THURSDAY, APRIL 12
Assessing Vulnerabilities

7 am–5 pm
REGISTRATION CONTINUES

7:00–8:00 am
EERI COMMITTEE MEETINGS

6:30–8:00 am
CONTINENTAL BREAKFAST

8:00–8:20 am
PLENARY
2010-11 EERI/FEMA NEHRP GRADUATE FELLOW: Moving Minds, Moving Policy: What the City of Berkeley’s Soft-Story Ordinance Can Teach Us About Motivating Property Owners to Retrofit: Sharyl Rabinovici, University of California Berkeley

8:20–9:00 am
PLENARY
2012 EERI DISTINGUISHED LECTURE
The New Normal for Natural Disasters: Thomas O’Rourke, Cornell University

9:00–10:30 am
PLENARY
LARGE, VULNERABLE AND CRITICAL INFRASTRUCTURE
Dams, bridges, and nuclear power plants: What can be done to ensure their functioning without serious interruption after an earthquake?
Moderator: Shahram Pezeshk, University of Memphis
Speakers:
Challenges to Dam Hazard Mitigation in the U.S.: Sandra Knight, FEMA
Seismic Design Practice of the Tennessee Department of Transportation: Ed Wasserman, Modjeski and Masters
A Reassessment of Seismic Hazards and Risk at Nuclear Power Plants in the U.S.: Jon Ake, U.S. Nuclear Regulatory Commission

10:30–11:00 am
BREAK

11 am–12 noon
PLENARY
EARTHQUAKES AND CASCADING FAILURES
Moderator: Rob Williams, USGS
Speakers:
How Can Our Understanding of the Risk of Cascading Failures Be Used to Help Build Resilience? Chris Poland, Degenkolb Engineers
Cascading Failures in Catastrophic Earthquake Events — The Risk Finance Perspective: Craig Tillman, Weather Predict Consulting

12:00–1:30 pm
LUNCHEON AND PRESENTATION
Timothy Galarnyk, Construction Risk Management, Inspector America (History Channel)

1:30–3:00 pm
FOREST ROOM
1. Advances in Early Warning
Moderator:
Bill Steele, University of Washington
Speakers:
ShakeAlert: Earthquake Early Warning in the U.S.: Doug Given, USGS; Peggy Hellweg, UC Berkeley; John McPartland, BART

2. Overcoming Barriers to Mitigation & Retrofitting
Moderator:
Sandra Knight, FEMA
Speakers:
Challenges in Seismic Retrofitting MLGW Facilities: Jay Stressel, Memphis Light Gas & Water
University of Memphis Cecil Humphreys Law School Retrofit: Scott Fleming, Fleming Assoc.
Memphis/Shelby County Building Code Adoption and Challenges: Robert Paullus, Paullus Structural Consultants

3. Incorporating Aftershocks in Risk Analysis
Moderator:
Oliver Boyd, USGS
Speakers:
Revising Canterbury, New Zealand, Seismic Levels to Account for Time-Varying Hazard from Continuing Canterbury Earthquake Sequence: Matt Gerstenberger, GNS Science
Quantifying Mainshock-Aftershock Collapse Probabilities for Woodframe Buildings: John van de Lindt, University of Alabama
Aftershock Collapse Fragility for Mainshock-Damaged Reinforced Concrete Buildings: Abbie Liel, University of Colorado

1:30–3:00 pm
HERNANDO DESOTO ROOM
Moderator: James Beavers, JEB Consultants
Speakers:
The Central and Eastern U.S. Seismic Source Characterization for Nuclear Facilities (CEUS SSC) Project: Larry Salomone, EPRI Consultant
Challenges in Seismic Hazard Analyses in the U.S. in the 21st Century: Are We Addressing the Extreme Events? Ivan Wong, URS Corporation
The Fukushima Dai-Ichi Nuclear Plant Accident: George Flanagan, Oak Ridge National Laboratory

CONCURRENT SESSIONS 1-6

132
1:30–3:00 pm  LOUIS XVI ROOM  
5. Network Analysis: Complexity of Interdependency  
Moderator:  
Chris Poland, Degenkolb Engineers  
Speakers:  
A Three-Service Utility’s System Interdependencies: Analysis and Mitigation Efforts: Rick Bowker, Memphis Light Gas & Water  
Understanding Interdependent Infrastructure Systems: Modeling Insights and Practical Challenges: Leonardo Duenas-Osorio, Rice University  

1:30–3:00 pm  SKYWAY ROOM  
6. Community Preparedness  
Moderator: Cecil Whaley, Tennessee EMA  
Speakers:  
Earthquake Preparedness Initiatives Taken by the American Red Cross: David Kitchen, American Red Cross  
Memphis South Main Retrofit Demonstration Project: Dmitry Ozeryansky, Ozeryansky Engineering  
Ken Skalitzky, FEMA  

3:00–3:30 pm  GRAND BALLROOM C,D,E,F  
BREAK  

3:30–5:00 pm  PLENARY  
UNDERSTANDING AND COMMUNICATING RISK  
What are effective means of understanding and communicating risks to the public and what are examples of successful communication?  
Moderator: Maiclaire Bolton, RMS  
Speakers:  
Earthquake Policy: Communicating Information to Those in Power: John Bwarie, USGS  
From Awareness to Action: The Values-Based Message: Kate Long, California EMA  
Incorporating Societal Safety Issues into Businesses: Lucy Arendt, University of Wisconsin  

5:00–5:15 pm  PLENARY  
CLOSING REMARKS, DAY 2  

5:15–6:00 pm  PLENARY  
EERI BUSINESS MEETING  

6:00–7:30 pm  GRAND BALLROOM C,D,E,F  
GENERAL RECEPTION & POSTER SESSION  

7:00–8:00 pm  LOUIS XVI ROOM  
EERI SUBSCRIBING MEMBERS AND MAJOR DONORS RECEPTION  

8:00–10:00 pm  FOREST ROOM  
COMMUNITY EVENING PRESENTATIONS
Social Science Committee Meeting

Chair: Lucy Arendt

THURSDAY, APRIL 12
7:00 to 8:00 a.m.
Ben Hollander Room

AGENDA

1. Introductions

2. Request from the EERI Board:
   Developing a topic or topic options for a social science monograph
   a. Ideas for a topic (e.g., the role of the social sciences in reconnaissance research, raising funds for social science research, enhancing the role of social science researchers in the seismic safety community)
   b. Who’s interested in researching and writing a monograph
   c. Timeline for researching and writing a monograph

3. Updates on what social science researchers are doing

4. Other items as requested by those attending the meeting
2012 STRONG MOTION FORUM

As the chair of the EERI Strong Motion Committee, I would like to invite you to attend the 2012 Strong Motion Forum. The forum will be held this year on April 12, from 7:00 to 8:00 AM in the Louis XVI Room of The Peabody Memphis Hotel. Historically, the committee has provided EERI members the opportunity to share ideas and projects related to strong motion instrumentation at the annual meetings. The guidelines of the committee are to:

1. encourage the continued development, expansion, and the maintenance of strong motion instrument deployment in the United and other strategic locations throughout the world,
2. recommend uniform standards for the processing and interpretation of strong motion records and advise on how the data can be related to the performance of structures and the preparation of design criteria and
3. recommend methods for dissemination of data, including educational programs and seminars.

The term “Strong Motion” no longer refers solely to instrumentation and data used by engineers and seismologists. Rather, it has been greatly expanded to include tools that provide valuable information to the public for emergency planning and response, and databases that store and provide data to users in a user-friendly manner.

This meeting is open to all conference participants, as is membership on the Strong Motion Committee.

Marcia McLaren, Chair
EERI Strong Motion Forum Agenda
April 12, 2012
7:00 – 8:00 AM
Louis XVI Room
The Peabody Memphis Hotel
Memphis TN

Continental breakfast for all attendees!

7:00 – 7:15  **Opening Remarks/ Improving Seismic Monitoring in the Las Vegas Valley and CESMD Update** – Woody Savage, Consultant, Las Vegas, NV (Forum chair for Marcia McLaren, PG&E, San Francisco CA)


7:25 - 7:35  **Strong Motion Recordings from the 2008 Wenchuan Main Event and Aftershocks** – Zhenming Wang, Univ. Kentucky, Lexington KY

7:35 – 7:45  **Automated Damage Detection and Alerting System of Instrumented Hospital Buildings** – Erol Kalkan, USGS, Menlo Park CA

7:45 – 7:50  **NEES building monitoring of aftershocks in Christchurch** – Bob Nigbor, UCLA, Los Angeles, CA

7:50 – 8:00  **Comparison of Various Ground Motion Prediction Equations Using the Hybrid Empirical Method** – Ken Campbell, EQECAT, Oakland CA-
Seismic safety deficiencies in existing buildings pose a serious threat to community resilience, economic security, and human welfare worldwide, and developed nations are not immune. Despite steady progress in the creation of technical mitigation know-how, however, seismic safety advocates still struggle to get earthquake risk reduction onto the agendas of policymakers, organizations, and individuals alike.

This presentation summarizes a qualitative investigation into the earthquake beliefs and structural mitigation behaviors of a group of rental property owners in Berkeley, California. In 2005, 16 years after the Loma Prieta earthquake, the City of Berkeley passed a Soft-Story Ordinance (BSSO) that placed notice on the title of 321 suspected soft-, weak-, or open- first story wood frame pre-1997 apartment buildings with five or more units. It required each owner to have an engineer evaluate their property within two years, and if a soft-story condition is confirmed, they must post warning signs on-site and inform tenants in perpetuity. Even though the law did not require owners to do a seismic upgrade, over twenty percent voluntarily took that costly extra step. As such, the BSSO constitutes one of the most comprehensive and promising policy experiments on this topic to date.

To explore the case, I conducted 43 in-depth interviews with a sample of affected Berkeley apartment owners (N=38) plus a small set of owners who did soft-story retrofits prior to the law (N=5). Using a mix of open-ended and survey questions, I developed a rich description of who these owners are and how they think about earthquakes and mitigation. My strategy for understanding how the law influenced owner decisions was to compare pre- and post- law retrofitters to non-retrofitters with an emphasis on risk perceptions, social perceptions, and individual differences (including demographic traits, personal background, and personality factors). To put this information in context, I also interviewed 22 key stakeholders involved in developing and implementing the policy.

My central finding is that the ordinance set in motion a series of mutually reinforcing changes to the social context surrounding owner mitigation decisionmaking. These altered social perceptions were instrumental to the BSSO’s moderate but encouraging degree of impact, producing behavior change that exceeded what mere changes in hazard awareness alone could have accomplished. In particular, I found that new concerns about earthquake risk were accompanied by new concerns about the financial position and regulatory “vulnerability” of the property. Removing stigma (and its perceived economic implications), gaining freedom from added administrative hassles, and eliminating fear of increased liability exposure and escalating future regulation were all powerful motivators cited by the post-law retrofitters, reinforcing, amplifying, and in some cases surpassing concerns about the actual hazard. In general, non-retrofitters emphasized barriers like cost, the unpredictability of both costs and benefits, and the inability to recoup their investment (because of rent control and lack of tenant willingness to pay for seismic safety), rather than lack of concern about the threat.

The overarching implication is that to change minds and behavior on this issue, intervention strategists would be wise to focus on changing the social context in ways that promote mitigation. Some example approaches include: developing evaluation, labeling, and disclosure policies that make mitigation choices more visible and its potential outcomes easier to understand; passing laws that clarify the rights and responsibilities of various stakeholders with regard to seismic safety; and publicly rewarding those who take socially-desirable steps.

Ultimately, Berkeley’s approach influenced enough owners to take voluntary action that the social norm regarding retrofitting was flipped on its head. Local soft-story owners now accept that their property is worth less and believe that either they or a future owner will have to retrofit eventually. In total, 76 retrofits were initiated from 2006 to 2009, which is about six times the number undertaken between 2000 and 2005. Eventually, the city ran short on resources and key personnel retired. As a result,
there was no analysis or learning from the technical information collected and plans for a follow-up mandatory retrofit law remain indefinitely on hold. However, an EERI-funded special project is nearing completion that will provide some insights. To date, four other Bay Area cities have taken steps based on the Berkeley precedent.

In an exploratory aspect of the research, I found suggestive evidence that the law motivated retrofits among persons with a different personality profile. Post-law retrofitters were on average less emotionally stable and had a more “problem-avoidant” as opposed to “goal-attainment” regulatory orientation than people who retrofit prior to the ordinance. Personality factors might help explain why some individuals are inherently more sensitive than others to changes in the social context and the reversed decision framing. Although the number of study participants does not allow me to draw statistical conclusions, retrofitters and non-retrofitters appear to own similar buildings and were indistinguishable in terms of demographic traits and personal backgrounds.

Overall, the BSSO shows that mandatory evaluations, combined with the credible threat of mandatory retrofit, can produce a substantial increase in the number of voluntary retrofits initiated in a relatively stable and competitive rental housing market. This research adds an empirical data point to the growing belief that social cognitions are absolutely central to motivating action about disasters. On a practical level, the case demonstrates some of the challenges and trade-offs involved in targeting legislation at certain high hazard building types. The city’s greatest difficulty in implementing the law was the development, communication, and consistent application of technical standards for the evaluating engineers and review consultants.

Sharyl J. M. Rabinovici
PhD Candidate
UC Berkeley Goldman School of Public Policy
sjmr12@yahoo.com

Mrs. Rabinovici is a Ph.D. candidate at the University of California, Berkeley Goldman School of Public Policy, where she specializes in policy design and program evaluation in the domains of community wellbeing, natural hazards, and the environment. She holds a B.S. in Geologic and Environmental Sciences from Stanford University with distinction and a Master of Public Policy degree from the University of Chicago where she was a Harris Fellow. From 2000 to 2005, Mrs. Rabinovici developed earthquake loss estimation and geospatial risk assessment methodologies for the U.S. Geological Survey and advised senior staff on science policy, stakeholder involvement, and social science program planning. She is a published author in such journals as Environmental Science & Technology and International Geology Review and a two-time National Science Foundation grantee. In 2010, Mrs. Rabinovici was honored as one of the few social scientists ever chosen for the EERI-FEMA graduate fellowship in earthquake hazard reduction.
The effects of the Tohoku Earthquake and Tsunami, Canterbury Earthquake Sequence, and Hurricane Katrina are discussed with respect to their impact on regional and international economics, national practices for security and recovery, and worldwide energy policy. The severity and far ranging consequences of these extreme events have established in effect a new normal for natural disasters. The lecture explains why these events require a fundamental re-thinking of the way we evaluate the risks of extreme events, as well as define and protect critical infrastructure. Examples of critical infrastructure at risk are discussed with respect to earthquake effects on the water supply of Southern California and hurricane effects on New York City. Selective lessons learned from recent earthquakes are described with respect to mitigation measures. To address the need for protection against rare, high consequence events with limited financial resources, a strategy for improving infrastructure resilience is proposed.

Tom O’Rourke

Thomas R. Briggs Professor of Engineering
Cornell University

Tom O’Rourke is the Thomas R. Briggs Professor of Engineering in the School of Civil and Environmental Engineering at Cornell University. He is a member of the US National Academy of Engineering and a Fellow of American Association for the Advancement of Science. He received a number of distinctions for his research and teaching, some of which are ASTM C.A. Hogentogler Award, ASCE Collingwood, Huber Research, C. Martin Duke, Stephen D. Bechtel Pipeline Engineering, and Ralph B. Peck Awards, and the British ICE Trevithick Prize. He gave the 2009 Rankine Lecture. He served as President of the Earthquake Engineering Research Institute and as a member of the US National Science Foundation Engineering Advisory Committee. He authored or co-authored over 350 technical publications. His research interests cover geotechnical engineering, earthquake engineering, underground construction technologies, engineering for large, geographically distributed systems, and geographic information technologies and database management. He is a member of the NIST Advisory Committee for Earthquake Hazards Reduction. He has served as chair or member of the consulting boards of many large civil construction projects, as well as the peer reviews for projects associated with highway, rapid transit, water supply, and energy distribution systems.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
9:00 a.m.

PLENARY

LARGE, VULNERABLE
AND CRITICAL INFRASTRUCTURE

Moderator:
Shahram Pezeshk
University of Memphis

Speakers:
Challenges to Dam Hazard Mitigation in the U.S.
Sandra Knight
FEMA

Seismic Design Practice of the
Tennessee Department of Transportation:
Ed Wasserman
Modjeski and Masters

A Reassessment of Seismic Hazards and Risk at
Nuclear Power Plants in the U.S.: An NRC Perspective
Jon Ake
U.S. Nuclear Regulatory Commission

Learning from the Past to Protect the Future
Shahram Pezeshk

Shahram Pezeshk, Ph.D., P.E., F.ASCE is Professor and Chair of the Department of Civil Engineering at the University of Memphis. Dr. Pezeshk worked as a bridge engineer for Hanson Engineers, Inc. before joining the faculty at the University of Memphis in 1989.

Through his research and publications, Dr. Pezeshk has made contributions to structural engineering by integrating seismic hazard, structural vulnerability, and structural optimization into the design process. His recent work on ground motion prediction is being used in development of probabilistic seismic hazard maps.

During the past ten years, Dr. Pezeshk has published numerous papers and reports, seven book chapters, and delivered many invited lectures. He has been the PI or Co-PI on funded research such as: nonlinear site response of deep deposits, selection of scaling of ground motion time histories for structural design, ground motion and site-specific studies and seismic site characterization. He has received many awards recognizing his research including the ASCE State-of-the-art award.

Dr. Pezeshk has been actively involved with ASCE’s Structural Division on multiple technical committees, as well as participating as a member of the Earthquake Engineering Research Institute and other national associations. He was appointed by the Governor of Tennessee to serve on the West Tennessee Seismic Commission. Dr. Pezeshk is a licensed professional engineer in Tennessee and received his B.S. and Ph.D. from the University of Illinois, Urbana-Champaign and his M.S. from the University of California at Berkeley.
Challenges to Dam Hazard Mitigation in the U.S.

James E. Demby, Jr.
Presenter: Sandra Knight

It’s been over 120 years since the Johnstown flood when a dam failure sent a wall of water crashing down a mountainside, killing over 2,200 people and destroying the town. A series of dam failures in the 1970s, including the Buffalo Creek Dam in West Virginia, the Teton Dam in Idaho, and the Kelly Barnes Dam in Georgia, killed hundreds and caused $1 billion in damages.

Since the establishment of FEMA by Executive Order in 1979, FEMA has had the lead role in coordinating national efforts in dam safety. The passage of the National Dam Safety Program Act (NDSP) of 1996 reflected the culmination of years of collaborative effort on the part of many in the dam safety community. Since then, Congress has reauthorized the NDSP twice, most recently in 2006.

Public Law 109-460, which reauthorized the NDSP through Fiscal Year (FY) 2011, continues all of the legislatively-mandated activities established by the 1996 Act and the 2002 reauthorization. These activities include grants to the states for the improvement of state dam safety programs; training for state dam safety staff and inspectors; a program of technical and archival research; and funding to the U.S. Army Corps of Engineers (Corps) for maintaining and updating the National Inventory of Dams (NID).

There are now about 27,000 dams in the United States that present a risk to lives and property downstream. Of these dams, 14,000 are classified as high-hazard potential, meaning their failure would result in probable loss of life. According to the 2009 update to the NID, only about 55 percent of these dams have an Emergency Action Plan to protect against the loss of life and property damage that can result from a dam failure. To effectively reduce the risk to life and property from dam hazards in the U.S., the NDSP must address the following challenges:

- The public is largely unaware of their individual dam risks
- Many dams are not included in the state or local governments’ Hazard Mitigation Plan, Response Plan, or Recovery Plans
- Local Officials and the Emergency Management community must be engaged
- State Dam Safety Officials lack resources
- Privately owners need support
- Risk analysis are need to the quantify and prioritize
- Information about dam risk must be shared with the public so that they can make risk informed decisions

This presentation will briefly discuss these challenges.
Sandra K. Knight  
Deputy Federal Insurance and Mitigation Administrator, Mitigation  
Federal Emergency Management Agency

At FEMA, Dr. Knight provides executive leadership, oversight and supervision for the development and administration of regulations, policies and procedures for the Risk Reduction and Risk Analysis Divisions and Offices of Environmental Planning and Historic Preservation, and Regional and Disaster Support. This includes Floodplain Mapping, Floodplain Management, Hazard Mitigation Assistance Grants, Building Sciences, Mitigation Planning, Dam Safety, the National Earthquake Hazards Reduction Program, and hazardous risk assessment methodologies. She received her doctorate in Civil Engineering from the University of Memphis in 1996. She is a registered professional engineer in the state of Tennessee. Dr. Knight is a member of the American Society of Civil Engineers, the Society of Women Engineers, the Women's Aquatic Network, Sigma Xi, and Fellow for PIANC.
Despite existing next to the New Madrid Fault zone, which produced the largest historically recorded earthquake in the Continental United States, the Tennessee Highway Department and its successor, the Tennessee Department of Transportation had no established Seismic Design Policy until after the 1989 Loma Prieta Earthquake in northern California. Had the event not been televised nationally during the World Series that year, it could be argued that we might still not have a policy. The images broadcast during that event and the ongoing coverage of the rescue attempts involving the 880 Viaduct collapse and efforts to repair and re-open the Oakland Bay Bridge prompted a large portion of the US population to begin asking questions about seismic safety in their own states.

For the last 22 years, the Department has been engaged in the planning and execution of a program to address the seismic threat to the bridges on public roads in Tennessee. An overview of TDOT’s program implementation will be presented.

Ed Wasserman

Edward P. Wasserman is a graduate of Vanderbilt University School of Engineering with a BSCE degree. For 46 years he was employed by the Tennessee Department of Transportation as a member of the Division of Structures, serving as Director for 25 years. During the 25 years as Director, he also served as TDOT’s member on the AASHTO Subcommittee on Bridges and Structures, where he served as chairman of the Technical Committee for Structural Steel Design, and a member of the Technical Committees for Concrete Design, Bearings and Joints as well as Seismic Design.

Since his retirement in August 2011, he has joined the firm of Modjeski and Masters, serving as a Senior Engineer.

Mr. Wasserman is a Professional Engineer registered in Tennessee, member of ASCE, NSPE, Structural Engineering Institute, American Iron and Steel Institute’s Bridge Design Task Force, and is a Fellow in the Precast/Prestressed Concrete Institute and member of the Institute’s Bridge Committee. He has also chaired or been member of numerous FHWA and National Cooperative Research Board research projects on the topics of steel bridge design, fabrication and erection; prestressed concrete design and fabrication; bearings and joints; and seismic design.
The currently operating fleet of nuclear power reactors in the United States was licensed prior to 1997 (50% prior to 1979). Significant advancements in both our understanding of seismic hazards as well as the state of practice in estimating those hazards have occurred since the operating reactors were licensed. The evaluation of the impact of these changes on perceived plant safety is not a straightforward endeavor. A deterministic process was utilized in the development of the original seismic design bases for power reactors in the United States. Current Nuclear Regulatory Commission (NRC) practice utilizes a probabilistic approach in the development of seismic design parameters. Recent regulatory actions taken by the NRC have requested licensees to reassess the seismic hazards at all operating reactors utilizing current regulations and guidance. Depending on the results of the hazard assessment additional risk evaluations may be necessary for some plants.

**Jon Ake**

Dr. Ake has been employed as a Senior Seismologist by the NRC Office of Research since April 2007. Prior to coming to the NRC he was a Senior Technical Specialist at the U.S. Bureau of Reclamation from 1989 to 2007 dealing with seismic hazard and risk analysis issues. He was employed in consulting practice from 1978-1982 and from 1987-1989.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
11:00 a.m.

