatest economic loss potential. ATC 63 is looking at procedures to establish design parameters for new buildings. Prevention of collapse during the Maximum Considered Earthquake is assumed to be the fundamental target performance for new building design. Experimental data of biaxial behavior and systems to collapse is almost nonexistent.

Current opportunities are described in more detail on the web site: www.atcouncil.org

NEESit Plenary Session

NEES

Wednesday, June 21, 2006

9:30 – 10:30 am

NEESit Plenary Session *(Salon A+B)*

***Session Chair:* Jon Lea**, NEES Consortium, Inc.

Overview of the Year for NEESit
Anke Kamrath, NEESit/San Diego Supercomputer Center

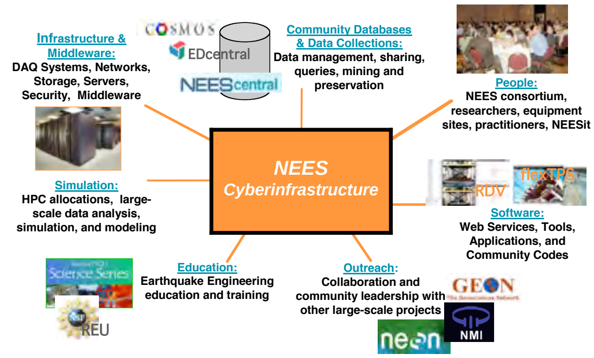
Demonstration of New Data and Telepresence Capabilities
Lelli Van Den Einde and Shannon Whitmore, NEESit/San Diego Supercomputer Center

Future Directions for NEES Cyberinfrastructure
Ahmed Elgamal, University of California, San Diego

NEES

NEES 4TH ANNUAL MEETING ~ JUNE 21–23, 2006

Presentation Summary



Speakers:

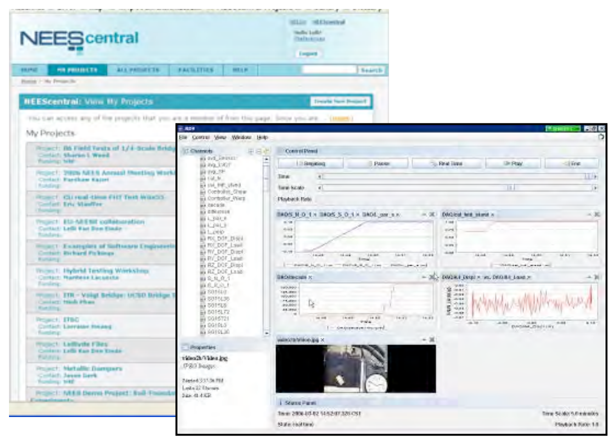
Anke Kamrath, Lelli Van Den Einde, Shannon Whitmore, and Ahmed Elgamal
NEESit/San Diego Supercomputer Center

Session:

NEESit Session
Wednesday, June 21, 9:30 – 10:30 am

Presentation title:

Current Status and Future Directions for NEES Cyberinfrastructure



Major points/topics:

- Overview of the Year for NEESit
- New Data Capabilities (NEEScentral)
- New Capabilities for Remote Participation in an Experiment (Real-Time Data Viewer, RDV)
- Future Directions for NEES Cyberinfrastructure

Abstract/Summary

This presentation will provide an overview of the NEES Cyberinfrastructure Center’s (NEESit) accomplishments this year including a summary of services that are available, outreach efforts, and software development efforts. A live demonstration of the NEES data capabilities (NEEScentral) will be conducted in the context of the Sharon Wood pre-NEESR Soil Foundation Structure Interaction project. Data development efforts this year were driven by requirements generated by the Wood project with special emphasis on reproducing the UC Davis centrifuge report. The current NEES data model that supports the NEEScentral database will be highlighted showing metadata fields necessary to structure experimental research data in order to reproduce the tests. Benefits to uploading and structuring data and metadata will also be discussed.

The presentation will also highlight the new capabilities available for remote participation in an experiment (telepresence). Telepresence development efforts were driven by a use case group consisting of Sri Sritharan, Jerry Hajjar, and Laura Lowes. A live demonstration using the Real-Time Data Viewer (RDV) telepresence tool will be conducted.

The development roadmap for the remainder of this fiscal year in the areas of Data, Telepresence, and Hybrid Simulation will be presented as well as the future directions for NEES Cyberinfrastructure.

Advanced Tools Plenary Session

NEES

Wednesday, June 21, 2006

11:00 am – 12:30 pm

Advanced Tools Plenary Session *(Salon A+B)*

Session Chair: **Sharon Wood**, University of Texas, Austin

Centrifuge Modeling for Soil-Pile-Bridge Interaction
Bruce Kutter, University of California, Davis

Model Development for a Reinforced Concrete Bridge Using Shake Table and Centrifuge Data
Marc Eberhard, University of Washington

Making Waves: Ground Response, Liquefaction, and Soil-Foundation-Structure Interaction at the NEES Permanent Experimental Field Sites
Jamison Steidl, University of California, Santa Barbara

High Performance, Parallel Simulation Platform for NEES
Boris Jeremic, University of California, Davis

Real-Time Hybrid Testing With Rate-Dependent Seismic Hazard Mitigation Devices
James Ricles, Lehigh University

Centrifuge Modeling for Soil-Pile-Bridge Interaction

Submitted By:

Mahadevan Ilankatharan and Bruce Kutter

Ph. D. Candidate and Professor, Dept. of Civil and Environmental Engineering, University of California, Davis.

Email: milankatharan@ucdavis.edu and blkutter@ucdavis.edu

Submitted to Session (please mark one):

X 1. Advanced Tools Session: ***Pushing Experimental Boundaries***

2. Advanced Tools Session: ***Sensors and Instrumentation***

3. Advanced Tools Session: ***Numerical Simulations of NEES Data***

4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*

5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*

6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***

7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Demonstrate the use of UC Davis - NEES Geotechnical Centrifuge for conduct of large-scale cross-disciplinary, multi-site research project on soil-pile-bridge interaction.
- Resolution of issues associated with comparing models tested at different sites, at different scale, using different boundary conditions and using different scaling laws.
- Large centrifuge model tests offer a unique capability to produce experimental data regarding seismic performance of soil-foundation- bridge systems.

Abstract/Summary

The goal of the project is to study the seismic response of a hypothetical two-span segment of a long bridge, schematically illustrated in Figure1, in 1-g shake table tests at the University of Nevada Reno, centrifuge tests at UC Davis, field tests using the large shakers at the University of Texas Austin, and column component tests at Purdue University. The team of researchers also included numerical analysts from the University of Washington, UC Berkeley, and UC Davis, as well as a team of researchers to coordinate archiving and sharing of data, and an education and outreach component (Wood et al., 2004). In small-scale centrifuge tests, it is difficult to accurately model reinforced concrete structures; in large-scale 1-g shake table tests it is difficult to accurately model geotechnical aspects of soil-pile-structure interaction. The tests at various facilities were intended to provide a means for comprehensive validation of numerical procedures for analyzing the behavior of a bridge supported on piles. Pictures of bridge model set-up on the centrifuge model container and on the shake tables are shown in Figures 2 and 3.

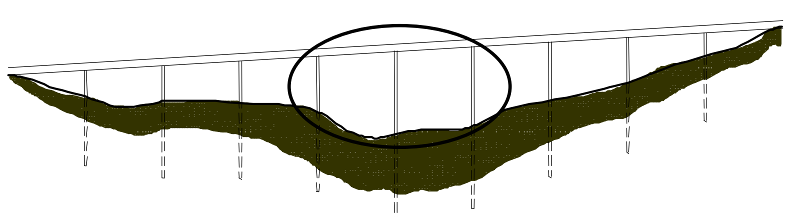


Figure 1. Hypothetical prototype multi-span bridge. Models of the circled portion of the bridge were tested in the 1-g shake table tests and on the centrifuge.

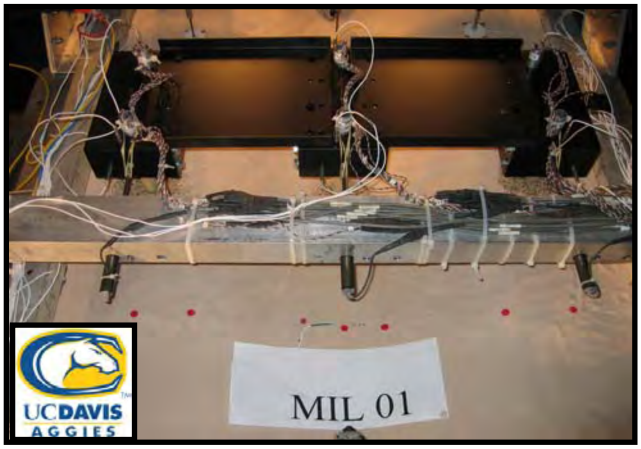


Figure 2: Photograph of bridge model set-up on centrifuge model container at the University of California, Davis. (After Ilankatharan et al., 2005)

Figure 3: Photograph of bridge model set-up on shake tables at the University of Nevada, Reno. (After Johnson et al., 2006)

Two seemingly basic questions that were difficult for the interdisciplinary research team to resolve were: What clear height (between ground surface and bridge deck) should be used in the centrifuge model to correspond to the fixed-fixed boundary conditions for the pile extensions in the shake table tests, and what input motions should be used in the shake table test to most closely correspond to the centrifuge tests? The clear height was chosen to produce similar natural frequencies (using the "equivalent depth to fixity" concept) under low amplitude excitation; however, it was not then possible to produce similar moment and shear distributions in the column/pile extensions in the shake table tests and the centrifuge tests. The free-field ground motion at the anticipated equivalent depth of fixity in the centrifuge was matched by trial and error to the shake table command motion in the 1-g shake table test. The design of the centrifuge model piles (made of aluminum) was performed to best simulate the capacity and stiffness of the reinforced concrete columns in the shake table tests. These assumptions enabled observation of reasonable comparisons between bridge deck responses in both experiments. The acceleration time histories of deck motions, the elastic response spectra of free field soil motions at the equivalent depth of fixity, shake table base motions, and deck motions from centrifuge and 1-g experiments are presented in Figures 4 and 5.

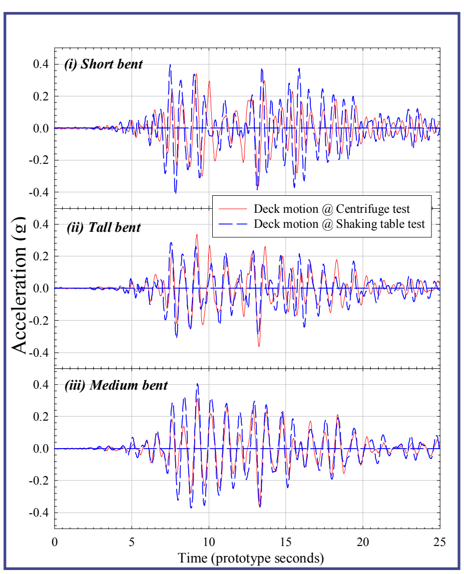


Figure 4: Deck accelerations during a medium- shaking event

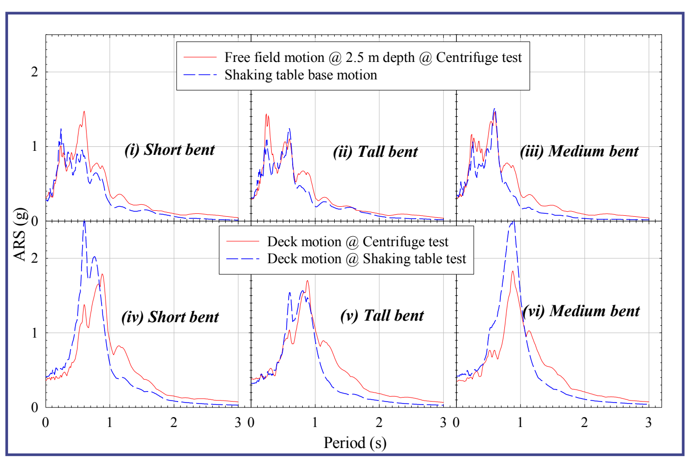


Figure 5: Response spectra of (5% damping) of free field motions @ 2.5 m depth in centrifuge & shake table base motions, and deck motions for medium level shake (peak base acc = 0.25 g in centrifuge test)

Both bridge models had two primary modes that involved a combination of translation in the direction of shaking and torsion about a vertical axis. As shown in the above figures the results are in reasonable agreement for tall and medium bents. Some differences are apparent in deck motions for short bent due to the different amount of torsional responses in two experiments.

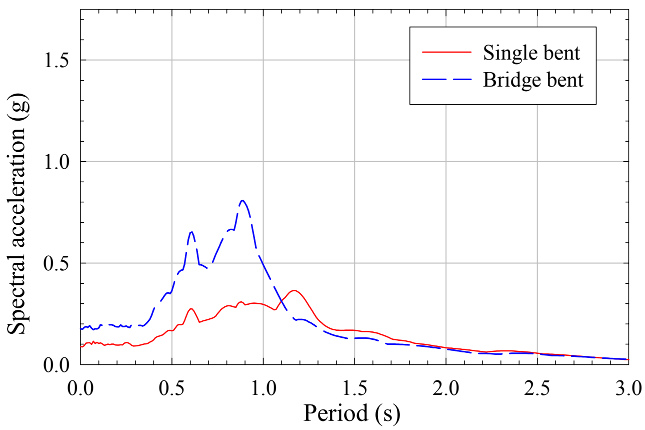


Figure 6: Response spectra of the tall (middle) bent accelerations before and after attaching the bridge deck

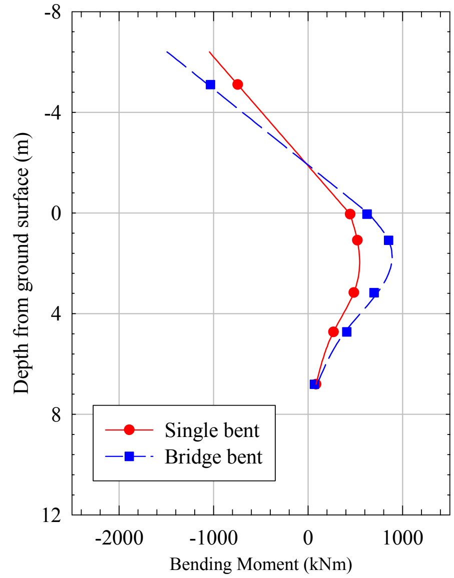


Figure 7: Comparison of bending moment distributions in the columns/piles (in the tall bent) before and after attaching the bridge deck

The bridge deck in the centrifuge model consisted of aluminum plate bolted to the bridge bents. This afforded the opportunity to first test each the three bents simultaneously while they were unconnected and then to test them as a three-bent system. Figure 6 compares the response spectra for horizontal acceleration of tall bent when it was unconnected (single bent) and when it was connected to the neighboring bents. Figure 7 compares the bending moment distributions at the time of maximum bent cap displacement for tall bent, comparing behavior when the bent was connected to the bridge to those for unconnected (single) bent. The bent cap accelerations of tall bent and the bending moments in the tall bent columns increased significantly when the deck was connected. The above results clearly illustrate that the system response is quite different from individual bent response. While experiments on bridge components will continue to be valuable, tests on soil-foundation-superstructure systems leads to a more complete understanding of system performance and promotes cross-disciplinary education of researchers. Continued multi-institution, multi-disciplinary research on systems could lead to a new paradigm for design in which foundations and superstructures are design to have stiffness, capacity, and energy dissipation characteristics that compatible and complementary with the goal of optimizing system performance.

References

Wood, S.L., T. Anagnos, P. Arduino, M.O. Eberhard, G.L. Fenves, T.A. Finholt, J.M. Futrelle, B. Jeremic, S.L. Kramer, B.L. Kutter, A.B. Matamoros, K.M. McMullin, J.A. Ramirez, E.M. Rathje, M. Saiidi, D.H. Sanders, K.H. Stokoe, and D.W. Wilson. (2004): "Using NEES to Investigate Soil-Foundation-Structure Interaction," *Proceedings, 13th World Conference on Earthquake Engineering,*, Paper 2344, Vancouver, Canada, Aug 1-6.

Model Development for a Reinforced Concrete Bridge using Shake Table and Centrifuge Data

Submitted By:

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Submitted to Session (please mark one):

- ❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- ❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ● 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- ❍ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- ❍ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- ❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- ❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Shaking table tests were conducted at the University of Nevada, Reno on a 1/4 scale 2-span reinforced concrete bridge with fixed-base foundations.
- Centrifuge tests were conducted at the University of California, Davis on a 1/52 scale 2-span aluminum bridge with drilled shaft foundations.
- Numerical models were developed to simulate each experiment.
- System identification techniques were used to objectively assess the performance of the two experimentally calibrated numerical models.
- The two numerical models were combined to simulate a reinforced concrete bridge on drilled shaft foundations.
- The effects of various modeling assumptions were investigated using the three numerical models.
- This paper is related to an experimental paper submitted by the Nevada research team.

Abstract/Summary

Soil-foundation-structure interaction (SFSI) during earthquakes is difficult to observe experimentally with a single type of test. Shaking table tests rarely model the foundation and soil conditions realistically. The small scales at which centrifuge tests are conducted make it impossible to model reinforced concrete structures accurately. As part of a project to demonstrate the use of the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) to study SFSI in bridges (Wood et al. 2004), the authors combined the results of shaking

table and centrifuge tests to develop an analytical model of the soil, foundations and structure of a reinforced concrete bridge.

Shaking table tests conducted at the University of Nevada, Reno provided earthquake-response data for a two-span reinforced concrete bridge, fixed at its base (Johnson et al. 2006). Centrifuge tests conducted at the University of California, Davis provided structure and soil response data for a two-span aluminum bridge, supported by drilled shafts in dense, dry sand (Shin et al. 2006).

An autoregressive with exogenous excitation (ARX) algorithm was used to identify the modal properties of the reinforced concrete bridge on the shaking table. Using this algorithm, the mean periods of the first three modes were identified as 0.67s, 0.51s, and 0.16s. The bent stiffnesses and the slab modulus of rigidity were estimated using the identified modal properties along with a linear numerical model of the shaking table specimen (Fig. 1). The stiffness of bents 1, 2 and 3 were estimated to be approximately 1/3 of the gross bent stiffness. The gross bent stiffness of each bent was estimated as the stiffness of the bent assuming gross section properties and a rigid cross beam ($k_g = 24EI_g/L^3$).

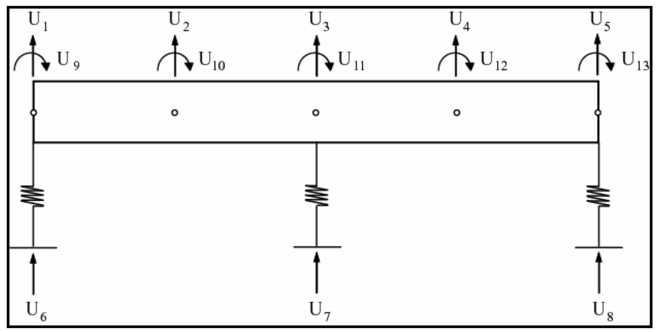

Figure 1. Linear numerical model of the shaking table specimen.

A nonlinear model of the centrifuge specimen was developed in OpenSEES (OpenSEES, 2002). The numerical model was developed using three-dimensional linear structural elements with coupled two-dimensional nonlinear soil elements. An illustration of the numerical model of the centrifuge specimen is shown in Fig. 2. The numerical model was calibrated using the response data from the centrifuge tests (Shin et al. 2006). Acceleration responses were compared between the numerical model and the experimental specimen at three levels: the free-field accelerations at the assumed point of pile fixity, the pile accelerations at the assumed points of pile fixity, and the bent acceleration responses.

The numerical model was also assessed using the ARX algorithm to compare the modal properties of the specimen to those of the numerical model. For the low-amplitude centrifuge tests, the first two periods estimated from the centrifuge specimen were 0.84s and 0.64s. The first two periods identified from the OpenSEES model of the centrifuge specimen were 0.82s and 0.64s.

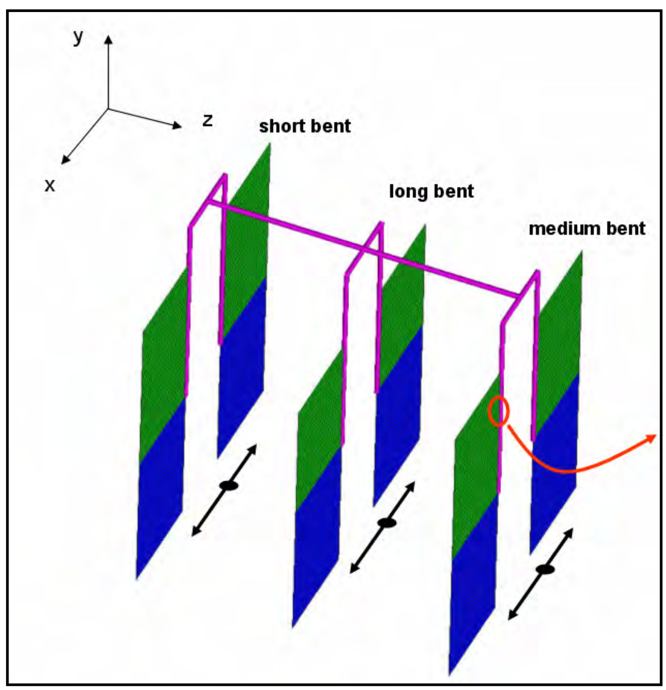

Figure 2. Nonlinear numerical model of the centrifuge specimen.

Once the numerical model of the centrifuge specimen was calibrated for the aluminum structure, the centrifuge soil properties of the centrifuge model were combined with the structural properties of the shaking table model (slab dimensions, masses, and the average estimated bent stiffnesses) to simulate a reinforced concrete bridge on drilled shaft foundations. The effects of various modeling assumptions were investigated using this prototype model in combination with the two experimental numerical models. The effects of the modeling assumptions are illustrated by comparing the displacement response histories of the medium height bent (bent 1).

The effects of material approximations were investigated by comparing the response from the prototype model (reinforced concrete bridge on drilled shaft foundations) to the response of the centrifuge model (aluminum bridge on drilled shaft foundations) (Fig. 3a). This comparison illustrates that the aluminum bridge approximated the reinforced concrete bridge well during the low-amplitude excitations. The maximum displacement, displacement waveform and periodicity of the two responses are similar.

The effects of structure approximations were investigated by comparing the response of the prototype model to the response of the shaking table model (reinforced concrete bridge with fixed base foundations) (Fig. 3b). The base fixity of the shaking table model affected the periodicity and wave form of the displacement history, but the maximum displacement between the two models were similar.

The effects of fixity approximations were investigated by changing the depth of column fixity in the shaking table model (Fig. 3c). This comparison showed that fixing the columns at the ground surface significantly affected all aspects of the displacement response. For example, the maximum displacement for the fixed at surface model was approximately 25% of the maximum displacement in the shaking table model.

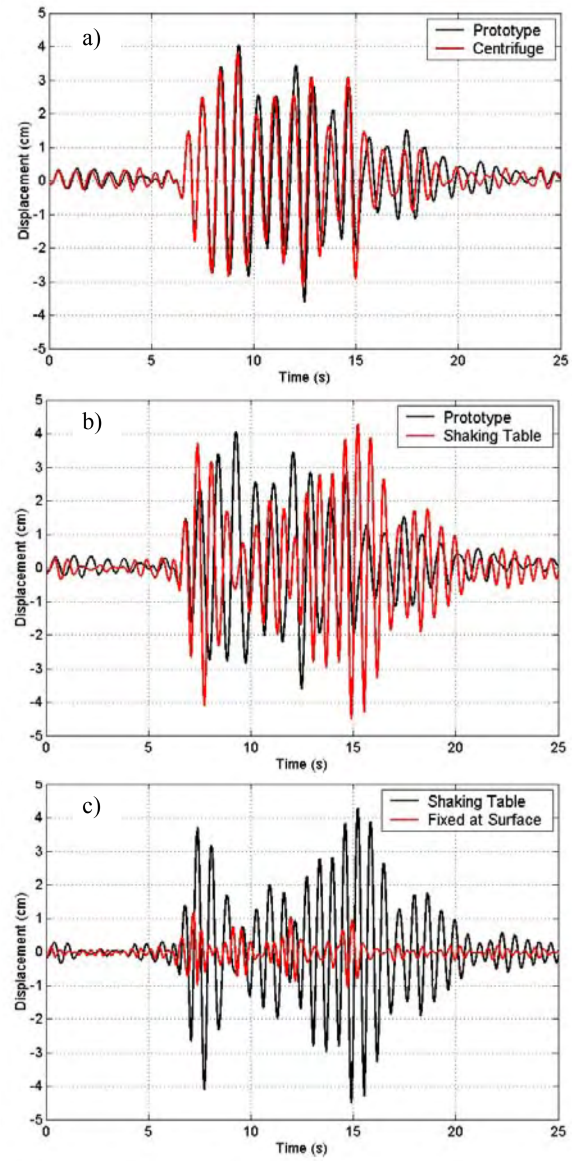

Figure 3. Measured response from the four numerical models.

Future research for this project involves identifying the components of soil-foundation-structure interaction, including the inertial and geometric components and foundation compliance. A nonlinear structural model has also been developed in OpenSEES and calibrated using data from the shaking table tests. This nonlinear structural model will be implemented with the nonlinear soil model to investigate the effects of soil-foundation-structure interaction.

Making Waves: Ground Response, Liquefaction, and Soil-Foundation-Structure Interaction at the NEES Permanent Experimental Field Sites

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Submitted to Session (please mark one):

μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
λ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Active source experiments and nonlinear soil behavior
- Pore pressure generation by active source and earthquakes
- Structural response changes due to environmental factors

Abstract/Summary

A goal of earthquake engineering research is to generate analytical and empirical models for accurate prediction of ground shaking, pore water pressure generation, ground deformation and soil-foundation-structure interaction (SFSI) and to understand how these predictions will affect the built environment. A required element for the development of these models is well-

instrumented test sites where actual ground response and deformation can be monitored during earthquake shaking to provide benchmark case histories for verification of the models.

The experimental field site component of the NEES equipment portfolio consists of permanently instrumented field arrays at two sites in Southern California: the Garner Valley Downhole Array (GVDA) in Riverside County, east of Hemet, California, and the Wildlife Liquefaction Array (WLA) in Imperial County near Calipatria, California. Both sites are located close to major faults and have previous histories of recording ground motions and pore-water pressures. The two sites are underlain by soft, liquefiable ground. The field sites are well suited for ambient noise studies, passive earthquake monitoring, and active testing. Since they have become operational, all of these methods have been used.

While the NEES field site facilities have only just completed the first year of the 10-year planned operational period, some important results from these experiment techniques have already been obtained. These include: the direct observation of nonlinear soil behavior as active source loading increases in amplitude; observations of pore pressure generation and its relation to ground shaking level; and, changes in the natural period of structural response due to changes in environmental parameters such as temperature and soil saturation. Here we provide a synopsis of the research activities at the NEES permanent field sites since they became operational and the important multi-agency collaborations that made these activities possible.

High Performance, Parallel Simulation Platform for NEES

Submitted By:

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Submitted to Session (please mark one):

μ	1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ	2. Advanced Tools Session: ***Sensors and Instrumentation***
X	3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
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μ	5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
X	6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
X	7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- High performance, parallel, scalable, simulation system for NEES,
- Designed and implemented for distributed memory, heterogeneous parallel computers (heterogeneous compute node performance , heterogeneous (local and wide area) network performance and heterogeneous element/subdomain demands),
- Portable, runs on local BeoWulf clusters, large national parallel computers (SDSC, Teragrid)
- Follows OpenSees API, allowing use of all elements and material models that are available in OpenSees (and that follow OpenSees API)
- Development and simulation parallel computer platform GeoWulf, can be replicated at each NEES or off-NEES site with limited budget.

Abstract/Summary

Civil engineering design process comprises iterative changes on configuration (shape) and constitution (material) of the infrastructure object (building, dam, bridge...). Design iterations using site specific simulation based tools need to take into account effects of civil engineering system on both normal operations and on operations during a range of emergency situations (man made and natural). Numerical simulations tools used for such performance assessment need to be both efficient and physics (mechanics) based.

Presented here is a high performance computational approach to numerical simulations of civil engineering infrastructure objects. In particular, parallel computing version of OpenSees finite element platform was developed and implemented for efficient and scalable computations with inelastic (elastic-plastic) finite elements on distributed memory parallel computers. The

development and implementation is centered around Plastic Domain Decomposition (PDD) set of algorithms, recently developed at UCD. Current implementation is using using ParMETIS graph library, PETSc numerical library, OpenSees application programming interface (API) and parts of the framework, and other libraries from the UCDavis CompGeoMech toolset. The use of OpenSees API is particularly important as it allows seamless use models and element available in OpenSees for high performance, parallel computations.

One of the main features of PDD-OpenSees of interest to the NEES community is the design wich allows scalable computations on heterogeneous parallel computers, with heterogeneous elements/sub-domains and with heterogeneous (local and wide) are networks. Heterogeneous element/sub-domains can include both numerical formulations (finite elements) as well as physical subsystems (used for hybrid simulations).

The PDD algorithm design targets currently predominant distributed memory parallel computer architecture. This is currently exclusive computer architecture of large national parallel computers. In addition to that, this design also features high computational performance (scalable) on heterogeneous (grid) parallel computers that feature multiple generation (heterogeneous) compute nodes, and heterogeneous (local and wide area) networks. The design of PDD method is such that it automatically takes into account heterogeneous element/sub-domain demands. This allows PDD to do efficient computations with various combinations of element types (solids and structural), combinations of elastic and/or elastic-plastic material models. This also allows PDD to be efficiently used for hybrid simulations, where the physical test specimen is treated as another element/sub-domain that has its own computational and networking demands on the finite element – physical system model.

The development platform for PDD is our locally developed, BeoWulf class, parallel computer GeoWulf. GeoWulf was developed and is maintained by the Author and number of graduate and undergraduate students. The design of parallel computer GeoWulf and that of PDD are closely related, particularly in allowing use of heterogeneous components and having heterogeneous compute demands. Development and simulation parallel computer platform GeoWulf, can be replicated at each NEES or off-NEES site using very fairly low budget.

Presentation will discuss current state of the endeavor. Presented results that indicate level of scalability (high) of the implementation for a variety of computer architectures, network performances and element/sub-domain types will be shown. Results from our current NEESR project on soil-foundation-structure interaction for bridge will be used to emphasize important points in both seismic response of SFS system as well as to demonstrate PDD set of algorithms. In addition to that, discussion of hardware platform will focus on comparison of use of local, in house versus large national parallel computers.

The source code, executables, theory manual and other useful information is available in public domain (GPL) through: http://sokocalo.engr.ucdavis.edu/~jeremic/PDD .
The description of the parallel computer GeoWulf is available at
http://sokocalo.engr.ucdavis.edu/~jeremic/GeoWulf.

Real-Time Hybrid Testing With Rate-Dependent Seismic Hazard Mitigation Devices

Submitted By:

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Submitted to Session:

- 1. Advanced Tools Session: ***Pushing Experimental Boundaries***

2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Load rate dependent devices can avoid seismic damage to structures, however their evaluation requires large-scale real-time testing capabilities.
- Improved existing real-time hybrid testing algorithms by using advanced control theory to overcome latency in displacement and force feedback.
- Performed system identification of hydraulic components (servo valves, actuators) of the Lehigh University NEES Equipment Site. These identified components are used to develop real-time simulation models for tuning advance control laws as well as enable numerical simulation of real-time hybrid testing.
- Performed real-time hybrid testing of a 3-story structure with a rate-dependent passive elastomeric damper to demonstrate algorithms and control laws.

Abstract/Summary

Numerous devices have been recently developed which can reduce the seismic hazard of new and existing civil engineering structures. These devices include passive and semi-active dampers. A majority of these devices are load-rate dependent. Real-time hybrid testing offers a viable method to evaluate the performance of these devices and the structural system which contains them. The devices alone, or the devices combined with part of the structure (e.g., dampers and the adjacent braces) can be physically modeled, and

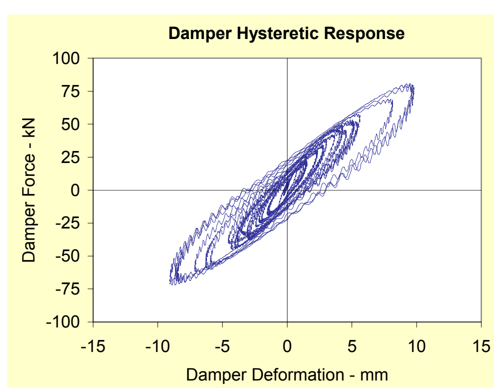

Fig. 1 Real-time performance of a load-rate dependant elastomeric damper.

the remaining part of the structural system analytically modeled. As a result, the use of the hybrid testing method avoids the need to include a physical representation of the complete structure in the test structure, yet captures the interaction effects between the devices and the complete structure, and thereby results in realistic demand on the devices. The need for real-time testing to evaluate the above devices was part of the vision that resulted in the development of the Lehigh NEES Equipment Sites, whose focus includes real-time hybrid testing and simulation.

Real-time testing has several challenges. These include: the need for continuous actuator motion to capture the proper velocity and acceleration effects; minimizing latency between the command and feedback displacement of actuators imposing motion to the test structure; and, minimizing phase and amplitude error in the restoring forces fed back to the integration algorithm. An inadequate integration algorithm can result in inaccurate results, where the effects of real-time are consequently not properly captured during the simulation. Latency results in an error in the phase and amplitude of the restoring forces, which can cause the test to be inaccurate and the algorithm to become unstable.

These aspects are presented and their effects on the accuracy of real-time hybrid testing are discussed. Using advanced control theory to improve the servo-hydraulic control laws, solutions to reduce latency and errors due to phase and amplitude in the actuator displacements and restoring forces associated with the test structure have been developed and implemented at the Lehigh NEES Equipment Site. The implementation included performing system identification of the hydraulic components (servo valves, actuators) to develop real-time simulation models for tuning advanced control laws as well as enabling numerical simulations.

The solutions to improve real-time hybrid testing are illustrated using numerical simulations in Simulink and through real-time large-scale hybrid testing of a three-story steel frame with elastomeric dampers using the real-time hybrid testing capabilities at the Lehigh NEES Equipment Site.

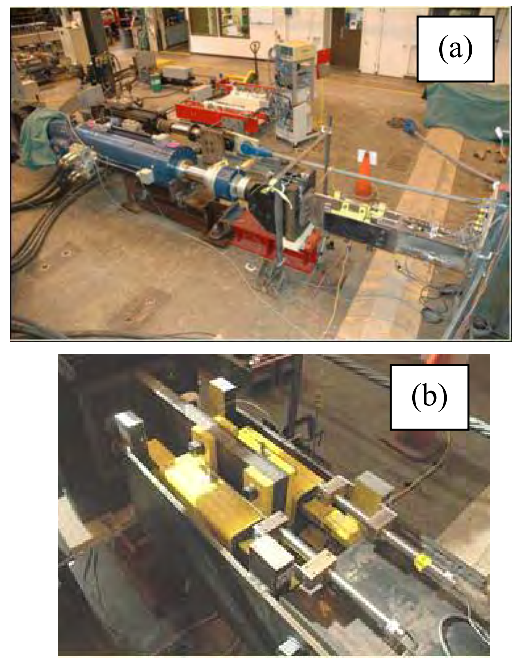

Fig. 2 Hybrid testing: (a) damper test setup, and (b) close-up of elastomeric damper.

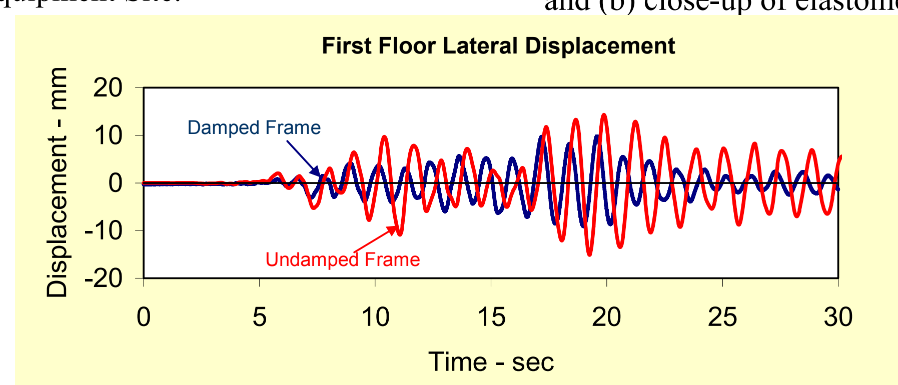

Fig. 3 Real-time hybrid test results showing response of the first-story of the three-story structure.

Luncheon EOT Presentations

NEES

Wednesday, June 21, 2006

12:30 – 2:00 pm (presentations begin at 1:30)

Luncheon EOT Presentations *(Washington Ballroom)*

Session Chair: **John van de Lindt**, Colorado State University

The EOT Execution Plan
Shirley Dyke, Washington University of St. Louis

Report on NEESreu Program and Efforts to Enhance NEES Community Diversity
Melanie Brown, NEES Consortium, Inc.

Speaker:

Shirley Dyke
EOT Committee Chair/Washington University in St. Louis

Session:

EOT Luncheon Presentation
Wednesday, June 21, 1:30 – 2:00 pm

Presentation title:

NEES EOT Execution Plan

Major points/topics:

- Vision
- Objectives and Deliverables
- Priorities and Activities
- Integration of Activities

Abstract/Summary

The NEES Education, Outreach and Training (EOT) Execution Plan is a detailed roadmap intended to accompany the EOT Strategic Plan. The Execution Plan focuses on activities that are planned to take priority over the next two years. The Plan lays the groundwork for use of NEES capabilities including data and cyberinfrastructure to provide attractive learning opportunities for groups from K to practitioner. Objectives and deliverables of the NEES EOT Plan are set forth in each area: Education, Outreach, and Training so that each user group can readily access the information. User groups are further identified with priorities and activities listed for each. Groups include K-12 students and teachers, undergraduate students, graduate students, faculty, practitioner, and the public.

Presentation Summary

Speaker:

Melanie Brown
Education & Diversity Coordinator/NEESinc

Session:

EOT Luncheon Presentation
Wednesday, June 21, 1:30 – 2:00 pm

Presentation title:

Diversity Strategic Plan and NEESreu

Major points/topics:

- Goals, Strategies, Activities of DSP
- Short-term Accomplishments
- Intermediate and Long-term Goals
- NEESreu Program

Abstract/Summary

Diversity Strategic Plan
An overview of the DSP will include the vision of the Diversity Working Group, a subcommittee of the EOT Committee, as well as the specific goals, strategies, and activities that will be employed to achieve the vision of substantially broadening participation in earthquake engineering. Demographic comparisons will include the workforce, academia and the NEES community. Optimizing NEES resources emphasize leveraging the cyberinfrastructure and using the website to increase awareness. Interaction with diverse communities and partnership with diversity organizations is seen as paramount in achieving the vision. Evaluation is key and obtaining assessment from experts will aid in program improvement, performed on an annual basis. The plan focuses on three time periods: short-term, intermediate and long-term in which to achieve stated goals. Diversity efforts should result in a positive impact of increased participation of underrepresented groups, and new and creative ways of thinking. A legacy of opportunity for future engineering students awaits.

NEESreu Program
(Research Experiences for Undergraduates)
This two-year NSF funded program was just approved in March 2006 and is currently underway. In 2006 there are 15 students participating at four node sites across the country for a 10-week summer session. In 2007 there will be 20 students. Sites were selected based upon detailed criteria. Recruitment efforts focused on minority groups and resulted in 60% being from underrepresented groups, and 87% non-host site students. A REU Oversight Subcommittee (ROS) was created to assist in recruitment efforts and to evaluate student applications. Students will participate in meaningful research opportunities and will learn to prepare scientific papers at a Communications Skills Workshop. These papers will be presented at a cohort experience with other REU students from the Earthquake Centers at the Young Researchers Symposium in August. NEESinc will reapply for funding after 2007 in hopes of continuing this excellent opportunity for undergraduates.