PLENARY

EARTHQUAKES AND CASCADING FAILURES

Moderator:
Rob Williams
USGS

Speakers:
How Can Our Understanding of the Risk of Cascading Failures Be Used to Help Build Resilience?
Chris Poland
Degenkolb Engineers

Cascading Failures in Catastrophic Earthquake Events:
The Risk Finance Perspective
Craig Tillman
Weather Predict Consulting
Rob Williams

Rob has 28 years of experience working with the USGS on studies of seismic hazard throughout the U.S. During that time he has led seismic imaging and site characterization studies of sedimentary basins in urban areas of California and in the New Madrid seismic zone. Currently he is leading a team made up of researchers from USGS, universities, and private industry to produce probabilistic seismic hazard maps of the St. Louis metropolitan area. He is also the USGS Coordinator for the Central and Eastern U.S. Earthquake Program. Rob is based at the Geologic Hazards Science Center in Golden and has a B.A. in geology from U.C. Berkeley and a M.S. in Geophysical Engineering from the Colorado School of Mines in Golden, CO.
How Can Our Understanding of the Risk of Cascading Failures Be Used To Help Build Resilience?

Chris D. Poland

Resilient communities have a credible disaster response plan that assures a place and ability to govern after a disaster has struck. Their power, water, and communication networks begin operating again shortly after a disaster and people can stay in their homes, travel to where they need to be, and resume a fairly normal living routine within weeks. The return to a “new” normal is expected to occur within a few years. While every building should protect its occupants from harm, a select few buildings need to remain operational and a larger group need to be at least usable during repair. Lifeline systems must be restored quickly to support response and reconstruction. The failure to achieve any of these performance goals can have cascading effects that will significantly expand losses and extend recovery. Understanding the relative risk each represents can inform preparedness planning, response and recovery priorities and minimize the needed mitigation efforts.

Rapid restoration of community and its economic vitality depends on supportive governance processes, the availability of workforce willing to tipping in, and financial resources. Workforce is probably the most important. People need safety, security, housing, neighborhood, lifelines and a sense of new normal to get back to work.

Education before the event is key to setting proper expectations about what is going to happen and how to best deal with it. Since “people” are the resource driving all aspects, restoring workforce touches every response and recovery activity. Education before and information after the event will generate a sense of security and accelerate the adjustment to the new normal. Conflicting messages before and after the event serve to destroy the credibility of the information and can slow and in some cases temporarily stop response and recovery.

The availability of permanent housing is second in importance. The traditional emergency response process usually focuses on providing temporary shelters followed by interim housing before consideration is given to repair and retrofit of existing housing and restoration of neighborhoods. Recovery plans should shift focus to moving displaced people from temporary shelters back into their homes and neighborhoods within a few days in a shelter-in-place environment. This not only requires rapid assessment of the damage, but also a refocusing of the emergency response and recovery priorities to the neighborhoods.

A streamlined and well coordinated governance structure is needed to orchestrate the recovery from the time the EOC closes until the new normal is established. It needs to understand the interdependence of the lifeline systems and that restoration must be prioritized and managed in order; transportation/access, power, water, sewer, and communications. It needs to be informed about the transformational opportunities that rebuilding provides to improve the overall living environment. It needs to be informed about land use planning changes that are needed in areas with disproportionately high risk. It needs to be free from requiring environmental review and community input to the extent possible to allow for timely decision making. It needs to benefit from reconstruction standards that are economically feasible but also leverage the opportunity to build back better. It needs to have multifaceted financial tools that can be applied quickly in support of reconstruction.
Chris D. Poland
Structural Engineer and Senior Principal
Chairman - Degenkolb Engineers

Chris Poland’s structural engineering career spans nearly 40 years and includes a wide variety of new design work, seismic analysis and strengthening of existing buildings, structural failure analysis, and historic preservation. As an internationally recognized authority on earthquake engineering, Mr. Poland routinely participates in policy-changing research and code development projects sponsored by the NSF, USGS, NIST and FEMA. As a passionate advocate and voice for seismic safety and Resilient Cities, he actively participates in the academic, ethical and social advancement of his field and lectures often. Chris presides as Chair of the congressionally mandated Advisory Committee on Earthquake Hazards Reduction for NEHRP. He is a member of the Board of Directors for the San Francisco Chamber of Commerce, the San Francisco Planning and Urban Research Association, and is a member of the National Academy of Engineering. He has been the leading force behind development of the SPUR Resilient City Initiative for the City and County of San Francisco and is the Co-Chair of the San Francisco Lifelines Council.
Cascading Failures in Catastrophic Earthquake Events: 
The Risk Finance Perspective

Craig Tillman

This talk examines the problem of cascading failures following earthquakes as it relates to the risk finance system, with special emphasis on the challenge of quantifying risk from these particular catastrophic outcomes and the creation of resilience mechanisms. The degree to which our megacities are interconnected often makes them vulnerable to systematic failures that amplify the impact of natural disasters. Critical infrastructure network failures, including those of power grids, water supplies, and transportation routes, compound destruction when caused by catastrophic events, significantly increasing recovery time and cost, and affecting a city’s economic potential well into the future.

We know that the costs of cascading failures are poorly represented in risk management approaches, whether from the perspective of business finance professionals, investors, or insurance companies. For instance, the evaluation of business interruption exposure likely does not consider the potential of rolling blackouts imposed on a megacity for multiple months, or the inability to get personnel to their jobs because existing housing stock is only a fraction of what it once was. Risk capital providers are similarly less able to consider conditions of tail dependence in loss distributions, where correlation tends to concentrate in the extreme tail. These loss outcomes can be the result of cascading effects, like transportation infrastructure failures that hinder early responses to earthquake fire ignitions, but also lead to massive changes in business patterns and expected rebuilding progress, all conspiring to significantly increase losses beyond the uncertainties currently modeled. While current simulation tools do capture the human and capital costs of natural disasters with some degree of reliability, selected mega-catastrophes can and do subject critical urban systems to unexpected and surprising failures. Given that these failures often result from underlying community interdependencies, identifying methods that quantify this correlation could reduce unexpected outcomes and promote resilience. The non-linear realizations of a catastrophe are the next challenge to better modeling, including better identification and quantification of these effects at the extreme tail of both individual and portfolio risk distributions.
Mr. Tillman serves as President of WeatherPredict Consulting Inc., a U.S.-based RenaissanceRe affiliate that provides intelligence on natural perils to a range of entities. WeatherPredict focuses on modeling natural hazards as well as quantifying their effects on the range of exposures at risk. Mr. Tillman leads a dedicated team of scientists with specialties ranging across oceanography, meteorology, wind engineering, aerodynamics and earthquake risk. He has been a key participant in the development of the StormStruck exhibit at Walt Disney World and the RenaissanceRe Wall of Wind, as well as RenaissanceRe’s series of Risk Mitigation Leadership Forums that examine the role of mitigation in natural catastrophe risk management. Mr. Tillman has been associated with RenaissanceRe since 1996. He was previously Chief Underwriting Officer for Glencoe Insurance Ltd., and also led RenaissanceRe’s Risk Modeling group. Mr. Tillman currently serves on the Executive Committee and Board of the Insurance Institute for Business and Home Safety (IBHS) and is Chairman of the Research Advisory Council for the newly built IBHS Research Center. He also serves on the Board of the Federal Alliance for Safe Homes, Inc. (FLASH) and the Governing Board of the Global Earthquake Model. Mr. Tillman holds Bachelors and Masters Degrees in Mathematics, as well as the Associate in Reinsurance (ARe) and Risk Management (ARM) designations. He is a longstanding member of the Earthquake Engineering Research Institute.
EERI Honorary Membership

Polat Gülkan
Professor of Civil Engineering

Polat Gülkan, Earthquake Spectra Editor since early 2008, served a term on the EERI Board of Directors (2005-2008), assisted EERI in many post-earthquake reconnaissance studies in Turkey, the Middle East, and Central Asia, and has contributed to the World Housing Encyclopedia. He served on the Board of Directors of the International Association for Earthquake Engineering (IAEE) 1996-2004, and was appointed for a four-year term as its executive vice president in 2004. He was elected to the presidency in 2008, and following a two-year period as President Elect, he is serving as President for the period 2010-2014. He has authored more than 250 professional articles, papers, and reports. He joined EERI in 1992 and is a licensed civil engineer in California. He is a former Fulbright scholar and the recipient of the 2004 NATO Summit Science Prize as well as the 2007 Science Award of the Scientific and Technological Research Authority (TÜBITAK), the highest medal of professional recognition of his country.

Mr. Gülkan was professor in the Department of Civil Engineering, Middle East Technical University (METU) until his retirement in 2011. He last served as director of the Earthquake Engineering Research Center. He is a graduate of METU (1966) and the University of Illinois, Urbana-Champaign (1971). He has now joined the academic ranks of Çankaya University as professor of civil engineering in the newly established Department of Civil Engineering. Mr. Gülkan is an earthquake structural engineer, and has been active in many areas of global hazard mitigation since 1971. He has been a visiting research scholar at the Earthquake Engineering Research Center of University of California, Berkeley. Other professional appointments have included staff consultancy at Basler and Hofmann of Zürich, Switzerland and visiting professorship at Purdue University.

He has been involved in many projects and consultancies with the UN, World Bank, EU Commission, NATO, OECD, and IAEA as well as commercial firms. His professional work culminated in earthquake hazard zone maps for Turkey that went into effect in 1996, spatial planning, urban hazard assessment, natural disaster insurance, structural intervention principles for buildings, and nuclear safety. He has served as a consultant for site selection studies for the Turkish Atomic Energy Authority. During his term as Editor of Earthquake Spectra, the journal earned the highest Impact Factor in the civil and earthquake engineering field included in the Core List of the Science Citation Index (SCI). He is serving on the Editorial Boards of Earthquake Engineering and Structural Dynamics, Engineering Structures, TÜBİTAK Turkish Journal of Engineering and Environmental Sciences, and Advances in Civil Engineering.
EERI Honorary Membership

Farzad Naeim
Vice President and General Counsel, John A. Martin and Associates

Farzad Naeim, most recently EERI Past President, has been an energetic contributor to EERI since he joined in 1983. With doctorate degrees in both Engineering and Law, he is Vice President and General Counsel at John A. Martin and Associates, a consulting structural engineering firm headquartered in Los Angeles, California. He is a registered civil and structural engineer in California; a member of the California bar, and a patent attorney. One of EERI’s first FEMA Professional Fellows in 1993, Farzad was also instrumental in bringing EERI into cyberspace in 1995 when he wrote the Institute’s first Electronic Information Management Plan. He served a five-year term as Earthquake Spectra Editor and is currently on its Editorial Board. After helping to create the World Housing Encyclopedia, his group at JAMA has developed and maintained the World Housing Encyclopedia database and web site. He endowed the Farzad Naeim prize, which underwrites the publication of an annual WHE insert featuring the Best Recent Report and updates on other WHE activities.

He was also, at various times, chair of the Special Projects and Initiatives Committee and Nominations Committee. In addition to his EERI activities, Farzad is a member of industry advisory boards to UCLA, USC, and CSUN civil engineering departments, a director of COSMOS, and serves on the Advisory Council of the Southern California Earthquake Center.

Farzad has served as technical director for the analysis and design of numerous award-winning structures, including the replication of the Eiffel Tower, at half-scale, for the Paris Hotel & Casino in Las Vegas, the seismic retrofitting of UCLA’s Royce Hall, the Los Angeles Convention Center expansion, the California State University, Long Beach, University Events Center, the Staples Center in Los Angeles, and the Walt Disney Concert Hall in downtown Los Angeles.

Naeim has developed more than 45 software systems for earthquake engineering applications, and is a nationally recognized authority on the evaluation of design ground motion issues as they relate to the design of structural systems. He conducted investigations of the 1994 Northridge earthquake and the 1999 Taiwan earthquake, and edited the first and second editions of The Seismic Design Handbook, used in all major U.S. universities.
The 2011 Shah Family Innovation Prize has been awarded to Veronica Cedillos, a project manager at GeoHazards International (GHI). Veronica was educated at M.I.T. (B.S. in Civil Engineering, 2005) and Stanford University (M.S. in Civil Engineering, 2008) and worked for one year in an engineering firm between her undergraduate and graduate studies. Upon graduating from Stanford, she joined GeoHazards International (GHI), where she has progressively increased her responsibilities to the point where she leads two very challenging and innovative earthquake risk reduction projects, reducing earthquake and tsunami risk in Padang, Indonesia and promoting seismic safety in a rural village in Peru.

Anyone who meets Veronica will soon realize that she is passionate about helping people through her work to mitigate earthquake risks in developing countries. However, Veronica’s success has not been achieved through passion alone. She has developed understanding and insights on the ingredients to a successful project – beginning with the project idea itself and then how to identify and nurture collaborations with relevant organizations. Veronica is fearless to enter a new community and has the confidence and abilities to develop effective working relationships with all sorts of organizations and people – ranging from top government officials, to university professors, down to local community members. She has the heart of an entrepreneur. She is also a strategic thinker, who can stay focused on the long-range goals of a project while attending to short-term planning and day-to-day operations.

One measure of Veronica’s commitment to her work of implementing life-saving measures is her willingness to live abroad in extremely demanding conditions (e.g. minimal hot water, occasionally functioning toilets, an unheated bedroom at 9,000 ft elevation, very simple food). Another measure of her keen interest in and commitment to the people she works with is that in Indonesia, on Sundays—her single “day of rest”—she often teaches local children violin.

Veronica is much more than an engineer applying her technical talents; she immerses herself in the communities that she serves. At 28 years old, she has much to contribute to the earthquake community. Over time, Veronica’s skills will continue to grow and mature, her influence will expand, and her ideas will take root in more communities and organizations.
Thursday Luncheon Presentation

TIMOTHY G. GALARNYK
Chief Executive Officer, Construction Risk Management
Inspector America, the History Channel

Timothy G. Galarnyk is the Chief Executive Officer of the international firm Construction Risk Management, Inc. Galarnyk, a seasoned and very rare Construction Forensic Investigator has been involved in the construction industry for more than 36 years. His field of expertise includes heavy construction, railway construction, residential and commercial construction, inspection and evaluation of highway and railway bridges and the evaluation and determination of proper construction means and methods for railway, residential, commercial and heavy construction operations. His specialty is infrastructure all over the world from oil and gas fields to bridges and dams. Galarnyk has been involved in the inspection of over 1000 bridges worldwide and in the construction, repair, replacement or renovation of over 3000 bridges since his career began in the mid 1970s.

Galarnyk is actively involved in the forensic investigation of construction collapses, defects, deaths and injuries. He is one of the world’s leading experts in the field of construction analysis, construction safety, construction defects and in identifying construction problems. He is an expert in the creation of programs that manage the risks associated with railway, highway and general construction projects. Galarnyk has personally investigated more than 300 construction related fatalities and literally thousands of construction injuries in his career.

Galarnyk was the Host of a 2011 History Channel reality-based television program where he appears as “Inspector America”. Galarnyk visited 6 cities in America inspecting roads, bridges, sewer and water and other vital pieces of American Infrastructure and provided conclusions on the State of America’s Infrastructure.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Forest Room

CONCURRENT SESSION
ADVANCES IN EARLY WARNING

Moderator:
Bill Steele
University of Washington

Speakers:
ShakeAlert: Earthquake Early Warning in the U.S.
Doug Given, USGS
Peggy Hellweg, UC Berkeley
John Partland, BART
Bill Steele

Bill Steele has managed educational outreach and public information program for the Pacific Northwest Seismic Network (PNSN) at the University of Washington, Department of Earth and Space Sciences, since 1993. He works closely with news reporters and film makers to provide background information and coordinate scientist involvement in development of accurate and interesting reports and documentaries. Bill supports interdisciplinary and interagency cooperation between university, government, and private sector communities to identify hazards, vulnerabilities, and mitigation opportunities. He is a current board member and founding member of CREW (the Cascadia Region Earthquake Workgroup) and is an active member of CPARM (Contingency Planners and Recovery Managers).
ShakeAlert: Earthquake Early Warning in the US

Doug Given (USGS), Peggy Hellweg (UC Berkeley), John McPartland (BART) and the Earthquake Early Warning Project Team

In California a team of scientists and programmers has been implementing a test earthquake alerting system using data from the California Integrated Seismic Network (CISN). This Earthquake Early Warning (EEW) project began five years ago. It is a collaboration between Caltech, UC Berkeley, ETH Zurich, USC/SCEC and the USGS, and is funded by the USGS. The statewide test system is now operational. It delivers alerts through a pop-up display to project scientists, to other interested scientists, and since the beginning of 2012, to beta users from a variety of organizations and institutions in California. Among the beta users are the California Emergency Management Agency (CalEMA) Warning Center, other response agencies, as well as institutions which operate critical and or sensitive infrastructure. Recently, the development effort in the US has expanded with funding from the G & B Moore Foundation to Caltech, UC Berkeley and also to the University of Washington. The research effort now includes West Coast regions that will be impacted by a megathrust earthquake on the Cascadia Subduction Zone. What is Earthquake Early Warning and how does it work? How can EEW reduce losses and help speed recovery? USGS and university scientists team up with a representative of the Bay Area Rapid Transit District to provide an introduction to EEW in the US, including scenarios of alerts, and to explore how EEW can be integrated into systems to reduce damage.
Doug joined USGS in 1978. He has pursued research onto the seismicity and tectonics of Southern California and conducted field investigations of several large earthquakes including Haiti in 2010. He has been an adjunct professor of geology at Pasadena City College since 1992. He earned a B.S. in geology in 1978 from the University of California, Los Angeles, and an M.S. in geology in 1983 from California State University, Los Angeles. Following are his main areas of responsibility at the USGS:

- **Project Chief, Southern California Earthquake Monitoring** – Doug manages two USGS earthquake monitoring networks in southern California. These networks process more than 12,000 earthquakes each year and provide real-time earthquake information to emergency responders, engineers, and scientists.
  - The Southern California Seismic Network (SCSN), in cooperation with Caltech, operates more than 350 real-time seismic stations.
  - The Southern California GPS Network measures geodetic strain with an array of 95 high-precision Global Positioning System instruments.

- **USGS, Earthquake Early Warning Coordinator** – In 2009 Doug was chosen to coordinate the efforts of USGS in the area of Earthquake Early Warning (EEW). USGS along with university partners is building a prototype EEW system in California.

- **State and National Seismic Network Coordination** – Doug serves on multiple committees within the California Integrated Seismic Network (CISN) and the Advanced National Seismic Network (ANSS) that work to integrate and coordinate earthquake monitoring activities within California and nationally.

- **Earthquake Systems Technology Development** – Doug leads the design and development of software systems for the rapid acquisition, analysis, and reporting of earthquake information using modern technologies.
Peggy Hellweg

Dr. Peggy Hellweg studied physics at the University of California San Diego. She spent her junior year abroad at the University of Goettingen, Germany, where she returned after she received her BA. After earning a masters in physics at Goettingen, she turned to seismology and worked at the seismological laboratory of Germany's Federal Institute of Earth Sciences and Resources. In the mid-1980s, she returned to the United States, where she worked on strong-motion earthquake projects at the United States Geological Survey. She earned her doctorate in 2000 at the University of Stuttgart, Germany, on seismicity associated with volcanoes. Since 2001 Dr. Hellweg is at the Berkeley Seismological Laboratory, where she is Operations Manager for the BSL's network of high quality seismometer/accelerometer stations. She is Project Manager for the Earthquake Early Warning activities at the BSL and spearheads outreach to users of the EEW system, CISN ShakeAlert, in California.

John McPartland

BART, President

Alameda County native John McPartland was elected to represent District #5, which includes the cities of Castro Valley (partial), Dublin, Hayward (partial), Livermore, Pleasanton, Sunol, Danville (partial) and San Ramon.

Before joining the Board, McPartland was a BART Safety Specialist for six years where he served as a liaison to, and facilitated disaster response training with, public safety agencies within the BART service area. He also planned and conducted disaster training exercises between BART emergency operations staff and state, county and local municipalities.

McPartland brought to BART a strong background in emergency management and leadership. Most recently, he was appointed by the governor to the State Seismic Safety Commission. He is retired from the Oakland Fire Department after 25 years as a Chief Officer. He was responsible for the mitigation of emergencies of every kind throughout the city. Additionally, he served as the Emergency Medical Services Manager and was a member of the Federal Urban Search and Rescue Task Force. McPartland is also an accomplished instructor of emergency command and operations courses and uses his expertise to teach at community colleges and serve on their advisory boards.

Prior to his career in the fire service, McPartland served in the armed forces for more than seven years, left active duty after his second Viet Nam tour and entered the Reserves. He continued to serve in a multitude of command and staff assignments was mobilized to active duty, including during Desert Storm, and retired after 36 years of service as a Colonel. His decorations are numerous and include, in part, the Distinguished Flying Cross, Bronze Star and Meritorious Service Medal with Oak Leaf Cluster.

McPartland has been an active community supporter for his entire adult life. Most notable among his involvement include being a member of the Alameda County Emergency Managers Association, the national Disaster Medical Assistance Team, the Alameda County Sheriff’s Dive Unit, the Castro Valley Chamber of Commerce and the Veterans of Foreign Wars Post 9601.

McPartland holds a B.A. from St. Mary’s Moraga, a M.P.A. from Cal State East Bay, is a “Command and General Staff College” graduate from the U.S. Army and holds a number of technical degrees in management and emergency/disaster operations.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Venetian Room

CONCURRENT SESSION
OVERCOMING BARRIERS TO MITIGATION & RETROFITTING

Moderator:
Sandra Knight
FEMA

Speakers:
Challenges in Seismic Retrofitting MLGW Facilities
Jay Stressel
Memphis Light, Gas, & Water

University of Memphis Cecil Humphreys Law School Retrofit
Scott Fleming
Fleming Associates Architects

Memphis/Shelby County Building Code Adoption and Challenges
Bob Paullus
Paullus Structural Consultants

Learning from the Past to Protect the Future
At FEMA, Dr. Knight provides executive leadership, oversight and supervision for the development and administration of regulations, policies and procedures for the Risk Reduction and Risk Analysis Divisions and Offices of Environmental Planning and Historic Preservation, and Regional and Disaster Support. This includes Floodplain Mapping, Floodplain Management, Hazard Mitigation Assistance Grants, Building Sciences, Mitigation Planning, Dam Safety, the National Earthquake Hazards Reduction Program, and hazardous risk assessment methodologies. She received her doctorate in Civil Engineering from the University of Memphis in 1996. She is a registered professional engineer in the state of Tennessee. Dr. Knight is a member of the American Society of Civil Engineers, the Society of Women Engineers, the Women's Aquatic Network, Sigma Xi, and Fellow for PIANC.
Challenges in Seismic Retrofitting MLGW Facilities

Jay Stressel
Memphis Light, Gas, & Water

Organizations within MLGW have been extremely successful in planning and completing important seismic upgrades over the past several years. Since 1990, MLGW has spent nearly $81 million on seismic mitigation projects.

Some of these improvements include:

- Retrofits at four pumping stations consisting of aerator, filter, and pump buildings.
- Installation of reservoir-mounted high service pumps at three pumping stations to negate the effect of building collapse hazards on transmission or pumping capabilities.
- Emergency generators have been installed at six water pumping stations, with a second backup generator project nearing completion.
- Anchoring of transformers and other equipment at electric substations.
- Securing a total of $6 million in FEMA grants to help fund improvements to the electric and water systems.
- Replacing older cast iron gas mains with polyethylene pipe, which is more flexible and reliable.
- Relocating critical areas such as the Customer Care Center, Commercial Resource Center and Information Technology from the Administration Building to MLGW’s Netters Business Center location on Whitten Road for business continuity.
- Retrofitting truck canopies at work centers to prevent damage to parked crew trucks.
- Anchoring non-structural building elements at all support facilities.

After a Seismic Preparedness study was completed in 1989, MLGW started developing plans to protect the utility system against natural disasters such as earthquakes and high winds. In 2006 a Multi-hazard risk assessment was completed which included updated codes, and new seismic design guidelines.

In the early 1990’s, seismic projects were beginning to appear in the budget planning process. The original seismic study prioritized projects providing the largest benefit to cost ratios. Those systems included substation power transformers, cast iron gas pipe and water pumping stations. Retrofit projects protecting service to our largest customer base were given first priority.

At some point management realized we needed to start addressing vulnerabilities within our administrative building infrastructure, especially those areas critical to business continuity. Similar to the utility systems, many buildings were predated any seismic construction requirements. Existing buildings ranged in age from the early 1930’s to the late the early 2001. Up to the late 1980’s the Electric Systems and Operations Building, which houses our Supervisor Control and Data Acquisition (SCADA) system, was the only building constructed to any seismic standard. Seismic design was not required at that time. But due to the critical nature of the SCADA system, it was decided to incorporate provisions for seismic design. At the time only life safety level design guidelines were considered. Since then, elevated seismic performance levels and design guidelines for essential facilities have increased dramatically.

In 2002 MLGW purchased and retrofitted a 94,000 square foot building to house areas critical for business continuity. These areas make up the divisions communication lifeline, comprising the primary Data Center, Dispatching, Customer Care Center, Commercial Resource Center, and the Emergency Operations Center.
MLGW mitigation efforts depended upon successfully dealing with each of the following challenges.

- **Understanding and Identifying Risks:** Seismic studies and conceptual plans, establishing seismic performance level, addressing Business continuity concerns and prioritizing retrofit projects.
- **Support from Upper Management:** Expose vulnerabilities and developing a preliminary financial plan. FEMA grants are big incentives.
- **Long range plans and budgets:** Long range plans to include structural and non-structural elements. Adopt plan to embrace seismic performance all new buildings and new building MP&E systems.
- **Managing the Design Process:** Working with the right consultant can save time, money and help assure a quality project. The owner must manage project quality assurance.
- **Managing the Construction Process:** Communicate to Contractor importance for structural and non-structural upgrades. Make sure Contractor understands scope of work. Structural Engineer of record, special Inspectors represent the quality control team.
- **Quality Control:** Owner needs to manage the level of quality. Good quality control is the best insurance against failure.

The following examples are some lessons learned during past water retrofit projects.

1. Engineers recognized water pumping stations were totally dependent on the electrical system. The need for redundancy drove the decision to install emergency generators.
2. The construction process usually uncovers unexpected structural conditions. Steps were taken to include contingency money in project budgets.
3. FEMA grants are based on B/C ratios. Accurate conceptual estimates are crucial to this funding process. No two Pumping stations are alike. Type of design and age of a water plant affect retrofit cost. Examples include, pumped backwash water verses gravity feed. Steel verses Reinforced concrete. Reinforced masonry verses un-reinforced masonry. Under estimated projects have jeopardized project funding.
4. To prevent conflict of interest, MLGW directly hires special inspectors.

**Jay K. Stressel**

Mr. Stressel has over 20 years of structural engineering experience. He is a registered professional engineer in TN. Currently employed with Memphis, Light, Gas, and Water Division in Memphis TN. as Lead Engineer, and Project Manager, over Facilities Capital Improvement projects. Prior to that he was a design engineer for Allen & Hoshall Engineers Inc. Jay is a Past Treasurer and Past Vice President of the West Tennessee Structural Engineers Association (WTNSEA). Jay also served on the Clients and Prospects Committee, for the National Council of Structural Engineers Associations (NCSEA)
University of Memphis Cecil Humphreys Law School Retrofit

Scott Fleming
Fleming Associates Architects

Overview of University of Memphis Cecil Humphreys Law School design and retrofit project. This award-winning project included the seismic retrofit and rehabilitation of a vacated early 20th century, unreinforced masonry post office into a modern university facility in downtown Memphis.

Scott Fleming

Scott Fleming is the president of Fleming/Associates/Architects, an architecture firm that began in the 1950s with his father, Robert Fleming. Scott attended Auburn University, where he received his Bachelor of Environmental Design in 1980 and Bachelor of Architecture in 1981. Over the years, Scott's leadership has allowed for the steady growth of his firm and a highly respected reputation with clients and the community. Recent projects include the Salvation Army Adult Rehabilitation Center, the Salvation Army Ray and Joan Kroc Corps Community Center, the University of Memphis Law School, and Hope Presbyterian Church. Scott is active in numerous professional organizations, including the American Institute of Architects, Memphis & Shelby County Land Use Control Board, Urban Land Institute, and several local area chambers of commerce. As a lifelong Memphian, Scott is passionate about being involved in the community. He serves on the board of directors for Streets Ministries, Christian Brothers High School, and Young Life, to name a few.

Memphis/Shelby County Building Code Adoption and Challenges

Bob Paullus
Paullus Structural Consultants

Overview of Memphis/Shelby County seismic building code adoption. Seismic building codes in the Memphis area have been in effect since the 1990s; however, their implementation is a topic of constant local discussion. This topic will focus on challenges faced in implementing and updating modern seismic codes at the local level.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Hernando Desoto Room

CONCURRENT SESSION
INCORPORATING AFTERSHOCKS IN RISK ANALYSIS

Moderator:
Oliver Boyd
USGS

Speakers:
Revising Canterbury, New Zealand Seismic Levels to Account for Time-Varying Hazard from Continuing Canterbury Earthquake Sequence
Matt Gerstenberger
GNS Science

Post-Mainshock Probabilistic Risk Quantification: Why and How?
Nicolas Luco
USGS

Quantifying Mainshock-Aftershock Collapse Probabilities for Woodframe Buildings
John van de Lindt
University of Alabama

Aftershock Collapse Fragility for Mainshock-Damaged Reinforced Concrete Buildings
Abbie Liel
University of Colorado
Dr. Oliver Boyd is a Seismologist with the U.S. Geological Survey. Starting with the National Seismic Hazards Mapping Project in Golden, CO in 2004, he is now with the Central and Eastern U.S. Seismic Hazards Project in Memphis, TN. He is an Adjunct Professor at the Center for Earthquake Research and Information at the University of Memphis. Oliver studies many aspects of earthquake hazards including time-dependent earthquake probabilities, declustering of foreshocks and aftershocks, and ground motion relationships. He has also helped to update the New Madrid source and ground motion models for the 2008 update of the National Seismic Hazard Maps. Other recent projects include a time-dependent seismic hazard map of Alaska and a seismic hazard analysis of Afghanistan, the latter being done in conjunction with other U.S. Agency for International Development’s reconstruction efforts in Afghanistan. Prior to joining the Survey, Oliver obtained his Ph.D. in Geophysics from the University of Colorado at Boulder where he performed laboratory experiments on seismic wave attenuation and produced and interpreted tomographic images of seismic wave attenuation and velocity beneath the western United States. To learn more about Oliver’s background and current work, please visit http://www.ceri.memphis.edu/people/olboyd/.
Revising Canterbury, New Zealand, Seismic Design Levels to Account for Time-Varying Hazard from the Continuing Canterbury Earthquake Sequence

M.C. Gerstenberger
GNS Science

We present updates, based on time-dependent hazard modelling, of the NZS1170.5 (2004) earthquake design standards for Christchurch based on the changes in seismicity following the recent Canterbury earthquakes. The sequence began in September 2010 with the Mw 7.1 Darfield earthquake. It has continued with a damaging sequence of events including the Mw 6.3 earthquake in February; the June Mw 6.0 earthquake; and the December Mw 6.0 earthquake. These major aftershocks have occurred in very close proximity to Christchurch in a moderate to low hazard area in the New Zealand National Seismic Hazard Model (NSHM).

Seismicity in the region continues to be very high relative to activity prior to the September 2010 earthquake, requiring development of earthquake hazard estimates that model time-varying seismicity rates (e.g., from aftershocks and longer-term clustering). Updates to the NSHM and the resulting changes to the design standard have occurred in a two-step procedure: firstly, in April 2011 a preliminary update was conducted which was followed by the convening of an international expert panel in November 2011 to update, re-evaluate, and finalize the results. The April 2011 NSHM update led to a revision of design levels for the Christchurch region in May, 2011; it is anticipated that the revision resulting from the November 2011 expert panel will lead to further revisions of design levels later this year.

In the preliminary update, we constructed a composite earthquake hazard model to give the magnitude-weighted spectral acceleration (SA) level with a 10% probability of exceedance in the next 50 years for both Class C and D soils. The composite model combines several earthquake source models that are based on different concepts and cover a wide range of time, space and magnitude scales. The models are: (1) the fault source model of the national seismic hazard model (NSHM; Stirling et al, 2012), with enhancement of the earthquake probabilities for the most major active faults near to the Canterbury region (Hope, Alpine, and Porters Pass Faults) to take account of the time elapsed since the last earthquake; (2) the Proximity to Past Earthquakes (PPE) smoothed seismicity model; (3) the Short Term Earthquake Probability (STEP) model (Gerstenberger et al, 2005), which targets aftershocks and; (4) the Every Earthquake a Precursor According to Scale (EEPAS) model (Rhoades and Evison, 2004) which looks at longer-term earthquake clustering. Earthquake hazard levels produced by the composite model are found to be high in the region of the city, and similar to the hazard levels close to the major active faults to the northwest of Christchurch.

A particular challenge in understanding the influence of the aftershocks on hazard and risk comes from the earthquake magnitudes that are driving the hazard in the region, on time-scales from one year to fifty years. Typically, at longer time-scales, the hazard is driven by larger magnitude earthquakes (e.g., M>=6.5); this was the case in Canterbury prior to this sequence. However, with the introduction of aftershock modelling, the dominant sources in the region are now M<6 earthquakes at close distances. While it has long been thought by the community that equivalent amplitude ground shaking from smaller events is less damaging than from a larger event (e.g., from duration), exactly how to quantify this is not well constrained.

In November 2011, a three day expert panel workshop was held to consider a time-dependent update of the NSHM for the Canterbury earthquake sequence. The panel, made up of international and NZ-based scientists, was presented with 50 questions for which they were expected to provide weights. The questions were divided into five categories: 1) Time-dependent seismicity models, 1- and 50-year forecast; 2) Long-term seismicity models, 50-year forecasts; 3)
Minimum and maximum magnitude of forecast models; 4) Depth distribution of forecast models; and 5) Variability in predicted ground motions. The experts were presented existing work done in response to the Canterbury sequence; the goal of the workshop was not to develop new ideas for immediate consideration in the NSHM. Understanding the uncertainty in the hazard was a primary goal of the workshop. To this end, the expert panel followed the methodology of Cooke where the responses of each expert were weighted based on answers to questions which targeted how well experts estimate the uncertainties in their own knowledge. Here we will present the model and forecasts that resulted from the workshop.

Matt Gerstenberger

Matt Gerstenberger is a seismologist at GNS Science, a crown research institute in Wellington, New Zealand. He received his doctorate from ETH Zürich in 2003, and has primary research interests of probabilistic hazard and risk assessment. He has a focus in time-dependent hazard assessment, including the modeling of aftershock sequences and the development of real-time hazard analysis systems. Recently he has been involved in incorporating such time-dependent modeling into more traditional probabilistic seismic hazard analysis and also building design standards in response to the Christchurch, New Zealand, earthquake sequence.
Post-Mainshock Probabilistic Risk Quantification: Why and How?

Nicolas Luco

Increasingly, probabilistic seismic risk (of damage) quantification is becoming the basis for longer-term or “pre-earthquake” mitigation approaches for buildings and other structures, e.g. seismic design standards in building codes. For example, the latest edition (2009) of the *NEHRP Recommended Seismic Provisions for New Building and Other Structures (FEMA P-750)* defines Risk-Targeted Maximum Considered Earthquake (MCE_R) ground motions for the United States by explicitly targeting a probabilistic 1% risk of collapse in 50 years, an approximation of the lifespan of a building. Maps of these probabilistic risk-based design ground motions have since been adopted for inclusion in the latest edition (2012) of the *International Building Code*. Moreover, the next generation of performance-based seismic design procedures for new and existing buildings being developed by the Applied Technology Council with funding from FEMA (http://www.atcouncil.org/Projects/atc-58-project.html) use probabilistic risk of earthquake-caused deaths, dollars (repair costs), and downtime (repair duration) as metrics for seismic performance assessment of buildings.

Probabilistic risk quantification has also been proposed as a basis for making shorter-term or “post-earthquake” mitigation decisions after a mainshock has occurred and when the threat of aftershocks lingers. For example, the Pacific Earthquake Engineering Research Center *Advanced Seismic Assessment Guidelines* (Bazzurro et al 2006) use the probability that an aftershock ground motion will exceed the capacity of a mainshock-damaged building (treated deterministically for simplicity) as a rational criterion for deciding whether and when to permit re-occupancy of the building. Similarly, Yeo & Cornell (2005) have developed a time-dependent building “tagging” (i.e. permitting or restricting occupancy) policy for the aftershock environment using probability of collapse as a proxy for fatality risk.

This presentation summarizes a methodology for post-mainshock probabilistic risk quantification being proposed for development of a computational tool for automatic (or semi-automatic) assessment (Luco et al 2011). The methodology utilizes the same so-called risk integral (e.g., McGuire 2004) that can be used for pre-earthquake probabilistic risk quantification. The risk integral couples (i) ground motion hazard information for the location of a structure of interest with (ii) knowledge of the fragility of the structure with respect to potential ground motion intensities. In other words, the risk integral combines information about both the ground motion demand and the capacity of the structure to withstand such demand.

In the proposed post-mainshock methodology, the ground motion hazard/demand component of the risk integral is adapted to account for aftershocks which are deliberately excluded from typical pre-earthquake hazard assessments. Correspondingly, the structural fragility/capacity component is adapted to account for any damage caused by the mainshock, as well as any uncertainty in the extent of this damage. The result of the adapted risk integral is a fully-probabilistic quantification of the post-mainshock seismic risk, i.e. the risk of further damage in aftershocks. By comparing it with tolerated pre-earthquake risk levels (e.g. the 1%-in-50-years risk of collapse mentioned above), the post-mainshock result can inform emergency response mobilization, inspection prioritization, and re-occupancy decisions.
Although the focus in this presentation is on mainshock-aftershock sequences, the post-earthquake risk quantification methodology presented can be applied after any earthquake (a mainshock, aftershock, or foreshock). Furthermore, to the extent that the post-earthquake ground motion hazard component of the assessment includes the potential for so-called triggered earthquakes, the methodology can apply for sequences like the 1811-1812 New Madrid Seismic Zone earthquakes in the United States and the recent 2010-2011 earthquakes near Christchurch in New Zealand. Besides buildings, the focus of this presentation, analogous methodologies can be applied to other structures such as bridges and dams. While the focus here is on collapse risk, the risk of exceeding any other state of damage can be considered with the same methodology.


**Nicolas Luco**

Nicolas Luco is a Research Structural Engineer with the United States Geological Survey (USGS) in Golden, Colorado. His research mainly lies at intersections of structural (civil) engineering, probability and statistics, and seismology. At the USGS he is co-Project Chief of the Engineering Risk Assessment Project, and leads the Seismic Design Maps Task of the US National Seismic Hazard Mapping Project, thereby serving as a liaison between the broader earthquake hazard, design/retrofit, and risk communities. Prior to joining the USGS in 2004, he was a Senior Analysis Engineer with the natural and man-made catastrophe loss modeling company AIR Worldwide Corporation in San Francisco, California. His education includes a Ph.D. in civil engineering (2002), M.S. in statistics (2000), and B.S. in civil engineering (1995) from Stanford University, as well as an M.S. in civil engineering (1996) from the University of California at Berkeley.
Quantifying Mainshock-Aftershock Collapse Probabilities for Woodframe Buildings

John W. van de Lindt and Negar Nazari
The University of Alabama

Yue Li
Michigan Technological University

Aftershocks have the potential to threaten life safety and cause substantial damage to buildings even when little damage is notably present as a result of the mainshock. The effects of aftershocks on buildings is not explicitly accounted for in engineering building design codes, nor in newly emerged methodologies such as performance-based seismic design. The occurrence of aftershocks following a mainshock is a complex statistical problem that is often modeled as a Poisson process. In this presentation part of the results of an on-going study to integrate aftershock hazard into performance-based seismic design are presented, specifically the quantification of collapse probabilities for a mainshock-aftershock model. In 2006 a two-story woodframe townhouse was tested as part of the NSF-funded NEESWood project at NEES@Buffalo producing a landmark data set publically available. A numerical model is fit to the global hysteresis generated during an MCE level tri-axial shake and individual shear wall hysteretic models backed out such that the story hysteresis and global hysteresis provide a best-fit. Incremental dynamic analysis is then run using the numerical model and a suite of 22 ground motions assumed to be mainshocks in this analysis and recommended for use in FEMA P-695. For each IDA a set of basic rules provides a means to select a collapse range on the IDA. Rank ordering these seismic intensity ranges from each of the 22 records provides a collapse band. This band represents the probabilistic range of collapse at a range of seismic intensities.

Then, for comparison the same type of collapse band is developed for a mainshock-aftershock combination. This is done through application of the Gutenberg-Richter relationship and assuming that an aftershock has an equal probability of occurring over a circular area (defining the mainshock as the center) with an assigned radius. It has been shown that this area is actually an ellipse but, at this stage, a simplified model is used to illustrate the approach. Once the aftershock magnitude (M) and site-to-source distance (R) are known from these two statistical distributions described above, a well-known attenuation model is used to compute the new spectral acceleration which can be either larger or smaller than the mainshock depending on M and R. Monte Carlo simulation is applied and the aftershock time history is selected randomly from the suite of 22 earthquakes described earlier, assuming a uniform probability across all these earthquakes. The record selected is scaled to the spectral acceleration computed from the attenuation equation and applied to the nonlinear numerical model.

Comparison of these collapse bands is made and the effect of aftershock hazard can be quantified for a woodframe building. Next steps in the project and reduction of epistemic uncertainties by systematically reducing the assumptions will also be explained. A number of archetype models will be examined within the project to generalize the investigation to the woodframe category instead of a single building. Steel frame buildings are also being investigated within the broader project but are not presented here.
John W. van de Lindt

Dr. John W. van de Lindt is a Professor of Structural Engineering at the University of Alabama and holds the Garry Neil Drummond Endowed Chair in Civil Engineering. He previously served on the faculty at Colorado State University and Michigan Technological University. Professor van de Lindt has led several large multi-university-industry projects including a project to develop a performance-based seismic design philosophy for mid-rise woodframe buildings which culminated with a full-scale 14,000 sq ft 6-story shake table test for validation of the design methodology. His work focuses on advancing design for building performance in earthquakes and other natural hazards such as tsunamis, hurricanes, tornadoes, and floods. Professor van de Lindt has published 90 journals papers, 100 conference papers, and 30 project reports during the last 12 years. He is currently an Associate Editor for the Journal of Structural Engineering and serving as a Guest Editor for the Special NEES Issue of JSE.
Aftershock Collapse Fragility for Mainshock-Damaged Reinforced Concrete Buildings

Abbie Liel

This presentation illustrates how a probabilistic methodology for incorporating aftershocks within the performance-based earthquake-engineering framework can be used to assess the effect of mainshock damage on a building’s resistance to earthquake-induced collapse. Specifically, the work presented explores how varying degrees of mainshock damage reduce a building’s capacity to resist collapse in subsequent events, accounting for strength and stiffness degradation that may have occurred in the mainshock.

The methods for assessing aftershock collapse fragility of mainshock damaged buildings are developed and illustrated through analysis of a 4-story concrete frame with design and detailing characteristics like those built in New Zealand in the 1960s and 1970s and similar to some of the high-profile structures which collapsed in the 2011 Christchurch Earthquake. The building is modeled with geometric and material nonlinearities capable of capturing the critical aspects of strength and stiffness degradation as it becomes damaged and collapses. Incremental dynamic analysis is used to predict response of the model to the mainshock (or first earthquake) event. Subsequently, we consider a large number of mainshock-aftershock sequences to quantify the increase in aftershock vulnerability due to the mainshock-induced damage. Analyses indicate that moderate damage (indicative of concrete cracking or rebar yielding in columns) during the mainshock does not significantly increase a structure’s collapse fragility to aftershock events. However, higher levels of mainshock damage may significantly reduce the safety of the structure. Extensive damage (such as spalling or rebar buckling in columns) jeopardizes a structure’s ability to withstand subsequent ground shaking, reducing the median collapse capacity by 27%. Results are generalized through comparison with a U.S.-type nonductile concrete building and to single-degree-of-freedom representations of the same structure.

Results presented provide quantitative evidence of the risk of earthquake-induced collapse in buildings damaged during a mainshock-type earthquake event, focusing on the prevalent nonductile concrete frame building type that is known to be vulnerable to earthquake-induced collapse. The presentation also serves to illustrate the application of the probabilistic aftershock risk-assessment methodology and the merit and usefulness of these computationally intensive analyses.

Abbie Liel

Abbie Liel is an Assistant Professor in the Department of Civil, Environmental and Architectural Engineering at the University of Colorado at Boulder. Dr. Liel earned a B.S.E. in Civil and Environmental Engineering from Princeton University, a M.Sc. in Civil Engineering and a M.Sc. in Building and Urban Design and Development from University College London, and a Ph.D. from Stanford University. Her research focuses on simulating the nonlinear response of building structures in order to quantify the risk of earthquake-induced collapse. Particular areas of interest include assessing the collapse safety of older, nonductile reinforced concrete frame structures, evaluating the impact of near-fault or subduction type ground motions on structural response and aftershock collapse risk and building tagging. Dr. Liel is involved in a number of committees, including the ASCE Structural Engineering Institute Young Professionals’ Committee and the Technical Council on Life-Cycle Performance, Safety, Reliability and Risk of Structural Systems, and the ATC 78 Project for Identification and Mitigation of Concrete Buildings. She is a licensed civil engineer in California.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Grand Ballroom A & B

CONCURRENT SESSION
NUCLEAR POWER PLANTS: FUKUSHIMA & US

Moderator:
James Beavers
JEB Consultants

Speakers:
The Central and Eastern United States Seismic Source Characterization for Nuclear Facilities (CEUS SSC) Project
Larry Salomone
EPRI Consultants

Challenges in Seismic Hazard Analyses in the U.S. in the 21st Century: Are We Addressing the Extreme Events?
Ivan Wong
URS Corporation

The Fukushima Dai-Ichi Nuclear Plant Accident
George Flanagan
Oak Ridge National Laboratory
James E. Beavers

James E. Beavers, Ph.D., P.E. is the sole proprietor of James E Beavers Consultants (JEBc), a consulting engineering firm in Knoxville, TN specializing in structural engineering, and natural and technological hazards. Dr. Beavers, has more than 35 years of experience as a university professor, private consultant, corporate manager, author, and editor. He was founder and co-editor of Natural Hazards Review, a journal of the American Society of Civil Engineers (ASCE). In addition, he has served on more than 80 national committees, authored or coauthored more than 200 papers, and participated in professional exchange programs with Russia, China, India, and Australia. In 2007, he received the Duke Lifeline Earthquake Engineering Award from ASCE. In 1990 he was appointed Corporate Fellow at Martin Marietta Energy Systems for outstanding service and contributions to the national and international scientific and engineering community and for exemplary leadership. In 1993 he was awarded the Professional Engineering Degree of Civil Engineering by the Missouri University of Science and Technology. Dr. Beavers also has a B.S. degree in Civil Engineering from Missouri University of Science and Technology and M.S. and Ph.D. degrees in Civil Engineering from Vanderbilt University.
The Central and Eastern United States Seismic Source Characterization for Nuclear Facilities (CEUS SSC) Project

Lawrence A. Salomone, P.E.

The Central and Eastern United States Seismic Source Characterization for Nuclear Facilities (CEUS SSC) Project was conducted from April 2008 to December 2011 to provide a new, regional seismic source model for use in conducting probabilistic seismic hazard analyses (PSHAs) for nuclear facilities in the Central and Eastern United States. Input to a PSHA consists of a seismic source model and ground motion models. These models are used to calculate seismic hazard, or seismic hazard curves, at a particular site.