UCSD/PCA/NEES Blind Prediction Contest Plenary Session

NEES

Wednesday, June 21, 2006

2:00 – 3:00 pm

UCSD/PCA/NEES Blind Prediction Contest Plenary Session *(Salon A+B)*

***Session Chair:* Robert Bachman**, RE Bachman Consulting Structural Engineers

The Seven-Story Test Structure
José Restrepo, University of California, San Diego

The UCSD/PCA/NEES Blind Prediction Contest
Robert Bachman, RE Bachman Consulting Structural Engineers

Presentation by Contest Winner—Academic/Researcher Division
Presentation by Contest Winner—Practitioner Division
Presentation by Contest Winner—Undergraduate Division

NEES

NEES 4TH ANNUAL MEETING ~ JUNE 21–23, 2006
Presentation Summary

Speaker:

Robert Bachman, S.E.
Convener, UCSD/PCA/NEES Blind Prediction Contest
RE Bachman Consulting Structural Engineers
Laguna Niguel, California

Session:

UCSD/PCA/NEES Blind Prediction Contest Session
Wednesday, June 21, 2:00 – 3:00 pm

Presentation title:

The UCSD/PCA/NEES Blind Prediction Contest

Major points/topics:

This session will include the following:

- Description of Test Facility, Design of Test Structure and Test Program and Discussion of Test Results
- Overview of Blind Prediction Contest, Entries and Computer Platforms Used
- Comparison of Predictions with Measured Values
- Announcement of Contest Winners
- Presentation by Contest Winners on Approach

Abstract/Summary

Between October of 2005 and January 2006, a full-scale vertical slice of a seven-story reinforced concrete wall building (shown above) was subjected to increasing intensity of uniaxial earthquake ground motions on the new NEES Large High-Performance Outdoor Shake Table located at UCSD's Engelkirk Structural Engineering Center. Responses were measured using an extensive instrumentation array, and all results have been archived for future release. The largest input motion was the Sylmar Medical Facility free-field record obtained in the 1994 Northridge Earthquake, which is one of the strongest recorded motions from that event and includes some near-fault ground-motion characteristics. The building slice was designed using a displacement-based and capacity approach for a site in Los Angeles that resulted in design lateral forces that are significantly smaller than those currently specified in building codes used in the United States.

This session deals with a blind prediction contest associated with this experiment. The contest was announced in mid-March and predictions were due mid-May. The prediction contest was "blind" and compared analytical response "predictions" with those measured during experimental testing. There are three categories of teams that have won prizes (undergraduates, researchers/academics and engineering practitioners. The contest was co-sponsored by UCSD, PCA and NEES and a $2500 prize will be awarded by PCA to each winning team.

The session will present a discussion of the experiment including the measured results. It will also include an overview of how the contest was conducted. The entries will be identified, their locations and the computer platforms used. It should be noted that the relative ranking of all entries are confidential except for the winning entry in each category. A comparison of the range of predicted values with measured values will be presented. Finally winners will be announced and representatives of each team will make a presentation on the approach (computer program, modeling, etc.) they used in making their winning predictions.

Issue Forums Plenary Session

NEES

Wednesday, June 21, 2006

3:00 – 4:00 pm

Issue Forums Plenary Session *(Salon A+B)*

***Session Chair:* Jill Andrews**, University of Michigan

IT Strategy Committee (ITSC) Issue Forum Introduction
Jacobo Bielak, Carnegie-Mellon University (*ITSC Chair*)
Jerome Hajjar, University of Illinois Urbana-Champaign
Andrei Reinhorn, University of Buffalo
Gregory Fenves, University of California, Berkeley
Stephanie Couch, CENIC/University of California, Davis

Education, Outreach, and Training (EOT) Committee Issue Forum Introduction
Shirley Dyke, Washington University of St. Louis (*EOTC Chair*)

Site Operations Committee (SOC) Issue Forum Introduction
Marc Eberhard, University of Washington (*SOC Chair*)

ITSC ISSUE FORUM:
"TOWARD A COMMON LONG-TERM VISION FOR NEES CYBERINFRASTRUCTURE & IT SERVICES"

ISSUE FORUM GOALS

The NEES community has embraced usage of advanced cyberinfrastructure and IT services as a visionary component of the NEES collaboratory mission and legacy. Among other capabilities, these tools offer the potential to facilitate research collaboration between people and facilities over distance and time; to fully integrate physical and numerical simulation capabilities; and to extend the knowledge and experience of NEES researchers for purposes of education and outreach.

The IT Strategy Committee (ITSC) is now in the process of refining the long-term vision for NEES' cyberinfrastructure for purposes of guiding emerging and future work plans. The ITSC recognizes many "vision elements" for NEES' IT that have been proposed by various specialized constituencies of the community and is seeking to capture and synthesize these elements into a consistent single overarching vision that represents NEES community values. This Issue Forum will:

- Present a range of proposed vision elements for the future of NEES' IT infrastructure;
- Engage the community in the review of these proposed vision elements and identify additional complementary vision elements not already described;
- Explore alternative strategies to combine these elements into a consistent overarching theme;
- Use wireless polling to assess resonance of the various 'overarching' themes with community views and values.

SESSION COORDINATION

Session Moderator:	Jacobo Bielak, ITSC Chair
NEESinc Facilitator(s):	Jon Lea, NEESinc Chief IT Engineer Cliff Roblee, NEESinc Executive Director

PANELISTS & PERSPECTIVE

Jerome Hajjar	UIUC Research Engineer – Experimental Emphasis: Telepresence & Hybrid Sim. *"IT as a Bridge for Research Collaboration Over Distance and Time"*
Andrei Reinhorn	UB Research Engineer – Data Archive Emphasis *"Achieving a Data Legacy from NEES Research"*
Gregory Fenves	UCB Research Engineer – Computational Emphasis *"Toward Seamless Integration of Numerical and Physical Simulation"*
Stephanie Couch	Corporation for Education Network Initiatives in California – IT for EOT Emphasis *"The EOT Potential of NEES' Cyberinfrastructure"*
Allan Blatecky (To confirm)	Deputy Director, Renaissance Computing Center – Cyberinfrastructure Emphasis *"Integration with Advanced CI Tools from Other Communities"*

EOT COMMITTEE ISSUE FORUM

ISSUE FORUMS COORDINATION

Session Moderator: **Shirley Dyke**, *EOT Committee Chair*
NEESinc Facilitator: **Parshaw Vaziri**, *NEESinc EOT Manager*

ISSUES FOR CONSIDERATION AND DISCUSSION

1. In what ways can the NEES cyberinfrastructure, including (multi-site) experiments, high-fidelity data, visualization, etc. be more effectively utilized for education, outreach, and/or training activities? How can the tools and outcomes facilitate other opportunities for EOT projects? What partnerships need to be established to accomplish these goals?

2. What type of model would a NEES Student Association follow, and what are the roles and responsibilities of the members? of the leadership council?

3. How will the NEES EOT community effectively develop and offer short courses and seminars designed to bring the latest research outcomes to practicing engineers? How can NEESinc assist with coordination? How does the community avoid duplication of efforts by different NEESR teams? How do we engage the practitioners?

4. What should be NEES' lasting EOT legacy? What programs/activities would need to be successfully undertaken in order to establish these legacy goals?

SITE OPERATIONS COMMITTEE ISSUE FORUM

ISSUE FORUMS COORDINATION

Session Moderator: **Marc Eberhard,** SOC Committee Chair
NEESinc Facilitator: **Jay Berger,** NEESinc Site Operations Manager

ISSUES FOR CONSIDERATION AND DISCUSSION

1. What is (or should be) User-Sharing?

2. What defines success at a NEES facility, and how should success be evaluated?

3. Expanding the NEES community. How can laboratories currently outside the NEES network contribute capacity/data? What would be the possible impacts on NEES equipment sites?

As part of this discussion, we will likely be presenting the current user-sharing policy (related to issue #1), the current site evaluation process (related to issue #2), and some initial thoughts about issue #1.

Advanced Tools Breakout Session 1: Pushing Experimental Boundaries & Hybrid Simulation

NEES

Wednesday, June 21, 2006

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session I: Pushing Experimental Boundaries & Hybrid Simulation *(Salon A)*

Session Chair: **Jerome Hajjar**, University of Illinois Urbana-Champaign

Hybrid Simulation of Structural Collapse
Bozidar Stojadinovic, University of California, Berkeley

The UB-NEES Site: Pushing Experimental Boundaries in Full and Large Scale Structural and Nonstructural Testing
Thomas Albrechinski, University of Buffalo

We've Only Just Begun -- A Dynamic New Use for NEES Capabilities
Andrew Budek, Texas Tech University of Washington

NetSLab Based Remote Hybrid Testing in a Hierarchical Network Environment
Yurong Guo, CIPRES-Hunan University

A High Performance Desktop Fast Hybrid Test Platform
Gary Haussmann, University of Colorado, Boulder

Hybrid Simulation of Structural Collapse

Submitted By:

Bozidar Stojadinovic, Associate Professor
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Kennneth J. Elwood, Assistant Professor, University of British Columbia, Vancouver, Canada
Bozidar Stojadinovic, Associate Professor, University of California, Berkeley

Submitted to Session (please mark one):

x 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Hybrid simulation is a method for examining the response of a hybrid model to an excitation.
- Hybrid model is a consistently scaled assembly of physical and numerical substructures.
- We extended the hybrid simulation method to consistently account for second-order effects of gravity loads on the response of the structure.
- The extension was achieved using large-displacement formulation in the numerical substructures and consistently computed displacements for the physical substructures.
- We demonstrated the method by simulating collapse of a portal frame under combined gravity and lateral loading with both loads applied numerically.
- The main reason to use hybrid simulation to model collapse is that there is no need to protect the laboratory equipment from the collapsing specimens.

Abstract/Summary

Hybrid simulation is a method for examining the response of a hybrid model to an excitation. A hybrid model is an assemblage of consistently scaled substructures. These substructures model the constitutive relations between displacements and forces of the prototype. At least one of the substructures is physically instantiated and at least one of the substructures is implemented using a computer model. The assemblage is constituted by coupling the displacement and force conditions at substructure boundaries to enforce compatibility present in the prototype. The response of the hybrid model to an excitation is obtained by solving its equation of equilibrium.

If necessary, the inertial forces and the energy dissipation unaccounted for by the substructures can be incorporated into the equation of equilibrium. The response of the prototype is interpreted using similitude relations.

Gravity loads affect the response of the structure in three ways:

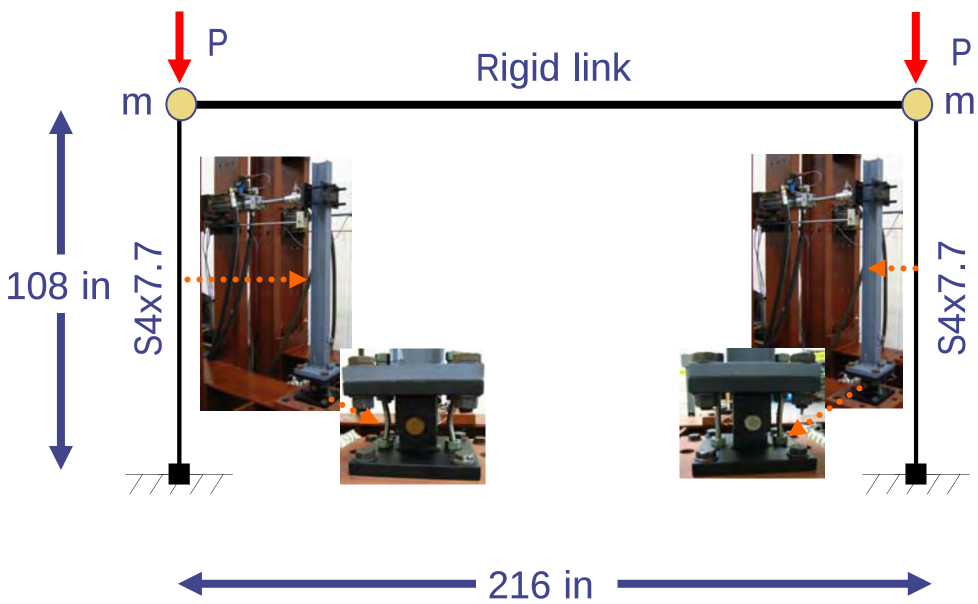
1. Gravity loads alter the stress-strain response of the material, causing interaction of moment, shear and axial loads at the cross section, commonly known as P-M or P-V interaction.
2. Gravity loads alter the stability of structural elements, causing local buckling of the element as well as element or sub-assemblage lateral-torsional buckling. Such effects are commonly known as $P-\delta$ effects.
3. Gravity loads affect the stability of the structure, causing additional overturning moments due to large structural displacements. Such effects are known as $P-\Delta$ effects.

The focus of this study is the extension of the hybrid simulation method to account for the structure-level ($P-\Delta$) effects of gravity loads. This extension was achieved by consistently accounting for large deformation (second-order) effects of gravity load on the computer substructures and by transferring the effect of gravity loads to the physical substructures by appropriately adjusting the displacements at their boundaries. This extension was implemented using the *nees@berkeley* hybrid simulation engine built within OpenSees using the OpenFresco framework and the OpenSees Navigator user interfaces.

This new capability is demonstrated by conducting tests of a steel single-story single-bay portal frame structure shown in Figure 1. The hybrid model comprises two physical substructures representing the columns of the portal frame, while a computer substructure is used to model the connecting beam. The computer model consistently accounts for large deformations using the second-order large-displacement formulation. Note that the physical substructures are not carrying any gravity loading. Thus, the cross-section and element level effects of the gravity load are not accounted for.

The response of the portal frame subjected to the SAC NF01 ground motion recorded during the 1978 Tabas earthquake scaled to 0.755g PGA is computed using the hybrid model described above. The first test was conducted without any gravity load. The second test was conducted with the gravity load. This load is applied to the computer model as two concentrated column forces, shown in Figure 1. The magnitude of the forces is set as 30% of the critical buckling load of the columns computed assuming the base supports of the frame are fixed. The story drift time history and the base shear vs. story drift response of the frame from the two tests are compared in Figure 2. Note that even though the frame maximum displacement and residual displacement are substantial for the first test without gravity load, the hybrid model does not collapse. The negative post-peak stiffness of the frame due to second-order effects during the second test with gravity load is clearly evident in the results. For the second test, at 6.6 seconds into the simulation, the lateral displacement of the frame increases rapidly. This may be considered as the initiation of frame collapse. Hybrid simulation is terminated when the actuators exceed their stroke (at approximately 7 % inter-story drift ratio), taken as the indication of collapse in the hybrid model.

The ability to correctly account for the second-order effects in hybrid models is crucial for simulating collapse of structures under gravity loads. It has been demonstrated that such hybrid simulations are possible. Hybrid simulation of structural collapse offers three significant advantages over conventional testing methods: 1) the effect of gravity loads is represented numerically (in the computer) eliminating the need for complex active or passive gravity load setups; 2) there is no need to protect the test equipment from specimen impact during collapse because the actuator controller will restrict movement of the specimen; and 3) only the critical, collapse-sensitive, elements of the structure need to be physically modeled allowing for a substantial increase in the number of different collapse tests afforded by the same project budget.



P = 0.003 kips, M = 0.003 kips-in/sec^2, T = 0.291 sec, $\zeta = 0.02$

Figure 1. Hybrid simulation model of the portal frame.

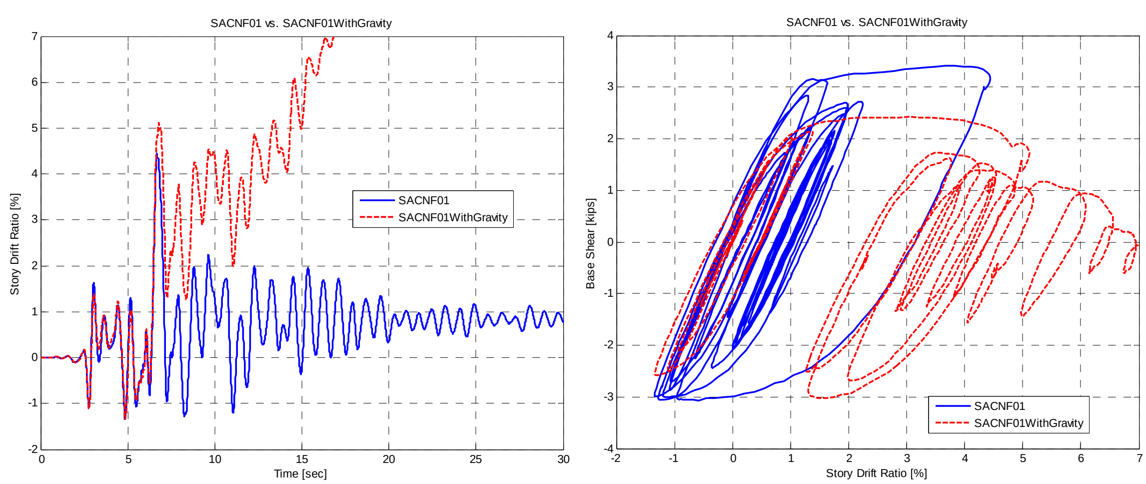


Figure 2. Story drift time history and story shear-drift hysteresis

The UB-NEES Site: Pushing Experimental Boundaries in Full and Large Scale Structural and Non-Structural Hybrid Testing

Submitted By:

Andrei M. Reinhorn, Thomas Albrechcinski, Andre Filiatrault, Sabanayagam Thevanayagam, Xiaoyun Shao, Mark Pitman, Jason Hanley, Goran Josipovic
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Submitted to Session (please mark one):

X 1. Advanced Tools Session: ***Pushing Experimental Boundaries***

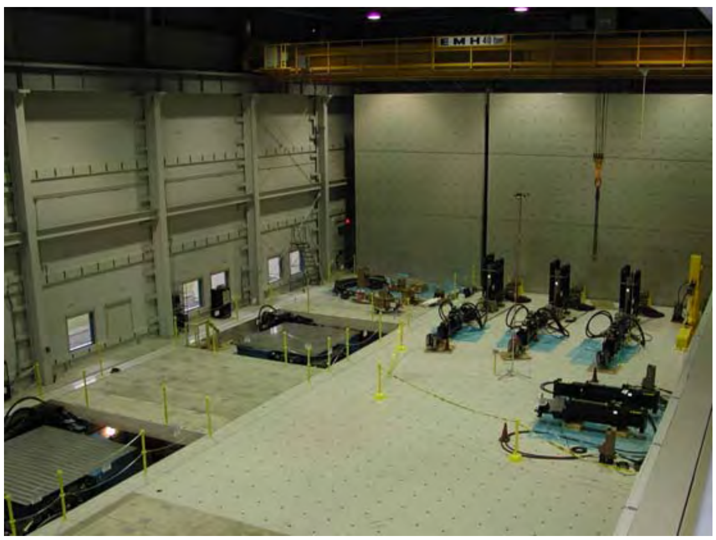
Major points/topics:

- The UB-NEES Site provides the earthquake engineering community with highly versatile capabilities to perform full and large scale structural and non-structural component testing under dynamic and static loading.
- Four unique capabilities and related research projects are discussed that will advance the state of the art in seismic testing and extend the knowledge base serving the broader earthquake engineering community.
- The Real Time Dynamic Hybrid Testing (RTDHT) technique developed by and uniquely implemented at UB continues to be refined with enhancements to the software framework and compensator controller verified by shake table and single actuator tests.
- The UB-NEES Site is commissioning a dedicated Nonstructural Component Simulator (NCS) system.
- The NEESR-SG: NEESwood: "Development of a Performance Based Seismic Design Philosophy for Mid-Rise Woodframe Construction" project is a full scale seismic benchmark test of a two-story wood frame townhouse is being performed at the UB-NEES site employing the twin reconfigurable shake tables requiring fully synchronized operation.
- The NEESR-SG: "Experimental and Micromechanical Computational Study of Pile Foundations Subjected to Liquefaction-Induced Lateral Spreading" project, will utilize the 2-D Geotechnical Laminar Box, developed by the UB-NEES site, for 1-g full scale tests of sand-pile and group pile liquefaction and interaction tests.

- The UB-NEES Site completed testing of an MCEER developed frame assemble with a "Zipper Frame" under a Pre-NEESR cooperative project in conjunction with Georgia Tech, the University of Colorado at Bolder and the University of California at Berkeley.
- The UB-NEES Site has fulfilled the vision of being the "most versatile large scale earthquake engineering research facility possible"

Abstract/Summary

The vision for the development of the UB-NEES Site, hosted by SEESL at UB, was to establish the most versatile earthquake engineering research facility possible, designed to provide testing capabilities to revolutionize the understanding of how very large structures react to a wide range of seismic activity, even when tested to complete failure. Key elements of the 13,000 square foot laboratory expansion include: twin re-configurable and re-locatable 6-degree-of-freedom shake tables, large-scale dynamic and static actuators, reconfigurable high performance control and hydraulic distribution systems, a greatly expanded strong floor, and a large reaction wall.

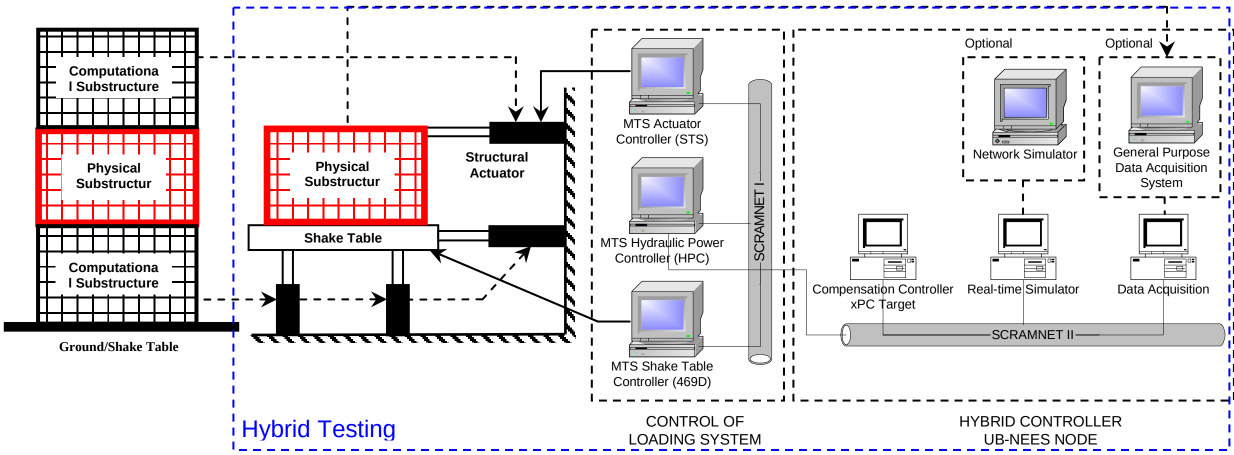


The facility is capable of conducting testing of full or large-scale structures using static or dynamic loading. The use of modern techniques such as *Pseudo-Dynamic, Effective Force,* and *Real-Time Dynamic/Fast Pseudo-Dynamic Hybrid testing is* possible, along with conventional *Static, Quasi-static,* and *Dynamic Force* techniques. *Real-Time Dynamic Hybrid Testing (RTDHT)* is a unique form of testing which has been implemented at UB in which shake table and/or dynamic force experiments on substructures are combined in real-time with computer simulations of the remainder of the structure. This provides a more complete picture of how earthquakes would affect large structures, including buildings and bridges, without the need to physically test the entire structure.

This paper will discuss five unique development and research projects being performed at the UB-NEES Site pushing experimental boundaries in large scale testing and will be providing the earthquake engineering community with data advancing the state of the art in the seismic performance of large scale structures and non-structural components.

Real-time Dynamic Hybrid Testing (RTDHT) is a novel structural testing method involving the combined use of shake tables, actuators and computational engines for the seismic simulation of structures. The structure to be simulated is divided into a physical substructure and one or more computational substructures. The interface forces between the physical and computational substructures are imposed by actuators and resulting displacements and velocities are fed back to the computational engine.

The earthquake ground motion, or motion of other computational substructures, is applied to the experimental substructure by shake tables. A schematic of the RTDHT system is shown below.



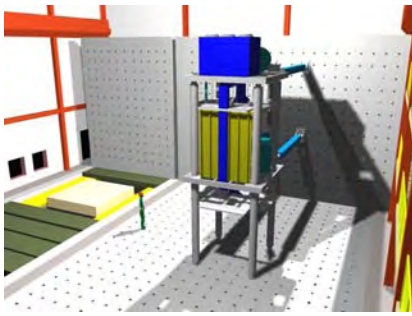
Schematic of Real-time Dynamic Hybrid Test System

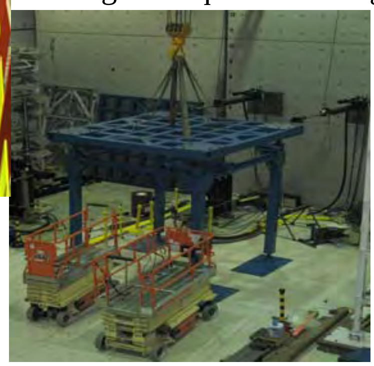
The unique aspect of the above hybrid system is force-based sub-structuring, developed at University at Buffalo, and a generic system controller based on parallel real time computing at rates of actual earthquakes,. Since the shake tables induce inertia forces in the experimental substructures, the actuators have to be operated in dynamic force control as well, since either the force or the displacement, but not both can be controlled at a given point. Since it is easier to drive hydraulic actuators in displacement control, a method has been devised to obtain force control by a cascade control over a displacement closed-loop. The Compensation Controller shown in the figure performs this task. This controller also compensates for time-delays that are inherent in the physical system and those that are introduced by filtering, computation, network communication.

UB has continued to optimize the RTDHT with the design of the Software framework for performing real time hybrid dynamic test based on the UB-NEES facility capabilities. Two essential components are the structure simulator and compensation controller. The structural simulator is a Finite Element Structural Analysis program which simulates the numerical substructure and calculates the boundary loading information. The compensator controller determines the real time command to the structural actuator and shake table based on the performance of the hydraulic loading system and interface loading command so that the exact load can be applied to the experimental substructure at the desired rate.

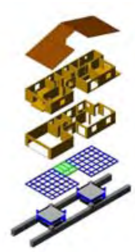
A unified controller which is capable of dividing the load between the structure actuator and shake table was proposed and verified by tests in a single degree of freedom. The dynamic response of a three story model was simulated with only the second story physically tested while the top and bottom story numerically modeled in the computer. The interface loads were applied by the structure actuator and shake table. This test validated the software and hardware development designed for real time dynamic hybrid test. These continuing enhancements and packaging of the RTDHT test capability, at the UB-NEES Site, provides the earthquake engineering community with an efficient means of testing large scale structures and nonstructural components integrated within whole structural systems.

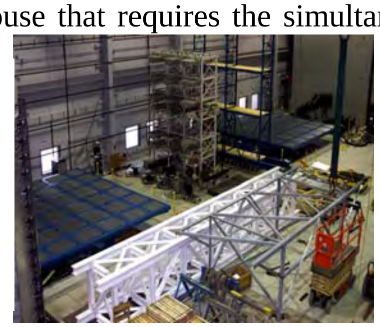
Under extended NSF funding, the UB-NEES Site developed a unique Nonstructural Component Simulator (NCS). The NCS is a modular and versatile two-level platform for experimental performance evaluation of nonstructural components and equipment under realistic full scale floor motions as shown. The NCS can provide the dynamic stroke necessary to replicate full-scale displacements, velocities and accelerations at the upper levels of multi-story buildings during earthquake shaking. Both displacement sensitive and acceleration sensitive nonstructural components and equipment can be experimentally evaluated under full-scale floor motions to understand, quantify and control their seismic response. The NCS testing frame is composed of two square platforms having an inter-story height of 14 ft. The platforms are activated using two identical high performance dynamic actuators, supplied by MTS Corporation. The NCS is capable of subjecting nonstructural components and equipment up to 3g horizontal accelerations. Uni-axial and bi-axial testing configurations are possible. Vertical accelerations can also be included in an experiment by mounting the testing frame on one of the existing shake tables at the SEESL UB-NEES facility.





The first phase of the NSF NEESR-SG funded NEESwood project entitled “Development of a Performance Based Seismic Design Philosophy for Mid-Rise Woodframe Construction" involves shake table testing of a two-story woodframe townhouse that requires the simultaneous use of the twin shake tables at the UB-NEES Site, operating in three degrees of freedom. As the largest full-scale three-dimensional shake table test ever performed in the U.S., the results of this series of shake table tests will serve as a benchmark for woodframe performance as well as for the validation of numerical models. This project is enabled by the combined payload capacity and more importantly, the unique capability of the UB-NEES shake tables to operate fully synchronized in all six degrees of freedom. The woodframe townhouse structure will remain on the twin shake tables for a 9-month period of time and will involve six different phases of testing and evaluation as the structure is

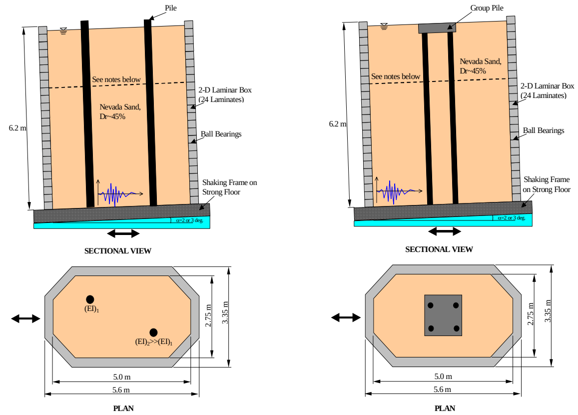




progressively built. The results of this program will lead to the development of a new seismic performance based design philosophy for woodframe structures.

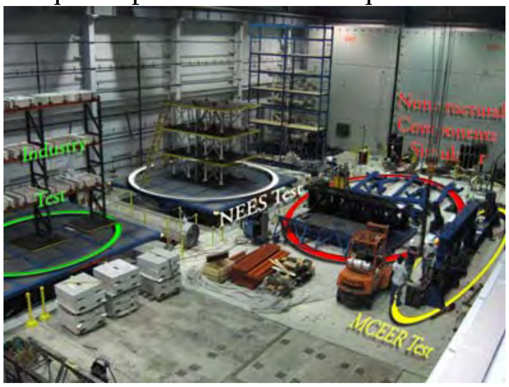
The first phase of the NEESR-SG: “Experimental and Micromechanical Computational Study of Pile Foundations Subjected to Liquefaction-Induced Lateral Spreading” project, will utilize the

2-D Geotechnical Laminar Box, developed by the UB-NEES site, for 1-g full scale tests of sand-pile and group pile liquefaction and interaction tests. Six full-scale tests will be conducted utilizing the strong floor with laminar box placed on ball bearings. Horizontal shaking will be applied using two high performance dynamic actuators connected to the strong wall. Instrumentation in piles and soil will include advanced sensors and as many key sensors (piezometers, accelerometers, etc.) as feasible near the piles and pile cap (pile group), to provide a detailed picture of the soil and foundation behavior.



The UB-NEES Site completed testing of an MCEER developed frame assemble with a “Zipper Frame” under a Pre-NEESR cooperative project in conjunction with Georgia Tech, the University of Colorado at Bolder and the University of California at Berkeley. To solve the traditional problems associated with conventional braced frames, a new class of bracing systems, known as a zipper frames, was developed and tested as part of this project. This proposal represents the first phase of a two-phase collaborative approach to the problem. In the experimental portion of the project, tests were conducted to study the behavior of whole systems, sub-assemblages, and individual elements. These tests were conducted under a variety of load regimes, ranging from shake table tests to quasi-static ones, to provide comprehensive data on which to base design recommendations.

In summary, the UB-NEES Site is pushing experimental boundaries and advancing the state of the art in earthquake engineering research and testing through the continued development of unique experimental techniques and capabilities and in the support and execution of truly novel



research programs. The uniqueness and scale of the projects described here, in addition to the many other programs that have been performed, in parallel, since the commissioning of the facility on October 1, 2004 clearly demonstrates that the vision of establishing the UB-NEES Site as the "most versatile large scale earthquake engineering research facility possible" has been realized.

We’ve Only Just Begun – a Dynamic New Use for NEES Capabilities

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Submitted to Session (please mark one):

X 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES’ Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- There is a perception, even in the civil engineering research community, that enough seismic research has been done
- This is not true – there is a whole field which has seen little investigation – dynamic testing of operating dynamic systems
- Many of these systems should be tested at full-scale, because operating parameters are very sensitive to scale effects (i.e., Reynolds number in pipe flow)
- The NEES Collaboratory offers unique opportunities for dynamic testing of operating dynamic systems. The large-payload shake tables at UCSD and E-Defense have the capacity to do meaningful work.

Abstract/Summary

At the American Concrete Institute Fall Convention in Fall, 2004, the question of whether “we’ve done enough seismic research” was raised as a ‘Hot Topic’. While this is patently not true, the mere fact that the subject could be raised at so august a gathering is a red flag for future research opportunities in the field. Research dollars are limited, and we in the seismic field have to be competitive. The assembly of the NEES collaboratory has presented unique opportunities to experimentally address seismic problems on the ‘systems’ level, but we have to go further. In the fight for funding we have to continue to justify the future use, maintenance, and upgrading of this research infrastructure.

It is the purpose of this presentation to point an avenue in seismic research that can help to keep the seismic research 'skill and hardware sets' current, relevant, and vibrant in the years to come.

Where We Are

The overriding priorities in past seismic research have been simple –

- Keep large, heavy structures from collapsing and squashing people
- If said structures do collapse, keep the collapse progressive and predictable
- Try to limit damage to said structures so that they can be repaired

By and large we've done this. Research into building, bridge, and foundation elements and systems is at a stage where robust detailing and structural geometry are either known, or can be extrapolated. We can build 'stuff that doesn't fall down', though whether the detailing to do so is done properly (within the limits of economy and politics) is another question entirely.

Where We Can Go – Dynamic Testing of <u>Operating</u> Dynamic Systems

Most seismic research in the past has examined static systems subjected to dynamic loads. The majority of this work has been in the quasi-static regime, in which forces and displacements are imposed slowly, rather than in 'real-seismic-time', and much NEES capability is geared toward the quasi-static regime. There are excellent reasons for this:

1. Dynamic testing is ferociously expensive – it requires high-capacity oil flow (through pumps or accumulators), large servo-valves on actuators, and high-end controllers
2. Quasi-testing is usually more useful – incremental damage to reinforced concrete, for instance consists of cracks and reinforcement distress, which tell us a lot about the constitutive state of the material and structure. In quasi-static testing these can be recorded and quantified at leisure
3. Quasi-static is usually conservative – high-strain-rate loading of concrete typically gives a strength increase of 10-15%
4. The inertial effects which are modeled through dynamic loading are implicitly accounted for in the case of systems dominated by first-mode response, and can be modeled for 'multimode' systems with pseudodynamic testing (as was done for the PRESSS 5-story building tested at UCSD in the late 1990s).

However, NEES's large-scale dynamic testing capabilities (specifically the UCSD and collaborative E-Defense shake tables) allow something new…***dynamic*** testing of ***<u>operating</u> dynamic systems.***

For example, the shakedown project for UCSD's large-capacity shake table was the seismic response of a wind-turbine mast. But a wind turbine ***system*** is fundamentally dynamic, with a huge amount of rotational inertia coming from the rotation of the blades. Testing of a system in operation, which couples this rotational inertia with inertial dynamic loading of the entire system certainly has the potential for producing useful (and, perhaps, spectacular) results.

Perhaps this not the best example with which to begin – the specter of a disintegrating wind turbine raining bits and pieces across the nearby traffic on I-15 would give any insurance underwriter nightmares.

A more reasonable candidate is an operating pump and pipe flow system. High-velocity fluid moving through pipes carries a large amount of inertia. Adding in dynamic inertial effects from seismic attack will create inertial force resultants which were very likely never directly considered, and which can easily cause system failure through a number of mechanisms – pipe rupture, unbalanced loads on pumps, anchorage, to name a few. The perils which can arise from an actual failure are serious – the failure of an oil pipeline system can create environmental damage, local safety hazards, and economic losses which are simply not acceptable.

Testing a pipe flow system in operation is not a simple task. Large-scale testing is a needed, because scaling down the system will move its operating system too far from reality. Reynolds number and the shape of the velocity field within the pipe are seriously affected by scale effects. Scale effects in aerodynamics can be verified through full-scale prototype air- or spacecraft performance, but verification of the response of a scaled piping system will require an actual seismic event.

Granted, testing a pipe flow system in operation is technically difficult. To begin with, an inert working fluid with similar dynamic characteristics as its real-world counterpart would be needed, for health and safety reasons. Another challenge would be the layout of the test system. Most realistically-modeled systems could not be completely accommodated on the payload area of the shake table itself, so an interface of slip and/or universal pipe joints would be needed to provide continuity from the payload area to the 'ground'. And…the cleanup of a system which failed during testing would be a nuisance. A possible test configuration for a simple centrifugal pump and pipe system is shown in Fig. 1.

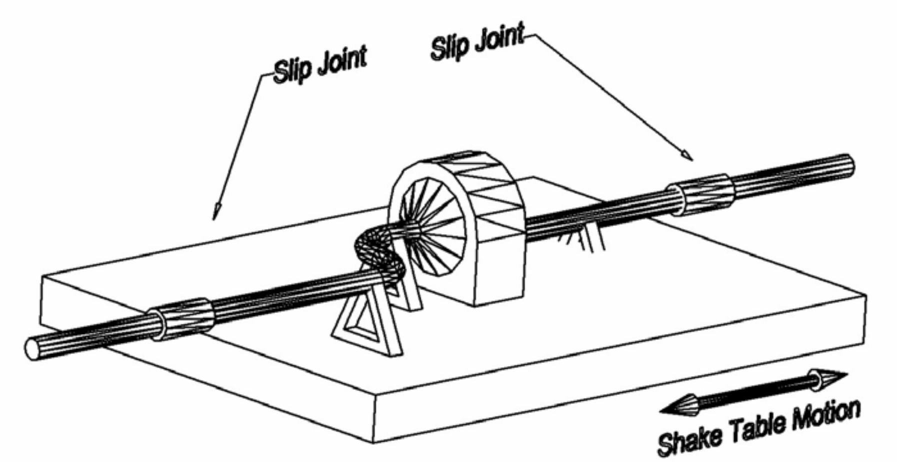

Fig. 1 – Possible test configuration – centrifugal pump and pipes

Other candidates for testing are power turbines, conveyors and material handlers, and large machine tool systems. Failure of any of these systems has the potential for causing loss of life, and loss of economic function.

If we consider the hypothetical pipe flow system test, the quasi-static capabilites of NEES can be brought into play through initial testing of components. Numerical modeling marrying computational fluid dynamics and structural analysis can pinpoint critical elements, and multiaxial testing systems such as UIUC's MUST-SIM facility can be used for to design systems which will be verified in a full-dress large-scale dynamic test.

Conclusion

There is a lot of work yet to be done in seismic engineering; today we have tools and capabilities that were undreamed of twenty years ago. But the increased capabilities come at increased cost, and we need new directions, such as high-profile testing of operating dynamic systems, to compete for a finite pool of research dollars.

NetSLab Based Remote Hybrid Testing in A Hierarchical Network Environment

Submitted By:

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Submitted to Session (please mark one):

● 1. Advanced Tools Session: ***Pushing Experimental Boundaries***

μ 2. Advanced Tools Session: ***Sensors and Instrumentation***

μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***

μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*

μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*

μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***

μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Developed a socket based network communication platform
- Communication issues passing across firewall/proxy
- Three schemes are presented for solving across firewall/proxy communication

Abstract/Summary

To facilitate remote hybrid dynamic test, a socket based network communication platform has been developed. The platform, named NetSLab, was developed based on client/server concept along with a proposed data model and communication protocols. Several concepts, such as Dynamic Unified Data Packet (DUDP) and Generalized Data Communication Agency (GDCA), were introduced to realize the platform and to provide relatively easier and friendlier interface for applications and further development by users. The platform is capable of transferring control and feedback data among remote structural testing laboratories or computers connected by the Internet with satisfactory efficiency. Trial tests were successfully carried out at the Hunan University, China and the University of Southern California, USA. Fig.1 is a screen copy of an application program for remote hybrid dynamic test.

The current Internet is based on hierarchical network infrastructure, which fully supports all kinds of network communication model efficiently. But as the security and privacy becomes one of the most important issues on the Internet, more and more firewalls and proxy servers have been introduced in different levels that cause a series of problem for the traditional point-to-point communication model. Most of firewall/proxy will block any kinds of TCP/UDP ports, except

for the standard HTTP(80) and HTTPS(433) ports. It also prevents the internal system to be connected by the outside system without certain permission.

NetSLab faces the same challenge of passing across firewall/proxy. Currently, according to the framework of remote hybrid test, a simple method has been adopted in NetSLab to provide across firewall/proxy communication. Other more general schemes are also in consideration. The first scheme is to utilize the Virtual Private Network (VPN) technologies. When a VPN is set up, remote hybrid test participants within different LANs are allowed to communicate with each other as if they were within the same intranet. The second scheme is to use Microsoft's Simple Object Access Protocol (SOAP) to develop a software system. In this scheme, a server computer (Called Web Bridge) with public IP address is introduced to help participants communicate with each other indirectly. The sever PC has nothing to do with structural testing, but serves as a bridge to connect all participants. With these schemes, remote hybrid test can be carried out more conveniently and widely under current hierarchical network environment.