The CEUS SSC project replaces previous seismic hazard models used by the nuclear industry, including the EPRI–Seismicity Owners Group (EPRI-SOG) model (EPRI, 1988, 1989) and the Lawrence Livermore National Laboratory model (Bernreuter et al., 1989). Unlike the previous studies, the CEUS SSC Project was sponsored through an industry-government partnership—namely the EPRI Advanced Nuclear Technology (ANT) Program, the Department of Energy (DOE) Office of Nuclear Energy (NE) and the DOE Office of the Chief of Nuclear Safety, and the Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (NRR).

The study was conducted using the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 assessment process. The SSHAC process ensures consideration of the knowledge and uncertainties of the larger technical community within a robust and transparent framework. The SSHAC process is detailed in the U.S. NRC’s NUREG/CR-6372, Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts and in NRC NUREG 2117, Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies.

The objective of the CEUS SSC project was to develop an up-to-date seismic source characterization model for the CEUS that included:

1. Evaluation: Consideration of the data, models and methods that have been proposed by the larger technical community
2. Integration: Representation of the center, body and range of technically defensible interpretations
3. Incorporation of uncertainties
4. Consideration of an up-to-date database
5. New approaches to systematically document and evaluate all data considered for increased transparency
6. Engagement of all stakeholders and a robust peer review.

Following the SSHAC process, the project team compiled a detailed work plan, which included three workshops held in support of the project. The workshops were opened to the public and those interested in contributing to this project in their field of expertise. One of the major tasks associated with the CEUS SSC project included the development of a new, comprehensive earthquake catalog. This catalog served as an important source of information for the quantification of geographic and historical distribution of earthquakes. Catalog development included review by seismologists with extensive knowledge and experience in catalog compilation. The result is an earthquake catalog with uniform moment magnitudes for all earthquakes covering the entire study area for the time period of 1568 through the end of 2008.

For purposes of assessing the CEUS SSC model, seismic hazard calculations were conducted at seven test sites throughout the study region. The site locations were selected to represent different hazard environments. The calculated CEUS SSC mean hazard results were compared with mean hazard results using the 2008 USGS source model and the source model used by Combined Operating License (COL) applicants for new nuclear power plants. The hazard results using the CEUS SSC model were judged by the project team to be reasonable. Sensitivities of the calculated hazard results readily explain the different aspects of the new model. The project team...
concluded that the SSC model provides reasonable and explainable calculated seismic hazard results.

In general at rock, at $10^{-4}$ annual frequency of exceedance, the average increase in ground motion from the COLA Ground Motion is about 11% at 1 Hz for the seven (7) test sites. At 10 Hz the average increase is 31% for the CEUS SSC model.

In general at rock, at $10^{-5}$ annual frequency of exceedance, the average increase in ground motion from the COLA Ground Motion is about 17% for the CEUS SSC Model at 1 Hz for the seven (7) test sites. At 10 Hz the average increase is 46% for the CEUS SSC Model.

The above hazard results above are not intended for engineering design. The hazard curves for operating plants should be calculated and reviewed to understand the significance of these results and to understand the variability of results among different sites in different hazard environments. All hazard calculations were conducted using the EPRI (2004, 2006) ground motion prediction equations.

The CEUS SSC Report is available at [http://www.ceus-ssc.com](http://www.ceus-ssc.com). The new CEUS SSC model will be used by utilities pursuing licensing for new nuclear power plants, for evaluating the seismic safety of existing nuclear power plants and by the DOE in meeting its requirements under DOE Order 420.1B. Products from the CEUS SSC Project will benefit the U.S. National Seismic Hazard Maps developed by the U.S. Geological Survey. These maps are used by the building community to guide building design and by the insurance industry to conduct risk assessments. Those involved in the evaluation of dam safety can also benefit from the products of the CEUS SSC Project. The CEUS SSC Project and the Sponsors of the CEUS SSC Project are also supporting ongoing work lead by the Pacific Earthquake Engineering Research Center (PEER) at U.C. Berkeley to develop new ground motion prediction equations.

Lawrence A. Salomone

Lawrence A. Salomone, PE, is a registered Professional Engineer with 40 years of experience in the environmental and earth sciences serving private industry and government. He was the Site Chief Geotechnical Engineer at the Savannah River Site (SRS) in Aiken, S.C. for nineteen years, where he developed and managed a $100 million geological, seismological, and geotechnical (GSG) characterization program to integrate geotechnical and geo-environmental work for mission-critical nuclear facilities at the SRS. He has directed 35-person and 70-person multidisciplinary groups. He currently serves as a consultant to the U.S. House of Representatives, the U.S. Senate, the Electric Power Research Institute and the Department of Energy on national energy policy issues. Mr. Salomone established the industry-government partnership that developed the new Seismic Source Characterization (SSC) model for the Central and Eastern United States (CEUS). In 2011, Mr. Salomone received an excellence in science award from the DOE Office of the Deputy Secretary, Chief of Nuclear Safety, for this work. Currently, he is a member of the Seismic Lessons Learned Panel that advises the DOE Nuclear Facility Safety Program, and he is the EPRI representative on the Joint Management Committee for the Next Generation Attenuation–East Project. Mr. Salomone earned his BCE in civil engineering from Manhattan College in Riverdale, N.Y., and his MS in geotechnical engineering from the University of California, Los Angeles. He is the author or co-author of over 40 published papers and many technical reports.
It has been a year since the 2011 M 9.0 Tohoku-Oki, Japan earthquake and the debate rages on (1) why this earthquake was not anticipated, (2) why the Tokyo Electric Power Company, the owner of the Fukushima Dai-ichi nuclear power plant did not adequately design the plant for the earthquake and its resulting tsunami, and (3) why the existing design was approved by Japan’s Nuclear and Industrial Safety Agency. The obvious question to be asked in the U.S. in regards to the nuclear power plant safety is: Are the tools and the knowledge we use today to evaluate earthquake threats adequate so that new nuclear plants will be properly designed? Can “extreme” events such as Tohoku-Oki occur in the U.S.? If so, can we accurately predict the resulting hazards, i.e., ground shaking and tsunamis?

Probabilistic seismic hazard analysis (PSHA) is the approach that is used in the U.S. to estimate the hazard for important and critical facilities such as nuclear power plants. Three key questions can be raised on whether extreme earthquakes and their associated hazard can be predicted using a PSHA methodology: (1) how good is the PSHA methodology, (2) how good are the scientific inputs, i.e., seismic source characterization and ground motion prediction models, and (3) how stable are the results. In the U.S., the PSHA methodology is well accepted and is well suited to predict extreme events or very low probability consequences assuming adequate inputs. Important advancements in the PSHA methodology include a set of guidelines developed by the Senior Seismic Hazard Analysis Committee (SSHAC) in 1997 and a supplemental set of guidelines by Hanks and others (2009) on implementation for Level 3 and 4 PSHAs. Both sets of guidelines focused on the use of expert judgment and the treatment of uncertainty.

Several significant advancements in PSHA inputs have been made in the U.S. Extensive research efforts continue in the U.S. in the characterization of seismic sources. Although that characterization is considerably more advanced in the western U.S. (WUS) than the central and eastern U.S. (CEUS), technological advancements such as GPS, LiDAR, broadband seismic monitoring, and seismic waveform analyses are helping to improve seismic source characterization in the CEUS. The SSHAC Level 3 seismic source model for the CEUS is a recent outcome of those efforts. Very significant advancements in ground motion prediction have also been made. The Pacific Earthquake Engineering Research Center’s Next Generation of Attenuation (NGA) ground motion models for tectonically active regions including the WUS is a major milestone. Efforts continue to refine these models and a parallel effort is being made for the CEUS as part of NGA-East. All of these improvements in PSHA inputs will reduce the uncertainties in hazard estimation in the U.S.

Finally, how long are PSHA results stable? A typical response to this question is that if the uncertainties in inputs have been properly incorporated into a PSHA, the resulting hazard should accommodate changes in input parameters and hence be stable over time. That observation is indeed true but because the design of facilities is based on the mean hazard, there can be significant changes. A good example is the impact of the NGA-West models, which resulted in decreases up to 30% or more in the National Seismic Hazard Maps. Looking back at the stability of mean hazard results in the U.S. suggests that they are stable for only one to at most two decades. The practice of monitoring advancements in earth sciences and their impacts on hazard
by a project even after a PSHA has been completed and a strong regulatory review process are essential to the PSHA process. As to the question of whether extreme hazards can be predicted, as long as the limitations and uncertainties in the available earth science are fully and continuously evaluated and incorporated into PSHTAs, Fukushima-type incidents can be avoided. “Available” is a key word and surprises will happen unless the necessary geologic and seismologic investigations are performed.

**Ivan G. Wong**

Ivan Wong is a Principal Seismologist and Vice President of URS Corporation in Oakland, California. He has more than 38 years of experience in the fields of engineering seismology and seismic geology. A major focus in his career has been earthquake hazard reduction and awareness and public outreach. At URS, Ivan has directed the seismic hazard evaluations of more than 300 critical and important facilities worldwide, mostly for the Federal government. He has managed some of the largest seismic hazard evaluations performed in the U.S. including the Yucca Mountain Project, the largest study ever performed. For FEMA, Ivan has been involved in the education and implementation of HAZUS in several areas in the U.S. He has been the recipient of numerous NEHRP external research grants from the USGS that have supported the development of urban probabilistic and scenario hazard maps and other earthquake hazard-related studies. Ivan has also been particularly active in serving the USGS on many review and advisory panels including the review panel for the 1996 National Seismic Hazard Maps. Ivan has been, and is currently, a member of numerous professional review panels, working groups, and committees in engineering and the earth sciences. He chairs the recently formed Working Group on Utah Earthquake Probabilities. For the Earthquake Engineering Research Institute, he is a past President of the Northern California Chapter, and past member of the Earthquake Spectra Editorial Board, and is currently a member of the Board of Directors. Ivan has authored or co-authored more than 300 professional publications including journal papers, map series, conference papers, and published abstracts.
The Fukushima Dai-ichi Nuclear Plant Accident

George Flanagan

On March 11, 2011 the “2011 off the Pacific coast of Tohoku Earthquake” occurred off the northeastern coast of Japan. Several nuclear plants are located along the northeastern coast. All were affected to some degree by the earthquake which resulted in shutdown of all the affected plants. The offsite electrical power supply was terminated at both the Fukushima 1 and Fukushima 2 plants located at Dai-ichi and Danai. Fukushima 1 had six reactors and Fukushima 2 had 4 reactors. Both plants responded to the earthquake and loss of offsite power as designed. Approximately 1 hour later the Dai-ichi plant was hit by a 9.3m tsunami which overwhelmed the sea wall and flooded the emergency diesel generators and the ultimate heat sink pumping systems. As a result, the stations suffered what is referred to as a total station black out, which means the plant had no AC power available. In the case of the Unit 1 reactor, the tsunami also destroyed the battery DC system.

With no power to operate the cooling pumps, the reactors began to lose cooling capability. The plants had in place some emergency heat removal systems that do not rely on electrical power, but did require DC power for control. As the station black out extended over several days, the battery systems were depleted and the emergency backup systems began to fail.

The result was that three plants (units 1, 2, and 3) suffered core damage. As a result of loss of cooling to the cores, a chemical interaction occurred between the hot Zircaloy cladding and the steam. This rapidly accelerated as more cooling was lost. The result was a rapid buildup of hydrogen which eventually led to an explosion at two of the plants. The uncooled fuel began to melt, releasing significant quantities of highly radioactive fission products to the interior of the plants. During the explosions significant quantities were released to the atmosphere in the vicinity of the plants.

Residents in the path of the radioactive plume (30 Km) were evacuated as were most of the workers on site. Those workers remaining on site struggled to control the releases. Based on current analysis there were not deaths as result of exposure, nor are there expected to be any significant long term health effects. However, large areas around the plant and up to 50km northwest of the plant remain inhabitable. In addition, leaking radioactive water from the plant has been a major concern.

After nine months the plants were finally declared to be in cold shutdown which means the water temperature in the reactors is below the boiling point, most of the release has stopped.

A massive cleanup effort is underway. The economic and social impacts are huge. It is not certain when residents of the evacuated areas will be allowed to return to their homes, if ever. Farm land and industries in the area remain nonproductive.

The presentation will discuss the progress of the accident as a result of the earthquake and tsunami, indicate some of the root causes that underlie the reason why the accidents progressed beyond the expected design basis, the impact on nuclear power worldwide, and what is being done to prevent such an event in the United States.
Dr. Flanagan has been with ONRL for 40 years, prior to that he worked at Atomics International Corporation for 3 years. He is recognized for his work in reactor safety, reactor licensing, and probabilistic risk analysis and Space Reactors. Most recently he led the ORNL response effort to support DOE in the Department’s early response to the Fukushima Reactor Accident. He is considered an authority on research reactor design and safety, and has authored training manuals on research reactor and critical facilities for the International Atomic Energy Agency. In addition to his research activities he spent 15 years with the ORNL Research Reactors Division, where he held several management positions including Section Head for Research Reactor Design, Safety and Compliance; Associate Division Director and Acting Division Director of Research Reactor Division. Prior to his work in the Research Reactors Division, he was the Program Manager for Liquid Metal Reactor Physics and Safety.

Dr. Flanagan is active in several professional societies. He was a founding and charter member of the Society of Risk Analysis, and served on the editorial board of the Risk Analysis Journal. He has been the general chairman for three American Nuclear Society (ANS) topical meetings dealing with the Safety of Liquid Metal Reactors and Probabilistic Risk Analysis. He has served as the chairman of the national ANS Nuclear Reactor Safety Division and on the national ANS Board of Directors as well as the chairman of the Oak Ridge/Knoxville Section of the ANS. Dr. Flanagan has received several awards for his work, including the Distinguished Engineer of the year award from ORNL for 2011.

Education
BS Engineering Science Iowa State University 1966
MS Nuclear Engineering Iowa State University 1967
PhD Nuclear Engineering, Iowa State University 1969
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Louis XVI

CONCURRENT SESSION
NETWORK ANALYSIS: COMPLEXITY OF INTERDEPENDENCY

Moderator:
Chris Poland
Degenkolb Engineers

Speakers:
A Three-Service Utility’s System Interdependencies: Analysis and Mitigation Efforts
Richard Bowker
Memphis Light, Gas & Water

Understanding Interdependent Infrastructure Systems: Modeling Insights and Practical Challenges
Leonardo Dueñas-Osorio
Rice University

Learning from the Past to Protect the Future
Chris D. Poland  
*Chairman - Degenkolb Engineers*

Chris Poland’s structural engineering career spans nearly 40 years and includes a wide variety of new design work, seismic analysis and strengthening of existing buildings, structural failure analysis, and historic preservation. As an internationally recognized authority on earthquake engineering, Mr. Poland routinely participates in policy-changing research and code development projects sponsored by the NSF, USGS, NIST and FEMA. As a passionate advocate and voice for seismic safety and Resilient Cities, he actively participates in the academic, ethical and social advancement of his field and lectures often. Chris presides as Chair of the congressionally mandated Advisory Committee on Earthquake Hazards Reduction for NEHRP. He is a member of the Board of Directors for the San Francisco Chamber of Commerce, the San Francisco Planning and Urban Research Association, and is a member of the National Academy of Engineering. He has been the leading force behind development of the SPUR Resilient City Initiative for the City and County of San Francisco and is the Co-Chair of the San Francisco Lifelines Council.
This presentation focuses on Inter-dependencies of MLGW's Electric, Natural Gas, and Potable Water supplies during a large scale natural disaster. Included in the presentation is a secondary analysis of how each utility service depends on certain external resources and how those services are dependent on external events, other resources, and prioritizations. The presentation will conclude with a review of the mitigation steps the utility has performed to minimize the impacts of a large-scale earthquake to MLGW’s customers.

Richard Bowker

Richard Bowker is the Manager of Information Services at Memphis Light, Gas and Water. He graduated in 1976 from the University of Memphis with a Bachelor of Science degree in Electronic Engineering Technology. He is well respected in the Memphis Information Technology community, having over thirty years of extensive experience in most aspects of Information Technology.

Presently, Richard is the Planning Section Chief for the MLGW Corporate Crisis Management Team and serves as an executive or advisory board member for; the Urban Area Security Initiative (UASI), the Community and Regional Resilience Institute (CARRI), and MemphisFirst. He chaired the operational assessment of the 2003 Summer Storm (Hurricane Elvis), and maintains a close relationship with the Center for Earthquake Research and Information (CERI) at the University of Memphis. He has served the National Science Foundation since 2004 in an advisory role for the development of earthquake engineering and disaster assessment research and is the Past President of the Mid-South Association of Contingency Planners (MSACP) Prior to coming to MLGW, Richard held the positions of; Director of Operations and Client Services at dotLogix, Program Manager for the United States Postal Service (USPS) Address Matching and FASTforward systems, Chief Information Officer (CIO) at the Naval Hospital in Millington, Program Manager of Submarine Warfare Training with Chief of Naval Technical Training and Engineer-In-Charge and District Specialist with Honeywell Inc.

Richard is founding MSACP member and 2009 MVP award winner. He is a FBI Citizen's Academy graduate, a CERT (Citizen Emergency Response Training) graduate and holds Incident Command System (ICS) certifications ICS-100, ICS-200, ICS-300, ICS-400 and National Incident Management System (NIMS) certifications IS-00700 and IS-00800.
Understanding critical infrastructure systems, including their interactions, performance, and evolution, constitutes one of the most significant challenges confronting modern societies today as built environments age, service demands grow, and resources for their operation and management networks among others, exhibit complexities that test the limits of existing performance assessment methods given their distributed nature, large scale, and heightened exposure. In this presentation, some of the salient features of infrastructure systems, starting with their interdependence, are explored from the perspective of their probabilistic response to natural hazards and optimal interface design. The lessons learned from models and field observations in the past decade are highlighted, where some of lessons are initially counterintuitive. Key insights observed across different lifeline systems in distinct regions reveal that interdependencies enable optimal functionality of utility systems during normal operation but also amplify lifeline system loss of performance during disruptive events. In addition, interdependencies are seen to only be critical for lifeline system performance at specific ranges of hazard intensity levels, while the strategies for controlling interdependence effect propagation must range from a mix of component strength and capacity increases to the modification of the interface that enables different lifeline systems to interact. These intricacies of interdependence are consistent across scenario events and also after convolving hazard with network level fragility at the regional level, thus confirming that interdependencies can meaningfully steer risk- and resilience-based decision making. Practical examples of the advances in infrastructure engineering and their impact on decision making and resilience will be presented, along with lessons learned from recent earthquake events with evidence of operational, logistical, and geographical interdependence.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
1:30 p.m.
Skyway Room

CONCURRENT SESSION
COMMUNITY PREPAREDNESS

Moderator:
Cecil Whaley
Tennessee EMA

Speakers:
Community Preparedness, Resilience, and Recovery
Elaine Clyburn
West Tennessee Seismic Safety Council

Earthquake Preparedness Initiatives Taken by the American Red Cross
David Kitchen
American Red Cross

Memphis South Main Retrofit Demonstration Project
Dmitry Ozeryansky
Ozeryansky Engineering

Ken Skalitzky
FEMA
Cecil H. Whaley, Jr.

- Cecil has served Tennessee State Government for over twenty eight years. He serves presently as Director, Planning, and Exercises Branch (TEMA). He was previously Director of Operations for Tennessee Emergency Management Agency (TEMA). Cecil also served as Supervisor of Planning for TEMA Domestic Preparedness and Weapons of Mass Destruction policy. His division provided long-range strategic planning input and assistance to the Tennessee Office of Homeland Security. Cecil has served with TEMA since 1988.
- Cecil’s previous positions with TEMA include: Director, Earthquake Preparedness Program; Director of the Disaster Preparedness Program; TEMA Liaison for the FEMA Accredited Urban, Search and Rescue Program, Tennessee Task Force #1.
- Cecil served as Assistant to the Commissioner of TN Employment Security, and Director of Public Relations 1975 to 1980

EDUCATION

- Undergraduate: Graduated: University of Tennessee, B.S. 1973
  Graduate School: Attended University of Tennessee, Masters in Public Administration course work (have not completed required hours or thesis)
- Teacher and Coach (High School), Nashville Metropolitan School System 73-74

MILITARY


FAMILY

- Married: Wife, Frances is retired Metro Nashville Elementary Teacher, 32 years.
- Son: Wes, B.S. in History, U.T. Knoxville. Currently, Director of Video Services Vanderbilt University Athletic Department.

MEMBERSHIPS—TEACHING

- Adjunct Instructor, U.T. Center for Government Training, Municipal Technical Assistance Service (MTAS) and County Technical Assistance Service (CTAS), 1975-1980.
Community Preparedness, Resilience, and Recovery

Elaine M. Clyburn

The presentation will cover the connection between community preparedness and resilience/long term recovery from the perspective of the American Red Cross national sector leadership.

Elaine M. Clyburn

Elaine Clyburn is currently a member of the West Tennessee Seismic Safety Commission and an American Red Cross leadership volunteer in disaster response planning, training and administration of major disaster relief operations. With a B.S. in social science and an M.S.W. in mental health, she has experience in family counseling, undergraduate social work curriculum development and instruction; community organizing; and in various paid and volunteer leadership positions in service to the Armed Forces and in disaster services in the American Red Cross.
Earthquake Preparedness Initiatives Taken by the American Red Cross

David Kitchen

My emphasis will be on new Community Preparedness initiatives taken by the American Red Cross … with special attention given to Earthquake Preparedness:

- **The American Red Cross strives to prepare for every type of event, and we strive to prepare every Community.**

- Specifically, we have begun to focus in a greater way on (1) our Audiences, (2) our Materials, (3) our Presentations, and our (4) Volunteer Initiatives.

1. **AUDIENCES:** We are targeting special audiences. For the first time, we are making a push into the Deaf community (in January of this year, we partnered with NOAA to host the first ever “Deaf/Hearing Impaired Sky-Warn” Class.) Furthermore, recognizing the many languages represented in our nation, we now have “Tear Sheets” available in approximately 20 different languages. Also, we have reworked the “Master of Disasters” program for children and are striving to develop different “M.O.D” programs with different disasters in mind: like Earthquakes.

2. **MATERIAL:** We go beyond “Build a Kit, Make a Plan, Be Informed.” We are trying to provide event/disaster specific information and facilitate event/disaster specific Community Preparedness. For example, one of our current areas being stressed relates to Earthquakes.

3. **PRESENTATIONS:** We are trying new concepts and methods in Preparedness Education. One example is our Preparedness Education Program (PEP) which is completely “interactive.” Another example is that we now have the flexibility to “tailor make” a presentation: I recently custom made a Presentation specifically for a Physician’s Organization. I stressed events such as Earthquakes, but I also stressed how it might impact the healthcare community.

4. **VOLUNTEER INITIATIVES:** In addition to that which has been noted, it is also importance to state that the American Red Cross is continually recruiting and training Disaster Services Volunteers! And while every class attended by a volunteer brings new knowledge that can be used to personally prepare the student’s family and community … we are going beyond that. We now have areas of emphasis as relates to Volunteer Recruitment and Training that especially lend themselves to Community Preparedness. We now recruit and train entire faith-based congregations … making them American Red Cross “Shelter Teams.” Each time we raise up a new “Shelter Team” … a Community is better prepared!
David Kitchen

I have been raised in Nashville all my life and have been educated here in Nashville. My Bachelor of Science and Master of Arts degrees are from a local university, Trevecca Nazarene University.

I have been in the emergency services arena for over 25 years. I took an early retirement from the Metro Nashville Fire Department, having served in both operational and administrative roles. I began as a firefighter, EMT, HMT. Later in my career, I was promoted to Lieutenant and worked in the Fire Marshal’s Office. My areas of specialty included public education, plans review, building codes, sprinklers, building compliance, and inspections.