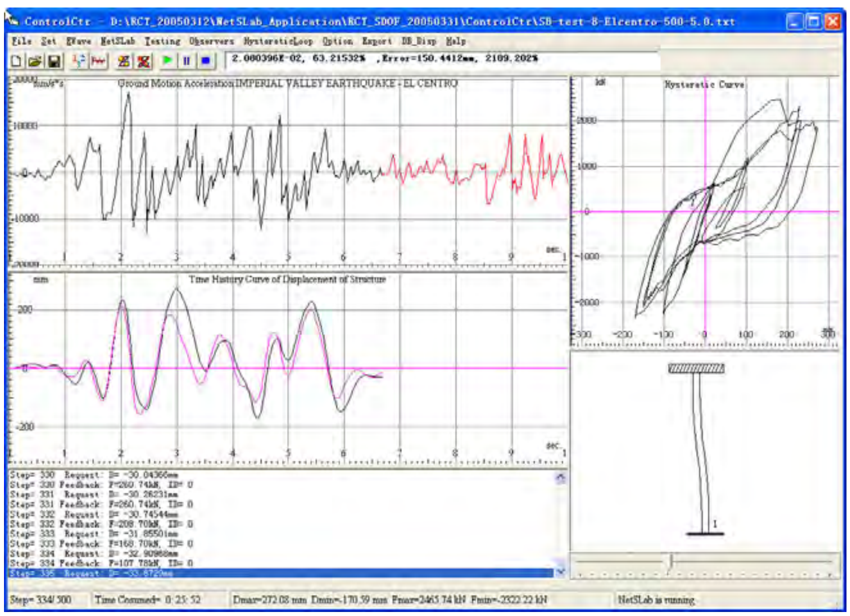

Fig. 1 Screen copy of an application program during a hybrid dynamic testing

A High Performance Desktop Fast Hybrid Test Platform

Submitted By:

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Submitted to Session (please mark one):

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Major points/topics:

- The FHT Desktop Platform provides a low-cost easily deployable implementation of the Fast Hybrid Test method.
- The small size and easy accessibility make the platform useful for outreach demonstrations and pedagogical purposes.
- Low cost and fast setup/modification allow the platform to be used for prototyping of larger-scale FHT experiments.

Abstract/Summary

From advanced researchers to interested young students, the desktop FHT platform is designed to facilitate insight and understanding into both the FHT technique and the element being tested.

While the CU-Boulder NEES site has implemented a complete FHT solution, the high cost and effort involved in setting up and running an FHT test may prohibitive for certain applications, including:

- Live demonstration of the FHT method in other locations
- Interactive experiments or classroom presentations
- Fast prototyping of new engineering ideas or concepts

To address these problems, a high performance desktop platform for realtime hybrid simulation is being developed at CU NEES. This system will make hybrid simulation capabilities available to a wider audience. The hardware and software requirements will provide basic FHT functionality with relatively lower cost and more portability than full-scale hybrid test sites.

Coupled with the FHT desktop platform is the Hybrid Simulation Hardware Interface (HSHI), an Object-Oriented library intended to bridge structural simulation software with physical hardware for use in hybrid simulation. When completed, the HSHI library will allow users to construct a Fast Hybrid test by combining simulation software (OpenSEES, FEAP, Nastran, and others) and hardware interfaces (SCRAMNet, LabView VISA, custom) into a complete FHT solution.

While FHT has a certain superficial appeal its real usefulness is largely dependant on the depth of the users understanding and how to apply the technology to a particular problem. The desktop platform will be a hands-on tool that develops the users' insight and creates an understanding of the inherent advantages of FHT over mere Hybrid Tests.

Advanced Tools Breakout Session 2: Sensors and Instrumentation

NEES

Wednesday, June 21, 2006

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 2: Sensors and Instrumentation *(Salon B)*

Session Chair: **Bruce Kutter**, University of California, Davis

High Strain Measurement in Concrete Structures Using POF Sensors
Omid Abdi, North Carolina State University

State-of-the-art Development of Distributed Coaxial Cable Sensors for Crack Detection with ETDR Measurements
Genda Chen, University of Missouri-Rolla

The NEES@University of California, Davis High-Speed Wireless Data Acquisition System
Daniel Wilson, University of California, Davis

Instrumentation for the NEESR Sand Aging Field Experiment
David Saftner, University of Michigan

High strain measurement in concrete structures using POF sensors

Submitted By:

[a]Omid Abdi, [a]Mervyn Kowalsky, [a]Tasnim Hassan, [b]Sharon Kiesel, [b]Kara Peters.

[a]Department of Civil, Construction, and Environmental Engineering, North Carolina State University, Campus Box 7908, Raleigh, NC 27695

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Submitted to Session (please mark one):

- ○ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- ● 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ○ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
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- ○ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Developing Polymer Optical Fibers (POF) sensors for high strain measurement applications.
- Providing acceptable bond between the fiber sensor and the cement carrier which protects the fiber.
- Providing enough bond between concrete surface of sensors and concrete in the structural member.
- Light transmission tests of POFs going through fibers.
- Testing of structures using POF strain gages

Abstract/Summary

The research summarized here investigates the use of polymer optical fiber (POF) sensors in order to measure high-strains in RC and steel structures subjected to dynamic load conditions, such as those imposed due to earthquakes loads.

Developing POFs, which provide a potential maximum strain range of 6-12%, is a major part of this research. These fibers are more flexible than silica optical fibers, and are more durable in harsh chemical or environmental conditions. Recent advances in the

fabrication of single mode POFs have made it possible to extend POFs to interferometric sensor capabilities. Furthermore, the interferometric nature of intrinsic sensors permits high accuracy for such measurements. Generally, POF sensor systems potentially offer a larger strain range measurement capability along with more long-term survivability. Prior to applying the single mode POF strain sensor, the response of the sensor to the applied strain was derived. In addition, the material properties (in this case both mechanical and opto-mechanical) that must be calibrated for the POF sensor were identified [Kiesel et al, 2006]. The second order strain optic effects and finite deformation of the POF were calculated [Kiesel et al, 2006]. Afterwards, the results for the case of uniaxial tension were obtained. The effects of non-linear photoelastic effect and finite deformation of optical fiber are needed and were obtained. These POF as strain gages are invaluable for monitoring the behavior of structures. Conventional strain gages for cyclic load applications can be reliable up to about 3% strain, in the case of steel structures. In the case of concrete structures, conventional strain gages are even less reliable, particularly at strain levels in excess of 1%. These limitations are particularly important for civil structures subjected to extreme loads where material strains can exceed 2% in the concrete, and 5% in the reinforcing steel. Using these POF sensors could give us the opportunity of measuring the unmeasured high strains in structures. The development of a strain gage that can measure large strains reliably is essential to address needs on localized and hence global structural response in these research in which the shake table test of five storey RC building in final stages will be done. In case of steel structures, the bare POF could be used in surface of structure. But in case of concrete structures, embedding bare fiber optic strain sensors in RC structures is not advisable because of their fragility. The procedure of casting of concrete and testing of structure can damage the sensors. The protection was provided by a special mixture of concrete which was chosen among several tested materials and mixtures, including mortar, hydrastone, and cement paste Fig1, which was the most effective at protecting the POFs. This is due to the

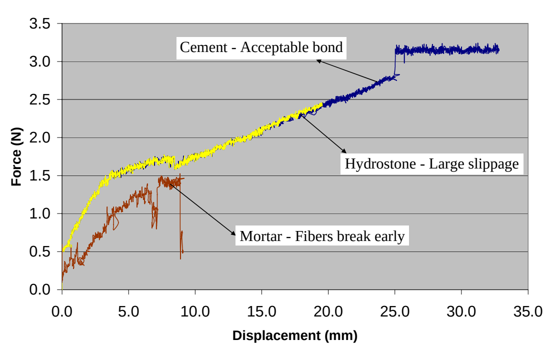

Fig1. Test of bonding three different material and POFs

compatibility and acceptable strain rate transfer between the structural concrete and the cement paste. There are number of challenging issues dealing with developing these special strain gages and testing of RC structures.

The bond between chosen protecting material and fibers was investigated as shown in Fig1. The specimens were loaded in tension at a rate of 2.5mm/min using a MTS QTest machine with a 10N load cell. Another issue is good bond between this strain gages and concrete used for construction. This problem was solved by providing deformation on the surface of the material used for making these strain gages Fig2 (a). POF sensors inside of these specimens are prestrained such that they may be able to measure the compression, as well as tension strains. POF sensors are also protected against damage as the polymer fiber leaves the cement with plastic protecting tubes as shown in Fig2 (b). It is noted that the optical properties of these strain gages was also verified using a setup for evaluating light transmission inside of the sensor specimens Fig2(c).

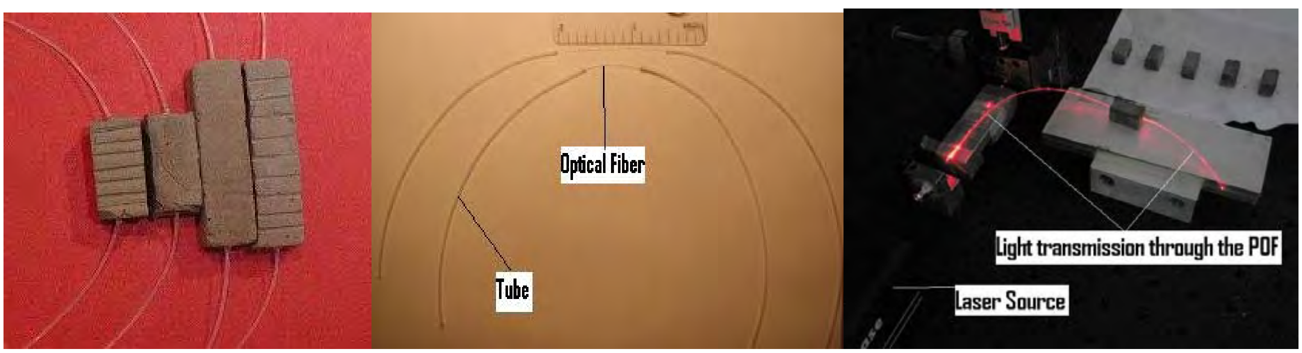

Fig2. (a) Ribbed surface of strain gages comparing with plane samples. (b) Protecting fibers inside tubes. (c) Light transmission test of specimens

The accuracy, durability, capability to measure high strains, and gage length will be used in next step of the research which will include monitoring strains in beams under static loads and a shake table test of a five storey building. It is the hope that these sensors will provide information that was previously unavailable to the researcher that may allow for more precise data on concrete performance limit states under seismic load conditions.

State-of-the-art Development of Distributed Coaxial Cable Sensors for Crack Detection with ETDR Measurements

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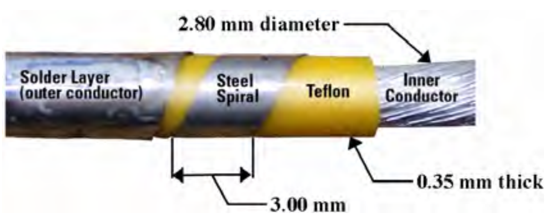
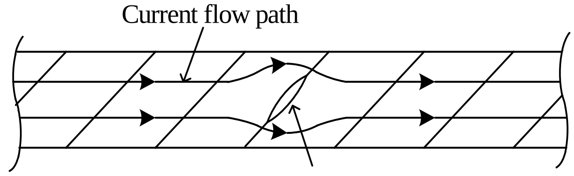
A fundamentally new, topology-based cable sensor design concept has recently been proposed and developed by the author and his research team. Cable sensors are basically communication coaxial cables with an innovative design of their outer conductor, spirally wrapped around dielectric or Teflon as illustrated in Fig. 1(a).



(a) Cut-away sample of a coaxial cable sensor



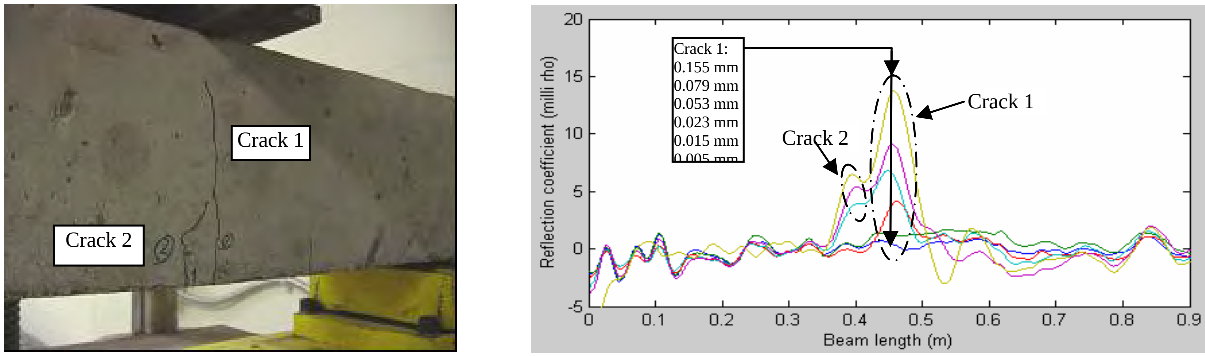
(b) Mechanism of topology-based cable sensors

Fig. 1 Coaxial cable sensor and working mechanism

Electric Time Domain Reflectometry (ETDR) is a remote sensing technology based on the propagation of electromagnetic waves in an electrical cable or a transmission line, which functions both as a signal carrier and a sensor. It uses a digital sampling oscilloscope with an ETDR sampling head. The sampling instrument launches a series of low-amplitude and fast-rising step pulses onto the transmission line and samples the reflected signal caused by an electrical property or topology change along the cable. The arrival time of the reflected signal represents the distance from the point of monitoring to the discontinuity while the intensity of the signal represents the degree of the discontinuity. The topology change in a cable sensor is realized after the spirals as outer conductor of the cable are separated due to local strain effects as illustrated in Fig. 1(b), resulting in a detour of current flow path along the outer conductor.

The new design concept enhanced the sensitivity of traditional cables by over 10 times and the spatial resolution of less than 50 mm. It enabled the sensors' application in structures as demonstrated by comparing the measured reflection coefficient waveforms under various crack widths, Fig. 2(b), with the crack pattern observed on the tested reinforced concrete (RC) beam, Fig. 2(a) [1].

Due to presence of the spiral outer conductor, when embedded near surface of a RC member, a specially-designed cable sensor can permanently record the most severe damage, surface and hidden cracks beneath Fiber Reinforced Polymer (FRP) sheets, distributed along the RC member provided the cracks intercept the sensor [2]. As illustrated in Fig. 3, this "memory feature" provides a high reliability of receiving damage data during a strong earthquake and a hurricane by allowing critical damage detected either in real time or after the catastrophic event.



(a) Crack pattern on a RC beam (b) Measured reflection coefficient at different loads

Fig. 2 Sensitivity and spatial resolution of a cable sensor

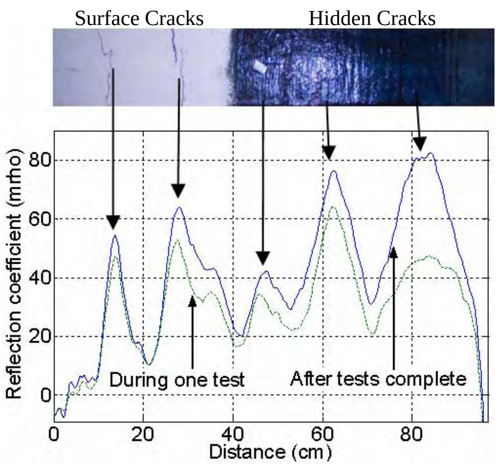


Fig. 3 Reflection coefficient during and after testing

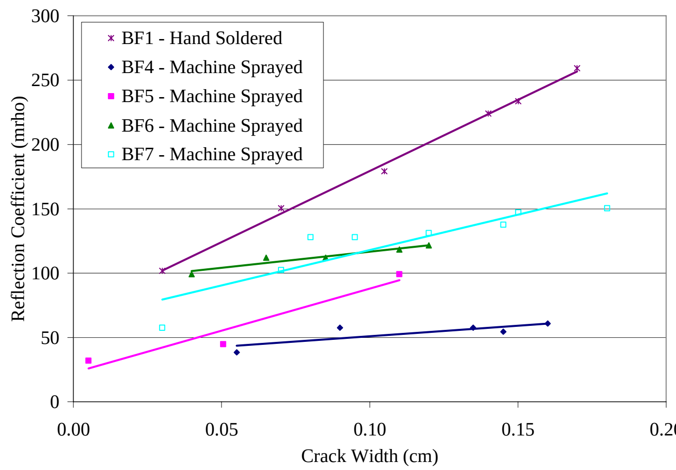
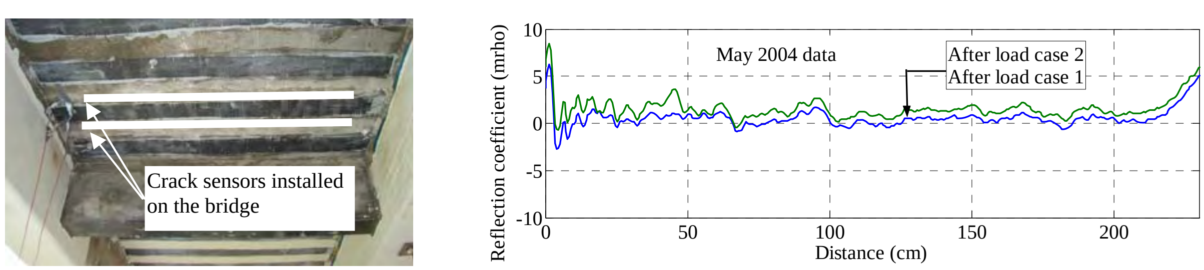


Fig. 4 Reflection coefficient and crack width correlation

Crack sensors have been calibrated and correlated with the crack width using RC beams of a single crack, and proven sensitive to cracks of various sizes from visually undetectable to excessive as indicated in Fig. 4. A crack sensor can give both the location and severity of damage simultaneously.

Two coaxial cable sensors were installed on a three-span bridge as shown in Fig. 5(a). The measurements from one sensor were presented in Fig. 5(b) for two load cases after the applied loads were removed. The test results were consistent and indicated no sign of cracks in this in-service structure. They also showed that in field condition the level of noise and/or environmental effects is around 3 mrho in reflection coefficient within an effective range of the sensors between 10 and 220 cm.



(a) Highway bridge and sensor application (b) Measurements after different loads

Fig. 5 Sensor implementation on Dallas County Bridge and load test results

More recently, to prove the concept of crack detection in real-time with cable sensors, a number of electronic parts were assembled into a bulky protocol for the measurement of a spatial and temporal distribution of cracks as illustrated in Fig. 6, which was recorded during shake table testing of a small-scale column. With one cable sensor, the crack pattern and its progression during an earthquake event can therefore be monitored.

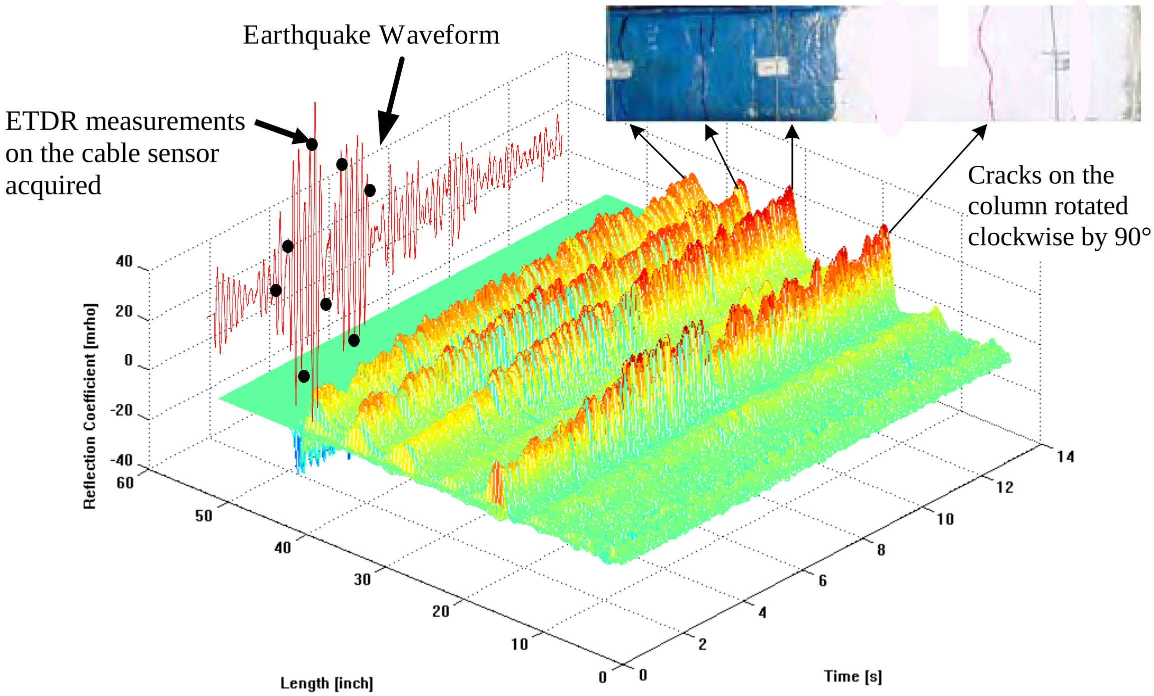


Fig. 6 Temporal and spatial distribution of cracks

In comparison with other sensors such as fiber optics, cable sensors have the following advantages [3]:

- Very rugged so that they can be used to measure a wide range of crack widths,
- Continuous in crack detection along each sensor,
- High in spatial resolution, and
- Inexpensive in measurement instrument
- Fast in crack detection under dynamic loads.

Potential applications of the developed crack sensors include:

- Monitoring the behavior of RC structures that are inaccessible, such as pile and shaft foundations as well as massive concrete structures (dams),
- Monitoring hidden cracks in RC columns retrofitted with steel, concrete, or FRP jacketing, and
- Recording damage that has occurred during a recent disaster event. This application is particularly attractive for a rapid post-event assessment of the structural condition of critical buildings or bridges to facilitate emergency responses.

References

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2. Chen, G. D., R. McDaniel, S. S. Sun, D. Pommerenke, and J. L. Drewniak, "Distributed Crack Sensors Featuring Unique Memory Capability for Post-Earthquake Condition Assessment of RC Structures," Smart Structures and Systems, Vol. 1, No.2, pp. 141-158, 2005.
3. Chen, G. D., B. Xu, R. McDaniel, X. Ying, D. Pommerenke, and Z. Wu, "Distributed Strain Measurement of a Large-Scale Reinforced Concrete Beam-Column Assembly under Cyclic Loading," *Proceedings of the 12th SPIE Annual Symposium on Smart Structures and Materials*, San Diego, California, March 6-10, 2005.

The NEES@UC Davis High-Speed Wireless Data Acquisition System

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Submitted to Session (please mark one):

1. Advanced Tools Session: ***Pushing Experimental Boundaries***

X 2. Advanced Tools Session: ***Sensors and Instrumentation***

3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- A high speed wireless data acquisition system (DAQ) was developed at UC Davis as part of NEES construction
- The new wireless DAQ enables a higher number of recordings by reducing the cost of signal conditioning and reducing the complexity of routing instrument cables
- Current research project have successfully used the wireless DAQ to record over 200 instruments in a single simulated earthquake event, more than double the number of recordings typically made before NEES.

Abstract/Summary

Dense sensor arrays provide the ability to study the physics of composite material behavior through measurements of the spatial variation in dynamic response, rather than inferring the physics from a few select measurement points. The number of instruments used in a centrifuge experiment is limited, however, by the cost of instruments and signal conditioning. More restrictive, perhaps, is the complexity of labor and bookkeeping involved in managing dozens of instruments.

At UC Davis we have developed a distributed high-speed wireless data acquisition system (WIDAQ) to reduce the number and complexity of signal wires emanating from highly instrumented centrifuge models. 56 miniature eight-channel high-speed data acquisition modules buried in the soil and water on the centrifuge combine to record data from 448 sensors at up to

20 kHz per channel with better than 10 μs synchronization between modules. A host radio controls the modules using a combination of Time Division and Frequency Division Multiplexing to efficiently download up to 56 MB of data collected in any individual event. These new modules combined with commercial off-the-shelf MEMS accelerometers make dense instrumentation arrays a practical option in testing at UC Davis. Modules also support strain gauge bridges, load cells, pore water pressure transducers, and other similar transducers.

The WIDAQ is being used in current research projects such as the one shown in Figure 1. In this test WIDAQ modules were used to collect data from MEMS accelerometers mounted on model bridge bents and from MEMS accelerometers buried in the soil. WIDAQ modules were also used to measure bending moments in the model piles. Over 200 instruments were recorded in each of several simulated earthquake events, more than double the typical number of instruments recorded on the UC Davis centrifuge prior to NEES. Many sensors continue to be routed through the traditional wired DAQ, and the bundles of wire visible in Figure 1 help demonstrate one clear advantage of the WIDAQ.

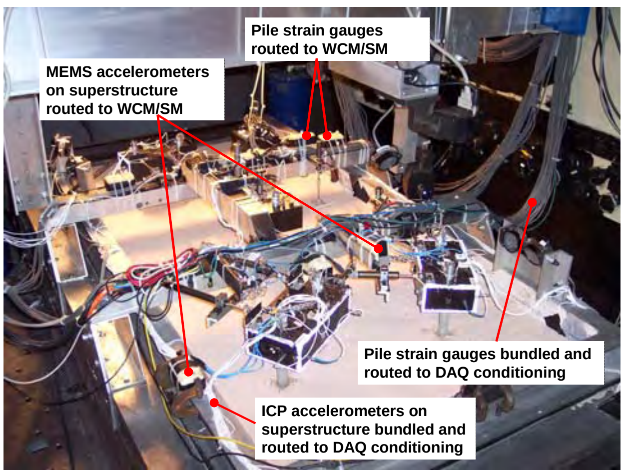
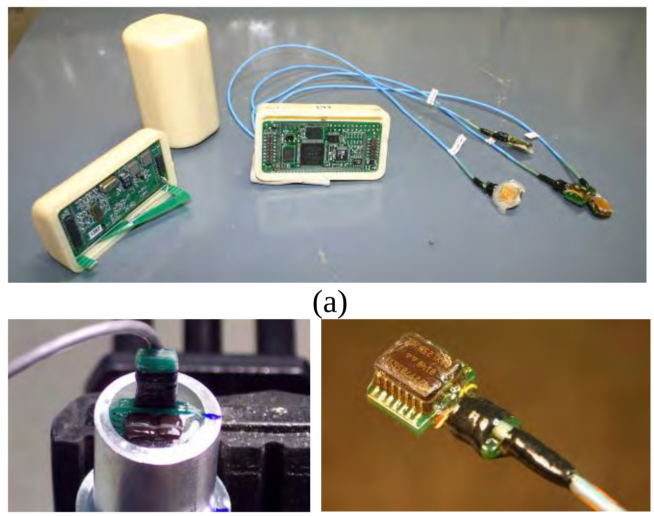


Figure 1: 1/52 scale model of bridge bents on the UCD Centrifuge. WIDAQ modules collect bending moments from instrumented piles and accelerations from structures and in the soil. Other instrument cables are bundled together and routed to data acquisition signal conditioning units some distance from the model.



(a)

(b) (c)

Figure 2: MEMS accelerometers and WIDAQ module ready for use. (a) A WIDAQ module configured with four Silicon Designs 1221L-100 accelerometers. (b) A low cost MEMS accelerometer potted into a model pile tip. (c) Custom printed circuit board and cable strain relief (shown with Analog Devices ADXL250 accelerometer).

The WIDAQ modules are designed to support typical commercial MEMS accelerometers. MEMS accelerometer chips have a significant cost advantage over more highly packaged accelerometer transducers. At UC Davis we have been successful applying some simple packaging techniques to keep the per unit price low. A few examples are shown in Figure 2.

Early results from the WIDAQ have been positive. In the experiment shown in Figure 1 the researcher placed several transducers at nearly identical locations and routed them through both the wired DAQ and the WIDAQ for direct comparison. Some results are shown in Figure 3.

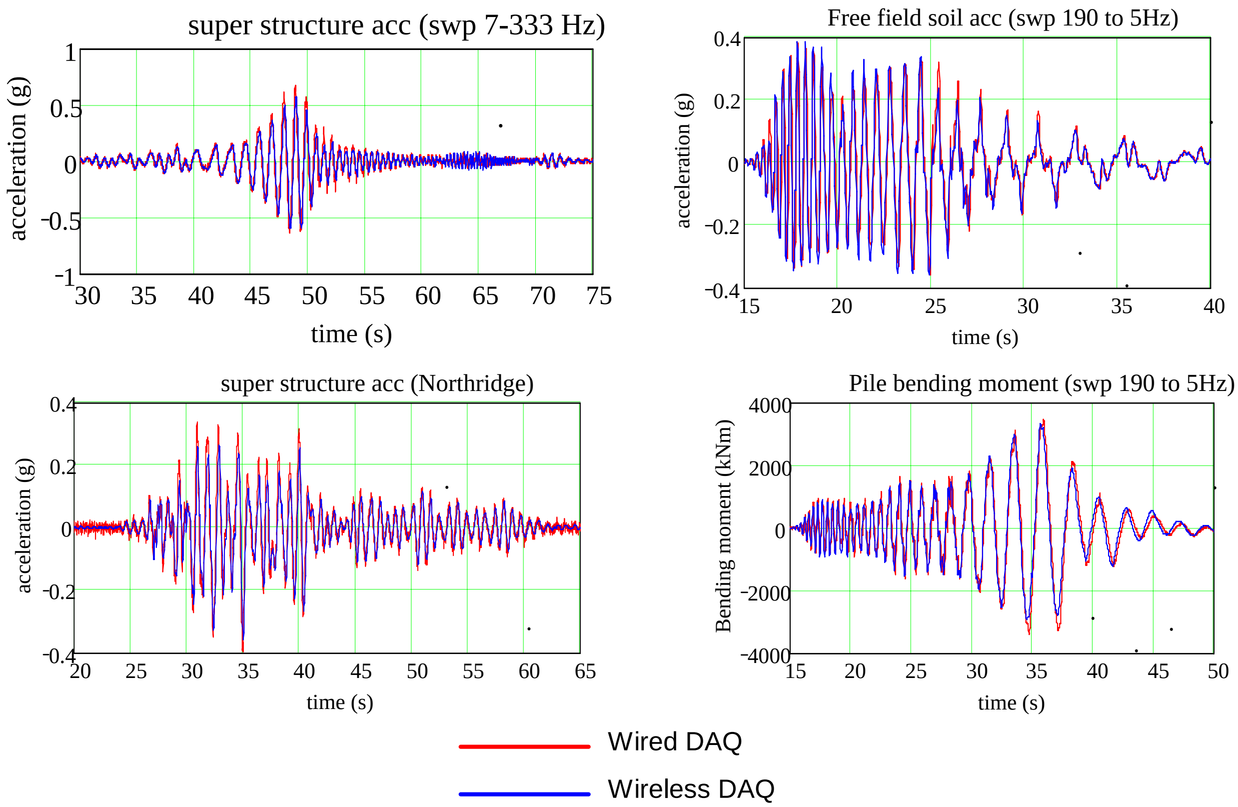


Figure 3: Comparison of data recorded with traditional wired data acquisition system and the new wireless data acquisition system at UC Davis. Transducers were placed at nearly identical locations for direct comparison.

The wireless data acquisition system was one of a host of upgrades performed at UC Davis as part of the construction of the George E. Brown, Jr. Network for Earthquake Engineering Simulation. The WIDAQ is proving to be a valuable new tool in studying the behavior of earthquakes at the NEES facility at UC Davis.

For further information on WIDAQ and other resources available at UC Davis or for information on current research projects please visit http://nees.ucdavis.edu.

Acknowledgements

The development of the wireless DAQ at UC Davis was supported by the National Science Foundation under award CMS-0086566. The centrifuge experiments presented herein were performed by Mahadevan Ilankatharan of UC Davis and Hyung-Suk Shin of the University of Washington as part of the pre-NEES project “Collaborative Research: Demonstration of NEES for Studying Soil-Foundation-Structure Interaction,” NSF award CMS-0324661.

Instrumentation for the NEESR Sand Aging Field Experiment

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Submitted to Session (please mark one):

- ○ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- ● 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ○ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- ○ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- ○ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- ○ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- ○ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Overview of the desired parameters to be measured during the field study.
- Description of instrumentation being considered/evaluated for use.
- Evaluation of data acquisition systems being considered for use, to include wireless sensors and cable-based monitoring systems.
- Integration of wireless sensors with instrumentation.

Abstract/Summary

As part of the NEESR project "NEESR – II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands", a field study will be performed which involves the induction of liquefaction in a loose, saturated, clean sand deposit via explosives, a vibroflot, and a NEES vibroseis. Subsequent to the induction of liquefaction, the time-dependent changes, commonly referred to as "aging," in the state and properties of the liquefied sand will be monitored for months to years. Central to the field study is the monitoring and measurement of various parameters before, during, and after the induction of liquefaction. In the following we discuss the site characterization tests that will be performed, as well as the sensors and instrumentation that we are currently evaluating for use in the field study.

Having an accurate picture of site conditions prior to the induction of liquefaction is essential to understand/interpret the post-liquefaction changes in state and properties of the sand. Using the vision cone penetration test (VisCPT) and the dilatometer test (DMT), we will quantify the site's pre-liquefaction strength in a manner that will easily allow for future comparisons. Tests

immediately following liquefaction and throughout the duration of the project will provide data that will allow time dependent property changes to be interpreted.

During and subsequent to the induction of liquefaction, we will measure accelerations, settlements, and pore water pressures. The acceleration measurements will allow correlations to be developed with excess pore pressure generation and will also provide a means of calculating the energy dissipated in the soil and its influence, if any, on aging effects. We are currently evaluating both piezoelectric and micro-electro-mechanical systems (MEMS) accelerometers. The evaluation is focusing on the accelerometer’s durability (especially a concern during emplacement and during the explosive compaction), and frequency range. We expect that both piezoelectric and MEMS accelerometers will be useful for different aspects of the field experiment (in addition to other factors, piezoelectric accelerometers are a factor of 10 more expensive than the MEMS accelerometers). Sondex settlement tubes will be used to measure post-liquefaction settlement as a function of depth, which is anticipated to be time-dependent. Pore pressure measurements will be taken both during and subsequent to the induction of liquefaction -- one purpose of which is to ensure that liquefaction is indeed induced and hence, there is a complete disruption of the soil fabric. The pore pressure transducers will be placed throughout the site, so we can monitor the spatial generation and dissipation of pore pressure. We are currently evaluating Sensotec, Inc. pore water pressure transducers that will be inserted into cones-tips developed by Dr. Kyle Rollins, Brigham Young University.

Duration of measurement and sampling rate vary with the proposed method of inducing liquefaction and the parameter being measured. For acceleration, vibroseis and vibroflot ease the selection of sampling rate and duration because their frequency and duration are controlled. We will sample at a frequency ten times to the input frequency to completely define the wave functions and measure acceleration as long as the machines run. Blasting generally produces high acceleration and frequency during explosive compaction, so we will sample the data at a rate of 5000 Hz for a duration of 10-15 seconds to ensure definition. In blast-induced liquefaction, pore water pressure is almost instantaneously increased by compression waves generated from the explosion, but, because its dissipation is a slow process, we plan to use a sampling rate of 1 Hz for a duration of several hours for each of the liquefaction generation methods. This sampling rate will not only give us good definition of the pore pressure generation, but also will ensure that the data acquisition system’s memory is not over taxed by an excessive amount of data.

We are currently evaluating two data acquisition systems, with the plan being that both will be used to collect different types of measurements. The first acquisition system is a series of wireless sensors that are being integrated with the MEMS accelerometers and pore pressure transducers. The wireless sensors being evaluated were developed at the University of Michigan. The wireless sensors are primarily constructed from commercial off-the-shelf embedded system components (see Figure 1) and perform analog-to-digital conversion, data aggregation, data processing, and wireless transmission of the raw and/or processed data to a laptop. The analog-to-digital converter (ADC) used in the sensor has a resolution of 16-bits and is capable of sampling as high as 100 kHz. The ADC is controlled by the wireless sensing unit's 8-bit Atmel ATmega128 microcontroller. With 128 kB read only memory (ROM), the ATmega128 can have many different algorithms embedded for execution. The microcontroller has an insufficient amount of random access memory (RAM) for data storage. In response to this limitation, 128 kB of off-chip RAM is included in the design of the wireless sensing unit computational core. After the data has been obtained by the microcontroller, the data is readied for transmission on the wireless channel. The Maxstream 9XCite wireless transceiver is integrated with the wireless sensing unit architecture. This 900 MHz radio can communicate up to 300 m line-of-site with an over-the-air data rate of 38.4 Kbps, with the data being transmitted to a laptop computer. We are currently evaluating the ability of the wireless sensor to transmit signals through the soil, which would alleviate the need to have wireless sensor units on the soil surface with cables connecting them to the buried accelerometers and pore pressure transducers.

The second data acquisition system being evaluated is a tethered monitoring system by Olson Instruments, Inc. The Freedom Data Acquisition System PC uses SHM Version 2.1 software and has 16 channels. The system has proven reliable at sampling rates ranging from 1 to 7000 Hz. The maximum duration of testing is dependent on sampling rate and available memory, but the system's 20 GB hard drive will support all of the tests we plan to execute. Data acquisition is accomplished using National Instruments 1.25 MS/s, 16 channel PCI Data Acquisition Card. Presently, we are working with Olson Instruments, Inc. to debug their data acquisition software and to perform comparisons with data acquired by the wireless and Olson systems (see Figure 2). At present, it is planned that both acquisition systems will be used in the field study, sampling data at different rates.

Figure 1. Fully assembled wireless sensing unit prototype developed at the University of Michigan by Professor Jerry Lynch (battery and external container not shown for clarity).

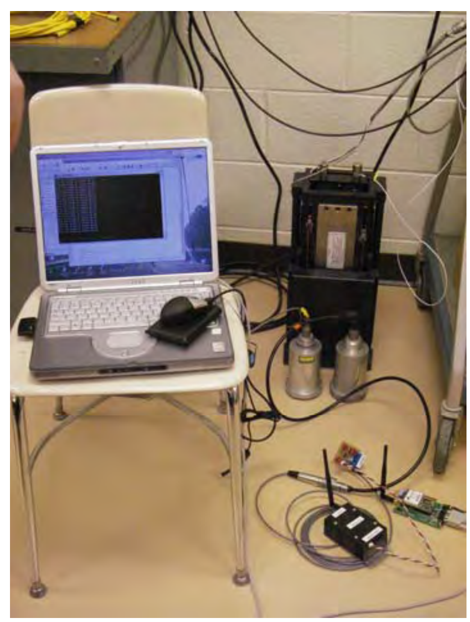

Figure 2. Test setup designed to compare the data acquired using the wireless and Olson systems. In this setup, geophones are being used to measure vibrations generated by a vibrator (Olson system not visible in photo).

Advanced Tools Breakout Session 3: Numerical Simulations

NEES

Wednesday, June 21, 2006

4:30 – 6:00 pm

Advanced Tools Concurrent Breakout Session 3: Numerical Simulations *(Van Buren Room)*

Session Chair: **Gregory Fenves**, University of California, Berkeley

VEES -- An XML-Driven Visualization and Development Environment
Alisa Neeman, University of California, Santa Cruz

Hybrid Simulation Evaluation of the Suspended Zipper Braced Frame
Tony Yang, University of California, Berkeley

Fiber Based Simulation of Rectangular Concrete Walls
Jonathan Waugh, Iowa State University

GrdVis: A Visualization and Data Analysis System
Daniel Kuchma, University of Illinois Urbana-Champaign

OpenSees Design Environment (ODEn)
Alisa Neeman, University of California, Santa Cruz

NEES

VEES - an XML-Driven Visualization and Development Environment

Submitted By:

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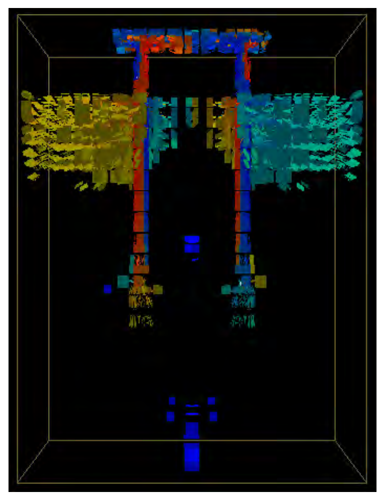
Submitted to Session (please mark one):

❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
✠ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
❍ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
❍ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- VEES: XML-based visualization system that works with OpenSees
- Open source, object-oriented and platform-independent solution
- Local or remote visualization
- Synchronous or asynchronous visualization
- Pluggable addition of element and material types
- Per-element visualization
- Pluggable addition of visualization techniques
- Prototype available through NEESforge



Bridge Bent Pushover, colored by stress isotropy, with thresholding

Abstract/Summary

There is a great need for a comprehensible visual interface to computer simulations. Visualization proves very useful in detecting patterns of behavior, assessing state, and prioritizing changes in configuration (shape) and constitution (material) of infrastructure objects. Engineers need visualization tools to explore ``what if'' scenarios and examine data (numerical or experimental) under multiple perspectives and assumptions.