After retiring from the Fire Department, I came to work for the American Red Cross in 2007; I began in the Emergency Services Department in the role of Planning & Response Manager for the Nashville Regional Chapter. In 2010, I became the Regional Chief Emergency Services Officer, with responsibility for 2/3rd of the counties in Tennessee. In addition I also serve as State Relations Disaster Liaison.
Memphis South Main Retrofit Demonstration Project

Dmitry Ozeryansky

Summary: The South Main Retrofit Demonstration Project is a grass roots, non-profit initiative, the work of local designers, preservationists, academics, and community members to stimulate natural-hazard retrofit, conservation measures, repair and maintenance to historic main-street style URM buildings in Memphis and the greater Mid-South.

The project consists of two phases:

Phase I: (Currently in Development) fundraising, design and construction of affordable high-benefit improvements to one building in the South Main Historic District to be used as an event and exhibit space.

Phase II: To work with the community to develop and implement strategies that will lead to most of these buildings being retrofit within 25 years. These buildings are about 100 years old, Memphis has begun to reclaim them from decay, and repurpose them for contemporary uses. Our goal is to prepare them to last another 100 years.

Background: We focus on smaller, older, often historic, and usually privately owned, store-front style buildings (Occupancy Category II, Performance Category: Life Safety or Collapse Prevention), especially with wood frame floors and roofs. Uses tend to be commercial or residential. These buildings are very common in the central US, as well as elsewhere. As a rule they have no rational lateral force resisting system or detailing. Some are poorly constructed and/or maintained. They were originally built on a tight budget and without design professionals involved, with a design life of about 100 years. However over the last generation they have come back into fashion, are experiencing reinvestment, are valued as historically important, and in Memphis are the sites of vibrant culture, strong communities, small businesses, art galleries, and some of the best food and drink establishments in town.

So while the community is investing in them, the opportunity this presents for seismic and natural hazard mitigation measures is usually missed. There is a lack of direction and clarity on this issue from local governments, while design and construction professionals often defer to the status-quo of doing nothing to improve lateral force resistance and integrity. Some of the common characteristics of this building type in the New Madrid region:

- No jurisdictions have passed ordinances and few have consistently enforced existing codes to address these buildings.
- Many of these buildings are in economically challenged, yet culturally important and rapidly gentrifying areas. However, due to lower property values, large resources cannot be deployed to retrofit them.
- The most likely earthquakes they will face in the near future are somewhat smaller than on the west coast.
- They generally do not get as much attention from the earthquake engineering community as larger, more modern, or more important structures.
- Many structural and policy lessons about how to approach these buildings can be derived from years of experience on the West Coast and Utah; also from the Christchurch, NZ earthquakes.
- The attitude of the public, government, and building industry are substantially different than on the west coast. For instance, the ability for cities to pass mandatory retrofit ordinances is extremely unlikely.

Our effort includes before and after retrofit modeling using HAZUS for a pilot inventory of 95 buildings in the neighborhood as well as two case studies of buildings in the neighborhood.
**Dmitry Ozeryansky**

Dmitry started his career as a Navy nuclear propulsion officer on the USS Enterprise, but a love of architecture brought him to UC Berkeley. At notable Bay Area structural engineering firms Dmitry developed a blend of careful analysis with the sensitivity that results from working with a wide variety of people and project types and developed particular affinity and expertise working on seismic retrofit of historic buildings.

In 2009 Dmitry embarked on a new adventure in Oakland, CA as a founder of Ozeryansky Engineering, using the opportunity to pursue his interest in working with creative architects and green building technologies.

2010 brought Dmitry to Memphis where he has been quick to establish himself in the design community through involvement with non-profit leadership in particular the Memphis USGBC chapter, while also maintaining the Oakland, California office of Ozeryansky Engineering under the direction of partner Joe Igber.

The South Main Retrofit Demonstration Project is Dmitry’s effort to contribute to the growth and vitality of his new home and community.

**Ken Skalitzky**  
*Voluntary Agency Liaison FEMA Region IV*

Ken Skalitzky is the Voluntary Agency Liaison for FEMA Region IV (Atlanta), which includes Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee. As FEMA’s liaison with other agencies, Skalitzky sees that FEMA is kept aware of what other agencies are doing to help disaster victims and makes sure those agencies understand what FEMA can do. He also sees to it that disaster victims get long term recovery help even after their federal assistance has ended by working with the other agencies to provide food, clothing, shelter and continuing repairs and construction on their damaged or destroyed homes. Prior to coming to FEMA, Ken was the Services Coordinator for the American Red Cross (ARC) in Baumholder, Germany, assisting military members and their families. Before that assignment, Ken was the ARC Field Service Manager for the State of Wyoming. He has been a long time ARC volunteer in health and safety, Armed Forces Emergency Services, and disaster relief. He is an instructor in many areas.
ASSESSING VULNERABILITIES

Thursday, April 12, 2012
3:30 p.m.

PLENARY

UNDERSTANDING AND COMMUNICATING RISK

Moderator:
Mai claire Bolton
RMS

Speakers:
Earthquake Policy: Communicating Information to Those in Power
John Bwarie
USGS

Evaluating and Communicating Seismic Risk in Low Probability-High Consequence Earthquake Regions
Terry Tullis
National Earthquake Prediction Evaluation Council

From Awareness to Action: The Values-Based Message
Kate Long
California EMA

Incorporating Societal Safety Issues into Businesses
Lucy A. Are ndt
University of Wisconsin Green Bay
Maiclaire Bolton

Maiclaire Bolton joined Risk Management Solutions (RMS) in July 2010 as a Manager of Earthquake Model Product Management based in the San Francisco Bay Area. She leads the commercial development and success of earthquake models in North, Central and South America. Before joining RMS, Maiclaire spent four years with Emergency Management British Columbia in Victoria where she was the head of the Seismic Program. Prior to that, she worked as a seismologist with the International Seismological Centre in England and a seismology research assistant with the Geological Survey of Canada in Victoria and Ottawa. Maiclaire holds a M.Sc. in Geophysics specializing in earthquake seismology from the University of Victoria and a B.Sc. in Geophysics from the University of Western Ontario. Maiclaire is currently a Director of the British Columbia Earthquake Alliance and was previously the Vice President of the Cascadia Region Earthquake Workgroup (CREW).
Earthquake Policy: Communicating Information to Those in Power

John Bwarie

Sitting down with the vice president of a national bank, talking on the phone with a state emergency manager, or meeting with a mayor each create an opportunity to increase the resiliency of the nation related to natural hazards. Each has their own personal or institutional interests, unique oversight, and diverse constituents; and each has the power to make decisions with long-term, institutional effects. You might have 5 minutes or 5 hours to make a case for the information you value as important, but how to spend that time (and the time you prepare for it) will directly affect the value your audience finds in what you have to say.

First, remember that changing policy is difficult. When talking to a policymaker – an elected or appointed official, an agency head, a corporate leader, or a community leader -- what you say may be important to you; but if you don’t communicate it so it is important to them, you might have missed your chance to effect change.

Change is often incremental and requires an understanding of how to get there: You have to create a path for a policy-maker to follow to the end result, sometimes with smaller wins along the way. Remember that everyone in the room may think your policy goals are good and valuable, but there are many reasons to not act. If you provide an easier, recognizable path, the policy maker is more likely to start the journey. Who communicates with the policy maker, what is communicated, and how it is communicated all can affect the outcome.

Next, determine your goals before speaking: What do you want your audience to do with the information you have? Be clear: are you trying to spark interest? inspire action? create advocates? How can these lead to enacted policies? Know what you want as an end result and decision to make on who talks, what to say, and what to do should reflect that end result.

Communicating for action is a dance between at least two sides. It helps to know your audience before communicating. What are their goals and interests, both professionally and personally? Try to understand what makes them “tick” so you can craft your message to resonate with them. Then, exhibit controlled passion. Your emotion will drive your message home, but being overzealous may turn people off or dilute your message. Be human and connect on a personal level, if possible. Communicating to policy makers requires personal interaction and not just lectures, slide presentations, and reports.

Focus on your audience, make them feel intelligent, and provide value to them. Delivering your message requires that you establish authority, provide value, and are accessible. Why should the policy maker listen to you versus others saying the opposite thing? Be concrete and use examples with which they connect. Avoid jargon and acronyms but don’t patronize them. Think about how others can establish your authority for you in advance? What can you provide to the policy-maker: don’t just ask for actions – offer your expertise and resources. Make yourself invaluable to them.
John Bwarie is the Strategy & Communications Officer for SAFRR: Science Application for Risk Reduction, a USGS project working to innovate the application of hazard science for the safety, security, and economic well-being of the nation. The project has helped communities reduce their natural hazard threats by directing new and existing science toward vulnerabilities, producing innovative products, and assuring that the benefit and results are effectively communicated. John has been involved with this project since 2008 with the ShakeOut Scenario and is currently developing strategies to engage decision-makers across the country. Prior to joining the USGS, John spent 8 years working for the Los Angeles Mayor and City Council overseeing economic and community development.
Evaluating and Communicating Seismic Risk in Low Probability - High Consequence Earthquake Regions

Terry E. Tullis
Brown University and Chair of NEPEC

The Central US is an excellent example of a region in which the annual probability of damaging earthquakes is small, but the consequences to society of such events is large. In such situations it is even more difficult than in more seismically active areas to assign accurate probabilities of earthquake occurrence, and yet the seismological community must do the best we can. Given the uncertainties, disagreements about realistic levels of seismic hazard are bound to arise. In addition, given the economic consequences of the occurrence of damaging earthquakes as well as of preparing for them, various groups with economic interests are bound to have differing views.

Attention is currently focused on the bicentennial of the large 1811-1813 earthquakes that occurred in the New Madrid region and some well-publicized questioning of the official probabilities of earthquake occurrence in this region has occurred. For these reasons, in the Spring of 2011, the National Earthquake Prediction Evaluation Council (NEPEC), which I chair, convened an “Independent Expert Panel on New Madrid Seismic Zone Earthquake Hazard.” We were lucky to convince a group of outstanding of scientists with a variety of relevant expertise to serve. The panel members were chosen to have no vested interests in the outcome of their review. They received input in writing and in face-to-face meetings with a variety of scientists, some having previously expressed strong opinions. The panel wrote a succinct 25-page report that contains their charge, their membership, their activities and procedures, an executive summary and their more-detailed assessment of the seismic hazard. The report is available at http://earthquake.usgs.gov/aboutus/nepec/reports/NEPEC_NMSZ_expert_panel_report.pdf, and my letter forwarding the report to the director of the US Geological Survey is available at http://earthquake.usgs.gov/aboutus/nepec/reports/NEPEC_LettertoMcNutt4-18-11.pdf.

The panel found that despite considerable uncertainties about the underlying origins, nature and history of earthquakes in the region, the seismic zone is at significant risk for damaging earthquakes, which must be accounted for in planning and development. The panel also examined the USGS national seismic hazard maps and the process by which they are produced and updated. They concluded that the hazard maps employ a scientifically sound, carefully implemented, open, and consensus-based process that incorporates a range of scientific data, views and interpretations, and represents the best means available to refine hazard estimates. Although the report acknowledges that uncertainties in our knowledge are sufficiently broad that the current USGS national hazards maps could somewhat overestimate the seismic hazard within the New Madrid Seismic Zone (NMSZ), the panel recommended that the 2008 national maps should continue to be used until they are updated in 2013. NEPEC hopes the report of our expert panel will be helpful for long-term and emergency planners facing societally relevant decisions in the New Madrid area. Significant seismic hazard in the NMSZ and broader central US region is evident.

In addition to dealing with long-term, time-independent earthquake probabilities, the subject of time-dependent earthquake probabilities is important. NEPEC is currently working to establish connections between those in the seismological research community who have the expertise to evaluate seismic hazard, and the community of emergency managers with the responsibility to decide what actions to take if there appears to be an increased hazard for some period of time. For example in the Pacific Northwest, the probability is high for the eventual occurrence of a large damaging earthquake similar to the Tohoku earthquake that struck NE Japan on March 11, 2011. However, the probability of occurrence of such an earthquake on any given day is extremely low. If various geological events occurred, for example a moderate-sized earthquake that might be a foreshock, then the probability would be multiplied by a large amount, i.e. there would be a significant time-dependent probability gain, even though the probability is still low. Scientists can
make imperfect estimates of these probabilities and their temporal changes, but we need to work with emergency planners and response personnel so we can learn how to provide them with timely information that is suitable for their needs. NEPEC is mandated to keep abreast of progress in understanding the predictability of earthquakes, and by extension to make this understanding useful to society. Only by working as part of a team that includes planners, engineers, and emergency managers can scientists be effective in communicating our understanding, including its uncertainties, in a societally relevant way.

Terry E. Tullis

Terry E. Tullis received a BA in Geology from Carleton College in 1964 and an MS and PhD in Experimental Geophysics from UCLA in 1967 and 1971, respectively. Since then he has been a Professor at Brown University: Asst. Prof., 1970-1976; Assoc. Prof., 1976-1989; Prof., 1989-2005; Emeritus and Research Prof. 2005-. He has also been a visiting professor or visiting scientist at the Australian National University, U.S. Geological Survey, Texas A & M University, Harvard University, and South Dakota School of Mines and Technology. He has served on review panels for the U.S. Geological Survey Earthquake Hazards Reduction Program and the National Science Foundation. He served as General Secretary, American Geophysical Union, 2002-2006. He was Organizer and Chairman of the first Gordon Research Conference on Rock Deformation; member of Southern California Earthquake Center (SCEC) Planning Committee 2001-; member of SCEC Board of Directors, 2001-2006; Chair, SCEC Fault and Rock Mechanics (FARM) Disciplinary Committee, 2001-2006; Chair, SCEC Earthquake Forecasting and Predictability Focus Group, 2006-2011; Chair, SCEC Technical Activity Group on Earthquake Simulators, 2011-; Organizer of three SCEC FARM and five SCEC Earthquake Simulator workshops, 2001-2011; Chair of National Earthquake Prediction Evaluation Council, 2009-; Member, Scientific Earthquake Studies Advisory Committee (advising the USGS), 2009-. He has authored over 70 peer-reviewed book sections or journal articles and over 150 abstracts for meeting presentations.
From Awareness to Action: The Values-Based Message

Kate Long

California Earthquake Authority (CEA) and California Emergency Management Agency (Cal EMA) partnered to invest in message development market research, intended to guide the development of a communications strategy that will be persuasive and effective in moving California residents to a higher level of earthquake preparedness than currently exists. Prior sociology research efforts form the foundation for the current engagement with the recommendations that earthquake educators “brand the message” and not the messenger and develop an evidence-based standardized message, to be delivered in a consistent manner over multiple channels, over a long period of time, via a coordinated campaign among the various local, state and federal programs and agencies engaged in earthquake preparedness. However, previous research studies did not address a key component of any communications strategy – the actual message - “what to say” - that will be needed to move more Californians to take more readiness actions.

The overall framework guiding the Value-Based Research undertaken by CalEMA/CEA in 2011 and conducted by Harris Interactive, is the VISTA™ (Values In STrategy Assessment) methodology. This proprietary research methodology focuses explicitly on understanding and identifying the most personally compelling personal values in the decision-making process. This approach allows identification of the underlying needs and motivations of California residents as it relates to readiness and preparedness. Just as important, the VISTA™ approach shows how the rational and emotional components of decision-making are linked. The outcome of VISTA™ is a communications template, or map, depicting the decision-making thought process that gives a blueprint for action – those important factors that motivate our target audience toward immediate and long-term action.

The qualitative and quantitative research identified two key “pathways” of communication that lead the audience from what actions we want them to take through the emotional and value-based reasons it is important to them. The short-term “response” pathway begins, at an attribute level, with gathering and organizing supplies, contact information and putting together a family disaster plan. This leads people to feel they will be “ready and able,” the functional, specific benefit of having those supplies, when an earthquake strikes so that they can take care of their families. Family protection was a strong and motivating element during every phase of research and was true for every demographic group interviewed. At an emotional level, being ready leads to feeling in control and that one will survive (both immediately and over the longer term). And ultimately, this gives people confidence and peace of mind which are the values associated with the seemingly simple task of gathering emergency supplies. The long term “recovery” pathway begins with concerns about one’s physical belongings and the structure itself leading to a benefit that one has mitigated their potential injury or damage, to themselves or their property. These actions and benefits lead to feelings of being in control and of survival which, like the short-term side of the map, leads to the values of peace of mind and confidence.

Importantly, when thinking about message development, regardless of whether subjects started at the short or long-term attribute level, they identified common emotional consequences (survival and control and common values (peace of mind and confidence). This suggests that all communications, regardless of the agency, program, product or service offered needs to communicate these emotions and values.
A third “negative” pathway was also identified. This pathway started with people admitting that they are in denial regarding earthquakes; that they procrastinate when it comes to getting more prepared and that in the course of their daily lives; that other things become more important. This general malaise regarding earthquake preparedness leads people to feel that they have not done enough to be prepared and will not be ready when an earthquake strikes. Ultimately, this pathway results in low self-esteem and lack of peace of mind. While it is important to be aware of this pathway and recognize that a significant portion of the population fits into this framework, we strongly recommend against negative messaging inducing feelings of guilt.

Based on this Value-Based Market Research, the following framework is recommended to agencies engaged in earthquake education when they evaluate existing communications or develop new ones: Talk about why preparedness is important to do (the emotional and value level), not just what they should do (attribute and functional consequence level). Every communication should connect the attribute (i.e., kit, disaster plan, etc) with the value associated with it (i.e., peace of mind, confidence). Emotions and values can and should be communicated using both words and images. Avoid using guilt as the emotional pull of communications. Communicate often using a variety of mediums; short term or one-off campaigns will likely not produce the desired result. Communicate in a consistent manner. The emotions and values identified here will apply to the short and long terms aspects of earthquake preparedness so it’s important to have that guide communications. The emotional and value level findings are true across demographic groups, regardless of age, race/ethnicity or where one lives in California (i.e. more risky or less risky area). Specific campaign strategies (i.e. media buying, placement, etc) may need to be tailored for different populations but the main themes of the message - family protection, survival, control - are true across the board.

Kate Long
California Emergency Management Agency
Earthquake and Tsunami Program

Kate Long is a the program deputy for the California Emergency Management Agency Earthquake and Tsunami Program where she provides knowledge translation to ensure advancements in science are available to policy makers, emergency managers, and the public. Long has expertise in intergovernmental relations and represents the state's interests in the California Integrated Seismic Network (CISN), a partnership of federal, state, and universities involved in California earthquake monitoring.

Since 2008, Long has served on the Earthquake Country Alliance steering committee, coordinating the Great California ShakeOut earthquake drill and community readiness campaign. As part of the ShakeOut team, Kate was awarded the 2009 USGS Eugene M. Shoemaker Award for Communications Excellence, which is given annually to recognize extraordinary effectiveness in communicating complex scientific concepts and discoveries into words and pictures that capture the interest and imagination of the American public.

Before joining the Earthquake and Tsunami Program, Kate worked as a planner for the Federal Emergency Management Agency's first National Emergency Response Teams; for the City of Los Angeles Mayor's Office developing a volunteer-led earthquake preparedness program; and for the California Governor's Office of Emergency Services, where she managed the public assistance grant review in the wake of the 1994 Northridge Earthquake. Before coming to emergency management, Long was a motion picture producer (she reports that the two industries have more in common than one might imagine). She holds a bachelor of arts degree in government with an emphasis in economics from Mills College in Oakland, California.
Incorporating Societal Safety Issues into Businesses

Lucy A. Arendt

Associate Dean and Director of the Austin E. Cofrin School of Business, University of Wisconsin
Green Bay

In the aftermath of an earthquake, people look for signs that their community is returning to “normal.” One of the key elements of any community is its business and industry. Business provides jobs, generating revenue and income. Revenue and income enable people to purchase goods, including necessities such as food and water, and other goods that may not be necessities, but that enhance people’s quality of life. Part of the “return to normalcy” is the opening and reopening of businesses. Without functioning businesses, people lose income. Without income, people may lose their homes, along with their reason for staying in the community. Without functioning businesses, people are unable to shop at their preferred grocer, buy gas at the corner station, purchase clothing in their favorite mall, and the like. Without functioning businesses, downstream and upstream businesses are unable to work with contracted suppliers and distributors. Without functioning businesses, utilities are unable to collect receivables. What used to be the community may not be after an earthquake.

Businesses must do what they can to withstand the effects of an earthquake. Certainly, this includes having buildings that are up to code, and perhaps, even better. It includes thinking about non-structural elements and contents. Structural engineers and architects are excellent sources of information for the “hard” aspects of being prepared for an earthquake.

Not always considered are the “soft” aspects of being prepared for an earthquake. The last several years have seen many attempts to engage potentially affected populations in thinking about and preparing for earthquakes. Events such as the Great California Shake Out, the Great Central U.S. Shakeout, and others around the world have involved high numbers of people, many of whom have been associated with PreK-12 schools, colleges and universities, medical facilities, government agencies, non-profit organizations, neighborhood groups, and businesses (http://www.shakeout.org/comparison/).

Events such as the Great California Shake Out and the Great Central U.S. Shakeout appear to do an excellent job of communicating and sensitizing people to earthquake risks and preparedness. One of the main and most effective conduits of sharing seismic safety information may be through businesses. People spend many if not most of their waking hours at businesses, whether they’re working, shopping, etc. In some respects, communicating seismic safety information to working adults through businesses is analogous to communicating seismic safety information to children through PreK-12 schools. For example, while 2,054,872 children participated in the most recent Great Central U.S. Shakeout (2012), the number of businesses participating was 443, including 60,745 individuals (http://www.shakeout.org/centralus/all_participants.php). These are great numbers! Still, these numbers suggest vast, untapped potential for reaching people through businesses, as the Central U.S. area of the United States was home to 899,982 firms, employing 18,511,508 individuals (http://www.census.gov/econ/susb/) in 2009.

What are the mechanisms by which seismic safety issues might be communicated through and in businesses? First, events like the Great Central U.S. Shakeout are an excellent means of energizing communities and communicating information across categories of organizations. Continually increasing the number of participants in these exercises will go a long way toward communicating a clear message to all possible participants. The numbers of participants have been excellent, but opportunity remains! For example, while the 2011 Great California Shake Out involved 488,389 individuals associated with businesses, California’s businesses employed 12,833,709 individuals in 2009.
Second, emergency preparedness experts might speak to Chambers of Commerce and other business organizations (e.g., Rotary) to communicate needed information. Third, businesses might be invited more frequently to earthquake conferences, perhaps to attend special sessions targeted specifically to businesses. Speaking the language of business will be critically important to effective communication. In every industry, including the earthquake preparedness “industry,” jargon enables members of the industry to communicate effectively and efficiently with other members of the industry. Too often, our jargon does not transfer especially well outside our own industry. Hence, we must tailor our messages appropriately. When speaking about the probability of an earthquake, for example, we need to compare the odds to the odds of other known events occurring, along with visually portraying likely consequences. In an age when computer visualization has made simulation more and more realistic (think of the latest video games available for Xbox), it’s important to produce accurate simulations of earthquake effects. Doing so will better communicate the need for preparedness, whether “hard” or “soft.”

Creating social and print media that may be accessed by all business employees will be essential to effectively distributing needed information. Short videos on Youtube that engage viewer emotions (positively or negatively) appear to have great potential, especially those that go “viral.” Print media that may be kept at one’s desk may also serve as regular reminders of what to do (e.g., “Drop! Cover! Hold on!”). Twitter feeds that remind employees about earthquake preparedness may be used sporadically to also remind employees what to do when they’re at work, when they’re at home, and when they’re out and about in their community.

Lucy A. Arendt

Lucy A. Arendt, Ph.D., is an Associate Dean and Professor of Business Administration (Management) at the University of Wisconsin-Green Bay. Her Ph.D. is in the field of Management Science, emphasizing Organizations and Strategic Management. She has extensive expertise researching the hazard mitigation investment decision process. Much of her field research has involved personal interviews in California, Oregon, Washington, Louisiana, and Mississippi with key stakeholders. She is the coauthor of Natural hazard mitigation policy: Implementation, organizational choice, and contextual dynamics (Springer, 2011) along with Daniel J. Alesch and William J. Petak. She is also interested in community resilience, and is the coauthor of Managing for long-term recovery in the aftermath of disaster (PERI, 2009) along with Daniel J. Alesch and James N. Holly. She participated in EERI-sponsored reconnaissance research after the September, 2010 earthquake in Christchurch, New Zealand. She is the lead trainer for the EERI-sponsored Housner Fellows leadership development program.
EERI Annual Business Meeting
Thursday, April 12, 2012
Peabody Hotel
Memphis, TN
5:15 – 6:00 PM

AGENDA

Reading of the Names: Moment of silence for deceased members

Introduction to 2012 Board of Directors

Introduction to 2012 Housner Fellows

Reports
- President’s Report – Tom Tobin
- Financial Report – Janiele Maffei, Secretary/Treasurer

Recognition:
New Subscribing Members

New Regional Chapters

New Student Chapters

Announcement of Bruce Bolt Medal to Norman Abrahamson, Pacific Gas and Electric, to be presented at the COSMOS Meeting

2010/11 EERI/FEMA NEHRP Graduate Fellow

Retiring Board Members

Retiring Committee Chairs

Retiring Spectra Board members

Introduction to EERI Staff

Comments from the floor!
2012 Housner Fellows Class

**Syed Mohammed Ali (GFDRR)**

Ali is the Director of the Earthquake Engineering Center at the University of Engineering and Technology in Peshawar Pakistan. He is currently installing a shake table and other seismic testing equipment in the center’s new lab.

**Cale R. Ash**

Cale is an Associate Principal with Degenkolb Engineers in Seattle. His work has focused on the seismic evaluation and rehabilitation of existing buildings and he is currently the President of the Cascadia Region Earthquake Workgroup.

**Carlien C. Bou-Chedid (GFDRR)**

Carlien is a Structural Engineer with a special interest in seismic risk reduction. She assisted in the formation of the Ghana Earthquake Society and serves on the National Platform for Disaster Risk Reduction.

**Danielle Hutchings**

Danielle is the Earthquake and Hazard Program Coordinator for the Association of Bay Area Governments. She has launched a Regional Disaster Resilience Initiative which focuses on recovery and restoration after major disasters.
2012 Housner Fellows Class

**Lindsey Maclise**

Lindsey is a licensed Structural Engineer with Forell/Elsesser Engineers in San Francisco, CA. She is currently the co-chair of the Structural Engineers Association of Northern California’s Sustainable Design Committee.

**Hassan Steven Mdala (GFDRR)**

Hassan is a geologist in the Seismology Section of the Geological Survey Department of Malawi. He has authored reports on the geological mapping of faults and earthquakes and is a member of the Malawi Disaster Risk Management Stakeholders.

**Vivek Rawal**

Vivek trained as an architect and has worked with communities in India on issues that include social housing and disaster safety. He is the founder of People in Center Consulting, which provides technical services for disaster safe housing.

**Kate Stillwell**

Kate is the Product Manager of Earthquake Products at EQECAT, Inc. She is a registered Structural Engineer in California. She co-founded and served as Acting Executive Director for the Global Earthquake Model (GEM).
Bruce Bolt Medal Recipient

Norman Abrahamson
Chief Scientist, Geosciences Department
Pacific Gas and Electric Company

Professor Bruce Bolt was recognized in his time by earthquake engineers and seismologists worldwide as the expert in engineering seismology. His PhD student, Dr. Norman Abrahamson, is now advancing the leading edge of the field and is arguably the world’s foremost authority on engineering seismology.

Following his PhD in 1985, Abrahamson worked for several consulting companies and as an independent consultant, then joined Pacific Gas and Electric Company (PG&E) in 1996, where he is currently employed as Chief Scientist in the Geosciences Department. In parallel, he has consulted on many projects worldwide and, since 2003, serves as an Adjunct Professor of Civil Engineering at the UC Berkeley and Davis campuses. He is an active member of SSA, EERI, and COSMOS, and has served terms on each organization’s Board of Directors.

Abrahamson authored with Bolt some of the pioneering papers to answer practical and significant engineering problems regarding seismic wave coherency and spatial variation of seismic wave forms, and also provided one of the first estimates of fault rupture velocity and direction, which has applications in directivity analyses. Abrahamson has become a leader in the development of ground-motion prediction equations (GMPEs) and in analyzing the statistical properties of peak parameters and their variability.

Abrahamson’s strong leadership is due in good part to his rare ability to not only focus on resolving technical issues arising in challenging, state-of-the-art projects, but also to recognize the need for changes in engineering practice and make them happen. He has improved regression procedures used in GMPE development, improved methods for spectral matching, and provided a verified Probabilistic Seismic Hazard Analysis (PSHA) code that is widely used in industry. This work has been part of his initiative to address practical issues of time-series selection and scaling in structural analysis. He has helped initiate and guide research efforts that directly impact engineering seismological practice, including the PG&E Lifelines, NGA-West, and NGA-East programs at PEER, and the Extreme Ground Motion Program sponsored by the Department of Energy. Abrahamson has also provided essential technical leadership in two recent and significant ground-motion characterization studies using expert elicitation: the Yucca Mountain nuclear waste repository project and the Swiss PEGASOS project. Currently, he is the Technical Integrator for the SSHAC Level 3 PSHA studies for the Diablo Canyon Nuclear Power Plant and BC Hydro. In these and like projects, his direction is to “focus on what matters.”

Building understanding and improving communications between the seismological and engineering communities is an ongoing outcome of Abrahamson’s efforts. As an adjunct professor and a guest lecturer, he has been teaching classes on strong-motion seismology and PSHA with the particular goal of preparing the next generation of engineering seismologists and earthquake engineers, thereby improving the health of the engineering seismology profession itself. He takes an active role in educating current practitioners and frequently speaks at public conferences and private meetings, where he focuses on PSHA and the proper use of strong ground motion data.
Thursday, April 12, 2012
6:00 p.m.

POSTER SESSION: GRADUATE STUDENTS

C. Argyrou
Non-Linear Inelastic Rotational Stiffness of Shallow Foundations

Kyle Bethay, Mamun Miah, and C. Mullen
Seismic Vulnerability of Select Critical Bridges in North Mississippi

Dimitra Bouziou
Seismic Wave Propagation Effects on Pipelines Rehabilitated with In Situ Linings

L. Burks
Prediction and Structural Response of Fling Effects in Near-Fault Ground Motions

Xiaohu Fan and Jason McCormick
Characterization of the Seismic Response of Corroded Steel Bridge Bearings

Kevin Foster, Adrian Rodriguez-Marek, Russell Green, Sam Lasley, and Nick Lacour
Static and Dynamic Properties of Coal Combustion Products

Michael Germeraad
Student Virtual Reconnaissance

Xuan Guo
Seismic Performance of Scoured Foundation-Structure Systems: Preliminary Findings

Ali Hajihashemi and Shahram Pezeshk
Applying Displacement-Based Methods in Seismic Design of the SR21-169 Bridge

Caitlin Jacques, Jason Adleberg, and Judith Mitrani-Reiser
Earthquake Outreach: Design of an Educational Module for K-12 Students on Performance-Based Design of Critical Structures

Masood H. Kafash and David Arellano
A Practical Design Example of Seismic Stability Analysis of Landslides Stabilized with Expanded Polystyrene (EPS)-Block Geofoam

Zhang Liu and Stefan Szymiszewski
The Study of Evacuation Time and Patterns after an Earthquake Using Agent-Based Modeling

Bryce Lloyd
Adapting Mobile Sensors for Structural Health Monitoring: Investigating Signal Accuracy of Automated Mobile Sensors on Surfaces with Varying Friction Coefficients

Armin Masroor and Gilberto Mosqueda
Impact Model Considering Surface Compliance for Simulation of Base Isolated Buildings Impacting Moat Wall

Chiara McKenney
Increasing Earthquake Resiliency in Developing Countries through Involvement of the Earthquake Engineering Community

Nitin Pangavane and Chris Mullen
Case Study of AASHTO-LRFD Seismic Provision Changes on Substructure Demands for a Composite Deck Bridge in North Mississippi

Shahram Pezeshk and S. Mehrdad Hosseini
Improved Inversion of Surface Waves; Comparison of Synthetic Seismograms with Observed Seismograms in the Field and Considering Higher Modes of Propagation

Andrew Rietz, Steven Halewski, and Yu Bao
3D Finite Element Modeling of Seismic Soil-Structure Interaction in Bridges

(over)
Ali Salehian and Michael Kalinski
Predicting the Dynamic Behavior of Mine Tailings Using State-of-Practice Geotechnical Field Methods

Alireza Shahjouei and Shahram Pezeshk
Implementation of the Genetic Algorithm and Neural Networks in Generation of Artificial Seismic Accelerograms

Lawrence A. Simonson, Ronald D. Andrus, and Tahereh Heidari
Liquefaction Potential Mapping of the Charleston Quadrangle, South Carolina

Chunli Wei, Ian Buckle, and Sherif Elfass
Lateral Stiffness of Piles in Sloping Ground under Bridge Abutments by Equivalent Analytical Model

D. Weiser
Relationships between Earthquakes and Mapped Faults

Brad P. Wham
Characterization of Polymer Lined Ductile Iron Pipes Subject to Seismic Induced Ground Deformations

Hartanto Wibowo, Danielle Smith, Ian Buckle, and David H. Sanders
Experimental Investigation on Combined Live Load and Seismic Load Effects on Response of a Horizontally Curved Bridge
NON-LINEAR INELASTIC ROTATIONAL STIFFNESS OF SHALLOW FOUNDATIONS

Authors: C. Argyrou, Civil Engineer

Affiliation: National Technical University of Athens

ABSTRACT

The compliance of underlying soil introduces additional degrees of freedom to the superstructure, affecting its overall response to vertical and mainly to seismic loading. In practice, the soil is usually simulated with springs whose stiffness is a function of soil properties and foundation characteristics. Due to the developing nonlinearities, this stiffness has variable values. In case of shallow foundations, the nonlinear behavior is manifested through three mechanisms; (a) detachment of the foundation from the underlying soil (uplift-geometric nonlinearity), (b) sliding at the soil-foundation interface (interface nonlinearity) and (c) mobilization of soil failure mechanisms (material nonlinearity). In case of slender structures, where the rocking oscillation prevails, geometric nonlinearity is dominant.

This study focuses on the response of rigid one-degree of freedom systems, such as bridge piers, founded on a homogenous clay layer of great depth under monotonic loading, through 2D Finite Element Analysis. As first approach, the effect of detachment of the footing from the underlying soil and the consequent decrease in soil-footing contact area (geometric nonlinearity) is investigated and thus the soil behavior is assumed to be linear elastic. Next, the inelastic behavior of soil is taken into account, introducing the material nonlinearity. A parametric analysis with respect to width of footing (B), aspect ratio of system (h/B), soil properties (E, S_u, E/S_u) and safety factor under vertical loading (FS_v) associated with the mass of the system (m), is performed. The basic parameter of this problem is the soil-foundation rotational stiffness K_{RR}, which in case of a rigid strip footing on elastic soil and under conditions of full contact is given by analytical expression (Gazetas, 1983).

The purpose of this study is the quantification of the decrease of the soil-foundation rotational stiffness with respect to the rotation angle of the footing. The derivation of normalized degradation curves, independent of the aforementioned parameters and applicable in every case, constitutes the ultimate goal.

A model using the code ABAQUS F.E. has been formed in order to implement the required parametric analysis, assuming plane strain conditions. The soil layer is simulated with 4-noded continuum plain strain elements (CPE4). The elastoplastic soil behavior follows the Von Mises failure criterion combined with nonlinear kinematic hardening law and associated plastic flow rule. The superstructure is a simple system, consisting of the mass element on the top of the system, the column and the footing. The column is simulated with linear beam elements of circular cross section (B21) and of high Young’s modulus and the footing with 4-noded continuum plane strain elements (CPE4) of high Young’s modulus as well. Special interface elements are used allowing the detachment of footing from the underlying soil. The boundaries of the model have been selected so as to ensure that they do not affect the results; the depth and the width of the model are set equal to H=12B and L=18B respectively. After the vertical static loads are imposed, a horizontal displacement on the top of the system is imposed till overturning (displacement controlled push over test).

Every analysis yields a M-θ curve; where M is the moment required for the system to balance at a specific rotation angle θ. Based on M-θ curve, the correlation of dimensionless secant stiffness K_p(θ)/K_{RR} with respect to rotation angle θ is derived, following the concept of an equivalent elastic stiffness corresponding to a given angle θ.

Regarding the first approach, based on the assumption of linear elastic soil behavior, which is reasonable for the case of light-loaded systems or very stiff clays, the main conclusions of the work are summarized as follows; (1) for very small rotation angles, the rotational stiffness of the system...
equals the value derived from the analytical expressions. (Gazetas, 1983). As rotation angle gets larger, the decrease in soil-footing contact area leads to a decrease in rotational stiffness. (2) the basic parameters affecting this degradation are the soil Young’s modulus E and the mass of the system m, and more specifically the ratio of these two parameters. The breakpoint of each curve coincides with the rotation angle required for the initiation of detachment $\theta_{up}$ (3) using $\theta_{up}$ for the normalization of the rotation angle $(\theta/\theta_{up})$, a unique degradation curve in terms of $K_R(\theta) / K_{RR} - \theta/\theta_{up}$ is obtained independent of the system’s aspect ratio $h/B$, the footing width $B$, the soil modulus $E$ and the mass of the system $m$.

As for the second approach, which accounts for both geometric and material nonlinearities, the results differentiate as follows: (1) the initial rotational stiffness does not equal to the value calculated from the analytical expression. The development of initial plastic deformation due to the vertical load leads to reduced stiffness of the system soil-foundation even for zero rotation angle of the footing. A correlation between the factor of safety against vertical load $FS_V$ and initial stiffness of the system normalized to the corresponding elastic can be derived. (2) the safety factor under vertical loading $FS_V$ has significant effect on the form of degradation curves and the type of failure. In case of the light - loaded foundations (large $FS_V$) uplift dominates as a way of undertaking the imposed moment from horizontal loads. In contrast, in case of heavy-loaded foundations (small $FS_V$) the mobilization of bearing capacity mechanisms prevails and consequently large settlements with increasing rotation angle, while the detachment is imperceptible. (3) in order to normalize the results, based on the elastic problem, an expression for the rotation angle corresponding to the initiation of uplift is defined $\theta_{up,in}$, taking into account the decreased initial rotational stiffness. Thus, a unique degradation curve is derived for every $FS_V$. The normalization holds better for light loaded and for small rotation angles, where the P-$\delta$ effects are not of major importance.
Seismic Vulnerability of Select Critical Bridges in North Mississippi

Kyle Bethay, Graduate Research Assistant
Mamun Miah, Graduate Research Assistant
C. Mullen, Associate Professor
Department of Civil Engineering, University of Mississippi

ABSTRACT

An October 2009 Federal Emergency Management Agency sponsored study entitled, “Impact of New Madrid Seismic Zone Earthquakes on the Central USA,” has evaluated potential direct damage and functionality of infrastructure over an eight state region as a consequence of a catastrophic scenario rupture along segments of the New Madrid fault. Damage and losses are estimated to be significant for most infrastructure systems in Desoto and Tate counties in Mississippi except for highway bridges. To further investigate this result, the Mississippi Emergency Management Agency sponsored a site-specific study focused on three Coldwater River crossings located on Interstate 55 and US Highways 51 and 78. Computer models of each structure were developed to provide more detailed information about potential damages to these major routes that direct vehicular traffic into and out of Memphis and north Mississippi communities.

Design drawings and soil data reports from Mississippi Department of Transportation have been used to develop simplified 2D and 3D finite element models of typical intermediate bents, single-column piers, and a 3 span continuous box girder segment. Discrete soil-spring parameters were developed for each of the bridge site to capture linear soil-pile interaction response in their models. Emphasis has been placed on 2D models of intermediate bents and piers. A site specific input time history data was developed using simulated motion at a nearby bridge site consistent with estimated peak ground accelerations predicted for the scenario earthquake of the regional study.

Time history analysis is performed using the site specific input motion applied to the discrete soil springs. Response simulations provide estimates of the dynamically generated axial forces, shear forces, and bending moments of the piles and columns in the bents and piers which are compared with design capacities to establish the risk for potential damage. Eigenmodes and computed peak response configurations provide insight into potential damage mechanisms in the transverse direction. Nonlinear material and geometric response are computed for some cases to further demonstrate the vulnerability with respect to local failures.

As both the design of the piles and the as-built pile conditions are uncertain, it is not possible to definitively state whether any residual capacity will exist in the event of the scenario level loading event. It is recommended that a larger study of more comprehensive scope be enabled to more reliably delineate the soil and structure conditions assumed in the present study and assess the influence of liquefaction on functionality of these bridges.
SEISMIC WAVE PROPAGATION EFFECTS ON PIPELINES REHABILITATED WITH IN SITU LININGS

Presenter: Dimitra Bouziou, Graduate Student, Cornell University, Ithaca, New York, USA

The performance of underground lifelines during earthquakes can be significantly improved with the use of in situ pipe lining technologies that involve the insertion of polymeric linings inside existing, underground pipelines. The effects of seismic wave propagation on pipelines that have been retrofitted with linings can be limited, and such technologies potentially ensure the serviceability of such networks even after considerably strong seismic events. Some of the advantages of using lining technologies include the secured continuity of pipeline flow, prevention of leakage and intrusion, as well as variable degrees of structural reinforcement. Current design and construction practices do not include in situ lining technologies for seismic risk mitigation, and the adoption of such methods for the rehabilitation of pipelines can be possible through experimental validation and analytical procedures.

This paper focuses on the response of cured in place pipe (CIPP) lining technology for seismic retrofit under strong seismic excitations. Finite element models are developed for simulating seismic wave interaction with buried pipelines and, consequently, the transient seismic wave induced relative joint displacements in segmented ductile iron pipes is estimated. In addition to the analytical work, full-scale dynamic tests are conducted on the twin re-locatable shake table facility of the Structural Engineering and Earthquake Simulation Laboratory (SEESL) at the University at Buffalo (UB). The dual shake table capabilities at the University at Buffalo NEES Site are uniquely qualified for simulating transient ground deformations caused by seismic waves.

The paper describes the modeling methodology of seismic wave effects on aging and defective pipelines, strengthened with CIPP linings, including the selection of representative ground motions. The ground motion interaction with a cracked pipe or defective joint subsequently retrofitted with a CIPP lining is simulated. The results of special tests on lined jointed pipe specimens to characterize their response to ground deformation are presented and they are subsequently used for capturing the behavior of the joint connections in the finite element simulations. The aforementioned special tests include monotonic and cyclic axial pull and four-point bending testing on 12 foot long single joint segmented pipelines. The resulting axial force – axial displacement and bending moment – rotation curves are used as the basis for developing simplified bilinear curves that are introduced into the finite element models.

Since pipelines are typically buried within shallow depths, i.e., 3 to 9 ft, below the ground surface, both body and surface waves may influence the response of pipelines during earthquake. This paper focuses on the seismic body wave effects on pipelines. An ensemble of real earthquake motions that have generated by seismic faulting is selected and used for both the finite element simulations and the dual shake table dynamic tests. The strong motion recordings are resolved in the direction of the pipeline such that the induced relative joint displacements are maximum and polarity effects are taken into account.

The finite element model is initially validated using closed-form solutions for the seismic body wave interaction with unlined jointed ductile iron pipe, as well as with CIPP. Soil-structure interaction effects are simulated using spring-slider elements capable of representing shear transfer as an elastoplastic process. The time histories of the strong input motions are converted to displacement versus distance records and are applied in the displacement field of the model. Each modified strong motion recording is scaled in a nonlinear fashion up to the degree at which failure of the liner is accomplished in the simulation.

The resulting relative joint opening time histories from the finite element analyses are used as input motions for the dual shake table dynamic tests conducted at the University at Buffalo in order to
account for the seismic soil-structure interaction. The response of the composite pipeline is monitored with acoustic emissions during each test. The results of full-scale dynamic tests of seismic ground wave effects on three pressurized water pipelines (5.9 in. in diameter and 32.8 ft long) retrofitted with CIPP linings with their two ends resting on each of the shake tables are presented. Asynchronous translational motions were applied to each shake table and the results are in good agreement with the monotonic tests, while the assumptions made for the finite element simulations are verified.

The research described in this paper is part of the NEESR-CR Earthquake Response and Rehabilitation of Critical Lifelines project that involves large-scale testing at the Cornell University and University at Buffalo equipment sites of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). The research involves a university-industry partnership with support from Insituform Technologies, Inc., Los Angeles Department of Water and Power (LADWP), and the Center for Advanced Microelectronics Manufacturing (CAMM).
A number of bridge failures (i.e. unseating and collapse of spans) observed during the 1995 Kobe earthquake were associated with the poor performance of steel bearings under seismic action. Considering the vast amount of steel bridge bearings installed in existing highway bridges of the Central and Eastern United States, it is important to understand the seismic response of these bearings given the significant seismic hazard for the area resulting from intra-plate seismic zones. According to past research findings, age-related deterioration also can lead to an increased hazard since deterioration in the form of corrosion can significantly undermine the capacity and behavior of crucial structural members, such as the steel bearings. Corrosion of steel bearings can result in section loss at the contact surfaces and debris build-up between contact surfaces, creating an adverse change (i.e. locking and change in friction coefficient) in the mechanical mechanism that the bearings rely on to accommodate translational and/or rotational displacements. For example, both failures of the Dunn Memorial Bridge, Albany, NY (NYSDOT 2005), and the Birmingham Bridge in Pittsburgh, PA (Splitstone et al. 2010) were directly caused by excessive rotation of steel rocker bearings as a result of “locked” behavior owing to decades-long build-up of corrosion (Figure 1). Meanwhile, there are over 58,000 highway bridges located throughout the Central and Eastern U.S. with median ages from 35 to 40 years, approaching the end of their design life (Padgett 2007). Considering the joint threats from seismic hazard and age-related deterioration, the seismic performance of the aged steel highway bridges needs to be addressed. To accomplish this, a study using analytical models is needed to describe the behavior of steel bearings with different levels of corrosion, given the critical role these bearings play in the seismic response of highway bridges. However, past research has been limited in considering the behavior of corroded steel bearings. In this study, a coupled methodology involving numerical simulation and experimental testing is presented for characterizing the cyclic behavior of corroded steel bearings and exploring their failure modes and capacity limits (Figure 2). Two types of steel bearings including steel bolster bearing (i.e. fixed bearing) and steel rocker bearing (i.e. expansion bearing) are studied under large cyclic loads. Preliminary results show that these bearings have unique hysteretic responses under displacement-controlled loading reversals and that changes in the friction coefficient lead to significant changes in the behavior when sliding occurs. The behavior of the bolster is characterized mainly through a Coulomb friction type behavior while the rocker bearing behavior remains mostly linear due to loading in the longitudinal direction. Experimental testing of previously in-situ bearings will provide further correlation between seismic loading and age related deterioration on the cyclic behavior of the bearings.

Figure 1 Toppled rocker bearing failures due to build-up of corrosion products

(a) Birmingham Bridge (Splitstone et al. 2010)    (b) Dunn Memorial Bridge (NYSDOT 2005)
(a) 3-D finite element simulation model for the steel bridge bearing

(b) Full-scale experimental testing scheme for the steel bridge bearing

Figure 2 Couple approach to characterize the cyclic behavior of steel bridge bearings

Reference:

New York State Department of Transportation (NYSDOT), (2005), *Structural Forensic Investigation Report: BIN 109299A, Ramp AC, Dunn Memorial Bridge Interchange, Albany, NY*.