We present a visualization system, VEES (Visualization for Earthquake Engineering System) that is designed to enable rapid iteration through the design-simulate-analyze-design cycle. In

addition to pre- and post-processing, visualization can occur synchronously with the simulation; both local and/or remote visualizations are possible. Interactive steering, where simulation and visualization occurs simultaneously, is particularly useful in catching flaws, saving on expensive computation time, and allowing the user to refine the design (of purely numerical and/or hybrid) models. VEES uses XML as a communication language between the finite element simulator and interactive visual display. Models are also defined using XML, which provides a human-readable format that is both self-documenting and self-validating. The language data type (text, rather than binary) is platform independent. This facilitates long-term storage and re-use of models. In this talk we will describe the object-oriented design of VEES and its use in partnership with the OpenSees simulator. VEES is available through NEESforge service at http://neesforge.nees.org/projects/vees/.

VEES is built of three modules. The first part is **OpenSees** (Open System for Earthquake Engineering Simulation), itself. We have added functionality so that objects in OpenSees can print their instance data as XML. Calling `printXMLModel` on an OpenSees Domain object causes a printout of Nodes, Materials, and Elements. The second module is the **DomainBuilder**. The DomainBuilder parses an XML document and builds a replica of the Domain instance. Naturally, the DomainBuilder can run on a separate compute node or machine. The third module is **VEES**, the visualization module. It receives a Domain instance from the DomainBuilder, and wraps it in a viewing object that has direct access to the Domain's structure, constitution, and state.

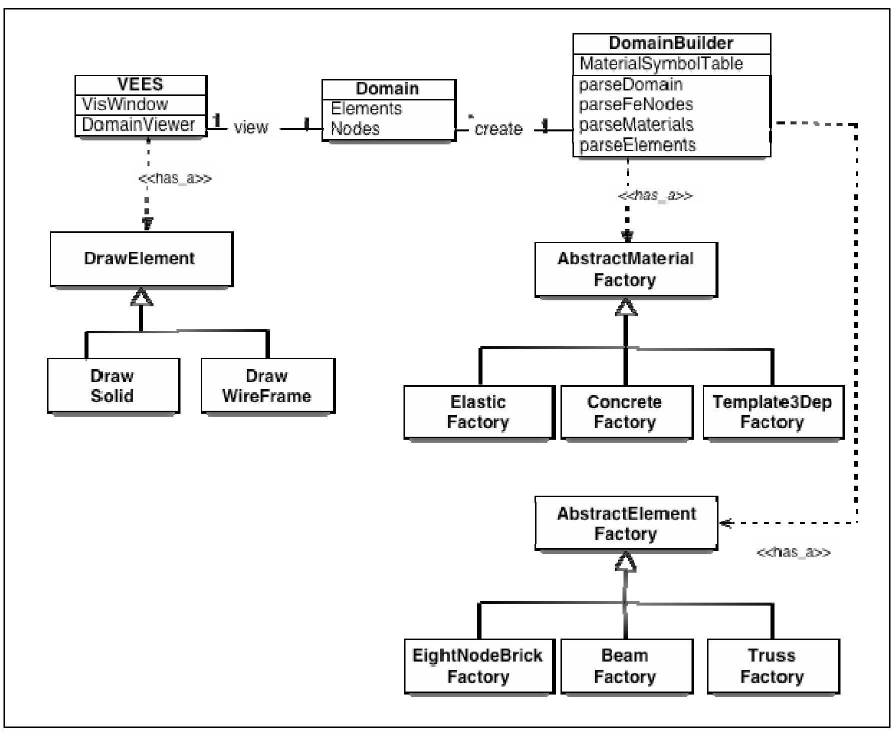


Figure 1. Class Diagram of VEES and DomainBuilder Modules

The DomainBuilder project starts with an XML Schema, a metadata description of finite elements and materials. Each element is described in terms of the parameters needed to create it. For an eight node brick this means a list of nodes, body forces, rho, pressure and an ND material.

The DomainBuilder uses the Xerces open source library to read the entire XML document into memory as a tree structure. From there, branches of the tree, such as those containing Material objects, can be retrieved. The elegance of the DomainBuilder lies in taking each Material, deciphering its type, and building the custom material. The idea is that for each material type we have a specific material *factory*, [1] whose job is to parse the parameters and call the constructor to create a new instance. In order to decide which material type to create, the XML leaf contains a class tag with a unique number identifying the material. Using a lookup table, we can quickly retrieve the material's factory, pass the XML to it, and a new instance is manufactured. Elements are treated similarly. This design makes it very easy to add new materials and element types. One simply has to create a new factory object to parse the XML, and add it to the lookup table.

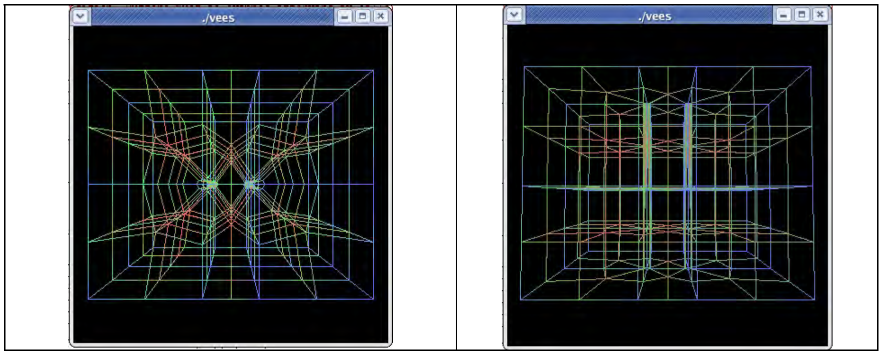


Figure 2. Small OpenSees Domain viewed in VEES

VEES is composed in three layers. The top layer is the GUI (graphical user interface) that responds to mouse clicks and key presses. The middle layer (VisWindow) controls the view with zooming, rotating etc. The third layer is the DomainViewer, which wraps an OpenSees Domain object. Every finite element is assigned a DrawElement object which defines how to draw it – as a solid or wire frame, displaced, whether to draw nodes or gauss points, etc. The user can threshold the range of values (as shown in the image on the first page) to highlight the most interesting data. The pluggable architecture means that it is very simple to add new, experimental drawing modules.

Future Work

VEES provides a solid basis from which to pursue new visualization approaches. Stress, strain, constitutive relations and damage measures (among others) provide ample challenges in showing meaningful views of simulation results. We also believe VEES will prove useful for visualizing experimental results, which can easily be converted to XML format. Further, while VEES has begun as a platform for experimental visualization techniques, we also believe it holds promise for use in hybrid testing. We envision two instances of VEES running side-by-side, one receiving data from a simulation and the other, from remote experimentation. Results could be compared immediately, enhancing understanding of the physics of various phenomena.

[1] Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, *Design Patterns: Elements of Reusable Object-Oriented Software* Reading, Massachusetts: Addison-Wesley, 1995

Analytical Simulations of the Suspended Zipper Frames

Submitted By:

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Submitted to Session:

Advanced Tools Session: ***Numerical Simulations of NEES Data***

Major points/topics:

- Simulations of the quasi-static tests for the suspended zipper frames conducted at Georgia Institute of Technology.
- Simulations of the shake table tests for the suspended zipper frames conducted at the University at Buffalo.
- Simulations of the hybrid simulation tests for the suspended zipper frames conducted at the University of Colorado at Boulder.
- Simulations of the hybrid simulation tests for the suspended zipper frames conducted at the University of California, Berkeley.

Abstract/Summary

This paper presents the analytical simulations of a 1/3-scaled suspended zipper frame prototype model that was tested under different experimental testing programs. The 1/3-scaled in-plan three-story prototype model was tested quasi-statically at the Georgia Institute of Technology (GT) and dynamically at the University at Buffalo (UB) NEES equipment site shaking table. In addition, the first story Chevron brace sub-assembly was tested with hybrid simulation testing method at the fast hybrid testing laboratory at University of Colorado at Boulder (UC) and at the nees@berkeley laboratory at University of California, Berkeley (UCB).

At Georgia Institute of Technology, the displacement loading history applied at the floor levels were obtained from a set of preliminary analytical simulations. The analytical simulation used the Open System for Earthquake Engineering Simulation (OpenSees) to model the system response of the suspended zipper frame. The analytical model consisted of a two- dimensional, three-story, 1/3-scaled suspended zipper frame, where the element response was modeled using the force beam column element in OpenSees. To properly model the buckling response of the brace, a slight imperfection is modeled at the mid-span of the brace and the boundary condition of the brace was modeled using rotational springs at the end of the braces.

After the experiments have been conducted, the parameter of the analytical model was adjusted. The yielding strength of the beams and columns was increased to R_yF_y, 55 ksi, instead of 50 ksi (R_y is 1.1 for A572 Gr. 50 steel), while the yielding strength of the brace and zipper struts was increased to 62 ksi rather than 46 ksi where R_y was set as 1.35 for A500 Gr. B steel, a little higher than the value 1.3 specified in the AISC Seismic Provisions. The initial imperfection ratios were increased to $L_w/300$ for the braces, where L_w denotes the distance between the working points. The end rotation spring stiffness for the braces was decreased to 500 in-kip/rad.

The comparisons between the experimental results and analytical simulation indicate that the analytical model can predict the behavior of the suspended zipper frame well until the brace starts to tear. This show with the current way of modeling the brace can not simulate the reduction of the brace cross-section after the brace tears. As for the yielding and initial buckling strength, the analytical results are in good agreement with the experimental data. The analytical results confirmed the experimental observation that the initial buckling strength of a brace subjected to tension first is smaller than the brace subjected to compression first. Furthermore, a three-dimensional model was established to simulate the out-of-plane buckling of the braces. There are two major differences between theses two analytical models. First, the initial imperfection for the three-dimension model is assigned in the out-of-plane direction, while the initial imperfection for the two-dimensional model is assigned in the in-plane direction. Second, the boundary condition for the three-dimension model is modeled as pin-pin, while rotation springs were used to model the boundary condition of the two-dimensional model. Comparisons between the simulation and experimental results indicate the three-dimension model can predict the trends of the trajectories but not the magnitude of the displacements.

At the University at Buffalo, the most important advantage of a shaking table test is its total independence of numerical models. It is then a good way to prove the accuracy of any analytical simulation. Before testing, an ideal model was built to predict some of the shaking table test results. The ideal model had hinge connections between braces and beams and between beams and columns. The model was subjected to the recorded base acceleration and the sequence of the tests was recreated. The braces show an enormous axial deformation and a very small compression capacity after buckling, therefore the zipper column carries a big tension force and the second story braces also buckle heavily. Results from actual test show, however, that the braces did not experience such big deformations; therefore the predicted and observed mechanisms are very different. In the specimen, the connections did transmit moments from braces to beams and from beams to columns. This example shows the importance of having a good analytical model when shaking table test is not available. Also, the fact that the braces buckled out of plane and its consequent torsion in the beam cannot be captured by a two-dimensional model. Efforts have been made by other sites to build better two-dimensional models. Those models were also subjected to the shaking table test sequence. The behavior is, in general, much closer to the test results. Details will be presented in the paper.

At the University of Colorado at Boulder, a series of numerical simulations was conducted to obtain an analytical model for the three-story suspended zipper frame. The analytical model uses OpenSees to model the response of the suspended zipper frame. The parameters of the analytical model was initially calibrated using the results of shake table tests conducted at University at Buffalo and then fine tuned with initial hybrid simulation tests conducted at the University of Colorado, Boulder. The tuning of the model involved the investigation of the influence of the loading history, the damping formulation, the material properties, the initial imperfection, the modeling of the structural mass, and the connection stiffness of the braces on the numerical results.

The analytical model was subjected to a sequence of six base motion time histories that were recorded during the shaking table test conducted at University at Buffalo. The analytical simulation accounted for the cumulative damage developed in the sequential excitations. The damping of the structure was modeled with Rayleigh damping, however, different combination of mass and stiffness proportional damping was studied.

The material property was modeled with the Menegotto–Pinto model that was calibrated to match the coupon tests conducted at University at Buffalo. The geometric nonlinearity was accounted using the corotational transformation in OpenSees and initial imperfection that was introduced at the mid-span of each brace. For the initial tests, the brace-to-gusset plate connections were considered pinned.

The analytical model was modified to conduct the hybrid simulation tests, where the first story Chevron brace sub-assembly was replaced with physical elements in the laboratory. The table acceleration recorded during the shaking table test conducted at University at Buffalo was used as the input motion to the hybrid simulation model. The hysteretic behavior of the first story braces was used to fine tune the analytical brace model. The refined analytical brace was then used for the second and third story braces in the next hybrid simulation test. The final model included a slightly lower damping coefficient for the stiffness proportional damping and rotational springs to account for the flexibility of the gusset plates at the ends of the braces. Additionally, the initial offset at the mid-span of the brace was altered and the material model was re-calibrated with the brace behavior obtained in the tests. The test results from the fourth specimen show good correlation to the numerical simulation results up to the fracture of a brace in the specimen which was not modeled in the analysis.

At University of California, Berkeley, a quasi-static test has been conducted to calibrate the brace hysteresis model developed in OpenSees. A Chevron brace sub-assembly with controlled and well-know boundary condition was tested using a quasi-static incrementally increasing symmetric displacement history. The results of the quasi-static test were used to calibrate the OpenSees analytical element to recapture the brace hysteresis of the Chevron brace sub-assembly.

The analytical model used to replicate the brace hysteresis, is a two-dimensional (in-plane) OpenSees model. Even though the buckling phenomenal happens in three dimensions, the brace hysteresis only accounts the brace axial force and axial deformation in the direction between the two ends of the brace. Since both ends of the brace stay in plane, the hysteresis of the brace can be modeled using a two-dimensional OpenSees model.

The analytical model uses a fiber sections with uniaxial Menegotto-Pinto steel material to model the cross sections of the braces. Each brace was modeled using two flexibility-formulation nonlinear beam-column elements, with five fiber cross sections along the length of each element.

Geometric imperfection of the brace was modeled using a slight misalignment of the middle node of each brace. The corotational transformation was used to capture the second-order geometry effects. To account for the rotational stiffness at the ends of the braces, three zero-length elements were used to model the gusset plate. Two rigid springs (elastic material with high stiffness) were used to restrain the translation degrees of freedom while the rotational degree of freedom is modeled using an elastic spring whose stiffness is calibrated to match the quasi-static test data.

The results of the quasi-static test and the analytical simulation shows with the appropriate selection of initial imperfection, rotational spring stiffness and the material properties used in the analytical model, the flexibility-formulation nonlinear beam-column element in OpenSees can be used to model the hysteresis behavior of the Chevron brace sub-assembly very well.

Fiber Based Simulation of Rectangular Concrete Walls

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Submitted to Session (please mark one):

μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
● 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- The fiber-based concept can be used to accurately simulate rectangular concrete wall behavior if all deformation components are accurately accounted for
- Recent additions to OpenSees have improved the accuracy of the simulation
- The behavior can be captured at the element level force-displacement response and the local level strain profile

Abstract/Summary

1. Introduction

Researchers at the University of Minnesota (UMN), Iowa State University (ISU), the University of Puerto Rico at Mayaguez, and a consulting engineer from the Nakaki Bashaw Group, Inc. in California have undertaken a collaborative PreNEESR project with financial support from the National Science Foundation (NSF). As part of this project, three rectangular walls will be tested in March – April of 2006 at the NEES Multi-Axial Subassemblage Testing (MAST) facility at UMN. Presented in this abstract is how the researchers advanced capabilities of OpenSees [1] to improve numerical simulation of the rectangular concrete wall behavior.

The objectives of the rectangular wall tests are: to check the adequacy of the design codes, validation and improvement of the existing analysis capabilities to predict the lateral load behavior of walls, to understand the interaction between the shear and flexure and the influence of using splices and the couplers in the plastic hinge region of concrete walls

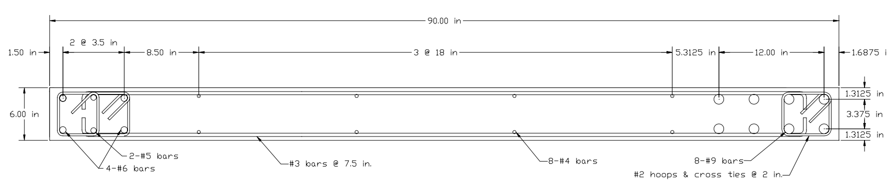

Figure 1a: Wall RW-N Cross-Section

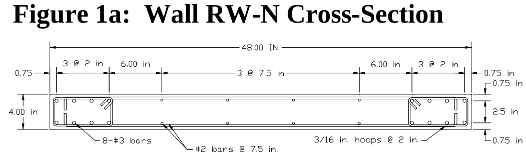

Figure 1b: Wall RW2 Cross-Section

Two analytic models are discussed and compared with the measured experimental response for two different walls. The first wall is the second of two rectangular walls tested by Thomsen and Wallace [2]; it is referred to as RW2. RW2 was a ¼-scale specimen of a four-story tall wall in a six-story office building, and measured 144 in. tall by 48 in. long by 4 in. thick. The transverse hoops in the boundary element were tightly spaced at 2 in. on center (o.c.) over the entire height of the wall, the close spacing for the transverse reinforcement was used to prevent buckling of the longitudinal reinforcement and promote failure of the specimen through crushing of the confined concrete. The second wall is the first of the three walls that are part of the PreNEESR project; referred to as RW-N. RW-N is 254 in. tall by 90 in. long, by 6 in. thick. The transverse hoops in the boundary elements are spaced at 2 in. o.c. and are provided over the bottom 90 inches of the wall. The wall is designed adequately to prevent shear failure and the longitudinal bars are anchored sufficiently into the pedestal at the base of the wall. Reinforcement details for RW2 and RW-N are shown in Fig: 1

2. Improvements to Analytical Capabilities

The existing capabilities of OpenSees were determined by modeling both RW2 and the second of two T-walls tested by Thomsen and Wallace, referred to as TW2. TW2 was 144 in. tall with a 48 in. flange and 48 in. web; both the flange and the web were 4 in. thick. The simulation of TW2 and RW2 revealed the needed improvements in OpenSees to accurately simulate the cyclic response of concrete walls. The two most critical improvements that were required for accurate simulation of the rectangular walls were the inclusion of the effects of strain penetration at the wall-to-foundation interface, and improvement to the cyclic concrete material model.

The strain penetration effects at the interface of the wall and the foundation block required that a relationship between the bar stress and the corresponding local bar slip at the interface resulting from penetration effects be developed. As described by by Zhao and Sritharan [3], this task was achieved and the capability was introduced to OpenSees using a zero-length interface element. The interface element provides additional flexibility to the force-displacement response that is associated with the strain penetration effects. The strain penetration effects lower the strains and curvature in the critical sections at a given displacement level. The predicted strains and curvatures, which indicate the damage in the plastic hinge regions, are significantly overestimated when the strain penetration effects are ignored.

The concrete models available in OpenSees did not address the problem of the wedging of the debris in the cracks that form after cracking. This phenomenon is responsible for compressive stress to be developed before completely closing the flexural cracks. Figure 2 shows RW2 simulated using the concrete models available in OpenSees. The effects of wedging of debris in the cracks are seen in the circled region. The concrete models do not adequately capture the unloading and reloading stiffness of the wall a high displacement levels. One concrete model that addresses this phenomenon is the model proposed by Chang and Mander [4]. The Chang and Mander concrete model simulates the uniaxial behavior of confined concrete, which is appropriate for use in a fiber-based analysis, discussed later. Other benefits of using the Chang and Mander model are: 1) it can be implemented without using a specific set of units, which make it attractive for use in OpenSees, 2) it has been validated using cyclic tension tests, unconfined cyclic compression tests, and confined cyclic compression tests conducted by a number of researchers.

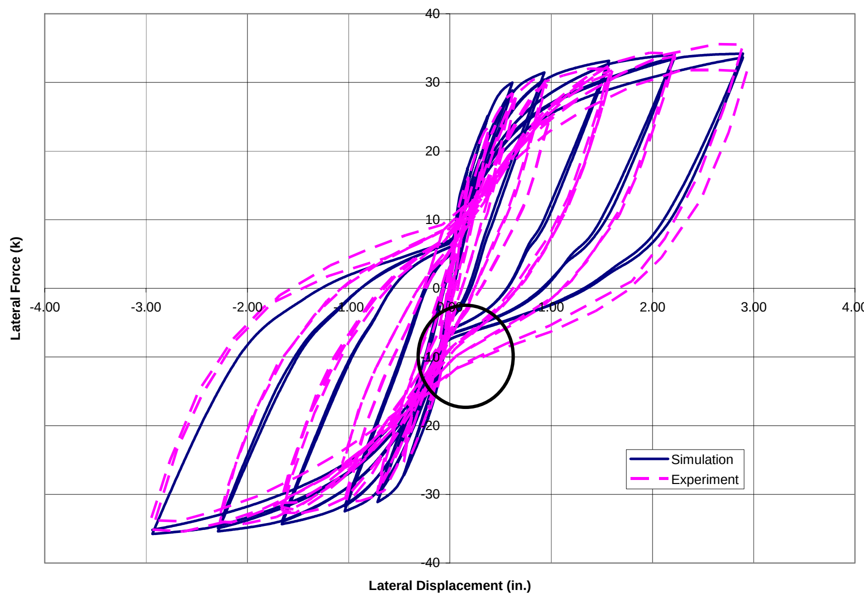

Figure 2: RW2 Cyclic Response Simulation

3. Description of Analytical Model

The rectangular walls were modeled using a beam-column element that uses iterative force formulation and considers the spread of plasticity along the length of the element. The development of the element is presented by Taucer, Spacone, and Fillippou (1991). This element is superior to the typical beam-column based on a cubic displacement shape function because a cubic displacement function forces the curvature to vary linearly along the element length.

The wall cross-section is discretized as a group of uniaxial fibers; this approach uses the uniaxial stress-strain relationships for both the concrete and the steel reinforcement. Consequently, this approach becomes computationally efficient while allowing various concrete regions and steel reinforcement to be modeled discretely. The increase in strength and ductility due to the confinement can be included for the various regions of the cross sections, depending on the details of the transverse reinforcement. The Chang and Mander concrete model discussed previously was used for both the confined and unconfined regions. The steel reinforcement stress-strain relationship was represented using a modified Mennegotto-Pinto function [1] that includes isotropic strain hardening.

A zero-length interface element, as discussed earlier, was used to capture the strain penetration effects. The interface element had the same fiber discretation as the wall; however, the strain penetration material was used in place of the steel reinforcement material. This element provides the additional flexibility, as was described previously. This approach to modeling the walls simplified the input and required only the values of engineering properties. Another approach to modeling RW2 was used by Orakcal, Wallace, and Conte (2004). Orakcal, Wallace, and Conte used a multiple-vertical-line-element model (MVLEM) to simulate the response of the rectangular wall RW2.

4. Results

The Chang and Mander concrete model is in the process of being implemented into OpenSees. Simulation of the monotonic and cyclic response will be conducted and compared with the experimental results. The simulation of the monotonic and cyclic response of RW-N will also be compared to the experimental results as soon as they are available. The comparisons of the simulated responses to the observed experimental responses will be presented at the NEES Annual Meeting.

Because of the capabilities of the NEEs MAST lab, the various components of the wall's response can be captured separately and compared to the simulated response. Comparing the contributions of the response components will give a better understanding of the accuracy of the simulation by removing the possibility of compensating errors.

5. Conclusions

The improvements made to OpenSees that were outlined in section 2 will allow the cyclic response of the rectangular walls to be predicted accurately. Both the global level force-displacement response and the local response that reflects the structural damage were accurately captured by the simulation. The approach taken to the modeling of the walls for analysis requires nothing beyond standard engineering properties, which can be determined by testing. By using a fiber approach in modeling the wall, the analytical model is computationally efficient without sacrificing accuracy of the results. The NEES infrastructure greatly assists with development of needed test data in a methodical and accurate manner, which improves validation of the modeling approach, ultimately improving the analytical simulation capabilities.

6 References

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2. Thomsen, J.H., and Wallace, J.W., "Displacement Based Design of RC Structural Walls: An Experimental Investigation of Walls with Rectangular and T-Shaped Cross-Sections," *Report to the National Science Foundation*, Department of Civil Engineering, Clarkson University, Potsdam, New York, 1995.
3. Zhao, J., and Sritharan, S., "Modeling Strain Penetration Effects in Reinforced Concrete Walls and Columns," In Progress.
4. Chang, G.A., and Mander, J.B., "Seismic Energy Based Fatigue Damage Analysis of Bridge Columns: Part 1 – Evaluation of Seismic Capacity," *NCEER Technical Report* No. NCEER-94-0006, State University of New York, Buffalo, N.Y., 1994.
5. Taucer, F.F., Spacone, E., and Filippou, F.C., "A Fiber Beam-Column Element For Seismic Response Analysis of Reinforced Concrete Structures," *Report to the National Science Foundation and the California Department of Transportation*, Earthquake Engineering Research Center, University of California, Berkeley, California, December 1991.
6. Orakcal, K., Wallace, J.W., and Conte, J.P., "Nonlinear Modeling and Analysis of Slender Reinforced Concrete Walls," *ACI Structural Journal*, American Concrete Institute, Vol. 101, No. 5, pp. 688-698, September-October 2004.

GrdVis: A Visualization and Data Analysis System

Submitted By:

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Submitted to Session (please mark one):

- µ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- µ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ● 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- µ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- µ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- µ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- µ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Developed an integrated visualization and data analysis system for viewing experimental data collected by the MUST-SIM advanced and traditional measurement systems.

Abstract/Summary

The use of advanced measurement systems in combination with traditional measurement systems and photographic images provide a very large amount of information about the experimental response of structures. Unfortunately, there has never been a visualization tool that allows a researcher to fully understand and compare the recorded information from all of these measurement sources. A prototype visualization tool was developed for both data visualization and analysis of experimental data collected using MUST-SIM advanced and traditional measurement systems as explained below.

The MUST-SIM facility utilizes non-contact measurement systems as well as traditional displacement transducers, strain gages, and photographs to record the experimental response of structures. During the development phase of MUST-SIM, some of these systems were evaluated through their use on a series of large experiments on structural concrete. In each of these experiments, over 300 MB of numerical data and 700 MB of pictures and video were acquired. The multiplicity of measurement sources increased the difficulty in data reduction, synchronization, and review. To better understand the test data, an integrated visualization system named GrdVis was developed which enables the results from multiple data sources to be displaced and provides a convenient and complete environment for data analysis. Figure 1 shows a screen shot of the user interface. GrdVis has three windows, avisualization window, a data window and an output window. The visualization window displays the structure elements and instruments, the data window displays data curves, and the output window shows numerical

results. GrdVis also provides many operations for exploring, manipulating and analyzing the mixed data.

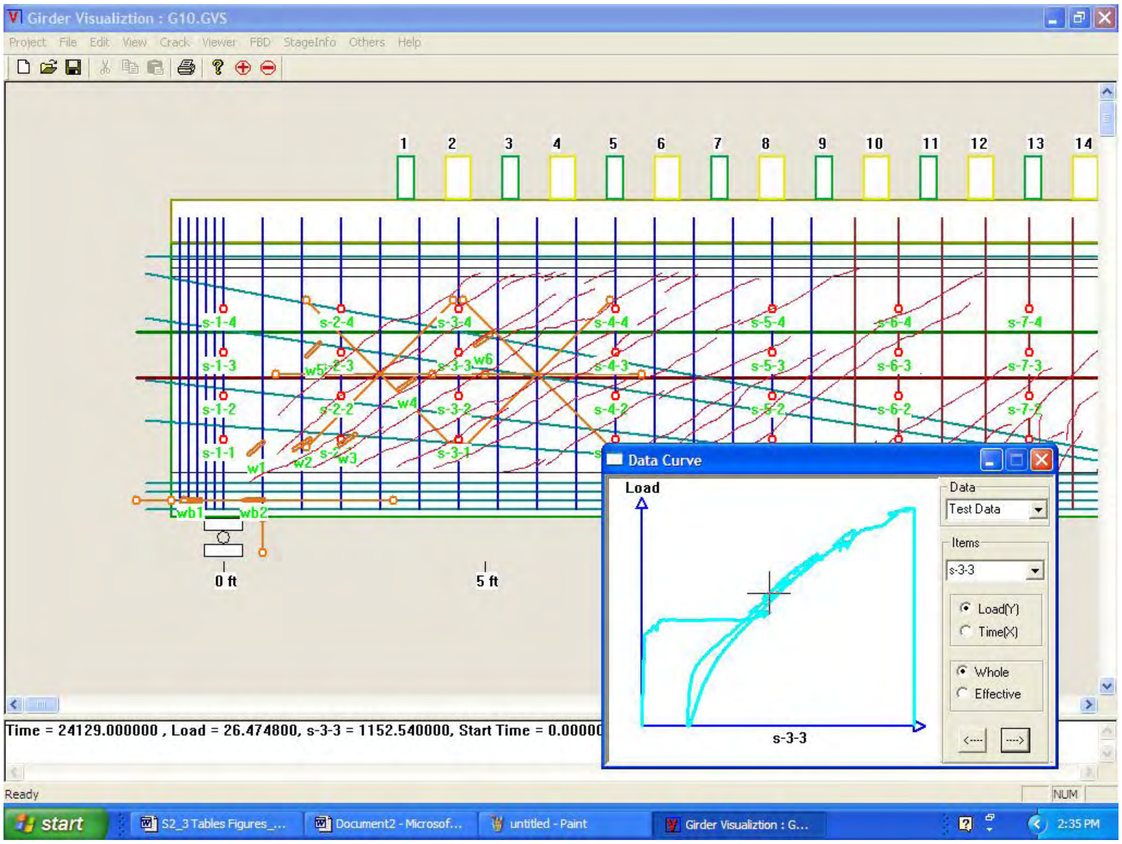
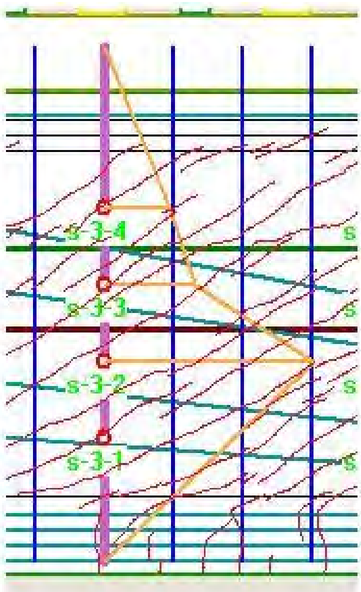


Figure 1: GrdVis Tool Interface

To produce the crack patterns, close range digital photogrammetry and image analysis methods were used to precisely identify crack locations. Through time stamping of these images, it was possible to develop an interface that allows the user of the visualization tool to advance through the loading history of the test structure and see the development of cracking. The user can choose to see any of the other measured values during the loading history overlaid on top of the crack pattern. For example, the user may wish to see the development of straining along a reinforcing bar. By choosing a particular reinforcing bar, the development of straining in this bar over the loading history can be shown as superimposed on the crack pattern. See Figure 2.

One of the advanced measurement systems available in MUST-SIM is the Krypton Measurement System that can be used to measure the coordinates (x,y,z) of up to 256 LED targets in 3-dimensional space to an accuracy of a little better than 0.001 inch (0.025 mm). By distributing these targets over a grid, see Figure 3, the accuracy of the Krypton system makes it possible to determine the distribution of strains in any direction of interest. The GrdVis program was written to take advantage of this information within selected free body diagrams to evaluate components of resistance to member capacity. See Figure 4.



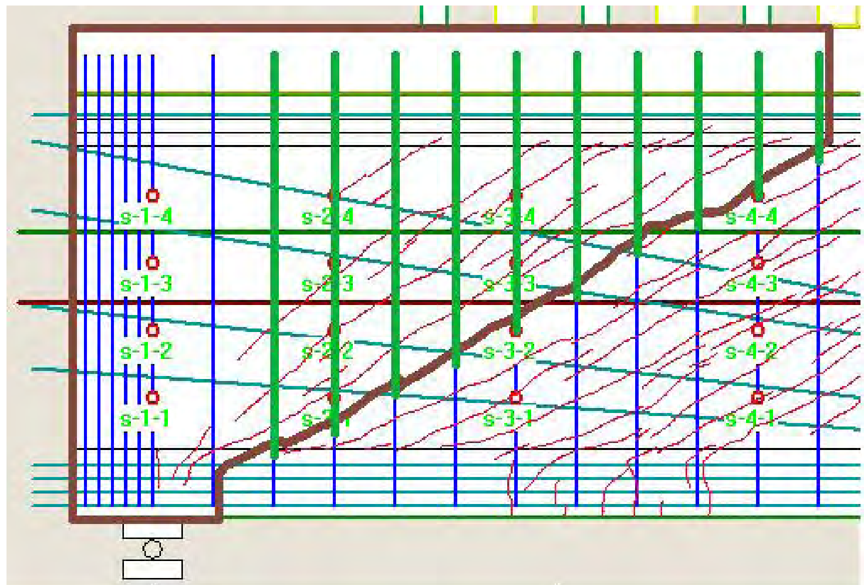


Figure 2: GrdVis for Display of Selected Strain Gage Readings

Figure 4: Use of GrdVis for Evaluation of Components of Resistance

Figure 3: Distribution of Krypton LED Targets in Grid on Test Structure

OpenSees Design Environment (ODEn)

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Submitted to Session (please mark one):

µ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
µ 2. Advanced Tools Session: ***Sensors and Instrumentation***
µ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
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Major points/topics:

- ODEn allows Visualization, Design, and modification of properties for OpenSees domains and objects (such as choosing materials for elements) using an intuitive Graphical User Interface (GUI)
- ODEn saves an OpenSees Domains in W3C compliant XML documents
- ODEn validates XML OpenSees domain models against the OpenSees Schema
- ODEn allows importing models from meshing applications (such as Abaqus)
- ODEn generates OpenSees main input and data file source code (C++)
- ODEn is available (open source) at http://neesforge.nees.org/projects/vees/

Abstract/Summary

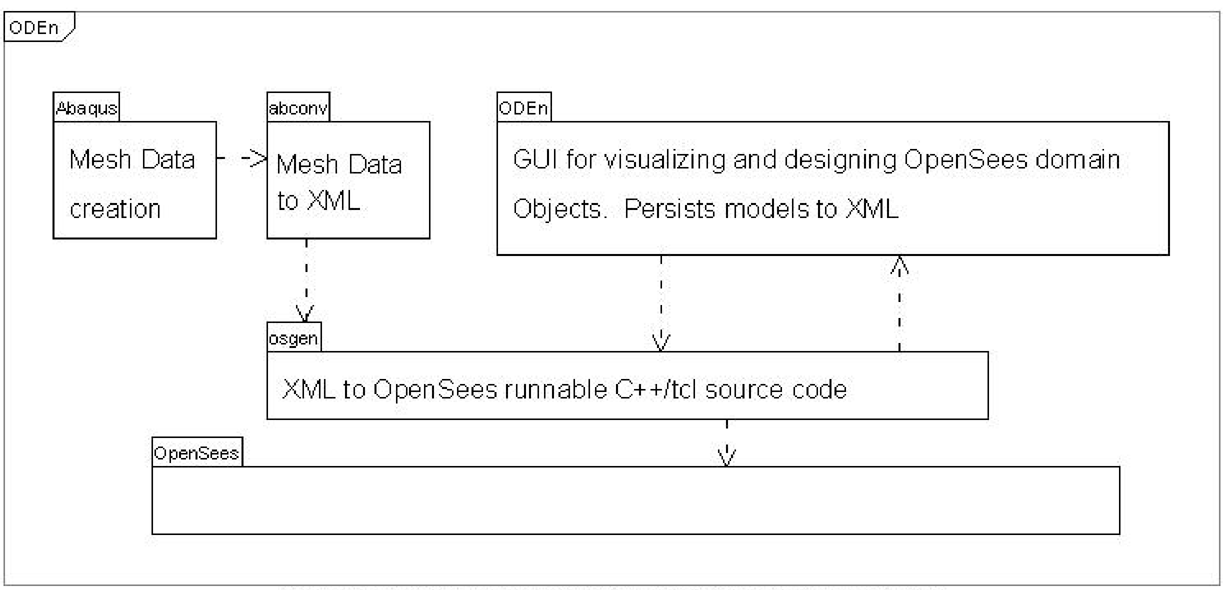
Creation of OpenSees models is traditionally done by hand-coding source, such as C++ or tcl, or transforming data from other applications so it can be run by OpenSees. These manual processes are quite cumbersome and increase the frequency of user error. Automatic code generation provides a means to hasten design time and reduce user errors, increasing OpenSees usability and accessibility. Additionally, a graphical picture of an OpenSees Domain provides an intuitive view of the data that assists the user with design decisions.

ODEn is designed to enable the viewing and manipulation of OpenSees Domain models (solid and structural elements) via an intuitive GUI and facilitates a more rapid design-generate-test-redesign cycle. ODEn has a *designer window* for viewing the OpenSees domain model and an *object inspector* to inspect and modify OpenSees objects. ODEn is implemented on top of multiple subsystems, each of which is used to handle specific language integration. Two such tools are *abconv*, which is used to import meshes from abaqus and convert them to XML, and *osgen* which is used to generate runnable OpenSees C++ code from within ODEn. The generator subsystem, *osgen*, allows for additional generators and/or translators to be registered, thus keeping the architecture open for the future. This still allows material model generators, including prescribing spatial distribution to be specified with ease.

Abconv is used to read abaqus mesh data and import that data into a simplified OpenSees XML document. This XML document can then be modified by ODEn for use within OpenSees. Within the GUI, the user can then begin adding properties to mesh elements. Elements are accessible through groups defined within the mesh, so a single property can be assigned to a large number of elements. For example, material properties such as elasticity/plasticity can be set for a large group of soil elements.

osgen takes as input an OpenSees XML document that it validates against the OpenSees XML Schema. This XML document represents a serialized OpenSees Domain and is used to generate runnable OpenSees source code automatically. Essentially, *osgen* acts like a compiler for the XML, where the output of the compilation is C++ source code. The generated source code can be used as is, or modified, before being executed by the OpenSees simulator (whichever the user desires).

The benefits of ODEn are its powerful capabilities of selecting finite elements such as EightNodeBrick, ElasticBeam3d, DispBeamColumn3d, etc. visually from within the designer window and modifying their properties. Properties for sets of elements may also be modified in a similar fashion. Materials are naturally an important part of the OpenSees model and are not neglected in ODEn. New, custom materials can be created and used just as any other material from within ODEn via an XML interface to OpenSees classes such as Template3Dep and FiberSection. These materials can be referenced from the appropriate finite elements.



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In this talk we describe the design and show how ODEn provides a simple to use, yet powerful, GUI interface for importing, modifying, and exporting new and/or existing OpenSees domain models. We describe planned future capabilities for ODEn including:

- Version Control Integration to version Domain XML documents
- Code generation plugins via ODEn API to generate alternate target output languages (such as tcl)
- Multi-platform GUI support

TAB 3

Day 2: June 22

NEES Showcase Day (Day Two)

Thursday June 22, 2006

Showcase Day Program At-A-Glance

Thursday June 22, 2006

7:00 – 8:00 a.m.	**Registration & Continental Breakfast** *(Salons C, D, & E)*
8:00 – 9:00 a.m.	**NEES Overview Session** *(Salons A & B)*
9:00 – 10:30 a.m.	**Active NEES Research Projects Spotlight I Plenary Session** *(Salons A & B)*
10:30 – 11:00 a.m.	**Break**
11:00 – 12:30 p.m.	**Active NEES Research Projects Spotlight II Plenary Session** *(Salons A & B)*
12:30 – 2:00 p.m.	**Luncheon** *(Washington Ballroom)*
12:30 – 2:00 p.m.	**Equipment Site Forum** Closed meeting. *(Van Buren Room**)*
2:00 – 3:30 p.m.	**New NEES Research Projects Spotlight I Plenary Session** *(Salons A & B)*
3:30 – 4:00 p.m.	**Break**
4:00 – 6:00 p.m.	**Concurrent Issue Forum Breakout Sessions** Three (3) concurrent breakout discussions, hosted by NEESinc's technical committees: ***Education, Outreach, and Training Committee Session*** *(Salon A)* ***IT Strategy Committee Session*** *(Salon B)* ***Site Operations Committee Session*** *(Van Buren Room)*
6:00 – 7:00 p.m.	**Reception** *(Lincoln Room)*
7:00 – 9:00 p.m.	**Banquet with NEESinc Business Meeting, polling, and awards presentation** *(Washington Ballroom)*

Session Descriptions

NEES Overview Session

The NEES Overview Session will feature presentations on the NEES Program from three different perspectives: from the sponsor's viewpoint (NSF), from the Consortium headquarters viewpoint (NEESinc), and from an Experimental Site's viewpoint (the NEES@UTexas Site).

NEES Research Program: Spotlights on Active and New NEESR Projects Sessions

This group of four plenary sessions (spread over two days) include presentations from investigators from NEES Research Program (NEESR) active and new projects. These brief spotlight will highlight activities that embody the ideals of the NEES: collaborative endeavors for project preparation, experimental and numerical simulations, data management/IT, involvement with engineering practice professionals, and educational, outreach, and training activities.

Issue Forums Concurrent Breakout Sessions

The Issue Forums sessions will feature group discussions on three separate topics selected by each of NEESinc's technical committees (the *EOT*, *IT Strategy*, and *Site Operations Committees*). The topics will be introduced in a plenary session, followed by group discussion during three concurrent breakout sessions. Each Issue Forum breakout group will be asked to provide a report on their discussions during a plenary session on the final day of the Annual Meeting.

Day Two: Thursday, June 22, 2006

7:00 – 8:00 am

Registration and Continental Breakfast *(Salon C + D+ E)*

8:00 – 9:00 am

NEES Overview Session *(Salon A+B)*

Session Chair: **Ian Buckle**, University of Nevada, Reno *(NEESinc President)*

A National Science Foundation Perspective on NEES
Joy Pauschke, National Science Foundation

A Consortium-Level Perspective on NEES
Clifford Roblee, NEES Consortium, Inc.

A Research Site Perspective on NEES
Kenneth Stokoe, II, University of Texas, Austin

9:00 – 10:30 am

NEESR Active Projects Spotlight Session I *(Salon A+B)*

Session Chair: **Joy Pauschke**, National Science Foundation

Large-Scale Tests of Structural Braces and the Validation of Micromechanical Ultra Low Cycle Fatigue Models
Amit Kanvinde, University of California, Davis

Self-Centering Steel Frame Systems
Richard Sause, Lehigh University

Tests of Zipper Frames
Roberto Leon, Georgia Institute of Technology

Earthquake Studies of a Two-Span Reinforced Concrete Bridge System with Varied Column Heights
Mehdi 'Said' Saiidi, University of Nevada, Reno

10:30 – 11:00 am

Break *(Salon C + D+ E)*

Day Two (con't): Thursday, June 22, 2006

11:00 am – 12:30 pm

NEESR Active Projects Spotlight Session 2 *(Salon A+B)*

***Session Chair:* Helmut Krawinkler**, Stanford University

Highly Damage-Tolerant and Intelligent Slab-Column Frame Systems Through Combination of Advanced Materials and Embedded Wireless Sensing
Gustavo Parra-Montesinos, University of Michigan

Dynamic Passive Procedures for Backfill Based on Full-Scale Pile Cap Testing (A NEESR Project)
Travis Gerber, Brigham Young University

Multi-Site Soil-Structure-Foundation Interaction Test (MISST)
Bill Spencer, University of Illinois Urbana-Champaign

A Database for Modeling Deterioration in Beams and Columns Subjected to Cyclic Bending Moments
Dimitrios Lignos, Stanford University

Full-Scale Testing of Polyethylene Pipelines at Fault Rupture
Michael O'Rourke and Thomas O'Rourke, Cornell University

12:30 – 2:00 pm (presentation at 1:30)

Luncheon with Presentation *(Washington Ballroom)*

Tsunami Reconnaissance Data Repository
Harry Yeh, Oregon State University

2:00 – 3:30 pm

NEESR New Projects Spotlight Session 1 *(Salon A+B)*

***Session Chair:* Robert Nigbor**, University of California, Los Angeles

Collaborative Study of Biaxial Seismic Response of Bridge Systems
Mehdi 'Said' Saiidi, University of Nevada, Reno

Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls
P. Benson Shing, University of California, San Diego

Seismic Simulation and Design of Bridge Columns Under Combined Actions, and Implications on System Response
Abdeldjelil "D.J." Belabi, University of Missouri-Rolla

NEESR-Grand Challenge: Seismic Risk Mitigation for Ports
Glenn Rix, Georgia Institute of Technology

Inelastic Web Crushing Performance Limits of High-Strength-Concrete Structural Walls
Rigoberto Burgueño, Michigan State University

NEES

Day Two (con't): Thursday, June 22, 2006

3:30 – 4:00 pm

Break *(Salon C + D+ E)*

4:00 – 6:00 pm

EOT Committee Issue Forum Breakout Session *(Salon A)*

Session Chair: **Shirley Dyke**, Washington University of St. Louis (*EOTC Chair*)

4:00 – 6:00 pm

IT Strategy Committee Issue Forum Breakout Session *(Salon B)*

Session Facilitators: **Jacobo Bielak**, Carnegie-Mellon University (*ITSC Chair*)
Jerome Hajjar, University of Illinois Urbana-Champaign
Andrei Reinhorn, University of Buffalo
Gregory Fenves, University of California, Berkeley
Stephanie Couch, CENIC/University of California, Davis

4:00 – 6:00 pm

SOC Issue Forum Breakout Session *(Van Buren Room)*

Session Facilitator: **Marc Eberhard**, University of Washington (*SOC Chair*)

6:00 – 7:00 pm

Pre-Banquet Reception with Poster Session *(Lincoln Hall)*

7:00 – 9:00 pm

NEES Banquet
Including the 2006 NEESinc Business Meeting,
Awards Ceremony, and Audience Polling *(Washington Ballroom)*

NEES

NEESR Active Projects Spotlight Session 1

NEES

Thursday, June 22, 2006

9:00 – 10:30 am

NEESR Active Projects Spotlight Session I *(Salon A+B)*

Session Chair: **Joy Pauschke**, National Science Foundation

Large-Scale Tests of Structural Braces and the Validation of Micromechanical Ultra Low Cycle Fatigue Models
Amit Kanvinde, University of California, Davis

Self-Centering Steel Frame Systems
Richard Sause, Lehigh University

Tests of Zipper Frames
Roberto Leon, Georgia Institute of Technology

Earthquake Studies of a Two-Span Reinforced Concrete Bridge System with Varied Column Heights
Mehdi 'Said' Saiidi, University of Nevada, Reno

Large-Scale Tests of Structural Braces and the Validation of Micromechanical Ultra Low Cycle Fatigue Models

Submitted By:

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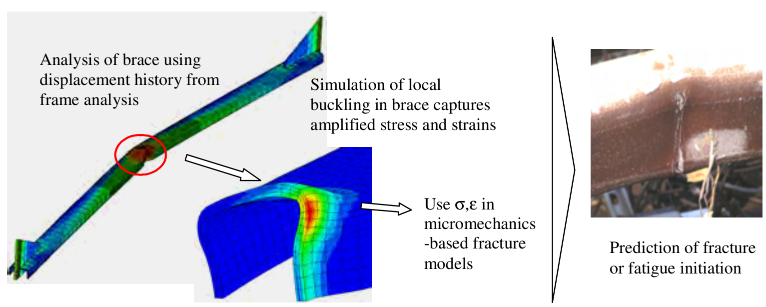
Submitted to Session (please mark one):

1. Advanced Tools Session: ***Pushing Experimental Boundaries***
2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. X NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Nineteen large scale cyclic tests of tests of structural bracing elements were completed in Summer/Fall 2005 (at NEES@Berkeley) and relevant data was recovered regarding seismic performance of several types of bracing members and connections
- Micromechanics-based models for Ultra Low Cycle Fatigue in Structural Steel Elements were validated through complementary FEM analysis
- Models are currently under development for weld metals and tests are planned for Summer 2006 to validate these models
- A technical report addressed to the professional engineering community is under preparation, and education and outreach activities are planned beginning Spring/Summer 2006.



Abstract

Nineteen large scale experiments are conducted to investigate Ultra-Low Cycle Fatigue (ULCF) in large-scale steel specimens intended to represent braces in Concentrically Braced Frames. The experimental findings are complemented by detailed continuum-based FEM and line-element-based OpenSEES analyses. The findings validate the micromechanics based ULCF models and provide valuable performance data for braces and connections. The validated micromechanics-based ULCF models can be used to conduct "numerical experiments" on various steel components reducing the reliance on experimental methods. Ongoing research includes developing of fundamental models for weld metals, planning of the next phase of testing in Summer 2006, and applying the validated ULCF models to situations of practical relevance. Data sharing, education and outreach plans are also discussed.

Self-Centering Steel Frame Systems

Submitted By:

Richard Sause, James Ricles, David Roke, Choung-Yeol Seo, Michael Wolski
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Submitted to Session (please mark one):

1. Advanced Tools Session: ***Pushing Experimental Boundaries***
2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. • NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- A current NEESR project conducted by Lehigh, Princeton, and Purdue Universities is developing innovative earthquake-resistant self-centering (SC) steel frame systems.
- Unlike conventional earthquake-resistant steel frame systems that are designed to develop significant inelastic deformation and structural damage under the design basis earthquake (DBE), these SC steel frame systems have the potential to avoid damage under the DBE.
- Both self-centering moment resisting frames (SC-MRFs) and self-centering concentrically-braced frames (SC-CBFs) are being developed.
- An overview of the project and the roles of the project team members will be outlined.
- Laboratory research, using the Lehigh NEES equipment site, on SC-MRF subassemblies is summarized.
- Analytical research that is developing the SC-CBF systems is also summarized.

Abstract/Summary

With funding from NSF's George E. Brown, Jr. Network for Earthquake Simulation (NEES) research program, new earthquake-resistant self-centering steel frame systems are being developed by a research project with participants from Lehigh, Princeton, and Purdue Universities. These innovative self-centering (SC) structural systems are designed to be damage free and without residual drift under the design basis earthquake (DBE). This presentation provides an overview of the project, and summarizes current results of experimental and analytical work conducted at Lehigh, using the Lehigh NEES equipment site.

Unlike conventional earthquake-resistant steel frame systems that are designed to develop significant inelastic deformations under the DBE, resulting in significant damage as well as residual drift, the innovative SC steel frame systems developed by the project have the potential to avoid structural damage under the DBE as a result of several features: the lateral force-drift

behavior softens without inelastic deformation of the structural members, and, therefore, without the resulting structural damage and residual drift; the softening behavior is created by gap opening at selected post-tensioned connections (*e.g.*, a separation at the beam-column interfaces of an MRF); the ductility capacity of the lateral force-drift behavior can be quite large and is not controlled by material ductility capacity; and energy dissipation under seismic loading is not from damage to main structural members, but from energy dissipation (ED) elements that are specified in the design process and can be replaced if damaged.

Both self-centering moment resisting frames (SC-MRFs) and self-centering concentrically-braced frames (SC-CBFs) are being developed. The project goals are: (1) to develop fundamental knowledge of the seismic behavior of SC-MRF systems and SC-CBF systems, (2) to use the research facilities of NEES to conduct integrated design, analysis, and experimental research on SC-MRF and SC-CBF systems, and (3) to develop performance-based, reliability-based seismic design procedures and criteria for SC-MRF and SC-CBF systems.

The project team is organized as follows. Lehigh University is leading the project team and has primary responsibility for developing ED elements for SC-MRFs, for developing the SC-CBF system, and for conducting large-scale earthquake simulations on SC-MRF and SC-CBF laboratory specimens. Princeton University has primary responsibility for developing reliability-based performance-based seismic design procedures for SC steel frame systems, for developing sensor networks for SC steel frame systems, and for performing nonlinear time history analyses of both SC-MRF and SC-CBF prototype buildings. Lehigh and Princeton are sharing responsibility for developing nonlinear finite element models of SC steel frame systems. Purdue has primary responsibility for subassembly experiments needed to further develop the SC-MRF system, and Princeton and Purdue are sharing responsibility for further developing the SC-MRF system, and for seismic design of a set of prototype buildings with SC steel frame systems.

Current laboratory research at Lehigh is developing an improved beam-column connection for SC-MRFs. The connection has post-tensioned high strength steel strands running parallel to the beams, and a friction ED device is attached to the beam bottom flange and the column (Figure 1). This device is referred to as a bottom flange friction device (BFFD). The BFFD consists of a vertically oriented slotted plate that is shop welded to the bottom beam flange, and two outer built-up angles that are field bolted to the column. Sandwiched between the two outer angles are brass friction plates on both sides of the slotted plate. High strength bolts with disc spring washers provide the normal force, compressing the entire assembly together.

The connection is designed so the beam remains compressed against the column under service loads. Under a selected level of seismic loading, the beam decompresses from the column flange and a gap opening occurs as the beam rotates about either the beam top flange (for positive moment) or the beam bottom flange (for negative moment). Upon load reversal, the post-tensioning force closes the gap at the beam-column interface, and returns the connection to its initial configuration. During gap opening and closing the BFFD provides energy dissipation.

A series of experiments on SC-MRF beam-column connections with BFFDs were conducted (Figure 2). These experiments studied the level of friction force and therefore the level of energy dissipation provided by the BFFD, as well as the effectiveness of disc-spring washers in maintaining the bolt tension force and the effects of frequency and amplitude of loading. The experimental studies show good overall performance under cyclic loading of frequencies ranging from 0.05 to 1.0 Hz and also under simulated earthquake loading. The results indicate that the connection can be designed to provide exceptional ductility while minimizing inelastic deformations to the beams and column, and to provide self-centering behavior by returning the connection to its pre-earthquake position. The presentation summarizes these results.

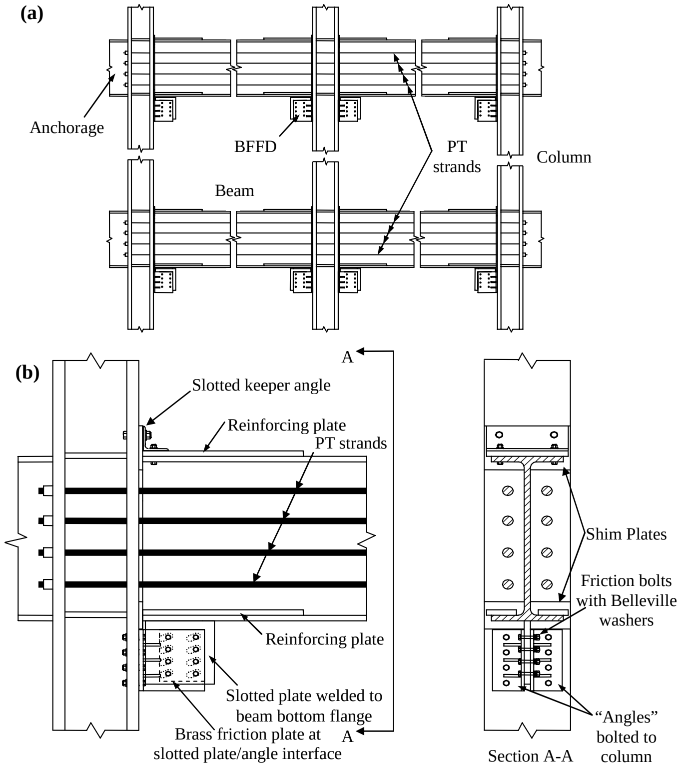

Figure 1. Schematic: (a) post-tensioned SC-MRF with BFFDs, and (b) connection details.

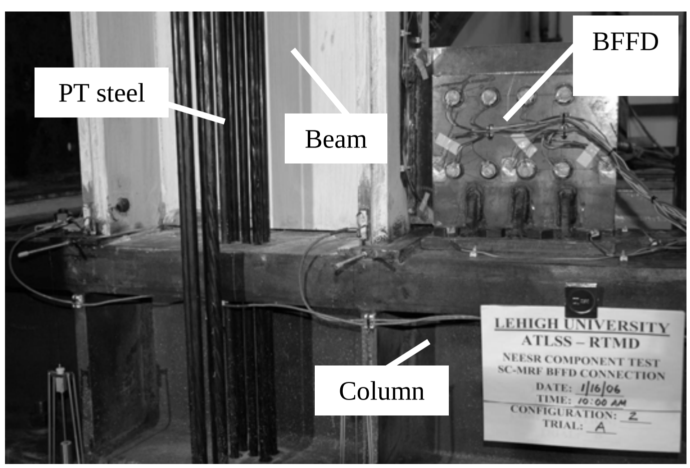

Figure 2. Photo of SC-MRF beam-column connection specimen with BFFD.

Current analytical research at Lehigh is developing the SC-CBF system (Figure 3). Conventional CBF systems have limited drift capacity before brace buckling and related damage lead to deterioration in strength and stiffness. CBFs with buckling-restrained braces have greater drift capacity, however, these systems may sustain substantial permanent drift during seismic loading.

The SC-CBF is a new type of CBF system, with increased drift capacity (before damage) and decreased permanent drift under seismic loading. The SC-CBF system is intended to provide significant non-linear drift capacity while limiting damage and residual drift. Initial seismic performance objectives have been developed. The hazard levels considered are the design basis earthquake (DBE) and the maximum considered earthquake (MCE), and the performance levels are immediate occupancy (IO) and life safety (LS). The initial performance objectives are to achieve IO performance (effectively no damage) under DBE level ground motions, and to achieve better than LS performance (some minor damage) under MCE level ground motions.

The fundamental lateral load behavior of the SC-CBF system is rocking on its foundation (Figure 3(b)), which occurs when the column under tension from overturning moment decompresses and uplifts from its support. To control the rocking behavior, high strength post-tensioning (PT) bars, oriented vertically over the height of the CBF, as well as gravity loads, prestress the CBF to the foundation. The CBF is designed for the tension column to decompress at the base at a selected level of lateral loading, initiating a rigid-body rotation (rocking) of the frame. The PT bars provide a restoring force to return the CBF to the foundation (to self-center the CBF). The rigid-body rotation substantially limits the member forces that develop in the beams, columns, and braces. However, the rigid-body rotation induces deformation and eventually yielding of the PT bars. The PT bar yield limit state is the initiation of structural damage (the IO performance level), which also (neglecting strain hardening in the PT bars) establishes the lateral load capacity of the frame. To minimize structural damage before PT bar yield, the frame members (braces, beams, and columns) are designed to resist the internal forces that develop at PT yield. The LS performance level should be reached at lateral drift levels far beyond the PT bar yield limit state.

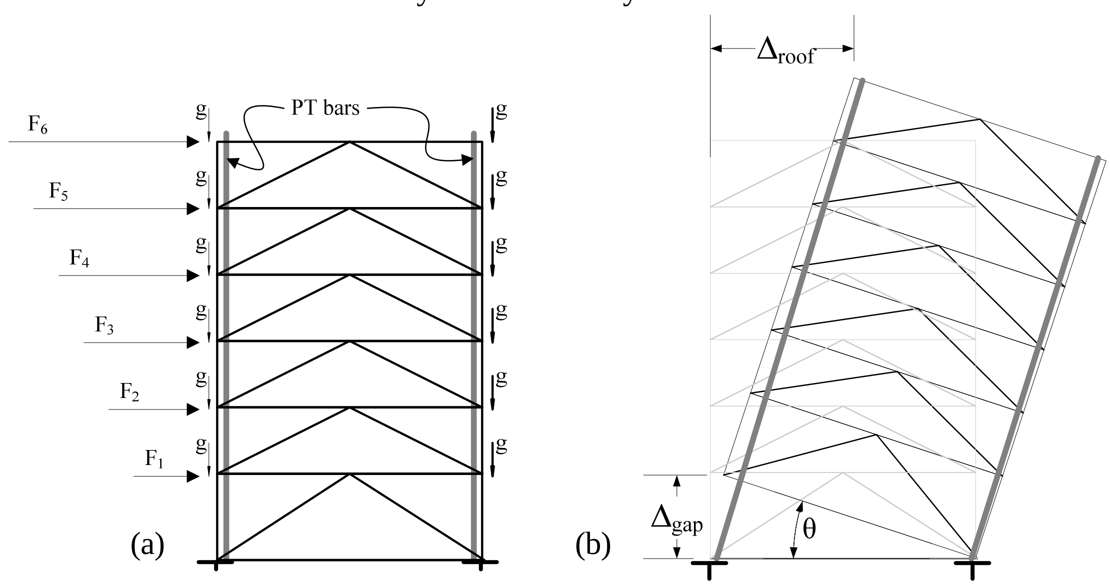

Figure 3. SC-CBF schematic: (a) frame configuration, (b) rocking behavior.

The presentation summarizes current design and analysis studies of several different SC-CBF configurations. Dynamic analysis results confirm the expected drift capacity and self-centering behavior of the system.

Tests of Zipper Frames

Submitted By:

Walter Yang *Georgia Tech*	*Macarena Schachter* *University at Buffalo*	*Tony Yang* *University of California - Berkeley*	Andreas Stavridis *University of California – San Diego*
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Submitted to Session (please mark one):

μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
X 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Tests of zipper-braced frames at Georgia Institute of Technology using quasi-static testing.
- Tests of zipper-braced frames at the University at Buffalo using shaking table testing.
- Tests of zipper-braced frames at the University of Colorado at Boulder using fast hybrid simulation testing.
- Tests of zipper-braced frames at the University of California at Berkeley using local/global hybrid simulation testing.

Abstract/Summary

This paper presents the collaborative results of evaluating the behavior of a ⅓ scale model of a special inverted-V braced steel frame with suspended zipper struts (zipper frame) from tests using different experimental methods: (a) quasi-static testing, (b) shake table testing, and (c) local/global hybrid simulation testing. Zipper frames are intended to improve on the behavior of conventional inverted-V-braced frames, which exhibit poor performance arising from the early buckling of the lower story braces. A zipper frame provides better performance by forcing simultaneous buckling of all braces, and in this work that behavior is tied to the use of an elastic hat truss at the top of the building, which prevents the formation of an overall collapse mechanism. The prototype frame was designed on the basis of the preliminary design procedure to carry similar loading as the 3-story frames designed for the Los Angeles area for the SAC project. Applying similitude rules to the prototype gave a 1/3-scale model zipper frame. The presentation will discuss the modeling issues related to the use of different testing methodologies, significant differences encountered, and make some general conclusions about the validity of conducting multi-method seismic testing.

The followings are brief overviews of the experimental results from four different sites, Georgia Institute of Technology (GT), University at Buffalo (UB), University of Colorado at Boulder (UC), and University of California at Berkeley (UCB).

At Georgia Tech (GT), three specimens of a three-story zipper frame were tested by using the quasi-static testing method. The first experiment was performed to investigate the behavior of the zipper frame under the LA22 SAC earthquake (Kobe 1995), a ground motion that has a significant large pulse with a PGA of 0.92 g. A total of three quasi-static tests with three different amplitudes of the LA22 earthquake were conducted on the 1/3-scale zipper frame model. The displacement histories applied at the floor levels for each test were obtained from nonlinear dynamic analyses of the model under three-level amplitudes of the earthquake, 50%, 75%, and 100% of LA22 (corresponding to 0.41 g, 0.69 g, and 0.92 g, respectively). After the fracture on the first-story tension brace occurred, the frame showed great ductility and retained about 2/3 of the ultimate strength. The reduced-scale suspended zipper frame exhibited great initial strength and stiffness, good capacity to dissipate hysteretic energy, and remained stable up to the maximum imposed drift of approximately 2.6%.

At the University at Buffalo (UB), 3 tests were performed at the new NEES 7m x 7m shaking table. The objective of the experiments was to test the zipper mechanism under ground motions and identify motions for use in the collaborating sites. The zipper frame was tested in plane attached to a self-supported structure providing the structural mass and inertial effects. The setup consisted of 2 independent structures "sandwiching" the zipper frame including six steel heavy plates supported by double hinged columns sitting on spherically shaped plates. The independent structures carried the structural mass and their weight for the experiment and did not provide lateral resistance. The selected input motion was LA22 because the pre-testing analytical results showed that it would be the most damaging one for the model. In all tests, the load was applied in an incremental way, i.e., during each test, the model was subjected repetitively to the input motion whose amplitude was incremented from 15% (elastic behavior) to 50% and up to failure.

The zipper mechanism developed as predicted and was observed in tests #2 and #3. Buckling of the diagonals occurred out of plane. Therefore, not only an unbalanced vertical force was transmitted to the beam and zipper column, but also an important out of plane moment (torque) was transmitted to the beam. Because the test setup was not designed to prevent torsional rotations in the beams, the beam rotated significantly during test #1. Thus, the beam was restrained laterally for test #2. Results from this test show that the braces buckled out of plane and the torsion in the beam was very small; the restraint worked and the zipper mechanism was observed. Test #3 was a repetition of test #1, without restraint and with a dense instrumentation to record torsion. The zipper column was engaged and the zipper mechanism worked as expected. The beam was not forced into excessive rotation. The gusset plate with the corrected detail proved to be much more flexible than in previous tests, therefore, it was able to dissipate energy through deformation instead of rigidly transmitting the out of plane moment (torque) to the beam.

At the University of Colorado at Boulder (CU), the tests were conducted using the Fast Hybrid Test (FHT) facility. The FHT system is based on the substructure pseudo-dynamic test concept that combines the physical testing of the most critical structural component with the analytical modeling of the rest of the structure. The equations of motion for the structure are solved with the α-method, an unconditionally stable implicit time integration scheme. The value of α was set to 0 and a special iterative scheme was adopted to handle structural nonlinearity. The scheme uses a fixed number of iterations for each integration time step which not only circumvents the uncertainty associated with the iterative solution of the implicit time integration scheme but also allows the actuators to move in a continuous and smooth fashion. A convergence study was conducted prior to each test to determine the required integration time step. During the tests, the structural model was divided into an experimental substructure and an analytical substructure. The displacement and restoring force vectors were partitioned into analytical, experimental and interfacial degrees of freedom. For the degrees of freedom at the interfacial nodes, the restoring forces from both the analytical and experimental substructures were added.

In the hybrid tests carried out at CU, only the bottom-story braces of the three-story zipper frame were tested, while the rest of the frame was modeled in a computer using OpenSEES. A total of 4 specimens were tested at CU. The first specimen was used to evaluate the testing facility and the algorithm. The second specimen was tested as a part of a multi-site hybrid simulation with UC-Berkeley. The third specimen was used to fine tune the analytical model. The final analytical model was used for the tests conducted on the fourth specimen and the modeling assumptions were validated. In the model calibration, the base motions recorded from the shake table tests conducted for test 1 at SUNY, Buffalo (UB) were used. The first 3 specimens were subjected to a sequence of motions consisting of the acceleration recordings obtained from the shake table tests at UB. In the tests of Specimen 4, the structural model was sequentially subjected to 3 excitation levels - 15, 40 and 100%. For the 100% level, the original LA22 record was scaled accordingly as this excitation level was not used in the shaking table tests. All experimentally tested braces buckled out of plane, and the first 3 specimens failed at mid brace due to low cycle fatigue caused by the out of plane motion of the braces. The fourth specimen fractured in tension near a brace-to-gusset plate connection at an inter-story drift ratio of 5.3%.

At the University of California at Berkeley (UCB), the seismic response of the suspended zipper frame under the LA22 SAC motion recorded during the 1995 Kobe earthquake was studied using the hybrid simulation testing method. The test specimen is the same 1/3-scale model of the prototype suspended zipper frame tested quasi-statically at the Georgia Institute of Technology and dynamically at the University of Buffalo NEES Equipment Site shaking table. The hybrid simulation model consists of an in-plane three-story suspended zipper frame. The first story Chevron brace sub-assembly is modeled using a physical substructure in the laboratory while the rest of the structure is modeled using the force-beam-column elements in OpenSees. To properly model the boundary conditions between the elements, a number of zero-length elements are introduced in the hybrid simulation model. The foundations of the columns are assumed to be fixed. The beam-to-column connections are modeled using a semi-rigid connection developed by Astaneh-Asl (Astaneh-Asl 2005), while the beam-to-brace connection and zipper-column-to-beam connection is calibrated using the experimental data obtained from previous quasi-static test. The gravity load was ignored in the hybrid simulations.

In order to conduct hybrid simulation tests utilizing the *nees@berkeley* Equipment Site, a continuous testing algorithm and a hybrid simulation test architecture were developed and implemented in OpenSees. The hybrid simulation algorithm combines the element forces measured on the physical sub-structure in the laboratory, computed by the analytical elements in the finite element model and the applied force to solve the displacement response of the suspended zipper frame at each time step. Because the differential equation governing the system dynamics is highly nonlinear, due to large-deformation nonlinear geometry transformation and buckling of both the analytical and experimental elements in the hybrid model, a Newmark time step integration method with constant acceleration and a Newton-Raphason-type initial stiffness were used to solve for the displacement response of the system. Once the displacement response is obtained, the whole process is repeated in the next time step until the entire time history analysis has complete.

The results of the hybrid simulation test are verified by comparing them to pure analytical simulation. Based on these preliminary comparisons, it is evident that the hybrid simulation method used in this study is a reliable and economical testing method to investigate the seismic response of complex and highly non-linear structural systems, such as the suspended zipper frame.

Earthquake Studies of a Two-Span Reinforced Concrete Bridge System with Varied Column Heights

Submitted By:

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Submitted to Session:

- 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- 2. Advanced Tools Session: ***Sensors and Instrumentation***
- 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***

X 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*

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- 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- The seismic response of a two-span reinforced concrete bridge system under different levels of excitations was studied through experimental testing of a large-scale bridge model and through extensive analytical studies.
- This research was encompassed by a multi-university NEESR project with the goal of studying the effects of Soil-Foundation-Structure-Interaction (SFSI). However, this paper will focus on the University of Nevada (UNR) shake table studies.
- Experimental work was conducted at the NEES equipment site at the University of Nevada, Reno (UNR) and was a joint effort between UNR and the University of Washington. The quarter-scale bridge model was designed to current code and was composed of three two-column bents with column aspect ratios ranging from 2.5 to 4. The measured bridge response provided data that was used to evaluate current analytical modeling techniques, study column interaction in a global system, and develop computer models for further study.
- The analytical research at UNR was composed of four major components and focused on the shake table specimen and four related systems that had the same total lateral substructure stiffness. The four components were: 1) Evaluation of existing nonlinear response history models. (2) Evaluation of bridge performance relative to the design motion. (3) Implications of multiple shake table testing. (4) System effects on bent response.

Abstract/Summary

As part of a multi-university collaborative project to study soil-foundation-structure interaction (SFSI) effects, a quarter-scale, 67 ft (20.5 m) long asymmetric reinforced concrete bridge model with two-spans supported on three, two-column piers was tested to failure using the shake table system at the University of Nevada Reno (Figs. 1 and 2). The SFSI project was conducted, in part, to examine the collaborative aspects of the NSF Network for Earthquake Engineering Simulation (NEES), and included experimental components at University of Texas,

Austin (UT), University of Nevada, Reno (UNR), Purdue University, and University of California, Davis (UCD) to cover different aspects of SFSI. The research in this document will focus on the experimental testing of the shake table bridge specimen at UNR and analytical study of the linear and nonlinear response of bridge systems. The shake table testing objective was to study the response of a reinforced concrete bridge model subjected to mostly transverse earthquake excitations. This included the effects of in-plane rotation irregularities on distribution of forces among different piers and the interaction of different components of the bridge.

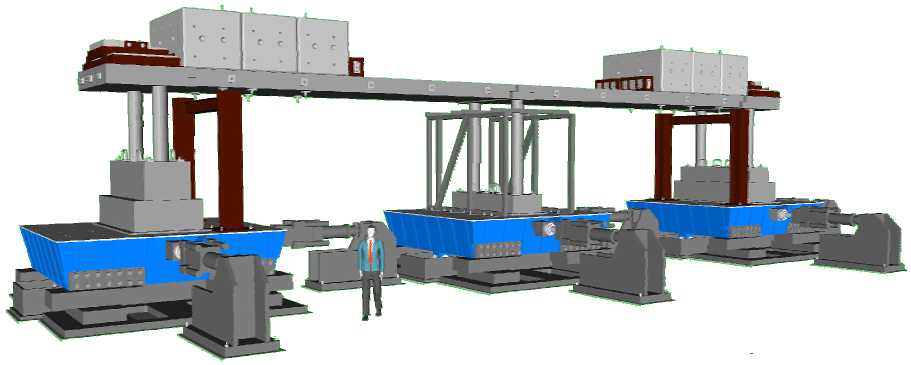


Figure 1 – Rendering of the bridge specimen on shake tables.

Figure 2 – South end of specimen.

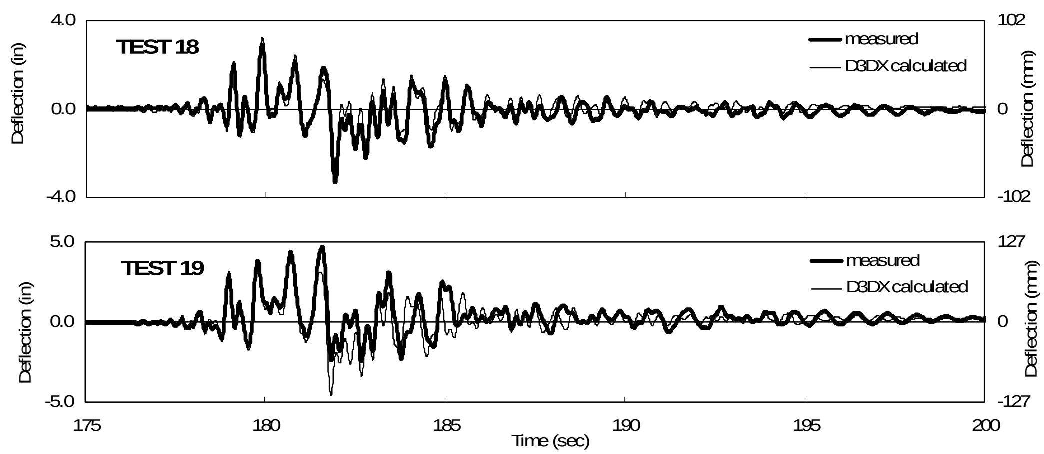


Figure 3 – Measured and Drain-3DX calculated response histories for bent 3.

The bridge frame was subjected to a set of low amplitude (pre-yield), and high amplitude acceleration record target motions that were derived from the Century City accelerogram of the 1994 Northridge, California earthquake. The low amplitude testing consisted of uniaxial coherent and incoherent motions, biaxial coherent motions and achieved centrifuge motions from the UC Davis test. High amplitude testing of the bridge consisted of uniaxial coherent target excitation with a motion that began with pre-yield amplitude and was applied at increased amplitudes in the transverse direction of the model until the first bent failure. The shortest of the three bents (bent 3) failed in flexure when the bridge was subjected to a 1.66 g motion.

The failure mode and damage progression of the bridge showed that the design methodology that was used led to good seismic performance. Low amplitude modal frequencies that were measured during the high amplitude tests were identified as a valuable tool in assessing damage. It was determined that using actuator pressure to measure bent shear force is an accurate method. Existing elastic and post-yield shear stiffness equations were shown to have good correlation with measured results. Measured concrete compression in plastic hinges suggested that either the Mander model is conservative by a factor of at least 2, or that the displacement capacity failure occurs substantially later than crushing of the confined concrete occurs at the extreme confined compressive fiber.

Upon completion of testing, in depth analytical modeling using SAP2000 and Drain-3DX was conducted to evaluate the accuracy of conventional methods in reproducing the bridge model response and to develop a model for further study. Figure 3 shows the bent 3 (the bent that failed) Drain-3DX calculation superimposed on the measured response for tests 18 (pre-failure run) and test 19 (failure run). Contemporary analytical methods were accurate in determining the response of the flexurally dominated system up to bent failure. However, the specialized reinforcement bond slip element that was utilized in the Drain-3DX model and the more refined distributed plasticity element, combined with the method of numerical integration showed that the Drain-3DX model was more accurate, required less processing time, and provided more stable results. Consequently, the Drain model was selected over the SAP2000 model to proceed with further investigation. The computer model was used to determine effects of cap beam stiffness and to aid in the verification of the force estimates from the shake table actuator pressures.

The following three aspects of bridge system response were studied utilizing the analytical model:

1) Performance of the bridge compared to the design performance objectives: The NCHRP 12-49 design methodology was shown to satisfy earthquake performance requirements. Both the measured response from shake table tests and the analytical response based on the design spectra satisfied the performance criteria.

2) The effect of differences between the target and achieved shake table motions on the progression of damage in the bridge: Contrary to the predictions of the pre-test analytical models, bent 3, the shortest of the bents was the first to reach failure. Both the effects of acceleration and pseudo-static displacement inconsistencies with the target motion were investigated and it was determined that the large demand that led to the failure of bent 3 was due to acceleration overshoot from delayed compensation in adjusting the shake table controllers for the yielding of the bents. Two possibilities for solution to the achieved motion errors will be presented and discussed.

3) Investigation of the system effect, comparing the system and response of individual bents as well as the response of several other bridge models: The introduction of higher modes and interaction among the bents (system effect) changed the amount of damage the bents underwent compared to the damage they would have experienced had they been individually tested. A simple irregularity index was found to be a good indicator to identify whether the system will have an effect on the bents. The failure progression of the bridge model and the analytical comparisons suggested that the reserve capacity from varied column heights could provide a beneficial substructure redundancy.

NEESR Active Projects Spotlight Session 2

NEES

Thursday, June 22, 2006

11:00 am – 12:30 pm

NEESR Active Projects Spotlight Session 2 *(Salon A+B)*

Session Chair: **Helmut Krawinkler**, Stanford University

Highly Damage-Tolerant and Intelligent Slab-Column Frame Systems Through Combination of Advanced Materials and Embedded Wireless Sensing
Gustavo Parra-Montesinos, University of Michigan

Dynamic Passive Procedures for Backfill Based on Full-Scale Pile Cap Testing (A NEESR Project)
Travis Gerber, Brigham Young University

Multi-Site Soil-Structure-Foundation Interaction Test (MISST)
Bill Spencer, University of Illinois Urbana-Champaign

A Database for Modeling Deterioration in Beams and Columns Subjected to Cyclic Bending Moments
Dimitrios Lignos, Stanford University

Full-Scale Testing of Polyethylene Pipelines at Fault Rupture
Michael O'Rourke and Thomas O'Rourke, Cornell University

HIGHLY DAMAGE-TOLERANT AND INTELLIGENT SLAB-COLUMN FRAME SYSTEMS THROUGH COMBINATION OF ADVANCED MATERIALS AND EMBEDDED WIRELESS SENSING

Submitted By:

Gustavo J. Parra-Montesinos[1], Jerome P. Lynch[1], Carol K. Shield[2], Min-Yuan Cheng[1], Tsung-Chin Hou[1], Andrew Zimmerman[1], Vineet Kamat[1]
[1]University of Michigan, [2]University of Minnesota
Department of Civil and Environmental Engineering
2340 G.G. Brown Building
Ann Arbor, MI 48109-2125

Submitted to Session (please mark one):

µ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*

Major points/topics:

- Increase in punching shear and deformation capacity of slab-column connections through the use of strain-hardening, high-performance fiber reinforced cement composites.
- Development of wireless sensors with data processing capabilities for real-time assessment of structural health during earthquakes.
- Integration of new slab-column connection design with wireless sensing technology to develop next generation of slab-column framed systems with increased displacement capacity and damage tolerance.

Abstract/Summary

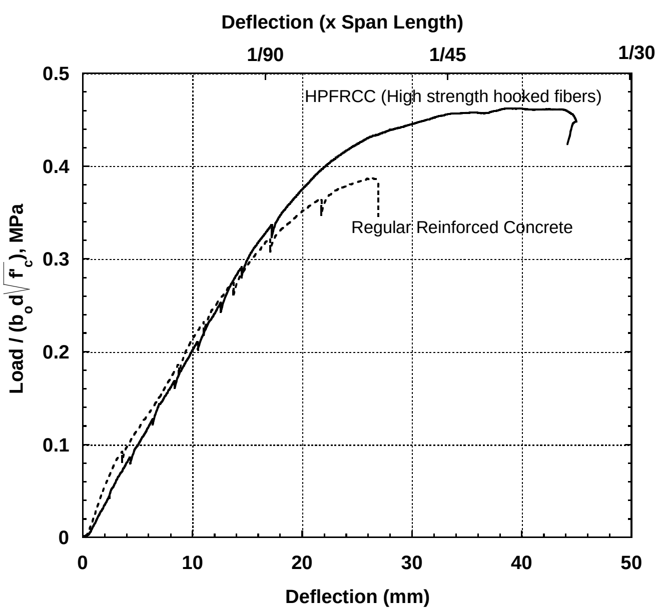
The purpose of this project is to develop a highly damage tolerant and “smart” slab-column framed system for use in earthquake-resistant construction. This innovative system integrates the latest developments in fiber cement-based materials, wireless sensing, and information technologies. While these new technologies have all been developed in isolated research communities, this study investigates their fusion to deliver next-generation slab-column frames capable of 1) resisting extreme dynamic loads with outstanding damage tolerance, and 2) self-sensing their performance including self-identification of structural damage.