The United States produces more than 100 million tons of coal combustion products (CCP) annually (Kalyoncu, 2001). In the state of Virginia alone waste production exceeds 10 million tons per year (Daniels et al, 2010). CCP typically contain trace quantities of heavy metals, e.g. arsenic, chromium and mercury. Environmental considerations logically require that solid coal waste be landfilled or impounded according to the most responsible engineering and management practices; the consequences of a failure are environmentally and politically severe as witnessed by the 2008 Kingston Fossil Plant coal fly ash slurry spill (see e.g. Ferrar, 2009; Tucker, 2009).

CCP waste disposal facilities take various forms including ash ponds, rim ditches, dredge cells, wet gypsum stacks and dry ash or gypsum stacks. Some of these are developed over retired ash ponds (which presents the possibility of deep-seated slope failures). Designing these works is challenging because the geotechnical and chemical properties of solid coal waste vary significantly with location, both across mining regions and at different locations within the same waste facility.

Many factors influence CCP material variability. These include coal geology, mining processes, chemical and mechanical separation processes, combustion process and temperature, and waste transport methods. In wet-sluicing disposal methods, waste is combined with water into slurry for transport to the disposal site, resulting in hydraulic sorting (i.e., heavier particles settle near the discharge point while fine particles settle further downstream) (Chang, 2009). CCP include several solid phases: bottom ash (uncombusted material collected from the incinerator floor), boiler slag (glassy fragments of rapidly-quenched molten ash from the boiler bottom), fly ash (airborne glassy spheres retained by air pollution control measures) and flue gas desulfurization sludge (Kalyoncu, 2001). These various materials are often combined for disposal at the same site, but practical and economic considerations related to mining and incineration processes dictate the relative constituents of the waste stream.

Coal waste disposal facilities, and mining waste facilities in general, have a troublingly high incidence of geotechnical failure worldwide when compared with comparable “traditional” geotechnical structures (e.g., highway embankments, dams). Davies (2002) provides a critical overview of the situation and cites the inherent material variability, the generally unprofitable nature of waste facilities, and other factors as causes of the industry’s poor track record. Static or flow liquefaction failures of saturated ash are not uncommon in the industry, due in part to material saturation from wet sluicing practices described above. Flow failures are costly both politically and economically, as they are often characterized by very long runout (in some cases two to three kilometers: Dawson et al., 1998; Fourie et al., 2001).

Despite a recent surge in sustainability-driven research, including substantial efforts in the geotechnical engineering field (e.g., Kim et al., 2005, and references therein), major gaps exist in the knowledge of the static and dynamic properties of coal waste. This is evidenced by the common occurrence of static liquefaction. Also, the recent Virginia earthquake (EERI-GEER, 2011) served as a reminder that Appalachian coal country is susceptible to potential future earthquakes and that seismically induced liquefaction of CCP needs to be considered. CCP disposal facilities are commonly analyzed for liquefaction susceptibility using engineering procedures developed for natural soils, yet the physical and chemical properties of ash differ dramatically from common natural soils.
To address these systemic problems, Virginia Tech (VT) is embarking on a major initiative in cooperation with the Tennessee Valley Authority and the Center for Geotechnical Practice and Research to quantify the static and dynamic properties of coal ash. Our research team is developing a comprehensive laboratory testing program, to be validated with case histories, with the intent of quantifying the engineering behavior of CCP and developing new procedures for liquefaction-resistant design of CCP facilities. The program builds on a related research at VT on coal ash, as well as substantial experience in both liquefaction of soils and CEUS seismicity.

The program, now underway, consists of several testing and development phases:

1. Obtain in situ test data and disturbed and undisturbed soil (CCP) samples from selected TVA and other CCP disposal sites;
2. Perform a comprehensive laboratory characterization testing program, including optical microscopic and scanning electron micrograph imaging and elemental characterization via EDS (energy-dispersive X-ray spectroscopy);
3. Perform cyclic triaxial and cyclic direct simple shear (DSS) tests to determine liquefaction characteristics;
4. Perform resonant-column, torsional shear, and direct simple shear tests to determine small-strain modulus, modulus degradation and damping degradation data of CCPs;
5. Develop new or modified design guidelines for static and dynamic liquefaction resistance of CCP disposal facilities.


STUDENT VIRTUAL RECONNAISSANCE

Michael Germeraad, California Polytechnic State University San Luis Obispo

Recent earthquakes, in particular the Christchurch, Japan, and Virginia earthquakes have highlighted the internet as a means to retrieve virtual reconnaissance data. As technology continues to reach a greater audience the files uploaded following an event have the potential to directly impact on the ground reconnaissance missions.

Growth and diffusion of technology provides a larger data source allowing for a comprehensive meaningful review of local data often taken during or directly after an event. Unfortunately, with increased technology large amounts of non-critical information will be uploaded. Filtering the uploaded data to produce concise useful information for reconnaissance teams and researchers to use is critical. Despite the vast amount of information on the internet, humans, and specifically students have the capability to find the best data. Students offer a means to retrieve and sift through large amounts of internet data on a growing number of internet platforms (Facebook, YouTube, Vimeo, Picasa, local news, etc.).

Currently EERI has the online reconnaissance clearinghouse which is a great start. Current limitations of the site are its navigation, timeliness, and participation. Development of a student virtual reconnaissance platform would aim to organize and simplify the data into an easy to navigate format. The EERI community has not yet been called into action to complete a comprehensive virtual reconnaissance, however I believe the next significant earthquake in a technology rich zone can produce a full and meaningful virtual reconnaissance database.

The key to success in a future event is the participation of the EERI community, specifically within the student chapters. Interest in the event may be enough motivation for students to participate, however incentivizing the project further would yield a more thorough report. Travel with EERI reconnaissance teams or student organized reconnaissance trips similar to UCSD’s trip to Chile in 2010 (http://ucsdchile.wordpress.com/) would provide incentive for students to become a key component to EERI’s reconnaissance work.
Seismic Performance of Scoured Foundation-Structure Systems: Preliminary Findings
Xuan Guo, Doctoral Student (xght8@mail.umkc.edu)
Department of Civil and Mechanical Engineering, Univ. of Missouri-Kansas City, 5100 Rockhill Rd,
Kansas City, 64110, USA
Faculty Adviser: ZhiQiang Chen, Assistant Professor (chenzhiq@umkc.edu)

Earthquakes and earthquake-triggered tsunamis are the most severe hazards that threaten lives and properties in coastal communities. In the aftermath of the recent tsunami events occurred in the past few years, a secondary hazard due to tsunami waves has documented by many field reconnaissance reports, which is foundation scour that has occurred to a large number of bridges and buildings (Figure 1a and 1b). Even though the scoured buildings and bridges do not sustain damage in superstructure in the main-shock and the triggered tsunami, scoured foundation-structure systems may be easily damaged considering the frequent occurrence of the ensuing aftershocks. Another type of scour type that has been recognized as a leading cause of bridge failure is flood-induced foundation scour. The distinct feature of flood-induced scour is that once scour is formed around a foundation, it may last its service life (Figure 1c). It is intuitive that a potentially more severe threat is the situation that the permanent scour is combined with other hazards, such as earthquakes. Considering thousands of scour-critical or scour-susceptible river-crossing bridges in the nation that also lie in seismically active zones, this multi-hazard risk to the bridge inventory cannot be underestimated.

Figure 1. (1a) tsunami-scoured bridge foundation (Francis 2006); (b) tsunami-scoured building foundation (Boulanger 2011); (c) bathymetric point cloud for a scoured bridge pier in Missouri River (Huizinga 2010).

Scour is the result of the erosive mechanism of flowing water that excavates and carries away material from the surface soil in the near-field of foundation systems. Regardless of the cause of scour (tsunami or flood), the resulting scour usually manifests a complex modification of geometric boundary in the near-field soil of the foundation. Most of the available scour estimation methods are empirically formulated based on laboratory tests. For flooding-induced scour in river channels, the most influential scour equations are found in the FHWA’s Hydraulic Engineering Circular report that give conservative answers for the design and evaluation of most bridges. For tsunami-induced scour occurred to man-made structure, available empirical formulas predicting scour depth are more limited. This is largely due to the boundary condition for tsunami is much different than that in a river channel. In addition, tsunami scour also has a shorter duration of loading than that in river scour. An existing design method is reported in the FEMA’s Coastal Construction Manual. These methods will be evaluated in this poster for a typical foundation-bridge system.

For designing bridges resisting both seismic and scour hazards, the current design codes, as primarily represented by the AASHTO’s LRFD Bridge Design Specifications, require that bridge foundations be designed at both the service and strength limit states and be checked at the extreme-event limit states. At the strength and service limit states, the foundations should be designed with sufficient bearing capacity and lateral resistance assuming that the sediments within the estimated scour depth. To supplement the
design at multi-hazard extreme states, the NCHRP Report-489 explicitly considers the joint occurrence of scour and other extreme hazards considering that scour will be long-term presence and the probability of co-occurrence with other hazards is not insignificant. Therefore, when earthquake loading is considered, NCHRP Report-489 recommends the load combination ‘.25DC+1.00EQ; 0.25SC’. This procedure provides a principled approach to considering the joint scour and seismic hazard. However, there are no established procedures or software tools that can accommodate a system-level dynamic scoured foundation-structure simulation subject to seismic excitation. For designing buildings in coastal areas, there are no explicit provisions in current design standards and codes that specify the multi-hazard combination of scour and seismic loading.

In this poster presentation, we assert that foundation scour should be treated as more of a set of nonlinear modifications to the dynamics of a foundation system (including the foundation’s near-field soil) besides the apparent changes of geometric boundary conditions due to foundation scour. However, all these modifications are far from fully understood in the engineering profession.

Herein we endeavor to explore the foundation impedance functions at linear elastic states as a preliminary study, which include both foundation stiffness and radiation damping, for scoured shallow footings with different geometric scouring profiles. The implicit 3D finite element solver of LS-Dyna is employed in this research. Our numerical preliminary results show that given different scour profiles, foundation impedance will be modified differently. Moreover, foundation impedance will be asymmetric as opposed to originally symmetric ones of non-scoured foundation. With the obtained results, we embark on studying the impact of scoured foundation on seismic response. A parametric soil-foundation-structure oscillator with equivalently linear soil-foundation Winkler springs and a bilinear superstructure stiffness model is utilized to generate the seismic response. By choosing earthquake ground motions with moderate to strong intensities, we observe that scoured foundation may give rise to ‘beneficial’ effect by reducing the ductility demand of the superstructure for a uniform scour profile. However, for a scour profile that partially undermines the footings, the seismic ductility demands can be dramatically increased. We conclude that foundation scour potentially has a complex impact to the existing impedance models in the literature and to the dynamic response of foundation-structure systems. The findings in this preliminary research and our ongoing research may contribute to the practice for assessing the multi-hazard risk to the civil infrastructure system threatened by tsunami or flooding and earthquakes.
We studied a highway bridge designed by the Tennessee Department of Transportation (TDOT) located on State Route 21 over Interstate 69 in this research. This bridge was designed according to the AASHTO specifications (2009). The bridge consisted of a two-span continuous 72 inches bulb-T girders, and the length of both spans was 148 feet. The only bent frame included four 3.5 feet square columns and the cap beam. We used the computer program SAP2000 V.14.2 (2009), which is a popular analysis software among bridge engineers (Shattant et al. 2008). In this study, we evaluated the seismic behavior of the bridge in the transverse direction only. The design response spectrum was obtained from the AASHTO GM (Leyendecker et al. 2009) computer program based on the bridge location’s latitude and longitude. The earthquake resisting system (ERS) of the bridge was Type 1 (AASHTO 2009), which requires the expected behavior of essentially elastic superstructure and ductile substructure. This ERS forced the nonlinear behavior to occur within the inspectable locations of the columns. Consequently, the plastic hinges were assigned at both ends of the clear height of the columns, for nonlinear analysis purposes.

We used the computer program SAP2000 to perform the modal analysis of the bridge structure. We applied conversion factors, which represent the fundamental mode shape of the bridge in the desired direction, to convert the pushover curve of the system to the capacity curve. The main part of every nonlinear analysis is the modeling of nonlinearity. In this study, the inelastic behavior was assumed to occur in the concentrated plastic hinge assigned at the ends of each column element. The pushover analysis was defined such that it started after applying gravity loads to the system. It was defined as a displacement control case, based on the transverse displacement at the control node (superstructure mid-point). The analysis was to stop when the monitored displacement reached 0.75 ft. The pushover curve was then converted to the capacity curves using the conversion factors.

We used three different displacement-based methods to evaluate the seismic response of the SR21-I69 Bridge. The first procedure is based on the AASHTO specifications (2009), and was used by the TDOT engineers in the actual design process of the bridge. The next two displacement-based procedures similarly are based on the intersection of the capacity (pushover) curve and the demand diagram to estimate the maximum seismic displacement, which is called the "performance point." They differ in reducing the elastic (µ=1) response spectrum to the inelastic (µi) demand diagram. FEMA-440 (2005) presents three procedures as modifications to the Capacity Spectrum Methods (CSMs) of ATC-40 (1996), from which we chose Procedure C for this study. This approach uses the modified acceleration-response spectrum for multiple assumed solutions (aπ, dπ) and the corresponding ductilities to generate a locus of possible performance points. The actual performance point is located at the intersection of this locus and the capacity curve (FEMA 2005). Procedure C, like the other procedures in FEMA-440, is an equivalent linearization procedure which adjusts the initial response spectrum to the appropriate level of effective damping, βeff. Constructing a family of demand curves for μ values of 1, 2, 3, and 4, the spectral displacement of the performance point was determined.

We used the capacity-demand-diagram method of Chopra and Goel (1999) as the third displacement-based seismic design procedure. This procedure determines the demand by analyzing the inelastic system instead of the equivalent linear systems in the CSMs of ATC-40. A family of constant-ductility demand spectra is constructed by reducing the elastic design spectrum by appropriate ductility-dependant factors, Rγ. Various Rγ-μ-T equations have been presented by Chopra (2007). In this study, we used the...
Newmark-Hall equations. For selected values of $\mu = 1.0, 1.5, 1.75, 2, \text{ and } 2.5$, the demand curves were plotted on the same chart as the bilinear capacity spectrum for each combination of support configuration and hinge property. At one relevant intersection point, the ductility factor calculated from the ratio of the displacement of the point to the yielding displacement, matches the ductility value associated with the intersecting demand curve, which determines the performance point of the structure.

Based on this study, it can be concluded that the current AASHTO specifications (2009) displacement-based seismic design method is more conservative than the other two studied methods proposed by Chopra and Goel (1999) and FEMA-440 (2005). Both the FEMA-440 Procedure C and the capacity-demand-diagram method showed that the SR21-I69 Bridge would perform within the Immediate Occupancy level if subjected to the selected seismic excitation. The studied bridge was designed following the AASHTO specifications procedure, considering the Life Safety performance criterion. The AASHTO specifications procedure also overestimates the value of displacement ductility of the system. Comparison of the seismic displacement demand (maximum displacement) values resulting from the different procedures also confirms that the AASHTO specifications procedure may be conservative. This also may reveal the deficiency of the AASHTO specifications procedure in determining the displacement demand through a force-based approach (response spectra analysis).

Analyzing the SR21-I69 Bridge using the capacity-demand-diagram method showed higher values for both the seismic displacement demand and the displacement capacity, compared with the results of FEMA-440 Procedure C. The capacity-demand-diagram could be used as an alternative to the AASHTO specifications procedure due to the more accurate concepts behind the procedure, in addition to its more straightforward nature over the FEMA-440 procedure C.

REFERENCES


In the summer of 2011, the Sensor Technology and Infrastructure Risk Mitigation (STIRM) Laboratory at Johns Hopkins University created and implemented a 90-minute educational module for K-12 students to teach basic concepts of earthquake engineering and performance-based design, and to inspire interest in STEM fields of study. The module, entitled “Shakedown: Engineering Economical and Earthquake-safe Hospitals on the Ring of Fire,” was first held as a part of the JHU Engineering Innovation Program. In this module, students learned about the economic and human impact of earthquakes in the US and around the world, reviewed the basics of seismic engineering, designed and built small-scale hospital structures, and tested these structures on a shake table.

Each team of three students received a budget to purchase building materials. When designing their structures, teams also had to consider strict building guidelines that included patient safety and both structural and non-structural damage limitations, as well as basic height and mass requirements. Teams tested their initial designs on a shake table and had the opportunity to make retrofits for subsequent testing. Based on the performance of their final structures under the Northridge earthquake, teams received bonuses or penalties. This module especially emphasized one of the major challenges of seismic engineering: balancing safety with economics.
A PRACTICAL DESIGN EXAMPLE OF SEISMIC STABILITY ANALYSIS OF LANDSLIDES STABILIZED WITH EXPANDED POLYSTYRENE (EPS)-BLOCK GEOFOAM

Masood H. Kafash¹, Graduate Research Assistant and David Arellano², Associate Professor, The University of Memphis, Memphis, TN

Landslides are among the most widespread geologic hazard on earth and occur in every state and U.S. territory. Active seismic activity contributes to the landslide hazard risk in areas such as Alaska, Hawaii, and the Pacific Coast and estimated damages related to landslides exceed $2 billion annually. Cause of landslides can be divided into two major categories: natural hazards and human activities. Natural causes of landslides include increases in ground water level, changes in natural vegetation, erosion of the bottom of the slope, earthquakes and decrease in soil or rock strength due to saturation. Human activities that contribute to landslides include vibrations from machinery or traffic, blasting, earthwork and construction. Slope stabilization and repair techniques can usually be classified into one of the following categories: (1) avoid the hazard, (2) reduce the driving forces, or (3) increase the resisting forces. The use of lightweight fill is a slope stabilization procedure that can be used to reduce the weight of the sliding mass and, thereby, reduce the driving forces of the sliding mass.

This poster will present a design example of seismic stability analysis of slopes stabilized or repaired with expanded polystyrene (EPS)-block geofoam for the function of lightweight fill. The design of slopes stabilized by EPS-block geofoam considers the interaction of existing slope material, EPS-block geofoam fill mass and pavement system, if present. Seismic design is separated into external and internal seismic stability analysis. External seismic stability considers overall stability of the EPS-block geofoam slope system and considers failure mechanisms that involve the existing slope material only as well as failure mechanisms that involve both the fill mass and the existing slope material. The steps to perform external seismic stability analyses include estimating the seismic-response acceleration at the existing ground surface or base (subgrade level) of the EPS fill mass by conducting a site-specific assessment and performing pseudo-static limit equilibrium stability analyses of the various external stability failure mechanisms. The failure mechanisms that are considered for external seismic stability analysis include slope instability, horizontal sliding of the entire EPS-block geofoam fill mass, overturning of a vertical sided embankment, bearing capacity failure of the existing foundation earth material, and settlement of the existing foundation material.

Design for internal seismic stability considers failure mechanisms within the EPS-block geofoam fill mass only. The primary steps to perform internal seismic stability analyses are (1) estimating the seismic-response acceleration at the existing ground surface or base (subgrade level) of the EPS fills mass by performing a site-specific assessment, (2) estimating the seismic-response acceleration at the top of the EPS fill mass, (3) performing pseudo-static limit equilibrium stability analyses of the various failure mechanisms. The failure mechanisms that are considered for internal seismic stability analysis include horizontal sliding between layers of blocks and/or between the pavement system and the upper layer of blocks and load bearing failure of the EPS blocks are the internal failure mechanisms.

This poster will provide a practical example of the overall seismic design of slopes stabilized by EPS-block geofoam which was presented as a poster session during the EERI 2011 annual meeting in LaJolla, CA.

¹mhssnzdh@memphis.edu
²darellan@memphis.edu
THE STUDY OF EVACUATION TIME AND PATTERNS AFTER AN EARTHQUAKE USING AGENT-BASED MODELING

Zhang Liu, graduate student of Civil Engineering Department of Johns Hopkins University

Stefan Szyniszewski, post-doctoral researcher of Civil Engineering Department of Johns Hopkins University

Caitlin Jacques, graduate student of Civil Engineering Department of Johns Hopkins University

Mehdi Jalalpour, graduate student of Civil Engineering Department of Johns Hopkins University

Judith Mitrani-Reiser, assistant professor of Civil Engineering Department of Johns Hopkins University

James Guest, assistant professor of Civil Engineering Department of Johns Hopkins University

Ben Schafer, professor of Civil Engineering Department of Johns Hopkins University

Takeru Igusa, professor of Civil Engineering Department of Johns Hopkins University

Studying evacuation time and patterns is an important issue to arrange rescue resources and reduce the loss of human lives after a strong earthquake. However, this kind of data is seldom recorded during historical earthquakes. Furthermore, it is difficult to use traditional methods to model this behavior because people who are escaping from a building form a complex adaptive system. Fortunately, along with the advent of computer science, many new approaches are emerging. Among them, agent-based modeling is extremely useful to explore complex adaptive systems. Therefore, in this paper we use this method to study the interaction of humans with a damaged built environment, and estimate the average evacuation time and patterns of evacuation after a strong shaking event. As an example, we simulate the evacuation event for a 3-story commercial building, whose damage is simulated using structural analysis and fragility functions. Then the occupants’ injury is estimated based on the damage state of the building. To investigate the patterns of the evacuation event, we run the model for different numbers of occupants ranging from dozens to more than one thousand. We also compare the average evacuation time between the damaged building and the undamaged building to study the factors which will delay occupants’ evacuation.
Adapting Mobile Sensors for Structural Health Monitoring:
Investigating signal accuracy of automated mobile sensors on surfaces with varying friction coefficients.

Bryce A. Lloyd
Masters Student of Structural Engineering
University of California, Davis

ABSTRACT

As modern civilization continues to advance, the demands placed on civil structures have become increasingly great in both scale and complexity. A promising method to improve the performance, resiliency, and longevity of these structures is to incorporate sensor systems onto the structure that monitor its integrity and activity during its lifetime. With the advent of wireless communication systems and onboard signal processing, sensors can be mounted essentially anywhere on a structure without a physical tether. The next evolution of structural monitoring sensors is to move from static wireless systems to mobile ones to further reduce the cost and number of sensors needed to effectively evaluate a structure. Several unique innovations in magnetics and micro-adhesives have led to the design of mobile robots that can transfer sensors to different parts of a structure. Sensors that are not permanently fixed to the structure can develop errors in signal analysis due to poor adhesion or slip. To evaluate the parameters that can affect this type of error, several sinusoidal and time history ground motions were tested against varying surface coefficients and friction force amplitudes between structure and sensor. Error associated with stick-slip friction was compared against 1-dimensional stick-slip friction models to determine the amount of error is associated with each parameter of adhesion.
Base isolated buildings subjected to extreme earthquakes can exceed their design displacements and impact against the surrounding moat wall. To better understand the consequences of impact on the superstructure, an impact element considering moat wall compliance is proposed based on impact theory and observations during experimental simulations of a base isolation building impacting against various moat wall configurations. It is demonstrated that numerical simulations using the proposed impact element can capture the dominant characteristics of the contact force observed in experiments for both concrete walls with soil backfill and rigid steel walls. The contact force is dependent on impact velocity, geometry and material properties at the contact surface, as well as the global dynamic flexibility characteristic of the moat wall. Properties of the moat wall impact element are derived here based on mechanics-based models considering material properties and geometric measurements of the experimental setup. For this purpose, the moat wall is modeled as a flexural column with a concentrated hinge at its base with soil backfill considered through a damped elastic foundation (Figure 1).

Figure 1. Schematic side view of a moat wall and representing beam.