Slab-column frames represent an attractive structural system when building functionality calls for large open spaces and increased story clear heights. In regions defined by high seismic activity and because of their relatively low lateral strength and stiffness, slab-column frames are used in combination with special moment frames or structural walls. However, these systems must be capable of sustaining the applied gravity loads while undergoing earthquake-induced displacements. In order to ensure adequate lateral displacement capacity in slab-column frames, shear reinforcement is often provided in the form of shear studs. Even though this type of shear reinforcement is effective for increasing connection punching shear capacity, it is expensive and

may lead to interference problems with mild and/or post-tensioning steel. In this investigation, a new approach has been taken to develop a slab-column connection design with increased punching shear and deformation capacity. Instead of stud shear reinforcement, a strain-hardening, high-performance fiber reinforced cement composite (HPFRCC) is used in the connection region. Besides increasing punching shear resistance through their large tensile stress capacity, the use of fiber reinforced cement composites with strain capacities in excess of 1% is expected to substantially increase connection rotation capacity.

The first phase of the experimental program, already completed, consisted of the testing of ten slab-column subassemblies subjected to monotonic punching shear loading. The purpose of this test phase was to select the best material in terms of punching shear resistance and ductility for further evaluation in slab-column subassembly tests subjected to lateral displacement reversals. Steel fibers with various shapes, length-to-diameter ratios, steel strength, and in various volume contents, as well as cement-based materials with and without course aggregate were evaluated in this test phase. Out of the various materials considered, an HPFRCC material that features a concrete mixture with high-strength steel hooked fibers in a 1.5% volume fraction was selected for further evaluation. Figure 1a shows a picture of a test specimen while Figure 1b shows the punching shear stress (load divided by critical perimeter, b_o, times the slab effective depth, d) versus displacement response for a specimen with regular concrete and that for a specimen with high-strength steel fibers. As can be seen, the selected material led to a substantial increase in punching shear resistance (governed by flexural yielding) and ductility.

a) Slab Test Setup



b) Punching Shear Stress versus Deflection Response

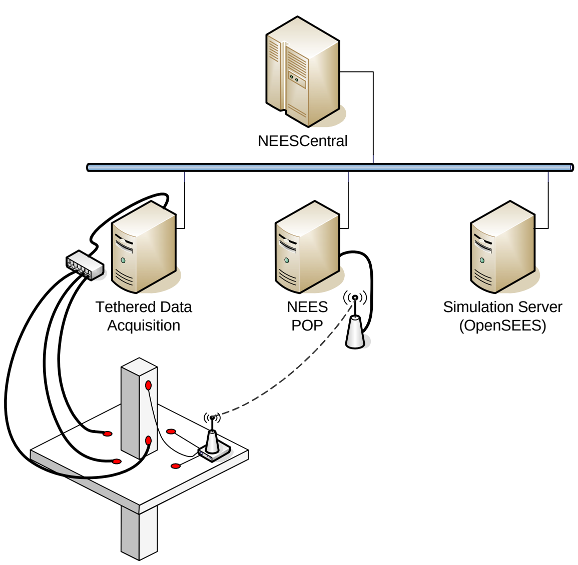
Figure 1 - Testing of Slab-Column Subassemblies under Monotonic Loading

Currently, construction is underway for the first series of tests of slab-column subassemblies to be subjected to unidirectional lateral displacement reversals. These tests will be conducted at the University of Michigan and will allow the evaluation of the lateral displacement capacity of HPFRCC slab-column connections subjected to various levels of gravity-induced shear stresses. Later this year, the testing of full-scale slab-column subassemblies will begin at the NEES

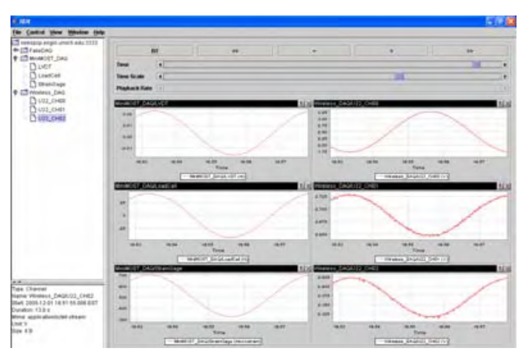
MAST Facility. These specimens will be subjected to bi-directional lateral displacement histories determined from inelastic dynamic analyses of slab-column framed structures under earthquakes of various intensities and characteristics, allowing the evaluation of the behavior of the proposed slab-column framed system under more realistic displacement demands.

Wireless sensors will be integrated with the HPFRCC slab-column connections to provide a means of monitoring their performance and predicting damage. Wireless sensors, installed upon large-scale test specimens, are able to wirelessly communicate sensor data from a heterogeneous set of sensing transducers to the point-of-presence (POP) server located in a NEES facility. The wireless monitoring system's software implementation passes the wireless sensor data into DataTurbine, where it can be time synchronized with data originating from other data acquisition systems. To preserve the wireless sensor data for ultimate upload to NEES Central, wireless sensor data is also recorded in data files upon the NEES POP server. Currently, the wireless monitoring system is being integrated with OpenSees for real-time model updating of OpenSees models of test specimens. A simulated annealing model updating procedure has been integrated within the cyberenvironment to automate the process of wireless sensor collection, simulation execution and model updating. An overview schematic of the modified NEES cyberenvironment is presented in Figure 2.

The constructability of HPFRCC elements by construction workers will also be addressed in this investigation. In order to objectively demonstrate and quantify the impact of the proposed system on the casting sequence, the following tasks will be performed: a) design and document the sequence of construction operations required to erect a structure using first the RC and then the HPFRCC slab-column framed system; b) verify the soundness of the construction operations and the resulting constructability of the structure when using the proposed HPFRCC system; and c) measure and document the cost impacts on construction when constructing a structure designed using the proposed HPFRCC slab-column framed system. The design and comparison of the alternate construction techniques will be performed using discrete-event simulation.



(a)



(b)

Figure 2. (a) Wireless sensors integrated within NEES cyberenvironment; (b) tethered and wireless data streams in real-time data viewer.

Dynamic Passive Pressures for Backfill Based on Full-Scale Pile Cap Testing (A NEES-R Project)

Submitted By:

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Submitted to Session (please mark one):

μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
λ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Project seeks to quantify passive force-deflection relationships for backfill soils based on full-scale pile cap testing.
- Testing was accomplished using major pieces of both NEES and non-NEES equipment.
- By bringing together resources from the NEES equipment site and the NEES-R institution, a method for testing soil at a high loading rate and large range of displacement was made possible.
- Collaboration between NEES and NEES-R personnel resolved challenges and helped produce success.
- NEES-R projects can attract interest and support from non-NEES entities, thus enlarging the benefit of NEES sponsored work.

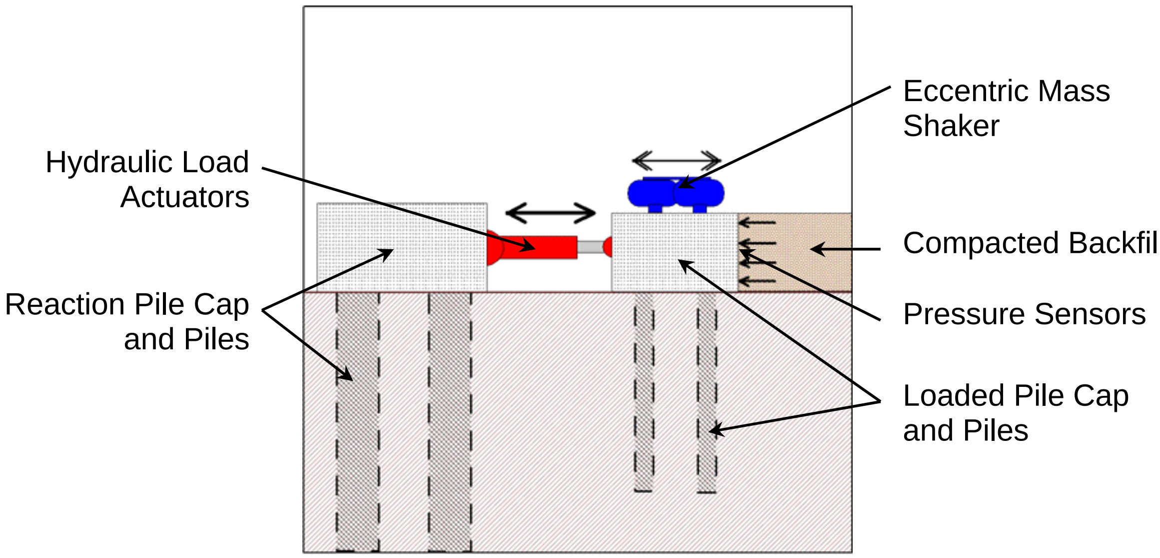
Abstract/Summary

Passive force-deflection relationships for soils adjacent to bridge foundations are typically based on static loadings. Recent research has improved these relationships by addressing cyclic loading effects. In order to more accurately describe soil behavior due to seismic loading, both cyclic and dynamic effects need to be quantified. Hence, this project was undertaken to develop passive force-deflection relationships for backfill soils subject to dynamic loads.

The first year of field testing was completed in 2005. Testing was performed in Salt Lake City, Utah, using a full-scale bridge foundation (pile cap) backfilled with a silty sand compacted to two different densities. Loading of the pile cap was accomplished using a combination of an eccentric-mass shaker from NEES@ucla and two 2.7-MN hydraulic actuators from BYU reacting against a larger, stiffer reaction pile cap. A schematic of the testing configuration is shown in Figure 1. The shaker was used to dynamically load the backfill soil with a force up to approximately 360 kN with a frequency ranging up to 8 Hz. The displacement produced by the shaker itself would have been insufficient to mobilize the soil's ultimate shear strength. Consequently, the actuators were used between individual shaker tests to incrementally displace the backfill from 0 to approximately 50 mm, thus capturing the load-displacement response of the backfill soil ranging from at-rest conditions to ultimate shear strength.

While analysis of the acquired data is ongoing, several features relating to the testing program are notable. With respect to the testing configuration, the concept of combining load actuators and shakers to perform dynamic load testing over a wide range of deflection levels appears to work. By bringing together resources from the NEES equipment site and the NEES-R institution, a method for testing soil at a high loading rate and large range of displacement was made possible. However, collaboration between the NEES equipment site and NEES-R researchers was essential. As a simple example, the existing foundation used for testing had to be retrofitted with embedded, high-strength anchors to attach the shaker. On prior NEES equipment site projects, such anchors were installed after the shaker had been mobilized to the site in order to accommodate relatively tight tolerances. To best accommodate the schedule of the NEES-R project, anchor installation had to be completed in the field before the shaker arrived from out of state. In response to this need, the project team created a 3 x 3-m template which matched the exact mounting dimensions for the shaker. Using this new template, anchors were installed successfully without hindering the schedule. Another challenge overcome by collaborative effort was the data acquisition for the project. Data was to be collected from both NEES and non-NEES devices, requiring that the NEES data acquisition system be properly conditioned to accept electronic signals from foreign instruments. The final data set for the project consists of a variety of different data types, including data from the mass-eccentric shaker, the load actuators, accelerometers, string potentiometers, and earth pressure cells.

One of most important aspect of this NEES-R project is the interest and support it has attracted from non-NEES entities. Since the award of the initial NEES-R contract, five state departments of transportation (Utah, California, Montana, New York, and Oregon) have committed $255,000 of additional funding to expand the scope of the project. By utilizing already-mobilized NEES equipment and existing test foundations, the effect of partial-width backfills on the dynamic response of pile caps will be studied. Since use of partial-width backfills is relatively common, this expanded scope will provide meaningful NEES-R based research results to an even broader range of parties.



Instrumentation not shown: string potentiometers and accelerometers

Figure 1: Schematic of Testing Configuration

Multi-Site Soil-Structure-Foundation Interaction Test (MISST)

Submitted By:

Bill Spencer[1], Amr Elnashai[2], Daniel Kuchma[3], James Ricles[4], Tarek Abdoun[5], Sung Jig Kim[6], Sougata Roy[7], Hassan Radwan[8], Curtis Holub[9], Narutoshi Nakata[10], and Tommy Marullo[11]

Submitted to Session (please mark one):

- ❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- ❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ❍ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- ● 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- ❍ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- ❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- ❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Vision and details of the test-bed project are provided
- Component test successfully reproduces field observed pier behavior
- Fully analytical distributed simulation utilized to validate multi-site communication
- Linear distributed and integrated simulation provides proof of concept
- Plan for culminating simulation is detailed

Abstract/Summary

The Multi-Site Soil-Structure-Foundation Interaction Test (MISST), conducted by collaborating partners at University of Illinois at Urbana-Champaign (UIUC), Rensselaer Polytechnic Institute (RPI), and Lehigh University (Lehigh) is presented. The project was developed to provide a realistic test bed application with which to verify and extend all components of the NEESgrid as well as all components of the sites taking part in the distributed simulation. Concurrently, it has extended and represents the current state-of-the-art in distributed and integrated experimental-analytical earthquake engineering simulation.

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The MISST structure is based on the Collector-Distributor 36 of the I-10 Santa Monica Freeway which was damaged during the 17 January 1994 Northridge Earthquake. To utilize current NEES experimental facilities and for simplification, an idealization of the original structure was employed (Figure 1). As shown, the bridge is assumed to have three piers of varying height and is supplemented with soil models to include the effects of soil-structure interaction. The Santa Monica strong motion record was used exclusively throughout this investigation.

As subsequently detailed, the project utilized the large-scale NEES facilities of both UIUC and Lehigh University, in addition to advanced geotechnical modeling at RPI, to fully model the behavior of the MISST structure. In an effort to manage the broad and complex scope of the project, testing was approached incrementally. As such, several subtasks were developed and are in various stages of completion. A description of each follows.

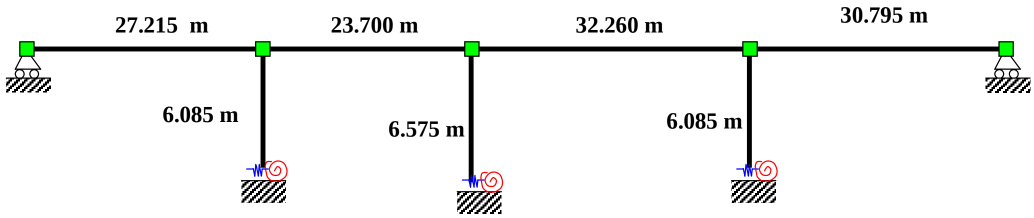

Figure 1. MISST test structure

Single pier component test

To reconstruct and verify the failure mode observed in the freeway structure, a single large-scale pier specimen was constructed and tested at UIUC. Figure 2 provides a comparison between the observed behaviors. As shown, the laboratory test successfully reproduced the shear failure observed in the field.

a. Field response b. Laboratory response

Figure 2. Observed pier behavior

Distributed analytical simulation

Following the component test, communication through NEESgrid between the various sites was established and validated through a fully analytical distributed simulation. The substructure scheme that was utilized is illustrated in Figure 3. As shown, 5 static modules at three separate sites were employed:

- Module 1: Four decks and second pier including soil 2 – UIUC
- Module 2: First pier – UIUC
- Module 3: Third pier – Lehigh
- Module 4: Soil 1 – RPI
- Module 5: Soil 3 – UIUC

The distributed simulation was orchestrated with UI-SIMCOR, UIUC's simulation coordinator. UI-SIMCOR handles all inter-module communication and houses the numerical integration scheme.

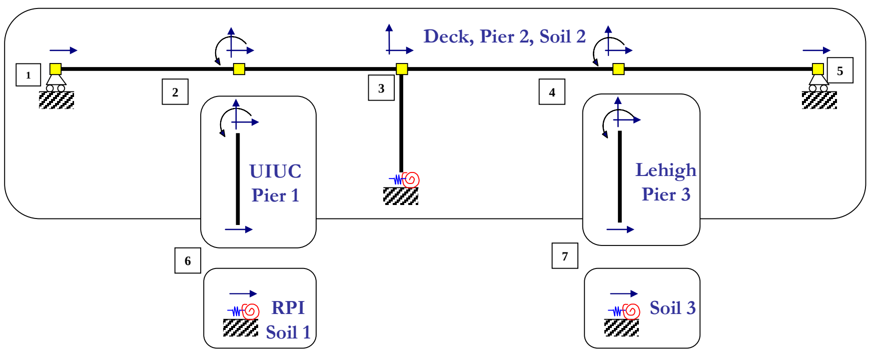

Figure 3. Analytical simulation

Preliminary integrated and distributed simulation

Again, following the incremental approach, a second simulation was conducted utilizing linear experimental specimens for piers 1 and 3 (modules 2 and 3, respectively). At Lehigh, an existing steel specimen was employed to model pier 3; whereas, Mini-MOST, the scaled and portable version of the Multi-Site Online Simulation Test (MOST), was utilized at UIUC to model pier 1. The structure was testing at a rate corresponding to 800 times slower than real-time. The behavior of the distributed simulation is compared to that of a single analytical model in Figure 4. As shown, the simulations recorded response matched quite well to that of the analytical model despite a downward drift displayed during the later portion of the experiment. The drift was later attributed to mechanical slip occurring in an experimental portion of the simulation. Thus, proof of concept was provided through this distributed and integrated simulation.

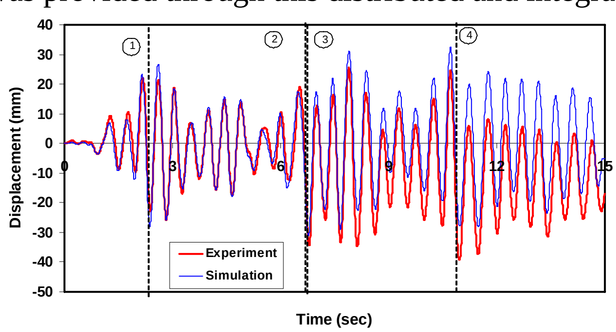

Figure 4. Response from preliminary simulation

Culminating simulation

The final culminating MISST simulation, scheduled for spring of this year, will build upon the linear test outlined above. During the simulation, piers 1 and 3 will be modeled with large-scale pier specimens at the Lehigh and UIUC sites (Figure 5). Results from the culminating simulation will be available for review during the event.

The success and results of MISST, a fully distributed and hybrid simulation, are of great interest to all members of the earthquake community. The concept and current achievements alone demonstrate the benefits of such collaborative endeavors. By virtue of its originality, MISST will attract interest and place the NEES community at the forefront of earthquake engineering research.

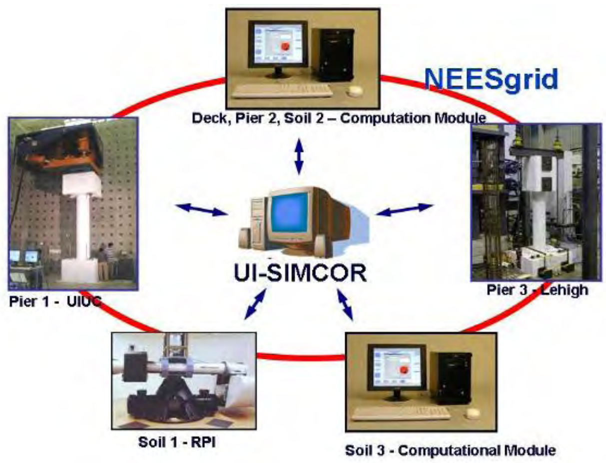

Figure 5. Culminating Simulation

NEES Annual Meeting Abstract

Submitted By:

Dimitrios G. Lignos and Helmut Krawinkler
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Stanford, California 94305-4020, Tel. (650) 723-4129 Fax. (650) 723-7514

Submitted to Session (please mark one):

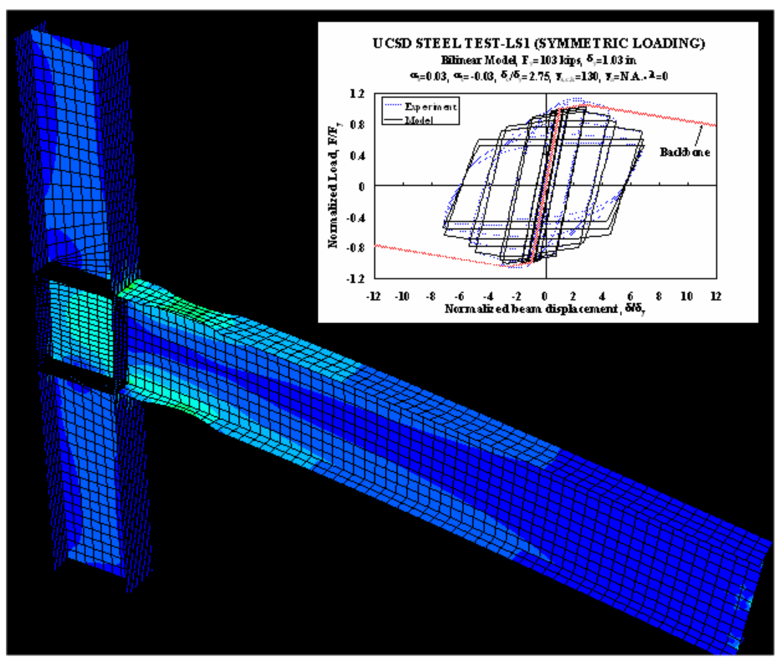
- μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- X 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Presentation Title:

A Database for Modeling Deterioration in Beams and Columns Subjected to Cyclic Bending Moments

Major points/topics:

- A comprehensive database of experimental results for modeling deterioration in steel beams and columns subjected to cyclic bending moments
- Finite element studies to quantify parameters that affect deterioration under cyclic loading
- Calibration of a component hysteretic model that incorporates strength and stiffness deterioration, for prediction of the collapse capacity of structural systems



Abstract/Summary

In recent years much effort has been devoted to the development of reliable analytical tools to predict global collapse of structural systems due to dynamic instability. Lack of data to model deterioration properties of structural components does not enable us to predict system collapse in a systematic and reliable manner.

One of the major tasks of the ongoing research is the development of an extensive database of experimental results from component tests to provide reliable data for component deterioration models, which in turn are employed to predict a critical mode of system collapse, namely that associated with sidesway instability in which an individual story (or a series of stories) displaces sufficiently so that the second order P-delta effects fully offset the first order story shear resistance and dynamic instability occurs. The database work focuses on deterioration properties of steel beams and columns subjected to cyclic bending moments. The database is based on monotonic and cyclic component and subassembly experiments for steel beams and columns performed over the last forty years. The database provides relationships that associate analytical model parameters such as plastic rotation capacity, cap strength, rate of post-capping deterioration, cyclic deterioration, and residual strength, with detailing criteria that control deterioration of steel components. A consistent format is established to store and search the worldwide data.

The database, in conjunction with finite element studies, is used to conduct a parametric study to examine the effects of connection type, section size, plate slenderness ratios, and composite floor contribution on the parameters of the deterioration models. These models will then be used to perform parametric system collapse studies. The process is illustrated on a 4-story steel moment resisting frame structure whose collapse prediction will be validated in Spring 2007 through a collapse test of a 1:8 model structure on the Buffalo shaking table.

Speaker:

Dr. Michael C. Palmer, T. O'Rourke *<Cornell University>* ***and M. O'Rourke*** *<RPI>*

Session:

NEESR Active Projects I
Thursday, June 22, 9:00 – 10:30 am

Presentation title:

Full-Scale Ground Rupture Effects on Critical Lifelines

Major points/topics:

- Tests were performed on 16-inch HDPE pipelines installed in a specially designed split test basin and subjected to 4 feet of lateral displacement.
- The test basin is approximately 35ft long and 11ft wide and contained nearly 100 tons of soil during these tests.
- Advanced robotics and laser profiling were used to take detailed pre- and post-test measurements and video of interior of test pipe.
- Laser profiling was performed of post-test ground rupture.
- Pre-test numerical simulations were used in design of the test basin and in determining instrumentation layout.
- A post-test comparison of numerical analyses with test results is underway to improve our understanding of pipeline behavior under large ground displacements.

Abstract/Summary

A large-scale lifeline testing program is underway at Cornell University and Rensselaer Polytechnic Institute. Tests have been performed on 16-inch diameter high density polyethylene pipe. The pipe was subjected to 4 ft of left lateral movement along a 65 degree fault. This resulted in the pipe being both laterally displaced and simultaneously put into tension.

The pipes were installed in a specially designed split test basin. One half of the basin is fixed while the other half is movable to allow simulated ground rupture. The basin is approximately 35 ft long and 11 feet wide and contained nearly 100 tons of sand during these tests. Numerical simulations were used to determine basin dimensions and pipe instrumentation layouts. Instrumentation consisted of 148 strain gages placed on the pipe and load cells placed at the pipe ends. Gage survivability during the test was about 85%.

The test results showed strains that were symmetrical with respect to the fault while the readings from the crown and invert gages were similar. Maximum axial strain was 8% and maximum circumferential strain was about 5%. Advanced robotics and laser profiling were used by one of Cornell's industry affiliates to take detailed pre- and post- test video and measurements of the interior of the test pipe. These were used to obtain visual evidence of the ovaling of the pipe that occurred during the test. Seven cameras were placed around the testing facility to capture video of the test in progress. Laser profiling was used to complete a post-test survey of the ground rupture evident on the surface of the test basin.

Post-test comparisons of the results with numerical analyses are currently being completed.

Luncheon with Presentation

NEES

Thursday, June 22, 2006

12:30 – 2:00 pm (presentation at 1:30)

Luncheon with Presentation *(Washington Ballroom)*

Tsunami Reconnaissance Data Repository

Harry Yeh, Oregon State University

NEES

Presentation Summary

Speaker:

Harry Yeh
NEES@Oregon State University

Session:

Thursday Luncheon
Thursday, June 23, 1:30 – 2:00 am

Presentation title:

Tsunami Reconnaissance Data Repository

Abstract/Summary

The massive tsunami that occurred in Asia on December 26, 2004 prompted many reconnaissance teams to visit the regions hit hardest and collect both scientific and sociological data. To preserve the data from these trips, NEESit created a tsunami reconnaissance data repository. Given the magnitude and infrequency of such disasters, this data will be extremely valuable in support of tsunami research efforts for centuries to come.

NEESit supports the IT infrastructure for the NSF's Network for Earthquake Engineering Simulation program. NEESit is responsible for preserving large amounts of earthquake engineering experimental and analytical data. After the tsunami in Asia, NEESit extended the NEES data repository to include tsunami reconnaissance data.

The tsunami repository consists of a web portal which supports data upload and download. The data are stored in a file hierarchy allowing users to browse data easily. Metadata is stored within each file. Additionally, the web portal provides an interactive map allowing users to browse data in the repository quickly based on where the data were collected. The repository is supported by a replicated storage system, relational database, tape back-up and high speed network.

NEESR New Projects Spotlight Session 1

NEES

Thursday, June 22, 2006

2:00 – 3:30 pm

NEESR New Projects Spotlight Session I *(Salon A+B)*

Session Chair: **Robert Nigbor**, University of California, Los Angeles

Collaborative Study of Biaxial Seismic Response of Bridge Systems
Mehdi 'Said' Saiidi, University of Nevada, Reno

Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls
P. Benson Shing, University of California, San Diego

Seismic Simulation and Design of Bridge Columns Under Combined Actions, and Implications on System Response
Abdeldjelil "D.J." Belabi, University of Missouri-Rolla

NEESR-Grand Challenge: Seismic Risk Mitigation for Ports
Glenn Rix, Georgia Institute of Technology

Inelastic Web Crushing Performance Limits of High-Strength-Concrete Structural Walls
Rigoberto Burgueño, Michigan State University

Collaborative Study of Biaxial Seismic Response of Bridge Systems

Submitted By:

M. Saiid Saiidi
University of Nevada, Reno
Civil & Env. Engineering (258), UNR, Reno, NV 89557, ph: 775/784-4839, fax: 775/784-1390, saiidi@unr.edu

Submitted to Session (please mark one):

μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
x 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Expertise from nine universities are mobilized to conduct a comprehensive study of a series of large-scale, four-span bridge models subjected to bidirectional horizontal ground motions.
- Researchers from five of the institutions focus on the core aspects of the project. Of the remaining four, three institutions are in the US conducting payload projects, and one is in Japan. The institutions and senior researchers who are involved in the project are: the University of Nevada, Reno (UNR) (Saiidi, Buckle, Pekcan, Cantrell), University of California, San Diego (UCSD) (Elgamal), University of California, Berkeley (UCB) (Fenves), Florida International University (FIU) (Mirmiran), and Stanford University (SU) (Kirmidjian). The other four are the University of Illinois, Chicago (UIC) (Ansari), University of Kansas (KU) (Browning and Olafsen), Georgia Institute of Technology (GT) (DesRoches), and Tokyo Institute of Technology (Kawashima).
- The experimental components of the study consist of three, quarter-scale, four-span bridge models at UNR, an abutment wall at UCSD, and five piers at FIU. The task at UCB is OpenSEES modeling and integration of abutment and footing soil structure interaction effects with the bridge response.
- The UCSD abutment wall has been constructed and preparations are being made for testing. The first UNR bridge model is under construction, and pretest analyses are being conducted using OpenSEES. The models in FIU are being designed. Development of wireless sensors at SU has been in progress and the sensors have been used in trial shake table runs at UNR.

Abstract/Summary

The objectives of the study are the investigation of (1) system seismic performance of medium-span bridges, (2) abutment wall shake table response, (3) feasibility of bridges with shape memory alloy reinforcement, fiber-reinforced polymer members, and other innovative materials, (4) integrating test results in comprehensive computer simulation of bridges, and (5) means to

educate the K-12 and the public on the importance of earthquake engineering research and to motivate K-12 students and undergraduates to study earthquake engineering. Paramount tools of this project are the NEES equipment at UNR and UCSD, the NEESit collaborative tools, and the NEES Central Repository. The study consists of a large number of highly linked components, some of which encompass all the tasks of the project. The broad tasks include the education and outreach activities and data management and data archiving.

The central focus of shake table testing is on three, four-span bridge models to be tested at UNR (Fig. 1). The first bridge model consists of conventional reinforced concrete piers with a post-tensioned continuous superstructure supported on bent caps. The piers will be fixed to the shake tables. The abutments are of seat type. The movements of the abutment back wall will be simulated using hydraulic actuators as shown at the end of the bridge. The input motion to the abutments will be based on the abutment shake table test results at UCSD. Figure 2 shows the test setup for the abutment tests.

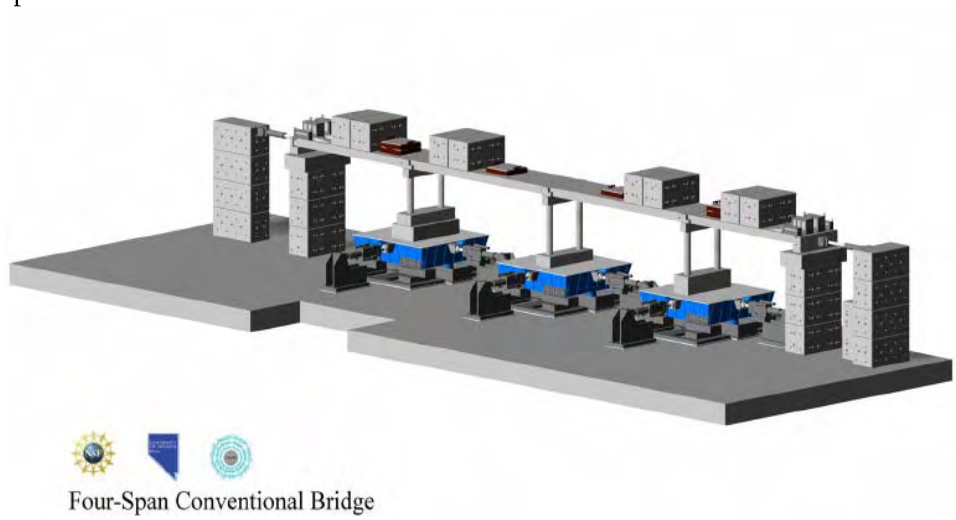


Figure 1 – Bridge model with conventional reinforced concrete piers.

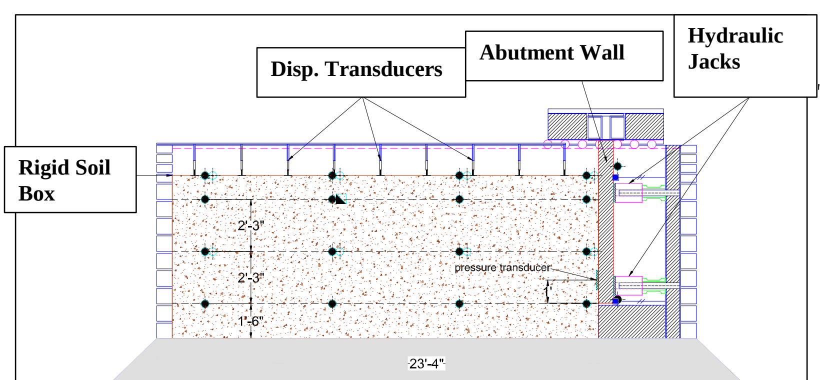


Figure 2 – Abutment wall test setup

Figure 3 – Beam steel

The abutment wall has been constructed. Preparation are being made to install the soil box and instrumentations. The wireless sensors developed at SU will be utilized in the tests. The abutment wall is supported on an sliding base and it will be tested under unidirectional shake table motions. The conventional four-span bridge model is currently under construction. Figure 3 shows some of the superstructure beam reinforcement.   The OpenSEES modeling of the bridge is currently in progress for pretest analysis of the model and to estimate the abutment actuator motions. The shake table motion will consist of bidirectional records that are based on the 1994 Northridge earthquake record measured at the at the Century City station. The three shake table motions will be synchronous.

The development of wireless sensors has continued, and the sensors were attempted in the shake table testing of a single reinforced concrete column at UNR. The trial runs allowed for the evaluation of the sensors and identified directions for refinement.

The substructure details in the second and third 4-span bridge models utilize innovative details. In the second model superelastic shape memory alloy (SMA) reinforcement along with engineered cementitious composite materials will be used in some of the column plastic hinges. Other columns might utilize post-tensioning and built-in elastomers. The common thread among these details is minimal damage even under large drifts. In the third bridge, concrete-filled fiber-reinforced substructures will be utilized. Preliminary component testing of innovative details are in progress before these details are implemented in the full bridge models.

The education and out reach element of the project has consisted of presenting informative lecture to science teachers and organizing laboratory visits for the teachers and students. A project website has been established. More than 20 presentations are given worldwide to different engineering and research groups. As testing of shake table models begins, the public and K-12 students and teachers will be more informed about the project.

Data archiving has already begun. Project documents and materials used for conference calls are posted on the project website. Meta data such as bridge model plans and instrumentations as well as information on computer simulation have been uploaded to the NEES Central Repository.

Preliminary slow cyclic load tests of SMA columns will be conducted this spring at UNR. The first bridge model shake table tests and abutment test are expected to take place early summer.

Preliminary development work on payload projects has been conducted. The research teams from UIC and KU have already tried their sensors on two single column shake table tests at UNR. The GT team has met at UNR and preliminary studies on design of GT SMA restrainers is in progress.

Seismic Performance Assessment and Retrofit of Non-Ductile RC Frames with Infill Walls

Submitted By:

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Sarah Billington, Stanford University
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Submitted to Session (please mark one):

1. Advanced Tools Session: ***Pushing Experimental Boundaries***
2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
5. • NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Seismic retrofit of masonry-infilled RC frames.
- Development of performance assessment methods.
- Strengthening of masonry infills with enhanced cement-based composites.
- Validation of methods with large-scale testing.

Abstract/Summary

Project Team:
University of California, San Diego (Lead Institution)
P. Benson Shing and Jose Restrepo, Faculty; Andreas Stavridis, Grad. Research Assist.
Stanford University
Sarah Billington, Faculty; Marios Kyriakides, Grad. Research Assist.
University of Colorado, Boulder
Kaspar Willam and Sivaselvan Mettupalayam, Faculty; Ben Blackard, Grad. Research Assist.
Rutherford & Chekene
Joseph Maffei, William Holmes, and Bret Luzundia

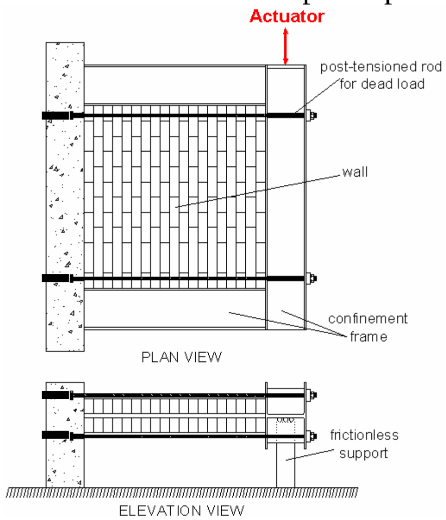
Masonry infills can be found in many old buildings in the western United States, and they are still frequently used as backup walls for masonry veneers in the east and midwest. Although they are considered as non-structural elements, they can develop a strong interaction with the bounding frames when subject to earthquake loads and, therefore, contribute significantly to the lateral stiffness and load resistance of the structure. Despite several decades of research, the performance of these structures in a severe earthquake remains a major controversy among structural engineers and researchers today. The main aim of this NEESR Small-Group Project is

to develop rational and reliable methodologies for assessing the seismic safety and performance of masonry infilled RC frames, and develop practical and cost-efficient techniques for the seismic retrofit of these structures using innovative materials. The project will include the development of reliable analysis tools that range from advanced computational models to simple analytical methods that can be used in engineering practice. The analysis methods and retrofit techniques will be first validated with small-scale component tests to be conducted at Stanford University and medium-scale infilled-frame tests to be conducted with the NEES Fast Hybrid Test facility at the University of Colorado, Boulder. Final proof-of-concept tests will be conducted on a full-scale three-story RC frame using the NEES Large High Performance Outdoor Shake Table at the University of California, San Diego. This research will lead to retrofit guidelines and assessment tools that can be readily incorporated into a performance-based engineering procedure. To facilitate technology transfer, the project has a Professional Advisory Panel consisting of experienced practicing engineers. Key components of this research program are summarized here.

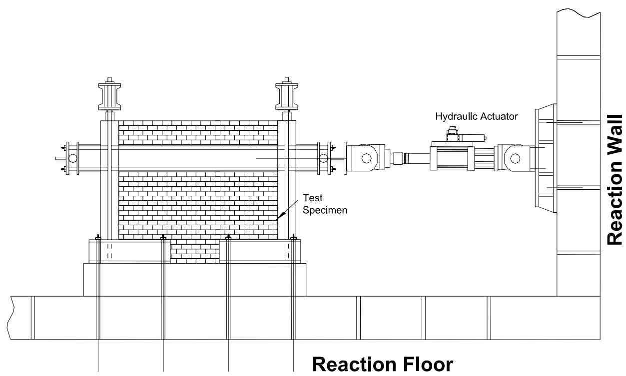
The nonlinear behavior of a non-ductile RC frame with masonry infills is complicated in that it can exhibit a number of possible failure mechanisms, which cannot be accurately captured with any existing simplified analytical approach such as the use of a braced frame with equivalent diagonal struts. A detailed finite element model is the only general means to predict the behavior of such a structure in a reliable manner. In this project, refined finite element models will be developed to predict the progressive damage and failure of infilled RC frames under earthquake loads. These models will represent major advancements of the existing modeling capabilities, and will help realize a main goal of the NEES program, which is to replace physical experiments with model based-simulation using high-performance computing capabilities. Existing finite element models for concrete and masonry suffer from a number of shortcomings. For example, traditional pressure-sensitive elastoplastic concrete models tend to over-predict strength and ductility and do not exhibit sufficient pinching under cyclic loading. There have also been severe problems with the convergence of numerical solutions when hard material nonlinearities are encountered in the form of discontinuous softening and localization. To remedy these serious shortcomings, the following simulation capabilities will be developed: (1) a continuum damage-viscoplastic model for dynamic degradation analysis using solid elements, (2) a discrete interface model combining elastic damage and viscoplastic degradation in zero-thickness elements, and (3) a robust numerical implementation into a dynamic time integration algorithm based on ‘consistent’ linearization of the algorithmic tangent operators. The introduction of damage will enhance the performance of continuum and discrete interface elements under cyclic loading, while viscosity will provide a means to examine rate effects and at the same time alleviate mesh-size sensitivity that is normally observed with rate-independent smeared crack models.

Cost-effective retrofit methods that can prohibit the shear failure of non-ductile columns and contain the soft-story mechanism of an infilled frame will be developed. In particular, the use of sprayable, high-performance fiber-reinforced cement-based composites (HPFRCC) as an infill retrofit method is being extensively studied. The HPFRCC material being investigated is one that exhibits fine, multiple cracking and a strain hardening response up to 3% strain in direct tension. The material is micromechanically designed to achieve this response using a small volume fraction of high-modulus polymeric fibers (less than 2% by volume). The fibers are randomly oriented and distributed and are typically 8-mm long. Sprayable HPFRCC contains fine sand but no coarse aggregate. The mix characteristics make the material conducive to being sprayed using a wet-mix shotcreting approach. The absence of coarse aggregate eliminates the size effect and will result in a stiffness that is roughly half the stiffness of traditional concrete. Therefore, it can be used for full-scale and small-scale applications (or specimens), and, as a sprayable coating (~45mm thick), it will lead to a relatively low increase in stiffness to a masonry infill wall. Furthermore, sprayable HPFRCC combined with reinforcement can be tailored by selecting the appropriate HPFRCC mix and reinforcement details to provide ductility without providing too much additional strength to an infill wall.

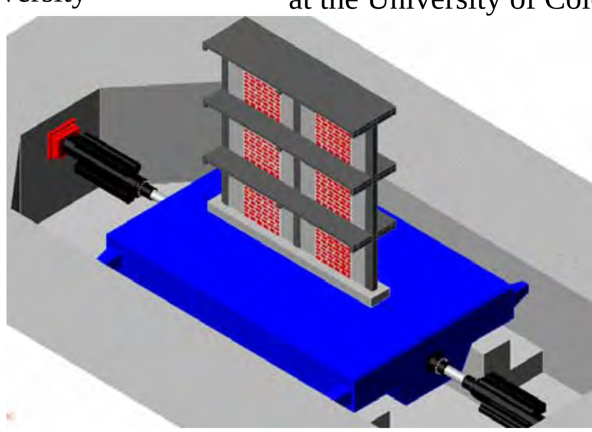
The analysis tools and retrofit methods developed in this project will be validated by experiments of various scales at the participating institutions as shown in Fig. 1.



Small-Scale Component Tests
at Stanford University



2/3-Scale Frame Tests
at the University of Colorado, Boulder



Full-Scale Tests at the University of California, San Diego

Fig. 1 – Experimental Program

NEESR-SG: Seismic Simulation and Design of Bridge Columns under Combined Actions, and Implications on System Response

Submitted By:

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Shirley Dyke, *Washington University, St. Louis*
Amr Elnashai, *University of Illinois-Champaign-Urbana*
Pedro Silva, *University of Missouri, Rolla*
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Submitted to Session (please mark one):

µ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
µ 2. Advanced Tools Session: ***Sensors and Instrumentation***
µ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
µ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
X 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
µ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
µ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- The effect of combined actions on the behavior and design of bridge columns is study through experimental and analytical studies.
- Design and analysis tools will be developed that incorporate combined loading effects.
- Models of bridge systems will be used to develop the loading protocols for the experiments and then will be used to determine the impact of combined loading on system behavior.
- An integrated education, training and outreach program has been developed for the project that spans from 4th graders to practicing engineers using teaching modules.

Abstract/Summary

Bridge columns are subjected to combinations of actions and deformations, caused by spatially-complex earthquake ground motions, features of structural configurations and the interaction between input and response characteristics. Combined actions/loadings can have significant effects on the force and deformation capacity of reinforced concrete columns, resulting in unexpected large deformations and extensive damage that in turn influences the performance of bridges as vital components of transportation systems. Current analysis methods, behavior theories and design practices do not take into consideration the full range of interactions, due to the scarcity of experimental data and a lack of behavioral understanding.

Therefore, the objectives of the project are to develop a fundamental knowledge of the impact of combined actions on column performance and system response and to establish analysis and design procedures that include the impact. The project utilizes an integrating analytical and experimental research where physical tests are driven by analyses and simulations that examine the system response of various bridge types under different loading conditions, and analytical models are calibrated by experimental data.

The experimental program includes quasi-static testing of twenty-four large columns providing fundamental behavior including the impact of torsional moments at University of Missouri, Rolla (UMR), pseudo-dynamic testing of three large and four small scale columns with variable axial load, within a bridge system simulation, at the University of Illinois at Urbana-Champaign (UIUC), real-time dynamic testing of eight large scale columns with bidirectional, torsional and variable axial load inputs at University of Nevada, Reno (UNR), plus an integrated experiment with three columns linked through simulation, conducted at UIUC by UMR. Fragility analysis will be undertaken, leading to the derivation of probabilistically-based fragility relationships for bridges subjected to combined action. Simplified analysis and design tools will be developed as well as the necessary code language to change the existing practice.

The focus at UMR is on determining the direct interaction of bending moments, torsion and shear under constant axial load. The tests at UMR include quasi-static cyclic combined loading to be applied to ½-scale bridge columns producing a combination of axial loads, bending, shear and torsional moments. The first four columns are being tested and will be subjected to a 7% cross-section capacity axial load and a varying bending and torsional moments as well as shearing forces. The columns are designed to have a dominating flexural and torsional failure. All cross-sections are circular in shape and reinforced with 2% longitudinal, 1% transverse reinforcement, and a column length to diameter aspect ratio of 6.25. The experimental results will provide some initial insight on the effect of torsion and complex loading on the residual twisting and flexural deformation of the column base (plastic hinge), which under reversed cyclic loading and large ductility levels, can lead to significant distortions of the longitudinal reinforcement, resulting in a drastic reduction of the axial load carrying capacity of these columns. The concurrent analytical study will focus on the development of new constitutive models for RC under combined axial/bending/torsional loads in conjunction with available inelastic frame-type elements and use of the experimental results to calibrate the proposed model.

At UIUC distributed hybrid simulations are being carried out at both the full-scale and 1/5-scale laboratories of the MUST-SIM facility. The small-scale tests currently underway will be combined with analytical parametric studies to steer the more costly and time consuming large scale testing. The group at UIUC has performed parametric analytical investigations of simple bridge structures subject to different levels of earthquake excitations considering vertical ground motion. From these studies, appropriate input motions for the specimens tested in the subsequent phases of the project have been determined. The process of selecting a testing prototype is currently underway. System identification of the MUST-SIM facility, especially the 1/5th scale facility, was performed. The System ID and calibration was performed using rubber and aluminum specimens to gain an understanding of the performance of the facility under action, deformation and mixed control modes. Three pilot small-scale RC bridge piers were constructed at 1/10th scale. The three specimens are intended for static pushover and online computer-controlled testing. The results of the small scale pilot tests will provide the necessary information to construct the large scale bridge piers for testing in the full scale facility at UIUC.

At UNR, the real-time dynamic test setup is being developed and tested. A column that was tested as part of a previous project has been repaired and will be tested under dynamic loading and variable axial load. Loading protocols will include those that were similar to the previous testing plus input that is received from the bridge system analysis at UCLA. Further experiments will be conducted at UNR after the completion of preliminary experiments at UMR and UIUC.

The research work at UCLA focuses on comprehensive dynamic analysis of bridge systems including bridge superstructure, foundation and surrounding soil. Two prototype bridges, originally published as FHWA design examples #4 and #8, were selected for simulation in the preliminary analysis. They each are reinforced concrete box girder type bridges, yet are different in several structural design details. The bridges are being modeled numerically using nonlinear beam elements and appropriate foundation elements. Two suites of ground motions were selected representing different hazard levels at a site located in metropolitan area of Los Angeles. These motions were selected according to a new methodology currently being developed at Pacific Earthquake Engineering Research (PEER) center where the seismological and geotechnical uncertainties are incorporated systematically. A series dynamic analysis will be conducted on these two prototype bridges to evaluate the seismic demand on bridges as a function of different ground motion and structural characteristics. The cases where combined actions can be significant will be identified. The work will serve as a linkage between the different experimental programs at UMR, UIUC and UNR.

An integrated education, training and outreach program, that is being lead by WU, has been developed for the project that spans from 4th graders to practicing engineers. Modules will be developed for teachers and professors that can be inserted in their courses. Modules will be used by the research team in summer camps, visits to local elementary, middle and high schools, undergraduate and graduate courses and in continuing education courses. Specific programs are targeted towards underrepresented groups. At this point, summer camps are planned for the summer 2006 at both UNR and UMR.

NEESR-GC: Seismic Risk Mitigation for Port Systems

Submitted By:

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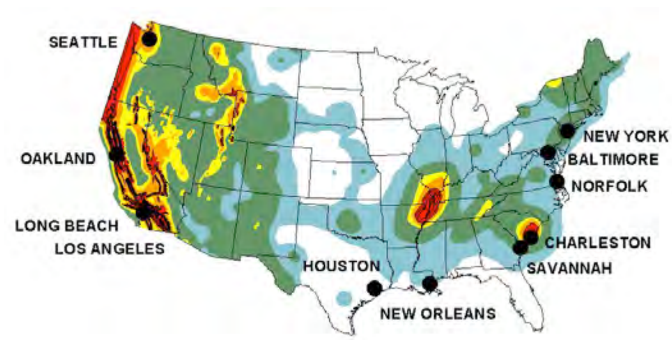
Georgia Institute of Technology
School of Civil and Environmental Engineering, Atlanta, GA 30332-0355

Submitted to Session:

❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
❍ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
❍ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
● 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- The nature of port infrastructure, operations, and governance requires a multidisciplinary approach to seismic risk mitigation.
- Seismic risk mitigation decisions are best made in the context of the overall performance of the port system rather than its individual components.
- The project seeks to improve the participation of under-represented groups in STEM fields with K-12 through professional education programs.



Abstract/Summary

Earthquakes pose a severe threat to the nation's seaports, which are critical assets in this era of global trade. Ports face unique seismic risk issues ports due to the nature of their infrastructure, long-range planning horizon, diversity of stakeholders, and the roles of port authorities. This NEESR Grand Challenge project integrates engineering, logistics, risk analysis, and decision sciences within a seismic risk reduction framework that uses the performance of the port system rather than its individual components as the basis for seismic risk mitigation decisions. This systems-level approach is essential for estimating the full scope of direct and indirect losses following an earthquake.

The project uses both experimental and numerical simulation to advance the understanding of the complex soil-foundation-structure systems that are typical of ports and develop geotechnical and structural mitigation alternatives targeted at all parts of the soil-foundation-structure system. The research program examines innovative soil improvement techniques to mitigate liquefaction hazards using the NEES@UTexas mobile shaker and the NEES@UCDavis centrifuge. Pile

configurations and pile-deck connections with improved strength and ductility will be developed using full-scale tests at NEES@UIUC. Emphasis will be placed on techniques that are “repair-friendly” and can quickly and inexpensively be returned to service following an earthquake. Tests will be performed at NEES@Buffalo to evaluate the behavior of large container cranes, and investigate innovative methods to mitigate damage from large ground displacements due to liquefaction. The experimental and numerical simulations will be used to develop fragility relationships for the soil-foundation-structure system with and without retrofitting that lead directly to the operational capacity of port facilities following an earthquake and aid the determination of repair requirements for the damaged components.

The multi-disciplinary project team includes logistics and behavioral decision-making researchers to evaluate the systems-level impacts of alternative risk mitigation strategies. Logistics researchers will develop analytical port operations models to predict port performance metrics that can be incorporated directly into an optimization-based risk mitigation framework. Real-time decision support tools will also be developed to optimize port operations following an earthquake. Behavioral decision researchers will use structured, collaborative techniques including interviews, surveys, and interactive decision-aiding sessions with port stakeholders to define port system performance objectives in a manner that clarifies underlying choices and explicitly addresses tradeoffs between alternative risk mitigation strategies.

The broader impacts of this project include the application of the real-time decision support models to minimize the impact of an act of terrorism at a U.S. port. Ports are thought to be one of the most vulnerable components of the nation’s transportation system. Like natural hazards, acts of terrorism reduce the throughput capacity of the port by damaging some or all of a port’s facilities. In this respect, the development of these decision support models that optimize throughput capacity during periods of disruption can contribute to increased homeland security.

Education, outreach, and training (EOT) programs promote education at K-12 through professional levels and addresses the dearth of under-represented students in STEM (Science, Technology, Engineering, and Mathematics) fields. The project will partner with Georgia Tech’s Center for Education Integrating Science, Mathematics and Computing (CEISMC) and Atlanta’s Westlake High School, a 99% African-American science and mathematics magnet school, to host teachers and students for summer internships; a collaborative HBCU-REU program will increase the number of under-represented students in the STEM areas that pursue advanced degrees; Minority Postdoctoral Fellowships will help bridge the link from graduate school to academia; and an Industrial Fellowship Program will aid in technology transfer to practicing engineers.

Inelastic Web Crushing Performance Limits of High-Strength-Concrete Structural Walls

Submitted By:

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[1]*Michigan State University,*[2] *Tufts University*
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Submitted to Session (please mark one):

- ❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- ❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- ❍ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- ❍ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
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- ❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- ❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Recent research on the seismic design of hollow piers has provided new insights on the accurate assessment of elastic and inelastic web crushing shear capacity of structural walls with boundary elements.
- Ductile shear failures, displayed as web crushing failures or yielding of the transverse reinforcement at relatively high levels of displacement ductility, could represent a new genre of ductile failure mechanisms.
- Rational assessment models indicate that high-strength concrete could increase the capacity provided by inelastic web-crushing mechanisms, yet its potential cannot be fully realized with current design criteria.
- A recently funded NEESR-II project focuses on evaluating the potential noted above. The research plan combines collaborative elements between two non-NEES-site universities, engineering practice, and outreach to professionals.
- The presentation will provide an overview and progress report of the NEESR-II project recently underway.

Abstract/Summary

Significantly lighter members for structural walls in moderate seismic zones are a viable possibility by using high-strength concrete and incorporating ductile shear failures as a new genre of ductile failure mechanisms. Recent research on the seismic design of hollow piers has provided new insights on the accurate assessment of elastic and inelastic web crushing shear capacity of structural walls with boundary elements. Ductile shear failures, displayed as web crushing failures or yielding of the transverse reinforcement at relatively high levels of displacement ductility, allow for easy repair since damage to the boundary elements can be minimal. The advent of high-strength concrete has generated great interest in the promise that it

may provide for cost-effective seismic design. However, its potential cannot be fully realized due to current outdated and prescriptive design criteria. Rational assessment models show that web crushing is linearly related to concrete compressive strength, indicative of new possibilities for increased shear capacities of lighter members with increased concrete strength.

A recently funded NEESR-II project has as its objective to verify the above-noted promise by investigating and establishing rational performance levels on the inelastic web crushing limits for high-strength-concrete (HSC) structural walls. Specifically, the project will: (1) investigate and establish the web-crushing performance limits of HSC structural walls at moderate ductility, (2) investigate the bi-directional seismic performance of structural wall assemblies in the context of hollow piers, (3) develop analytical modeling and analysis procedures for structural walls with boundary elements, and (4) develop simple assessment models for HSC structural walls.

The first part of the experimental investigation focuses on the determination of dependable limits to web crushing failures for ductile shear response in HSC structural walls through 8 quasi-static monotonic and cyclic tests on 1/4-scale walls with concrete strengths of 34, 69, 103, and 137 MPa. Analytical investigations are aimed at the development and validation of assessment tools for structural walls loaded in their principal and diagonal directions through nonlinear finite element models and simpler sectional analyses. Using improved assessment models, two 1/4-scale HSC (137 MPa) wall assemblies analogous to hollow piers will be designed and tested under bi-directional loading. One assembly will be designed to obtain a web crushing failure at low ductility levels to validate the established limits for systems under combined loading. The second unit will be designed to fail in a ductile shear failure mode at high ductility levels. Conventional and advanced non-contact strain measurements will be correlated with analysis results to fundamentally understand the associated deformation limits. Rational assessment models will be developed to provide designers with practical tools for the design of HSC structural walls with reliable ductile shear failure modes. A website is being developed to disseminate results to researchers, designers, educators and students. Transition to practice is being pursed by active participation in technical committees.

The research plan combines collaborative elements between two non-NEES-site universities, engineering practice, and outreach to professionals. The experimental resources of Michigan State University’s Civil Infrastructure Laboratory will be used to conduct the conventional pseudo-static investigations, and the Multi-Axial Subassemblage Testing (MAST) NEES facility at the University of Minnesota-Twin Cities will be used to evaluate the bi-directional performance of structural wall assemblies. The research effort will be assisted by an external advisory board with significant project-related experience.

The presentation will provide and overview and status of this recently funded NEESR project, with emphasis on the mechanisms and rationale behind ductile shear failures, evaluation of nonlinear analyses on single and pier-wall assemblies using available experimental data, and the design of the first series of single-wall tests to be conducted during the summer of 2006.

TAB 4

Day 3: June 23

NEES Annual Meeting Day Three
Friday June 23, 2006

Day Three Program At-A-Glance

Friday June 23, 2006

7:00 – 8:00 a.m.	**Continental Breakfast** *(Salons C, D, & E)*
8:00 – 9:30 a.m.	**New NEES Research Projects Spotlight II Plenary Session** *(Salons A & B)*
9:30 – 11:00 a.m.	**International Collaboration Plenary Session** *(Salons A & B)*
11:00 – 12:00 p.m.	**Issue Forum Report-Back Plenary Session** *(Salons A & B)*
12:00 – 12:15 p.m.	**Closing comments and meeting adjournment** *(Salons A & B)*

Post–Annual Meeting Activities

12:30 – 1:30 p.m.	**Invitational lunch for Board, Staff, Committee Chairs, and Site Personnel** *(Washington Ballroom)*
1:30 – 5:00 p.m.	**NEESit End-User Workshop** Separate registration required.
1:30 – 6:00 p.m.	**NEESinc Board of Directors Meeting** Closed Meeting. *(Van Buren Room)*
1:30 – 6:00 p.m.	**Site Operations Managers' Workshop** Closed Meeting. *(Jackson Room)*
1:30 – 6:00 p.m.	**IT Managers' Workshop** Closed Meeting. *(Monroe Room)*
7:00 – 9:00 p.m.	**Invitational dinner for Board, Staff, Committee Chairs, and Site Personnel** *(Washington Ballroom)*

Session Descriptions

NEES Research Program: Spotlights on New NEESR Projects II Session

This is the last of four sessions with presentations from investigators of NEES Research Program (NEESR) new projects. These brief spotlights will highlight activities that embody the ideals of the NEES: collaborative endeavors for project preparation, experimental and numerical simulations, data management/IT, involvement with engineering practice professionals, and educational, outreach, and training activities.

International Collaboration Plenary Session

Presentations from participants in the World Forum, as well as international research activities in Japan and China.

Issue Forums Report-Back Plenary Session

This session will provide final reports from each of the three Issue Forums breakout session discussions. Presentations will be made by NEESinc's technical committees (*EOT*, *IT Strategy*, and *Site Operations Committees*).

NEES

Day Three: Friday, June 23, 2006

7:00 – 8:00 am

Continental Breakfast *(Salon C + D+ E)*

8:00 – 9:30 pm

NEESR New Projects Spotlight Session 2 *(Salon A+B)*

Session Chair: **Harry Yeh**, Oregon State University

Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses
Gregory Deierlein, Stanford University

NEESWood: Full-Scale 3-D Testing, Numerical Modeling, and Other Progress
John van de Lindt, Colorado State University

NEESR II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands
Russell Green, University of Michigan

Development of Performance-Based Tsunami Engineering -- PBTE
H. Ronald Riggs, University of Hawaii at Manoa

Experimental Verification of Semiactive Control of Nonlinear Structures Using Magnetorheological Fluid Dampers
Richard Christenson, University of Connecticut

High-Performance Fiber Reinforced Cement Composites for New Coupled Wall Systems and Retrofit of Existing Framed Structures
James Wight, University of Michigan

Day Three (con't): Friday, June 23, 2006

9:30 – 11:00 am

Broadening Participation: International Collaboration and World Forum Report *(Salon A+B)*

***Session Chair:* Roberto Leon**, Georgia Institute of Technology

Report on the World Forum on Collaborative Research in Earthquake Engineering
Bill Spencer, University of Illinois Urbana-Champaign

World Forum Report: Cyberenvironments
Jerome Hajjar, University of Illinois Urbana-Champaign

World Forum Report: Data Infrastructure
Gregory Fenves, University of California, Berkeley

World Forum Report: Simulations
Ahmed Elgamal, University of California at San Diego

Report on International Collaboration Interest Survey
Clifford Roblee, NEES Consortium, Inc.

Progresses of Large-Scale Tests at E-Defense, NIED, Japan
Masayoshi Nakashima, E-Defense, NIED, and Kyoto University

Research on Networked Structural Laboratories in China
Yan Xiao, University of Southern California/CIPRES-Hunan University

11:00 am – 12:00 pm

Issue Forums Report-Back Plenary Session *(Salon A+B)*

***Session Chair:* Rigoberto Burgueño**, Michigan State University

IT Strategy Committee (ITSC) Issue Forum Report
Jacobo Bielak, Carnegie-Mellon University (*ITSC Chair*)

Education, Outreach, and Training (EOT) Committee Issue Forum Report
Shirley Dyke, Washington University of St. Louis (*EOTC Chair*)

Site Operations Committee (SOC) Issue Forum Report
Marc Eberhard, University of Washington (*SOC Chair*)

Annual Meeting Adjourns at Noon

For those who are attending the Workshops (Site Operations Managers, IT Managers, and NEESit) or the Board of Directors' Meeting, please visit the registration table for a schedule of these events.

NEES

NEESR New Projects Spotlight Session 2

NEES

Friday, June 23, 2006

8:00 – 9:30 pm

NEESR New Projects Spotlight Session 2 *(Salon A+B)*

Session Chair: **Harry Yeh**, Oregon State University

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High-Performance Fiber Reinforced Cement Composites for New Coupled Wall Systems and Retrofit of Existing Framed Structures
James Wight, University of Michigan

Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses

Submitted By:

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E-mail: ggd@stanford.edu

Submitted to Session (please mark one):

µ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
µ 2. Advanced Tools Session: ***Sensors and Instrumentation***
µ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
µ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
● 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
µ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
µ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Enhanced seismic performance of buildings through controlled rocking and self-centering capabilities
- Comprehensive performance-based approach to tune system design parameters based on damage states for structural and nonstructural components
- Replaceable energy-dissipating fuses to facilitate post-earthquake repair
- International collaboration with large scale subassembly testing at NEES-Illinois and shake-table testing at E-Defense
- Practical implementation through participation of design and construction professionals

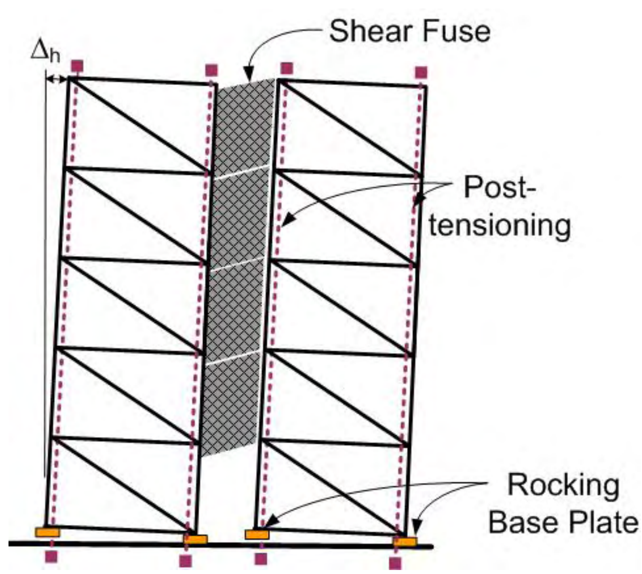

Figure 1 – Rocking braced frame with replaceable shear fuses and vertical post-tensioning

Abstract/Summary

Research and experience from past earthquakes suggest the need for buildings that are less vulnerable to damage and easier to repair after a major earthquake. Of particular concern are certain conventional systems, such as concentrically braced steel frame buildings, which are used prevalently in high seismic regions and whose design may rely on more inelastic energy dissipation than the systems can provide. Our research aims to develop a new structural system

that employs controlled frame rocking action and replaceable structural fuses to provide safe and cost effective resistance to earthquakes. The system combines desirable aspects of conventional steel-braced framing with energy dissipating shear fuses and column fuses that are mobilized through rocking action (see Figure 1). Vertical post-tensioning is provided to increase over-turning resistance and enhance the self-centering characteristics of the system. The fuses utilize novel materials and components, including high-performance fiber reinforced cementitious composite shear panels, steel shear panels with slits, and buckling-restrained axial column fuses, and other components. Guided by performance-based capacity design principles, the fuses are designed to be replaceable and can be tuned to provide optimal performance.

Through a combined program of computational and experimental research, the project encompasses component and complete system response and synthesis of the results through a methodology for performance-based design that directly assesses life safety and life-cycle economic factors. The proposed concept emphasizes damage prevention to foundations and other structural elements that are difficult to repair; inelastic energy dissipation in structural fuses that are easy to replace; story drift control so that nonstructural damage is reduced; elimination of residual drifts under moderate to large earthquakes; and acceptable safety against collapse.

Recent research in Japan has demonstrated the viability of controlled rocking as a mechanism to improve the seismic performance of braced frame structures. As shown in Figure 2, the Japanese study employed shake table testing of a braced frame with a specially designed flexing base plate. In the United States, rocking braced frames have been constructed on a limited basis within current code guidelines to improve seismic performance (Mar, D., "Emerging Ideas in Seismic Design", *ATC/JCSA 11th US-Japan Workshop on Improvement of Structural Design and Construction Practices, Oct. 2005*). Shown in Figure 3 is an example of a rocking frame system that employed vertical post-tensioning to enhance the self-centering characteristics. Our NEESR project seeks to further develop, improve, and validate the performance of rocking systems through the use of innovative design concepts and construction details.

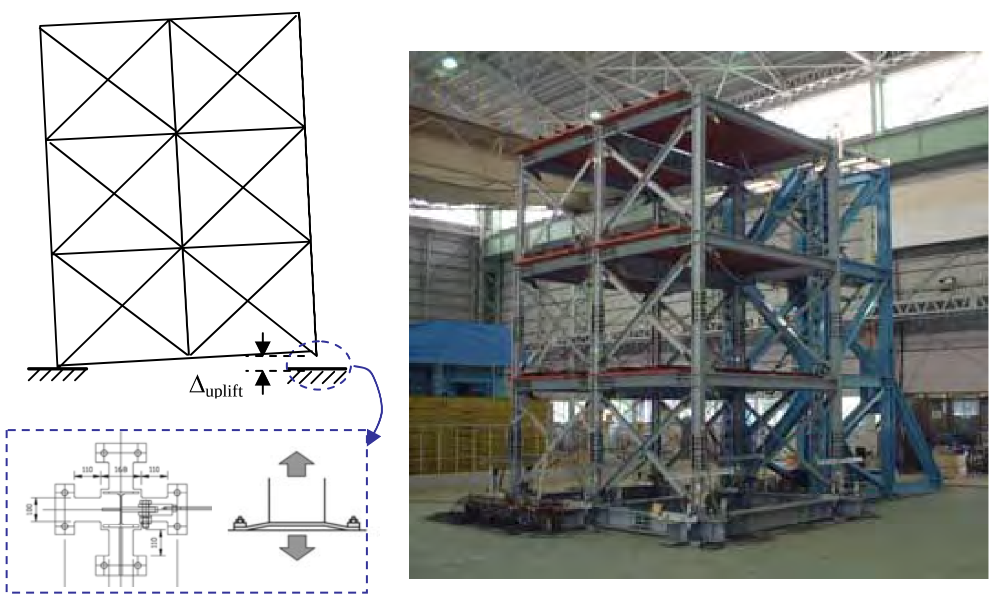

Figure 2 – Shaking-table simulation of steel braced frame with rocking (Midorikawa, M., Azuhata, T., Ishihara, T. ,Wada, A., "Shaking Table Tests on Rocking Structural Systems Installed Yielding Base Plates in Steel Frames," *Proceedings of STESSA 2003.* pp. 449-454, Naples, Italy, June 9-12,

Working in collaboration with researchers and engineers in Japan and the United States, our NEESR team is presently conducting parametric design studies and supporting nonlinear analyses to characterize the primary design variables for braced-frame rocking systems, including properties of the energy dissipating fuses and vertical post-tensioning. We are also evaluating alternative materials and designs for the replaceable shear and column fuses. Through these studies we have begun to establish the optimal range of design parameters (e.g., strength and stiffness of fuses and the column post-tensioning) to achieve the desired system performance under varying earthquake intensities. Ultimately, the design concepts and procedures will be validated through large scale quasi-static testing of a rocking-frame subassembly at the University of Illinois NEES facility (mid-2007) and a large-scale frame test at the E-Defense shaking table in Japan (mid-2008).

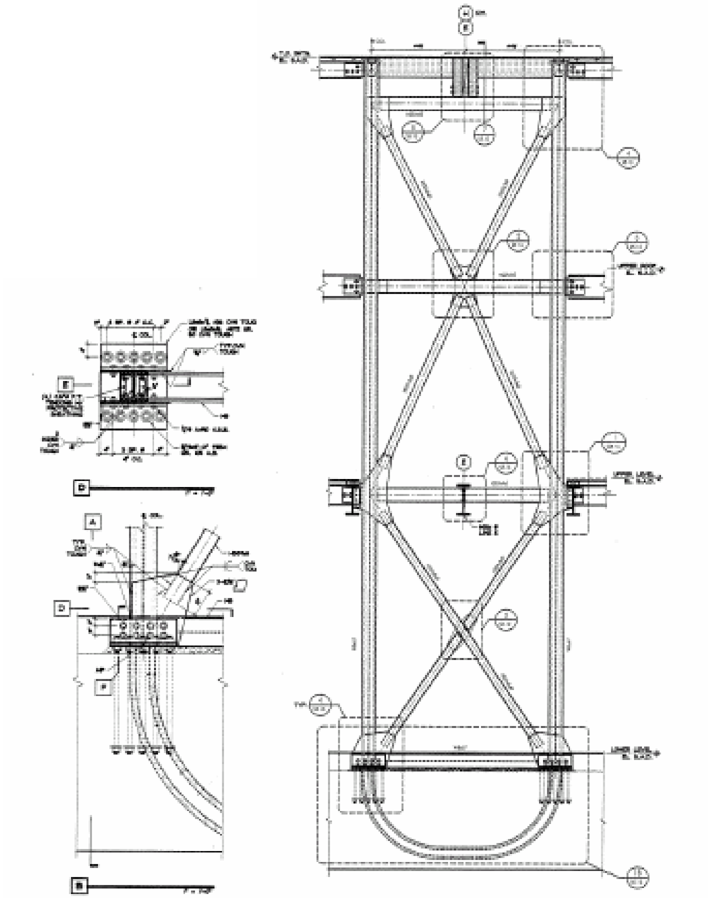

Figure 3 – Post-tensioned rocking frame design for low-rise building in Orinda, CA (courtesy Tipping-Mar Assoc).

Acknowledgements:

Our NEESR research team includes the following individuals: Professors Gregory Deierlein, Sarah Billington, and Helmut Krawinkler of Stanford University; post doctoral associate Paul Cordova and graduate student Eric Borchers of Stanford University; Professor Jerome Hajjar and graduate student Kerry Hall of the University of Illinois; Professor Mitsumasa Midorikawa of Hokkaido University; and David Mar of Tipping-Mar Associates of Berkeley, CA.

This abstract is based upon work supported by the National Science Foundation under Grant No. CMS-0530756. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessary reflect the views of the National Science Foundation.

NEESWood: Full-Scale 3-D Testing, Numerical Modeling, and Other Progress

Submitted By:

John W. van de Lindt; Andre Filiatrault; Michael D. Symans; David V. Rosowsky; Rachel A. Davidson
Colorado State University; University at Buffalo; Rensselaer Polytechnic Institute; Texas A&M University; Cornell University
(Contact: J. van de Lindt; Civil Engineering Dept., CSU, Fort Collins, CO 80523-1372; jwv@engr.colostate.edu).

Submitted to Session (please mark one):

- μ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- μ 2. Advanced Tools Session: ***Sensors and Instrumentation***
- μ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
- μ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
- ● 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
- μ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- μ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Largest 3-D shake table test ever conducted in the U.S. will be underway (2 of 7 phases completed); A two-story, 77 kip, 1800 sq ft townhouse spanning both shake tables at the UB NEES node. **A live feed of a 3-D test may be shown during the presentation, showcasing the tele-presence capabilities of NEES!** If for some reason this is not possible due to scheduling, a video will be shown from the Phase 1 testing.
- Viscoelastic damper design, installation, and effect on performance will be discussed.
- Version 1.0 of the SAPWOOD (Seismic Analysis Program for WOOD) software with graphical user interface will be introduced.
- Practitioner advisory committee (PAC) and other industry involvement to ensure technology transfer will be discussed.
- Payload project proposal submitted by D. Dinehart (Villanova) for integration into the NEESWood benchmark tests.
- Discussion of plans to utilize the E-Defense shake table in Miki, Japan and collaborate with Prof. I. Sakamoto (Univ. of Tokyo) and Dr. C. Minowa (NIED).

Abstract/Summary

The "NEESWood: Development of a performance-based seismic design philosophy for mid-rise woodframe construction" project has the objective of developing and articulating a new design philosophy that will provide a logical, economic basis for the design of mid-rise woodframe construction in seismic regions. The project consists of ten major tasks being carried out by PI's at five universities. Several of these tasks, which are already well underway, will be presented with overall emphasis of the presentation

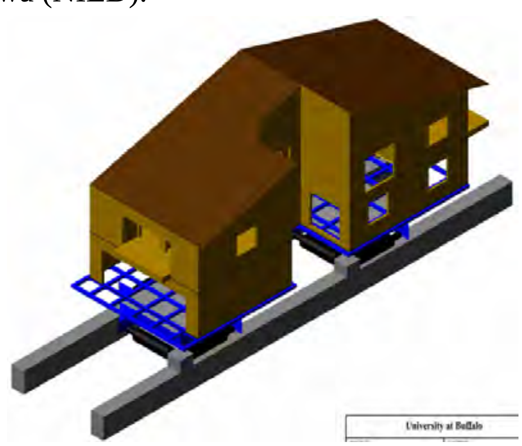

FIG 1: Solid model of the two-story townhouse spanning both UB NEES shake tables

being on the progress to date. The presentation will include: (1) The benchmark testing of the largest structure ever tested using a 3-D shake table in the U.S. including supplemental dampers during one phase of the tests. A solid model of this two-story 56 ft x 23 ft structure is shown spanning the two UB NEES shake tables in Figure 1. **A live web-feed test of the benchmark structure may be shown during the presentation, if timing aligns with the presentation, as hoped.** In the event that this is not possible, video of a prior test phase will be presented. The purpose of the benchmark testing phases will be explained along with their ties to the development of a new seismic design philosophy; and (2) Numerical predictions of the benchmark structure response using new and existing software including predictions of response with supplemental dampers installed in selected walls. A brief demonstration of the SAPWOOD software will be included, which includes a graphical user interface for both input and output. In addition, the presentation will include discussion on the involvement of the practitioner advisory committee (PAC), and the initial steps in the philosophical development of the seismic design procedure. The development of the design philosophy is currently being pursued as a two-prong approach, i.e. two different approaches for comparison.

The presentation will be given by J. van de Lindt (on site in Washington D.C.) and Andre Filiatrault (off site at the UB NEES node via NEESit).

NEESR II: Mechanisms and Implications of Time-Dependent Changes in the State and Properties of Recently Liquefied Sands

Submitted By:

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Submitted to Session (please mark one):

❍ 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
❍ 2. Advanced Tools Session: ***Sensors and Instrumentation***
❍ 3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
❍ 4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*
● 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*
❍ 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
❍ 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Overview of the NEESR project, to include objectives and outcomes.
- Description of field portion of the project.
- Description of laboratory portion of the project.

Abstract/Summary

The objective of this research project is to develop a better understanding of the mechanisms and implications of time-dependent changes, commonly referred to as "aging," in the state and properties of recently liquefied sands. Aging effects in sand, such as increases in penetration resistance with time after deposition, densification, and/or liquefaction, are known to occur in-situ, but the causes of these effects are not fully understood. Nonetheless, these effects have important ramifications in earthquake engineering. First, the lack of understanding of the phenomenon is an impediment to quality assurance/quality control (QA/QC) for ground densification projects aimed at mitigating the damaging effects of liquefaction. This can be understood by considering that most liquefaction evaluation procedures correlate liquefaction susceptibility to in-situ indices, such as penetration resistance (SPT and CPT) and small stain shear wave velocity (V_s), all of which are influenced by aging effects. Consequently, it is unclear as to how long after ground densification should QA/QC in-situ tests be performed to ensure that the densification was sufficient to mitigate liquefaction susceptibility. Aging effects also introduce considerable uncertainty in field-based liquefaction susceptibility correlations, as the

influence of aging on the in-situ test indices used to develop correlations is unknown but certainly varied among the case histories in the liquefaction database. Within the spectrum of probabilistic based earthquake engineering (PBEE) that is being embraced more and more by the profession, a probabilistic quantification of the influence of aging on in-situ indices is required.

Previous investigations into the underlying mechanisms of aging of sands have been inconclusive, sometimes raising more questions than resolving. Unfortunately, the boundary conditions for most published field studies have been too numerous and variable to conclusively identify the mechanisms underlying aging. Nevertheless, the results of such field studies add to the evidence that the aging phenomenon exists. Building on the lessons learned from previous studies, the proposed research entails synergistic field and laboratory investigations to be performed collaboratively by the University of Michigan and by the University of Rhode Island. Also included on the research team is Dr. Wilhelm Degen, Senior Vice President, Vibrofoundation, Inc., who will be donating equipment time and expertise and Dr. James K. Mitchell (Virginia Tech).

Several sites are being evaluated to perform the field investigation portion of the project, which will involve the inducing liquefaction by explosives, vibroflotation, and vibroseis at adjacent locations. The former two techniques were selected because they are common ground densification methods in which the aging phenomenon has been observed. However, both methods introduce foreign elements into the soil, as explosives generate gases and vibroflotation introduces heavily aerated water. The dissipation of the blast gases and air from the ground water with time after treatment may be one of the underlying causes of aging in sand. Also, the blast gases change the pH of the pore fluid, which may contribute to the aging effects. To determine whether the dissipation of gases from pore water and the change in pH of pore water influences aging, liquefaction will also be induced using a vibroseis. The vibroseis only introduces seismic waves into the ground and will thus serve as the control case.

Liquefaction will be induced by each method in three, non-overlapping regions at the site. It is estimated that each region should have a minimum 15 m radius to ensure the energy imparted to induce liquefaction in one region does not influence to the soil in an adjacent region, as well as to ensure elevated pore pressures do not migrate among adjacent regions. An example plan view of the site test layout is shown in Figure 1a. Within each of the regions, accelerometers and pore pressure transducers will be put in the top and lower thirds of the liquefiable layer, with an example plan view of the instrument layout shown in Figure 1b. Additionally, instruments to monitor settlement will be installed (e.g., Sondex settlement tubes).

The purpose of the pore pressure transducers is to confirm that liquefaction has been induced (i.e., excess pore pressure equal to the initial effective overburden pressure), and to allow the temporal and spatial monitoring of the excess pore pressure generation and dissipation. The accelerometers will allow the induced strains to be computed. Also, the accelerometers at different depths can be used to calculate the energy dissipated in the soil during the liquefaction process, which will allow an assessment of whether the amount of energy imparted in the soil influences the magnitude of aging effects. The Sondex settlement tubes will allow the amount of densification to be determined as a function of depth.

The post-liquefaction monitoring of aging effects in each of the three regions will be performed as shown in Figure 2. Initial plans call for the indices to be measured on a regular basis for the first four weeks after liquefaction is induced. However, the time interval between the radial sets of soundings will increase as the changes in the values of the in-situ indices with time decrease. Monitoring of the aging effects will continue for the duration of the project.

In conjunction with the field investigation, an aging study will be performed in the laboratory using soil and groundwater from the field site. The laboratory study will involve the systematic variation of boundary conditions so that the influence of each on aging can be ascertained, with the field investigation providing a comparative baseline of the cumulative influence of the various testing conditions and parameters. Figure 3 is a photo of a mini-calibration chamber that is being considered for use in the laboratory portion of the study.

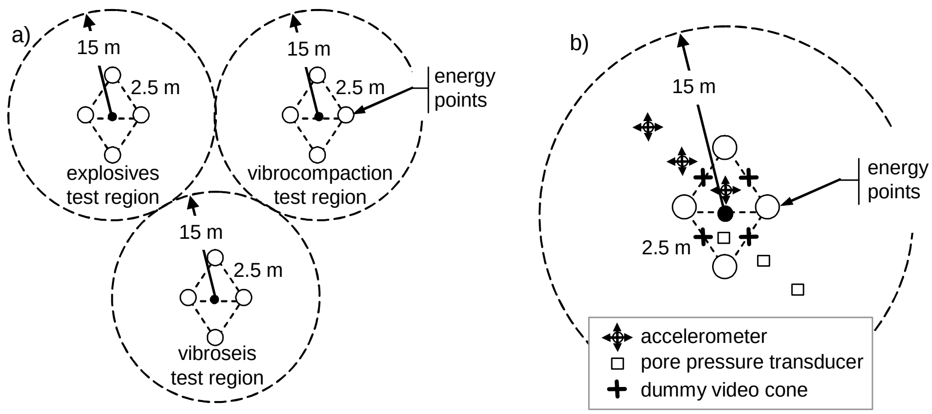

Figure 1. a) Example plan view of the site test layout, and b) Example plan view of the instrument layout within a given test region. The "energy points" are the location where liquefaction will be induced via vibro-compaction, explosive compaction, or using the vibroseis.

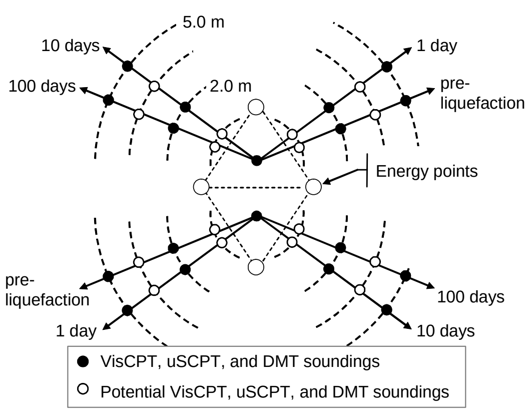

Figure 2. Idealized plan view of in-situ sounding locations for time-dependent changes of in-situ test indices.

Figure 3. Mini-calibration chamber being evaluated for use in the laboratory portion of the aging study.

Development of Performance Based Tsunami Engineering - PBTE

Submitted By:

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Submitted to Session (please mark one):

1. Advanced Tools Session: ***Pushing Experimental Boundaries***
2. Advanced Tools Session: ***Sensors and Instrumentation***
3. Advanced Tools Session: ***Numerical Simulations of NEES Data***
4. NEESR Project Spotlight **ACTIVE PROJECTS** *(NEESR Project personnel only)*

X 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*

6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Development of methodology and tools for PBTE
- Enhanced tsunami inundation modeling with tsunami wave basin validation
- Fluid-structure interaction modeling and wave tank calibration
- Development of tsunami loading criteria and time history
- Structural analysis for tsunami loading time history
- Development of code compatible design guidelines
- Tsunami wave basin testbed validation and demonstration

Abstract/Summary

This research will develop the methodology and tools for implementation of site specific Performance Based Tsunami Engineering (PBTE) for use in the analysis, evaluation, design and retrofit of coastal structures and facilities. The technical focus of the work is the improvement of tsunami inundation models, simulation of fluid-structure interaction, development of structural loading time histories, and the application of these in a non-linear structural analysis to determine the expected performance of the constructed facilities. Significant potential outcomes include: PBTE methodology; refined and validated analysis tools; requirements for tsunami-resistant structural design, including building code compatible guidelines; performance level specifications; significant efforts in outreach and education; and dissemination of the results.

This presentation will provide an overview of the project objectives and scope, an update of progress to date, and planned activities for the first phase of the project.

Experimental Verification of Semiactive Control of Nonlinear Structures using Magnetorheological Fluid Dampers

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Submitted to Session (please mark one):

- o 1. Advanced Tools Session: ***Pushing Experimental Boundaries***
- o 2. Advanced Tools Session: ***Sensors and Instrumentation***
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- o 6. Technical Advances Session: ***Results Demonstrating NEES' Technical Potential***
- o 7. Technical Advances Session: ***What have we learned about collaborative research***?

Major points/topics:

- Experimental verification of a semiactive control system employing three 200 kN Magneto-Rheological (MR) fluid dampers applied to a full-scale seismically excited steel structure with nonlinear material behavior. Experimental tests make use of the Fast Hybrid Test System at the University of Colorado at Boulder.
- Challenges conducting research from an off-site location and use of NEES cyberinfrastructure to meet these challenges.
- Experiences using NEES Central for data management.
- An update on the outreach activity to invite interested research from around the world to submit controllers for experimental testing/evaluation of the MR damper controlled structure at the Fast Hybrid Test System at the University of Colorado at Boulder.

Abstract/Summary

Structural control shows great potential for hazard mitigation in civil structures. Semiactive structural control, in particular, provides supplemental damping to more efficiently dissipate the energy due to dynamic loads and increases the safety and performance of the structure. Semiactive control has typically been designed for and applied to linear structures. Civil structures, however, are typically designed to yield, thus behaving nonlinearly during extreme dynamic loading. Because they cannot inject mechanical energy into the controlled system, semiactive devices are inherently stable and well suited for application to structures with uncertainties and systems with the potential to behave nonlinearly. Additionally, the low power requirements of semiactive devices ensure that during extreme events, when external power may not be available, the semiactive device can continue to fully function using an alternate power source. Despite these advantages, semiactive control in the presence of nonlinear structural behavior has yet to be demonstrated experimentally.

The full-scale experimental dynamic testing of a nonlinear building model is a challenging task that can be addressed by the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Fast Hybrid Test System at the University of Colorado at Boulder.

This presentation will describe project activities for a pre-NEESR project utilizing the NEES shared-use Fast Hybrid Test system at the University of Colorado at Boulder to experimentally verify semiactive control strategies applied to full-scale buildings exhibiting nonlinear behavior during large seismic events. The experiments described in this paper will employ hybrid testing of three semiactive 200 kN magneto-rheological (MR) fluid dampers while simulating in real-time the nonlinear response of a building structure subjected to suites of simulated and recorded earthquakes. Additionally, the challenges encountered conducting research from an off-site location and use of NEES cyberinfrastructure to meet these challenges will be discussed along with the PIs experiences using NEES Central for data management. Lastly, an update will be provided on the outreach activity to invite interested research from around the world to submit controllers for experimental testing/evaluation of the MR damper controlled structure using the Fast Hybrid Test System at the University of Colorado at Boulder.

HIGH-PERFORMANCE FIBER REINFORCED CEMENT COMPOSITES FOR NEW COUPLED WALL SYSTEMS AND RETROFIT OF EXISTING FRAMED STRUCTURES

Submitted By:

James K. Wight[1], Gustavo J. Parra-Montesinos[1], Sarah Billington[2], Sherif El-Tawil[1], Antoine E. Naaman[1], and James LaFave[3]
[1]University of Michigan, [2]Stanford University, [3]University of Illinois
Department of Civil and Environmental Engineering
2340 G.G. Brown Building
Ann Arbor, MI 48109-2125

Submitted to Session (please mark one):

μ 5. NEESR Project Spotlight **NEW/Recently Underway PROJECTS** *(NEESR Project personnel only)*

Major points/topics:

- Strain-hardening, high-performance fiber reinforced cement composites to develop highly damage-tolerant earthquake-resistant structures.
- Component tests will be conducted to evaluate the behavior of precast coupling beams and panels for use in new coupled wall systems and for retrofitting deficient framed structures, respectively.
- Hybrid system tests that combine state-of-the-art finite element simulation with large-scale experimentation will be conducted for evaluation of the behavior of the proposed coupled wall system and the efficiency of the retrofit scheme during earthquakes.

Abstract/Summary

This research integrates researchers in the field of fiber cement composites, reinforced concrete, computational mechanics and large-scale experimentation to develop new coupled wall systems and a cost-effective, rapidly implemented retrofitting technique for deficient framed structures.

This research was conceived from the idea that the next generation of reinforced concrete (RC) structures should utilize ductile cementitious materials in critical regions, rather than extensive reinforcement detailing to provide shear resistance, concrete confinement and thus, an increase in deformation capacity of structural members and systems. In other words, the approach is to use a "better material" rather than "more material". Recent breakthroughs in fiber reinforced concrete technology have made this possible by allowing the achievement tensile strain-hardening behavior in cementitious materials with the use of relatively low volume fraction of discontinuous fibers (approximately 1.5%). Tensile strain capacities that exceed 1.0%, and a compression behavior that resembles that of well-confined concrete are typical of this new generation of fiber reinforced cement composites. Because of their superior response compared to traditional fiber reinforced concretes, these materials are often referred to as high-performance fiber reinforced cement composites (HPFRCCs).

The two primary applications for HPFRCC materials to be developed in this research are coupled shear walls in reinforced concrete (RC) structural systems and infill panels used to upgrade steel or RC framed structures by adding stiffness, strength, and energy dissipation capacity. Coupled shear walls are a popular structural system for medium-rise structures in zones of moderate to high seismicity. During a large earthquake it is anticipated that the coupling beams will undergo significant inelastic deformations and it is important for these beams to have a high energy dissipation capability and good stiffness retention. Steel reinforcement detailing required in RC coupling beams to resist earthquake-induced deformations are labor intensive and costly, which often lead practicing engineers to discard their use in medium- and high-rise construction.

In this investigation, the behavior of coupled wall systems that feature precast, lightly reinforced HPFRCC coupling beams will be investigated through hybrid tests that combine refined finite element simulation with large-scale testing of structural subassemblies (Figure 1). To facilitate system construction, it is proposed that the HPFRCC coupling beams be precast at a remote location. The precast beams would then be brought to the site and placed between the wall forms before concrete is cast at that particular story level. HPFRCC materials will be used 1) as a replacement for steel confinement reinforcement, 2) to provide additional shear resistance, and 3) to increase coupling beam damage tolerance. The NEES MUST-SIM Facility at the University of Illinois, in combination with the NEES-grid, will offer the opportunity to take HPFRCC materials to the system level and develop the next generation of coupled wall systems capable of remaining operational after a major earthquake without the need for major repairs.

The second proposed application for HPFRCC materials is for the construction of precast infill panels that will be used to upgrade steel and RC framed structures by adding lateral strength, stiffness, and energy dissipation capacity (Figure 2). This phase of the research is focused on steel framed structures and in particular critical facilities (hospitals, emergency response centers, schools, telecommunications centers, laboratories etc.), that must remain in full service during any seismic upgrade construction activity, as well as during repair activities after a seismic event. Therefore, the emphasis is on small and light precast units that can easily be moved into the facility and installed without disrupting normal operations. These elements are sized for the ability to be transported in an elevator and handled by two workers. The NEES RRW-ESF facilities at UC Berkeley will be used to evaluate the effectiveness of HPFRCC infill elements for the seismic upgrading of existing frame structures through large-scale experimentation and simulation (Figure 2).

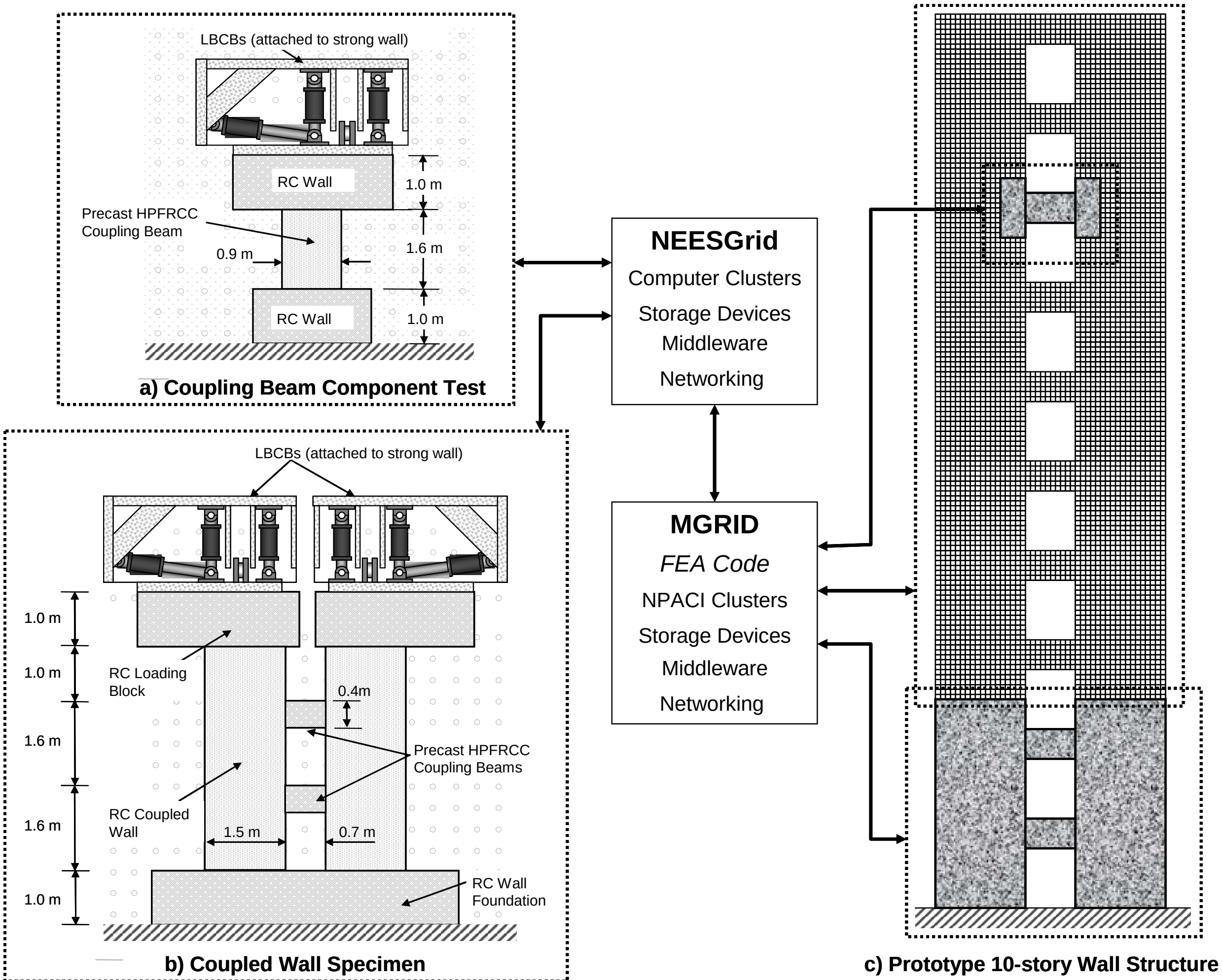

Figure 1 - Test specimen simulating coupling beams and coupled-wall base

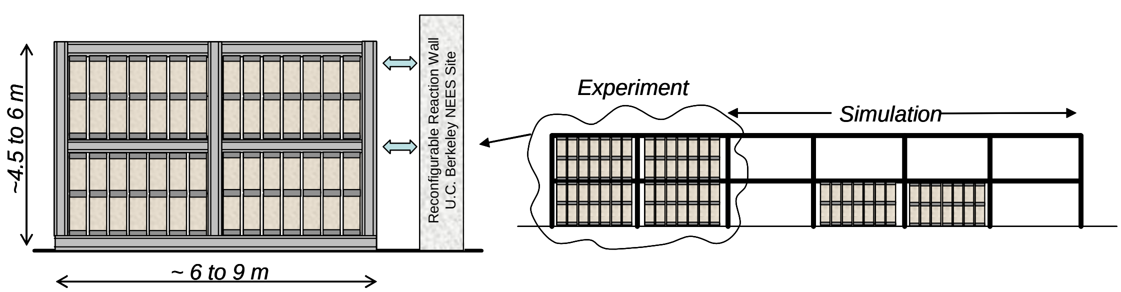

Figure 2 - Hybrid simulation of infilled steel frames for UC Berkeley NEES Site

Broadening Participation: International Collaboration and World Forum Report

NEES

Friday, June 23, 2006

9:30 – 11:00 am

Broadening Participation: International Collaboration and World Forum Report *(Salon A+B)*

Session Chair: **Roberto Leon**, Georgia Institute of Technology

Report on the World Forum on Collaborative Research in Earthquake Engineering
Bill Spencer, University of Illinois Urbana-Champaign

World Forum Report: Cyberenvironments
Jerome Hajjar, University of Illinois Urbana-Champaign

World Forum Report: Data Infrastructure
Gregory Fenves, University of California, Berkeley

World Forum Report: Simulations
Ahmed Elgamal, University of California at San Diego

Report on International Collaboration Interest Survey
Clifford Roblee, NEES Consortium, Inc.

Progresses of Large-Scale Tests at E-Defense, NIED, Japan
Masayoshi Nakashima, E-Defense, NIED, and Kyoto University

Research on Networked Structural Laboratories in China
Yan Xiao, University of Southern California/CIPRES-Hunan University

Presentation Summary

Speaker:

B.F. Spencer, Jr.
University of Illinois at Urbana-Champaign

Session:

Broadening Participation: International Collaboration and World Forum Report
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Report on the World Forum on Collaborative Research in Earthquake Engineering

Abstract/Summary

While the physical facilities funded as part of the NEES collaboratory are now on-line, a number of its key simulation, data and cyber-environment features are still being developed. Moreover, similar efforts are proceeding in parallel in Europe, Japan, China, Korea, Taiwan, and other countries, resulting in a large portfolio of unique testing facilities around the world. The broad mission of NEES and its sister organizations can be best accomplished through a strong international collaborative effort that links all major laboratories and individual researchers around the world. Recognizing the critical juncture in the development of NEES-type organizations and the need for agreement on basic issues related to communication protocols, data curation formats, and access to information, to name but a few, the World Forum on Collaborative Research in Earthquake Engineering was convened by NEESinc. in San Francisco on March 16-18, 2006. The World Forum included a combination of topical keynote lectures from international experts, updates on NEES and NEES-like activities from around the world, and working sessions on three distinct topics: Simulation, Cyberenvironments, and Data Infrastructure. This presentation provides a general overview of the World Forum.

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Presentation Summary

Speaker:

Jerome Hajjar
University of Illinois, Urbana-Champaign

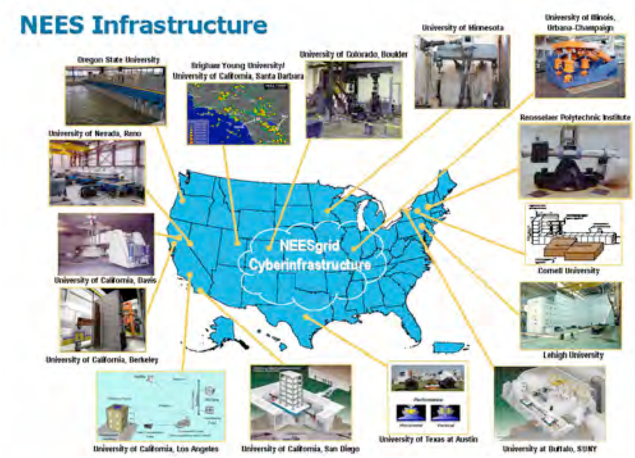
Session:

Broadening Participation: International Collaboration and World Forum Report
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Report on World Forum--Cyberenvironments

Courtesy of J. Myers, NCSA, UIUC, 2006.



Courtesy of B. Spencer, CEE, UIUC, 2006.

Major points/topics:

- Working group explored how cyberenvironments may be leveraged for earthquake engineering
- Many countries are building out cyberinfrastructure in earthquake engineering
- Working group focused on current status; issues and challenges, and future directions
- Resolutions include: funding international research initiatives and forming new international alliances on cyberenvironments; support pilot projects that document how to conduct earthquake engineering research through cyberenvironments

Abstract/Summary

The International World Forum included a working group on cyberenvironments that explored how cyberenvironments can be leveraged to connect a geographically distributed set of international researchers for meaningful collaborative research. With the earthquake engineering community already versed in the tools offered by NEES-like cyberenvironments, the working group focused upon (1) identification of technological barriers that currently hinder international collaboration and (2) formulation of solutions that would assist in overcoming such barriers. Many countries have committed to the development and support of cyberenvironments for use by the earthquake engineering community; examples include NEESit (United States), EDgrid (Japan), KOCED (Korea), ISEE (Taiwan) and RELUIS (Italy). These initiatives offer the broader international community unique opportunities to strengthen existing collaborations, to form new multinational collaborations, and to add vitality to earthquake engineering education. To identify how cyberenvironments can most effectively be leveraged by the entire international community, the working group structured its discussions along the lines of three major questions: (1) what do cyberenvironments offer the international earthquake engineering research community, (2) what issues and challenges currently impede international research collaborations, and (3) what future directions and actions should be taken to better utilize cyberenvironments for collaborative research? The working group concluded its discussions with a list of recommendations for future consideration.

Presentation Summary

Speaker:

Gregory L. Fenves
University of California, Berkeley

Session:

Broadening Participation: International Collaboration and World Forum Report
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Report on World Forum–Data Infrastructure

Major points/topics:

Sharing data is important because it:

- Builds common understanding and advances knowledge more rapidly than possible with isolated repositories.
- Researchers without access to experimental facilities can gain access to information.
- Data provides critical connections between analysts with experimentalists.
- Overcomes fragmentation, avoid repetition, better utilize scarce resources.
- Improves experimental procedures.

Abstract/Summary

The purpose of Working Group on Data Infrastructure at the NEES World Forum was to discuss issues related to the development of an international shared repository for earthquake engineering data. The working group considered basic policies, data models, metadata, and procedures for documenting experiments and numerical simulations, and protocols for data curation, management, and maintenance.

The discussions of Working Group 3 resulted in several recommendations.

Data Models–establish a common data model that can lead to federated international data repositories. The data model should be extensible for various types of data sets and enable customization by individual countries or research programs. An international working group should conduct a validation study of the common data model using pilot or example cases using experimental and analytical simulation data. Over the long-term, the working group should define a process and organizational structure for continuing development of data models.

Use Scenarios– An international working group should be established to establish use scenarios for data repositories to drive the development of data models and data use applications. Coordinate with existing efforts to find use scenarios and applications through NEES and in other groups. Identify international standards for access to data in international repositories.

Policies for Data Repositories– Identify and study current policies in various countries and research programs regarding ownership of and access to shared data. An international working group should develop policies for curation, management, and maintenance of international data repositories.

Presentation Summary

Speaker:

Clifford Roblee
NEES Consortium, Inc.

Session:

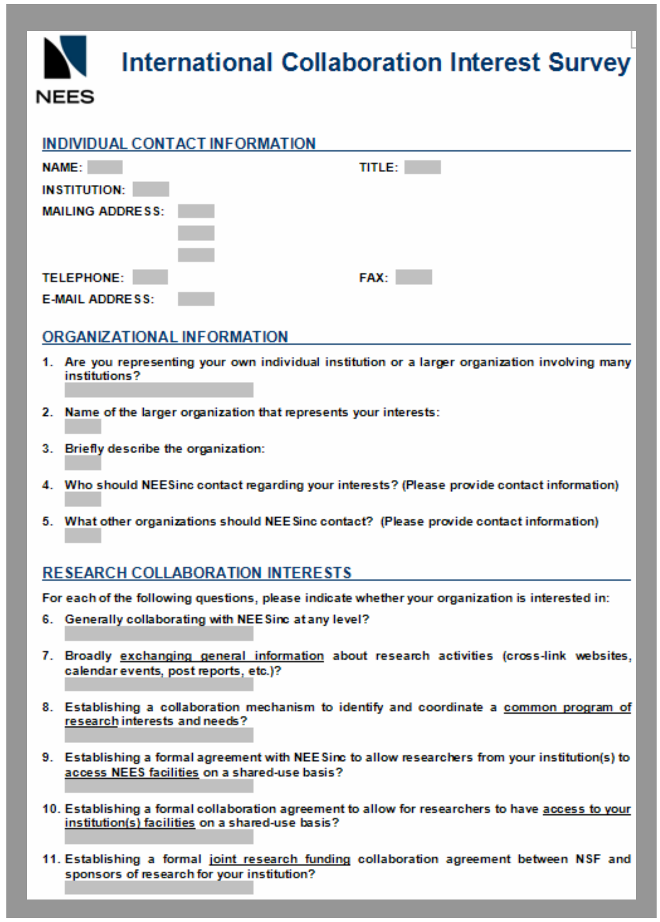
International Collaboration Session
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Report on International Collaboration Interest Survey

Major points/topics:

- Follow Up Survey to March 2006, "World Forum on Collaborative Research in EQ Engineering"
- Captured Specific Collaboration Interests from Potential International Partners
- Responses from 13 Organizations in 10 Countries
- Overwhelming Interest in Collaboration
- High Interest in Exchange of Shared-Use Facility Access, and NEES' Centralized Posting of Facility and Project Information
- Significant Interest in Data Sharing & Hybrid
- Cautious Interest in Live Video



NEES

International Collaboration Interest Survey

INDIVIDUAL CONTACT INFORMATION

NAME: TITLE:
INSTITUTION:
MAILING ADDRESS:
TELEPHONE: FAX:
E-MAIL ADDRESS:

ORGANIZATIONAL INFORMATION

1. Are you representing your own individual institution or a larger organization involving many institutions?
2. Name of the larger organization that represents your interests:
3. Briefly describe the organization:
4. Who should NEESinc contact regarding your interests? (Please provide contact information)
5. What other organizations should NEESinc contact? (Please provide contact information)

RESEARCH COLLABORATION INTERESTS

For each of the following questions, please indicate whether your organization is interested in:

6. Generally collaborating with NEESinc at any level?
7. Broadly exchanging general information about research activities (cross-link websites, calendar events, post reports, etc.)?
8. Establishing a collaboration mechanism to identify and coordinate a common program of research interests and needs?
9. Establishing a formal agreement with NEESinc to allow researchers from your institution(s) to access NEES facilities on a shared-use basis?
10. Establishing a formal collaboration agreement to allow for researchers to have access to your institution(s) facilities on a shared-use basis?
11. Establishing a formal joint research funding collaboration agreement between NSF and sponsors of research for your institution?

Abstract/Summary

Widespread enthusiasm for broader international collaboration expressed at the March, 2006 "World Forum on Collaborative Research in Earthquake Engineering" led NEESinc to conduct a follow-up survey with international participants to identify specific areas of collaboration interest. Respondents were asked to characterize their level of interest in opportunities ranging from simple information exchange, to exchange of shared-use access to facilities, to sharing of detailed project and facility information through the NEES Site Specifications Database (SSDB), to linking into NEES' advanced cyberinfrastructure, to establishment of joint research programs. Responses were received from 13 organizations located in 10 countries worldwide, and there is unanimous interest in some form of collaboration with NEES. Nearly all respondents expressed strong interest in posting details of their facilities on the SSDB and posting project information on the NEES Site Activities Monitor. More than half of the respondents expressed strong interest in using NEES' advanced cyberinfrastructure capabilities for archiving and sharing research data and for performing hybrid simulation. Respondents were cautious about providing live video streams from their facilities. Approximately three-quarters of respondents expressed strong interest in establishing mechanisms to coordinate a common program of research needs, and approximately half expressed strong interest in establishing formal funding collaboration agreements with NSF at the sponsor level. NEESinc governance and management intends to use these findings as the basis to initiate a broad-based international partnering program in the coming years.

Photo 1 A pair of thirty-years old wooden houses, one with retrofit (survived) and the other without (failed).

Photo 2 A six-story RC wall-frame (1,000 metric ton), subjected to 1995 JMA Kobe in all three directions

Speaker:

Masayoshi Nakashima
E-Defense, NIED, and Kyoto University

Session:

Broadening Participation: International Collaboration and World Forum Report
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Progresses of Large-Scale Tests at E-Defense, NIED, Japan

Major points/topics:

- Eight tests conducted in fiscal 2005
- Experiences on collapse tests
- Perspective of NEES/E-Defense joint research

Abstract/Summary

In 2005, National Research Institute for Earth Science and Disaster Prevention (NIED) established Hyogo Earthquake Engineering Research Center (E-Defense), which accommodates the world largest shaking table, having a plan dimension of 20 m by 15 m and being activated in three directions with the maximum velocity, displacement, and weight of 2m/s, 1m, and 1,200 metric ton. E-Defense is pleased to report that it successfully implemented eight full (or very large) scale tests from July 2005 to March 2006. The tested specimens included: a five-story stiff steel frame (20 m high), an energy facility (15 m high), a modern two-story wooden house, a pair of traditional two-story wooden houses (transported from Kyoto), a pair of thirty-years old two-story wooden houses (identical houses, with one retrofitted and the other not, Photo 2), a six story RC wall-frame (20 m high and 1,000 metric ton heavy, Photo 2), a soil-pile interaction system in a cylindrical laminar container (8 m in the diameter of the box), and a quay wall and soil system in a rectangular rigid container (16 m by 4 m by 4.5 m).

The pair of the houses was first shaken with the 1995 Takatori record (the one with a maximum ground velocity of 1.23 m/s, the largest recorded in the 1995 Kobe). The un-retrofitted house was completed crashed, while the retrofitted house sustained serious damage but survived without collapse. The six-story RC wall-frame was designed using an obsolete design practice of the mid-1970s and was subjected to the 1995 JMA Kobe record (the one with a maximum ground acceleration of 0.85 m/s). The frame sustained very serious damage including shear-failures of first-story columns and walls but escaped from complete crashes. These tests demonstrate the accuracies of existing analysis tools for the prediction of maximum responses and damage status.

NEES and NIED began its official collaborative research using the NEES and E-Defense facilities. To strengthen the collaboration, NSF and MEXT (the Japanese Ministry of Education, Culture, Sports, Science and Technologies) exchanged a MOU in September 2005, and NEES and NIED exchanges another MOU in August 2005. NEES and NIED set up a Joint Technical Coordinating Committee (JTCC) for effective implementation of the joint research. Researchers in the two countries met frequently for the past two years (April, June, July, and December 2004, January, February, May, August, and December 2005, and April 2006) to establish common objectives, specify work sharing, and form joint teams.

Speaker:

Yan Xiao
University of Southern California/CIPRES

Session:

Broadening Participation: International Collaboration and World Forum Report
Friday, June 23, 9:30 – 11:00 am

Presentation title:

Research on Networked Structural Laboratories in China

Abstract/Summary

Beginning 2003, the National Natural Science Foundation of China (NSFC) has funded two so-called NSFC key research projects on developing advanced experimental methodologies for structural engineering research. To some extent, these research projects reflect the inspiration of the Chinese research community towards the US NEES project, however, addressing the needs in China. One of the urgent needs is to develop technologies and mechanisms for the efficient sharing of research facilities at various laboratories and avoid low-level duplication as the government is increasingly investing in higher education. The advanced shake table research project was funded to Tongji University with collaborations from the Institute of Earthquake Engineering and the Institute of Engineering Mechanics (PI and coordinator: Prof. Lu). The networked structural laboratories and hybrid experiment research project was funded to the Hunan University with collaborations from the Qinghua University and the Harbin University of Technology (PI and coordinator: Prof. Xiao). This paper introduces the two key projects and the current research achievements. Possible collaboration between the Chinese researchers and NEES researchers is also suggested and discussed.

In recent years, the Chinese government has increased investment to the major universities in China in order to improve the obsolete research environment. However, due to the rapid development, some duplications are seen in building and purchasing experimental facilities. The fundamental research in developing experimental methods are not given full attention. To avert such trends, responsible researchers and funding agencies are constantly searching mechanisms and ways of efficient sharing of equipment among scholars at various universities [Ru and Xiao 2002].

The first trial of internet based remote structural testing in China was initiated between the structural laboratories of the Hunan University and the University of Southern California. An internet platform (the original format of the current NetSLab) was developed in 2001 by Xiao et al. With the initial success, a workshop participated by active researchers was held in Changsha in November 2002 to discuss the possibility of launching a national key project to investigate the advanced experimental methodology and remote sharing of structural testing equipment. In 2003, two NSFC key projects were funded following an open competition. These two projects are briefly described in this paper.

TAB 5

Polling

Wireless Audience Polling

NEES

The following long-term polling questions will be used to track the status and direction of NEES over its 10-year lifetime. The questions are grouped according to responsible party:

***CoV**) NEES Collaboratory as a whole – vision*

***CoE**) NEES Collaboratory as a whole – education, outreach & training*

***Gov**) NEESinc Governance (Consortium Board and Committees)*

***Inc**) NEES Consortium Inc. Headquarters in Davis*

***ES**) NEES Equipment Sites at 15 Universities*

***IT**) NEES Cyberinfrastructure Center in San Diego*

***NSF**) NEESR Program at NSF in Washington D.C.*

NEES

Long–Term Polling Questions

BASIC DEMOGRAPHICS

D-1) Please identify yourself within the NEES Community as most closely affiliated with:
- NEES Governance
- NEES Headquarters
- NEES Equipment Sites
- NEESit
- NEESR Program
- NEESR Researcher
- Other EQ Researcher
- EQ-Risk Stakeholder
- Other

D-2) Please identify your experience in the earthquake engineering field:
- Newbie (say < 5 years)
- Still Excited (5-15 years)
- Peaking (say 15-25 years)
- Elder Statesperson (say >25 years)

QUESTIONS RE: NEES COLLABORATORY AS A WHOLE - VISION

CoV-1) The NEES Collaboratory is moving forward in achieving its goal to accelerate progress in earthquake engineering research.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoV-2) The NEES Collaboratory is moving forward in achieving its goal to improve the seismic design and performance of civil and mechanical infrastructure systems.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoV-3) The NEES Collaboratory is successfully integrating people, ideas, and tools in a collaboratory environment.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoV-4) The NEES Collaboratory research facilities and data are open to all elements of the earthquake engineering community, including researchers, educators, students, practitioners, and information technology experts.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoE-1) The NEES Collaboratory is effective in reaching out to K-12, undergraduate and graduate students.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoE-2) The NEES Collaboratory is effective in increasing the diversity of the earthquake engineering research community.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoE-3) The NEES Collaboratory is effective in fostering linkages and partnerships with federal, state, and local government entities, national laboratories, the private sector, and international collaborators.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

CoE-4) The NEES Collaboratory is effective in facilitating transfer of research findings into improved industry practices.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

QUESTIONS RE: NEESINC GOVERNANCE (BOARD & COMMITTEES)

Gov-1) The NEESinc Governance efficiently and effectively supports critical project activities in accordance with the NEESinc Bylaws.

- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Gov-2) The NEESinc Governance provides coherent and fair policies that advance the longer-range vision and shorter-term goals of the Collaboratory.

- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Gov-3) The NEESinc Governance is responsive to your needs.

- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Gov-4) The NEESinc Governance is providing the leadership and planning to ensure that NEES remains an accessible state-of-the-art distributed facility.

- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Inc-1) NEESinc Headquarters effectively manages the primary relationship between NEESinc and NSF.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Inc-2) NEESinc Headquarters effectively facilitates Researcher access to Equipment Sites.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Inc-3) NEESinc Headquarters effectively manages the Consortium's business and facilities according to Board-approved policies and NSF requirements.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

Inc-4) NEESinc Headquarters applies Consortium policies and procedures in an efficient and fair manner.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

QUESTIONS RE: NEES EQUIPMENT SITES

ES-1) The NEES Equipment Sites maintain their facilities in top operating condition.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

ES-2) The NEES Equipment Sites willingly open their facilities to outside users in a user-friendly and simple manner.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

ES-3) The NEES Equipment Sites keep me well informed of upcoming experiments and educational activities, and provide remote participation opportunities.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

ES-4) The NEES Equipment Sites provide and maintain facility specifications and training materials that are current, accurate, and easy to use.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

QUESTIONS RE: NEESIT (SDSC IN SAN DIEGO)

IT-1) NEESit provides me with the IT capabilities and support services that address my research needs.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

IT-2) NEESit provides the documentation, training materials, and training opportunities I need to effectively use the IT infrastructure.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

IT-3) NEESit provides convenient data repositories that improve my ability to archive and/or retrieve experimental and simulation data.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

IT-4) NEESit provides efficient, effective and convenient simulation and visualization tools that facilitate my research and/or educational objectives.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

QUESTIONS RE: NEESR (NSF IN WASHINGTON DC)

NSF-1) NSF is a good partner to NEES in promoting realistic and meaningful goals for the earthquake engineering research community
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

NSF-2) NSF NEESR RFP solicitations are clear, effective, and well executed.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

NSF-3) NSF NEESR research addresses the highest priority uncertainties remaining in engineering modeling of the effects of earthquakes on the built infrastructure.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

NSF-4) NSF NEESR research addresses the highest priority risk-mitigation needs of earthquake engineering practice.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

S-1) The overall NEES initiative, including NEESinc HQ and Governance, the Equipment Sites, NEESit, and the NEESR Program, is generally moving in the right direction.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

S-2) The overall NEES initiative is generally moving at the right pace.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

S-3) This year's Annual Meeting was informative and a valuable use of my time.
- Strongly agree
- Agree
- Neutral or not sure
- Disagree
- Strongly disagree
- Insufficient experience to comment now.

S-4) My favorite part of this year's Annual Meeting was:
- Broadening the Domestic NEES Community Session
- NEESit Plenary Session
- Advanced Tools Sessions
- UCSD/PCA/NEES Blind Prediction Contest Plenary Session
- The three Issue Forum Sessions
- NEESR Project Spotlights
- Broadening Participation: International Collaboration and World Forum Report
- Banquet with Annual Business Meeting and Awards
- Electronic Polling

Notes

NEES ANNUAL MEETING June 21–23, 2006

NEES

NEES ANNUAL MEETING June 21–23, 2006

NEES

NEES ANNUAL MEETING June 21–23, 2006

NEES

NEES ANNUAL MEETING **June 21–23, 2006**

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NEES ANNUAL MEETING June 21–23, 2006

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NEES ANNUAL MEETING **June 21–23, 2006**

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NEES ANNUAL MEETING June 21–23, 2006

NEES

Schedule

Fourth NEES Annual Meeting

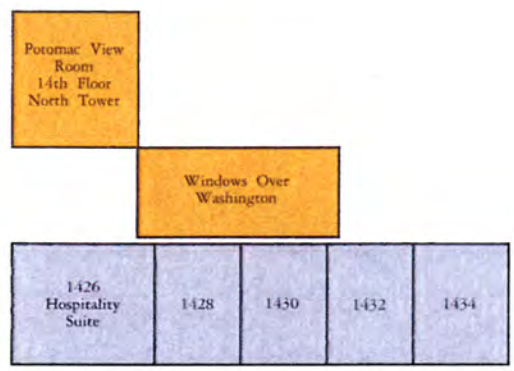
Time	Wednesday 21-Jun	Thursday 22-Jun	Friday 23-Jun
7:00-8:00 am	REGISTRATION DESK OPEN With Continental Breakfast	REGISTRATION DESK OPEN With Continental Breakfast	Continental Breakfast
8:00 – 8:30 am	Opening & Welcome Session (*Roblee*)	NEES Overview Session (*Buckle*)	NEESR Spotlights: New Projects II (*Yeh*)
8:30 – 9:00	Broadening the Domestic NEES Community (*Roblee*)		
9:00 – 9:30		NEESR Spotlights: Active Projects I (*Pauschke*)	
9:30 – 10:00	NEESit Session (*Lea*)		International Collaboration Session (*Leon*)
10:00 – 10:30			
10:30 – 11:00	Break	Break	
11:00 – 11:30	Advanced Tools Plenary Session (*Wood*)	NEESR Spotlights: Active Projects II (*Krawinkler*)	Issue Forums Report-Back Session (*Burgueño*)
11:30 – 12:00 pm			
12:00 – 12:30			ANNUAL MEETING ADJOURNS
12:30 – 1:00	Luncheon with EOT Presentation (*van de Lindt*)	Luncheon / Equipment Site Forum (closed mtg)	*Schedule for other events (workshops and Board meeting) is available at the registration table.*
1:00 – 1:30			
1:30 – 2:00			
2:00 – 2:30	Blind Prediction Session (*Bachman*)	NEESR Spotlights: New Projects I (*Nigbor*)	
2:30 – 3:00			
3:00 – 3:30	Issue Forums Plenary Session (*Andrews*)		
3:30 – 4:00		Break	
4:00 – 4:30	Break	EOT Issue Forum (*Dyke*) / ITSC Issue Forum (*Bielak*) / SOC Issue Forum (*Eberhard*)	
4:30 – 5:00	Adv Tools 1 (*Hajjar*) / Adv Tools 2 (*Kutter*) / Adv Tools 3 (*Fenves*)		
5:00 – 5:30			
5:30 – 6:00			
6:00 – 6:30	NEESR PI Awardees Meeting / Posters & Reception with Posters on Display, Cash Bar, and Appetizers (Begins at 6:00 pm)	Joint Poster Session & Reception	
6:30 – 7:00			
7:00 – 7:30		Dinner Banquet with: Business Meeting, Awards Presentation, and Polling	
7:30 – 8:00			
8:00 – 8:30			
8:30 – 9:00			

Session Chairs Listed in Italics

Room Locations

- Commonwealth Room
- Lincoln Room
- Madison Room
- Salon A
- Salon B
- Salon A + B
- Salon C + D + E
- Van Buren Room
- Washington Ballroom

MEETING AND BANQUET FACILITIES



Doubletree Crystal City offers up to 29,000 square feet of prime meeting and banquet space, many with panoramic views of the Washington, D.C. skyline. Our flexible space can be configured to accommodate 2-1100 people with the full support of state-of-the-art, on-site audio visual equipment and a dedicated, experienced staff to help you coordinate and host your event flawlessly. When it comes to catering, trust Doubletree to exceed the most demanding palettes.

Back in the guest room, you will find ample data and power connectivity and wireless high speed internet access. We even provide a self-service Business Center as well as an ATM convenient to all meeting rooms.

Our experienced, full service conference team looks forward to working with you.