The test model is extracted from a prototype frame of case study buildings designed for a high seismic zone by professional engineers. The prototype isolated superstructure is a rectangular three-story steel Intermediate Moment Resisting Frame (IMRF); the test specimen represents a single bay of an internal moment frame in the prototype structure. The prototype frame was reduced to a quarter-scale model according to similitude (Figure 2). Further constraints were imposed in properly scaling the strength and stiffness of the frame relative to the bearings properties so that realistic yielding mechanisms can be obtained. The scaled frequency of the fixed-based and isolated frame with the provided mass was also considered. A moat wall was modeled as a concrete wall with soil backfill. The moat wall gap was set to various displacement increments in proportion to the ASCE-7 MCE design displacements to examine the sensitivity of this parameter and also to assess the effects of impact on the superstructure at different velocities. The impact tests also investigated the effects of using rubber and other materials at the impact interface.
Simulation of impact forces in structural analysis should consider the two phases of impact to capture both the effects of local deformation at the impact point and the vibration aspect of the colliding objects. Famous Hertz damped model captures forces during the first phase of impact, which includes the local deformation of two objects and assumes that the force is a function of material properties and initial velocity. The second phase occurs after the first initial impact, sometimes followed by a quick separation, during which the two bodies stay in contact and push or generate forces against each other. The force in this second phase is primarily influenced by the dynamic properties of the moat wall including mass, stiffness and damping.

Figure 3 compares the experimental and numerical simulation results for the west wall impact force under Erzincan NS record. The local deformation and global vibration response phases are clearly shown in this figure. The first peak in the impact force is mainly due to local deformation of two bodies at the contact point, followed by a longer duration contact force and larger displacement mainly influenced by the dynamic properties of the wall as well as the applied ground motion.

The main objective of this study is to propose a new impact element that can simulate contact force during impact of base isolated structure to a moat wall. The proposed impact element is able to capture both local deformation and vibration response of the moat wall. The resulting impact element is shown to capture both local deformation and the vibration aspects of impact as well as the effects of impact on superstructure response.
INCREASING EARTHQUAKE RESILIENCY IN DEVELOPING COUNTRIES THROUGH INVOLVEMENT OF THE EARTHQUAKE ENGINEERING COMMUNITY

Chiara H. McKenney
M.S. Candidate, Civil Engineering, University of California, Davis

Poster Abstract

While the earthquake engineering field continues to advance remarkably, basic knowledge of earthquake resistant construction has still not been disseminated to many of the regions of the world with the highest earthquake risk. Urbanization has increased vulnerability in earthquake-prone developing countries, and the spread of earthquake resistant construction methods is far from catching up. As the cutting edge of the earthquake engineering field advances, it is also crucial that earthquake professionals are working to distribute the knowledge that is already available, and that they are applying research to find economical engineering solutions for these important and complex problems. Greater involvement of the earthquake engineering community in this monumental undertaking has the potential to greatly reduce the vulnerability of developing countries.

My poster highlights current efforts to disseminate earthquake safety knowledge in high risk developing countries and outlines methods for moving forward. The three sections are: 1. EERI's involvement in efforts to improve construction practices in seismically-prone areas of the world through the World Housing Encyclopedia, 2. The best practices of organizations working currently on these issues, 3. A vision for future action and involvement of the international community of earthquake professionals to decrease earthquake risk worldwide.

Through the World Housing Encyclopedia, EERI has been involved in promoting earthquake resistant technologies in developing countries. In late 2011, the website was relaunched in a more user-friendly format, and many new tutorials have already been completed or are in the works. The site is steadily becoming a dynamic, centralized hub of information and valuable documents, including: construction type overviews, summary reports for over 100 housing types, and construction tutorials in confined masonry, adobe, stone masonry, and reinforced concrete frame.

It is also vital to give recognition to the organizations and individuals that are working in this challenging field. The second section of my poster highlights examples of innovative programs and technologies that are working towards achieving earthquake resiliency in vulnerable countries.

Stepping up to stop the trend of increasing global earthquake risk is imperative. The third part of my poster outlines the many opportunities for the involvement of earthquake engineering professionals to help decrease risk worldwide. The vision is broad, and thus there are a wide variety of ways to contribute. One way is through the pursuit of research seeking innovative and economical solutions for vulnerable construction methods, such as adobe and unreinforced masonry. Another avenue is aiding in the growth of the World Housing Encyclopedia as a global hub for information and collaboration for passionate professionals and organizations. Yet another is through the creation of opportunities to get young professionals from across the world involved in solving these important, challenging, and interesting problems.
Case Study of AASHTO–LRFD Seismic Provision Changes on Substructure Demands for a Composite Deck Bridge in North Mississippi

Nitin Pangavane, Graduate Assistant
Chris Mullen, Associate Professor
The University of Mississippi, Department of Civil Engineering, 106 Carrier Hall, University, MS 38677 USA

(Email: nitin.pangavane@gmail.com; cvchris@olemiss.edu)

Abstract

In 2008, the Federal Highway Administration made it mandatory for state departments of transportation to use the AASHTO (American Association of State Highway and Transportation Officials) LRFD (Load and Resistance Factor Design) highway bridge design specification in order to be eligible for federal funds for infrastructure projects. The 2008 AASHTO LRFD bridge specification contained significant changes in the seismic provisions including increased ground motion intensity with spectral based maps replacing peak ground acceleration maps. A case study is presented of an interstate highway bridge located in north Mississippi of the potential effect of such changes on the design shear forces transmitted by the composite deck superstructure to the substructure elements.

The study provides a systematic attempt to explore the influence of various AASHTO-LRFD specifications from 1994 to 2007 revised (2008) on the process of seismic analysis and calculating earthquake load on the composite deck bridges. To understand the impact of the different AASHTO specifications on the seismic analysis procedure, an existing bridge has been selected that was designed prior to the introduction of LRFD specification. This bridge site is located within the influence of the New Madrid fault at a distance of 44 miles from the southern tip of New Madrid fault and expected to be potentially susceptible to the earthquake hazard.

Data obtained from Mississippi Department of Transportation (MDOT) is used to develop a three dimensional (3-D) model of the bridge using commercial software developed specifically for seismic analysis. AASHTO recommends performing response spectrum analysis using complete quadratic combination, so the model is used to perform the required analysis including generation of the earthquake loads. Model analysis results are validated against output from a matrix analysis program created by the first author for first mode response.

Important observations are that the procedure for defining the response spectrum recommended by the 2008 AASHTO-LRFD specifications is very different from that in the previous AASHTO Standard (non-LRFD) specification. Peak ground acceleration (PGA) estimated at the case study site using the 2008 AASHTO LRFD specification is almost hundred percent more than that estimated using the previous AASHTO Standard specification.

The analysis concludes that the earthquake bearing shear forces would increase by 34% if the existing bridge were designed using the newer LRFD provisions. The increased forces could potentially have a significant impact on the expected performance of structures designed to the older specifications.
Inversion algorithms for surface waves are based on minimizing the error between experimental and theoretical dispersion curves. The velocity profile associated with the dispersion curve with minimum error is considered representative of the real condition in situ. Regarding the two potential problems associated with inversion methods, namely non-uniqueness and instability, it is probable that the result of the inversion process is far from reality. There are limited methods by which we can suspect a profile to be different from expected results, such as prior knowledge about soil conditions. In general, all methods use additional information along with analogy between dispersion curves. It is quite intuitive that imposing boundaries on shear-wave velocity of soil layers or on the difference of shear-wave velocity between two consecutive layers can help partially overcome the two problems mentioned above. By avoiding the unrealistic velocity profiles that are involved in the inversion process, there will be numerical improvements.

On the other hand, it has been shown that consideration of higher modes of propagation improves the reliability of inverted velocity profiles at a level different than imposing numerical boundaries. Using a genetic algorithm scheme as the engine for the inversion process, we bring more information in, along with a multi-modal comparison of dispersion curves and numerical boundaries. The idea is to compare the synthetic seismogram from velocity profiles in each generation with the seismogram recorded onsite. This comparison will be used to eliminate a percentage of profiles in each generation that have a high difference between their synthetic and recorded seismograms. Seismogram comparison can be established based on the arrival time or the amplitude of first arrival, in which the former is more sensitive to the velocity of soil profile layers and the later parameter is probably more sensitive to attenuation properties of the soil layers. Two sets of synthetic data are analyzed using this method, and results are discussed to illuminate the potential strength or weakness of the proposed technique.
ABSTRACT

It has been proven that soil-foundation-structure interaction is beneficial to the behavior of structural systems under earthquake loading. This poster presents the results of three-dimensional nonlinear seismic soil-foundation-structure interaction analyses of integral abutment bridges with deep foundations. The analyses are performed using nonlinear finite element models in the computer program ANSYS. Integral abutment bridges are structures where the superstructure (deck and girders) and substructure (abutment) move together to accommodate the required translation and rotation. Integral abutment bridges are more economical than other bridges over their life span due to lower construction cost and easier maintenance. Both fully integral abutment bridges and semi-integral abutment bridges will be investigated. In the United States, there are more than 9000 fully integral abutment bridges and 4000 semi-integral abutment bridges. A fully integral abutment bridge is a structure where the superstructure is directly connected to the substructure. A semi-integral abutment is a structure where only the backwall portion of the substructure is directly connected with the superstructure. The most common type of deep foundations used in bridge abutments are HP driven piles because of their constructability, versatility with regard to subsoil conditions, and settlement controllability. During an earthquake the soil’s stiffness plays an important role in load distribution when the soil, piles, abutment and superstructure act as a combined system to resist the seismic loads. Due to the lack of knowledge on soil-structure interaction under earthquake loading, the real world design procedures are kept simple and conservative. While some researchers have investigated the soil-foundation-structure interaction in the bridge longitudinal direction using different approaches, the interaction mechanism in the bridge transverse direction is still unknown. There are more uncertainties in the bridge transverse direction because of the unconfined embankment where the mobilization of the soil’s passive pressure is questionable. In this poster, the dynamic soil-foundation-structure interaction mechanisms of bridges in both longitudinal and transverse directions will be investigated through the use of 3-D finite element models. The effect of HP pile orientation on the bridge seismic behavior will also be investigated. The numerical models will realistically simulate the soil-pile-abutment-wingwall-superstructure system subjected to seismic loads. Nonlinear Winkler springs will be employed to model the non-elastic backfill soil behavior, where the stiffness of springs is a function of the displacement or the rotation of the abutment wall. The analyses will provide theoretical support to the design practice.
The proposed research is concentrated on developing a method to predict the dynamic behavior of mine tailings dams under earthquake loading. Tailings dams are a by-product of coal mining and processing activities. Mine tailings dams are prone to instability and failure under seismic loading as a result of the behavior of the tailings. Due to the existence of potential seismic sources in close proximity to the coal mining regions in the United States, it is necessary to assess the post-earthquake stability of these tailings dams.

To develop the aforementioned methodology, 34 cyclic triaxial tests were carried out on undisturbed mine tailings specimens from two sites in Kentucky. Also, vane shear tests were performed on all of these samples following the triaxial tests. Therefore, the liquefaction resistance and the residual shear strength of the specimens were measured.

In Figure 1, the laboratory cyclic strength curves for the coal mine specimens are presented. In this figure the relationship between density, cyclic stress ratio, and number of cycles to liquefaction is demonstrated.

Since the samples were tested using the cyclic triaxial procedure, the cyclic stress ratio (CSR) is calculated based on the initial effective confining pressure and the cyclic stress amplitude [i.e., \( (CSR)_{tx} = \sigma_{dc}/2\sigma_{3c}' \)]. The samples from the Big Branch impoundment were generally loose samples.
with void ratios values ranging from 0.45 to 0.81 and averaging about 0.63. The Abner Fork specimens were dense samples with the void ratio ranging from 0.44 to 0.52 and averaging approximately 0.50. Also, the Abner Fork specimens were older and slightly cemented. The data suggest that the number of loading cycles required to initiate liquefaction in mine tailings, \( N_{L} \), decreases with increasing CSR and with decreasing density. This trend is similar to what is typically observed in soil.

On a number of selected specimens, a series of small-strain cyclic triaxial tests were performed. Consequently, for these specimens shear modulus was measured and modulus reduction curves were created. The variation of shear modulus over the range of different cyclic shear strains is presented in Figure 2. This set of data in conjunction with the maximum shear modulus recorded in the field, \( G_{\text{max}} \), will be used to find the linear cyclic threshold shear strain, \( \gamma_{cT} \), for mine tailings. As can be seen, the Abner Fork specimens have a different trend than the Big Branch specimen. This may be attributed to the higher density, age, or cementation of the Abner Fork samples.

The data obtained during the laboratory experiments will be correlated to existing geotechnical field data from the two sites. These field methods include SPT blow count (\( N \)), CPT cone tip resistance (\( q_{c} \)), and shear wave velocity (\( v_{s} \)), to estimate cyclic resistance ratio (CRR). Ultimately, practitioners will be able to use these correlations along with common state-of-practice geotechnical field methods to predict cyclic resistance in fine tailings to assess the liquefaction potential and post-earthquake stability of the impoundment structures.

**KEYWORDS:** mine tailings, liquefaction, cyclic stress ratio, modulus reduction curves

![Figure 2: Modulus reduction curves for mines tailings](image)
Implementation of the Genetic Algorithm and Neural Networks in Generation of Artificial Seismic Accelerograms

Alireza Shahjouei, Ph.D. Candidate, EERI Student Member, shhjouei@memphis.edu

And

Shahram Pezeshk, Ph.D., Professor, spezeshk@memphis.edu

Department of Civil Engineering
The University of Memphis

Despite the existence of an ensemble of earthquake records, the generation of artificial earthquake accelerograms has been a promising solution in the lack of appropriate time histories at a given site to be used in the time history analysis. Selection of an appropriate method from several seismological and engineering approaches has been a challenging subject for engineers. To avoid the complexity of the modeling of the faults (for low-frequency part of traces), various building and bridge specifications suggest applying the spectrum-compatible accelerograms for the purpose of the seismic analysis and design of structures in a broadband frequency range. In this study, we propose the following two new proposed engineering procedures, and statistically appraise them: (1) the hybrid evolutionary neural network method which uses the genetic algorithm, the neural network, the wavelet packet transform, and the principal component analysis; (2) the evolutionary neural network method, which is simpler and the more accurate procedure compared to the hybrid evolutionary-neural network method, and utilizes the wavelet transform and the genetic algorithm. The three main functions of the spectrum compatibility, the stochastic diversity of generated traces, and the computational efforts have been considered in the evaluation of various procedures to illustrate their strengths and weaknesses.
LIQUEFACTION POTENTIAL MAPPING OF THE CHARLESTON QUADRAGLE, SOUTH CAROLINA

Lawrence A. Simonson¹, Ronald D. Andrus², and Tahereh Heidari³

ABSTRACT

Charleston, South Carolina was the location of a magnitude 7 earthquake on August 31, 1886. This was the most damaging historic earthquake to occur in the southeast United States, causing 124 deaths and approximately $460 million (2006 dollars) in damage. A prominent source of damage was ground failure from liquefaction of loose, saturated soils that are common in the Charleston area.

This poster presentation outlines the methodology being used to develop a liquefaction potential map of the Charleston 7.5-minute quadrangle. All calculations are being done using an ArcGIS software package. This software allows the user to perform raster calculations and view the relationships between various layers. ArcGIS layers used in the calculations include: (1) a digital surficial geology map of the Charleston quadrangle by Weems et al. (2011); (2) a composite depth to top of the Tertiary-age Cooper Marl map created from Weems and Lemon (1993), Fairbanks et al. (2008), and topographic information from the South Carolina Department of Natural Resources GIS Data Clearinghouse; (3) an average shear wave velocity in the top 30 m ($V_{S30}$) map created from the surficial geology map, the depth to top of Marl map, the shear wave velocity statistics published in Andrus et al. (2006), and available shear wave velocity profiles; (4) a soft-rock peak ground surface acceleration map for a 475-year return period created from values obtained from the U.S. Geological Survey Earthquake Hazards Program website; and (5) a site-adjusted peak ground surface acceleration ($a_{max}$) map created from the soft-rock acceleration map, the $V_{S30}$ map, and site factors based on $V_{S30}$ published in Aboye et al. (2011).

Liquefaction potential curves from Heidari (2011) are used to characterize areas covered by the 100,000-year-old Wando Formation, the younger Silver Bluff beach sands, and the artificial fills. Liquefaction potential is expressed in terms of the liquefaction potential index (LPI) as defined by Iwasaki et al. (1978). An LPI value of 5 is assumed as the threshold for liquefaction induced ground failure. The liquefaction potential curves for LPI > 5 are combined with the surficial geology map, the top of Marl Map, and the $a_{max}$ map to calculate liquefaction potential. A groundwater table depth of 2 m is assumed for areas covered by the Wando Formation and 1 m for all areas covered by younger materials.

The preliminary liquefaction potential map is divided into regions of 0-20%, 21-40%, 41-60, 61-80%, and 81%-100% probability of LPI > 5. The preliminary map agrees well with previous liquefaction potential maps developed by Hayati and Andrus (2008) for the Charleston Peninsula and Heidari and Andrus (2010) for the town of Mount Pleasant based on the 1886 Charleston earthquake. Liquefaction potential maps can be used for regional earthquake hazard planning and mitigation studies, and for identifying areas where specific investigations for liquefaction hazard are needed.

This research is being supported by the National Science Foundation (NSF) under Grant No. NSF-1011478. The views and conclusions contained in this document are those of the writers and should not be interpreted as necessarily representing the official policies, either expressed or implied, of NSF.

¹Graduate Fellow, Glenn Dept. of Civil Engineering, Clemson University, Clemson, SC 29634 (presenting author).
²Professor, Glenn Dept. of Civil Engineering, Clemson University, Clemson, SC 29634.
³Geotechnical Engineer, MWH Americas Inc., Portland, OR, 97239; formerly, Graduate Research Assistant, Glenn Dept. of Civil Engineering, Clemson University, Clemson, SC 29634.
Abstract: Highway bridges by their nature are susceptible to earthquake damage and are often founded on poor soils at river and harbor crossings. Recent damage to highway bridges has confirmed their vulnerability and increased awareness of the importance of soil-pile-abutment interaction in their seismic response. During an earthquake, longitudinal inertia loads push the abutment and pile foundations against the backfill (level ground) at one end of a bridge and pull the abutment away from the backfill at the other. The stiffness of the foundation is markedly different in these two cases, not only because the backfill is engaged in one case and not the other, but because the ground beneath the end span adjacent to the abutment, is generally sloping ground (Figure 1) and the piles have a reduced stiffness when being pulled in the direction of the slope. Slope angles of the order of 45° are possible.

Whereas there is a great deal of information in the literature about the lateral stiffness of piles in level ground there is very little data on their stiffness in sloping ground. A common approach for modeling piles in level ground is to represent the complexity of the soil profile, the type and arrangement of piles, and nonlinear soil behavior by equivalent, lateral, pile-head springs with stiffness coefficients given by charts. These coefficients have been calibrated against rigorous numerical modeling and field observations. But there does not appear to be similar data for piles in sloping ground.

This paper describes a systematic analysis of laterally loaded single long piles located at the crest of slopes with increasing gradients using Deep Foundation System Analysis Program (DFSAP) based on the strain wedge model. Reduction factors for lateral stiffness were found for increasing angles of slope and various eccentricities of the lateral load above the ground surface. They were also found for typical sand and clay profiles. These factors were normalized against results for the same pile and eccentricity in level ground. Alternatively, as shown in Figure 2, equivalent eccentrically loaded piles in level ground are found that have the same stiffness as those in sloping ground, thus enabling existing design charts to be used for piles in sloping ground.
The results show that the lateral response of a pile foundation is different under a pushing load (towards level ground) than under a pulling load (away from level ground and towards the slope). Reductions in stiffness up to 58% are reported. Reductions of this magnitude should be included when using equivalent springs to model soil-abutment-bridge interaction to represent foundation effects. Such models are clearly nonlinear and iterative solutions may be necessary if equivalent linear methods are being used for analysis.

Figure 1. Three-span bridge with sloping ground at pile-supported abutments.

Figure 2. Equivalent analytical model of laterally loaded pile in sloping ground to level ground.
Can one use an existing fault map to accurately determine maximum magnitude for earthquakes in a region? It is generally assumed that fault traces constrain the location, orientation, and size of future earthquakes. Yet many earthquakes, like the M7.3, 1992 Landers, CA and M7.9, 1999 Denali, AK earthquakes, rupture beyond previously mapped traces or are transferred onto a splay fault. Other events, like the M6.7, 1994 Northridge, CA, the M7.0 2010 Darfield, New Zealand, and M6.3 2011 Christchurch, New Zealand earthquakes, serve as additional evidence that large earthquakes can and do occur where no fault had been identified. This is important because regressions between magnitude and rupture dimensions are based on post-earthquake maps of the surface rupture and instrumental data. These regressions are then employed to estimate magnitude of future earthquakes, using existing fault maps. Since future magnitude estimates are based on the possible extent of a rupture, and are typically guided by the geometry of the fault trace or historical ruptures rather than the rupture trace, it is valuable to examine the relationship between mapped faults and earthquakes. My study examines the relationship between earthquakes and pre-existing fault maps, extends Wesnousky's recent fault compilation [2006], and expands Black's [2008] fault-jumping probability models. I also include additional earthquakes for which surface rupture maps have recently been published.
CHARACTERIZATION OF POLYMER LINED DUCTILE IRON PIPES SUBJECT TO SEISMIC INDUCED GROUND DEFORMATIONS

Brad P. Wham
Graduate Research Assistant
Cornell University, EERI Cornell Student Chapter

This document outlines experimental and analytical research initiatives and results concerning underground pipelines currently being conducted in correlation with the Network for Earthquake Engineering Simulation (NEES) facility at Cornell University. Of the 1.3 million km of water distribution systems throughout the United States, approximately 60% are comprised of cast iron pipe with an average age exceeding 90 years. There is a dire need to repair and rehabilitate these systems while making them less susceptible to earthquake induced ground deformations. To avoid the complications of expensive excavation and replacement of these vital systems, the introduction of pipe lining technology has presented an effective means of repairing such infrastructure in situ. Preliminary testing has shown that polymer liner technologies provide a valuable repair technique to repair cracked or broken pipelines. However, little experimental testing has been conducted which quantifies the additional resistance liners provide pipelines against ground deformations such as those experienced during seismic events. Researchers from Cornell University, University of Buffalo, and California State University- Los Angeles have teamed up with Los Angeles Department of Water and Power (LADWP) and corporate sponsors to collaborate on a National Science Foundation funded research initiative addressing the seismic performance of underground pipelines equip with polymer liners.

Standard ductile iron pipes of 15.2 cm (6 in.) nominal diameter were chosen to represent cast iron pipelines. The ductile iron material provides a deformable medium that will not produce dangerous, brittle fractures during testing. In order to fully characterize the lined pipe composite, individual testing of the ductile iron pipe was necessary. A series of experiments were developed to characterize the bell and spigot push-on joints which join two segments of pipe. Leakage of internally pressurized water was used to develop a failure criterion for the joints. Combinations of axial displacement and rotation of the joint were identified as the mechanisms which lead to joint leakage and potential system failure. Two segments of pipe were joined and subject to a four-point bending test with the joint located at the center of the test setup. The pipe was pressurized at approximately 350 kPa (50 psi) of internal pressure, a prescribed axial displacement was presented at the joint, and the joint was rotated until a leakage rate greater than 1 drop per second was achieved. Specimens were tested at various initial axial displacements to develop correlations between axial displacement, rotation, and applied moment.

This procedure provides valuable results concerning the behavior of ductile iron, push-on joints. At initial displacements greater than 5.1 cm (2 in.) leakage was achieved at rotations less than 1 degree with no applied force besides the pressurized pipe’s self weight. As the spigot is inserted into the bell, greater rotations and additional force were required. At 3.5 cm (1.4 in.) of initial displacement the rotations necessary to cause leakage were constant at approximately 16 degrees until an axial displacement of 1.5 cm (0.6 in.). Beyond this point metal binding within the joint was present and the applied force and rotation increased dramatically. At an initial axial displacement of 0.63 cm (0.25 in.), rotation reached 27 degrees under a moment of 2650 kN-cm (235 kip-in). At these significant values plastic deformations of both the bell and spigot were recorded yet leakage did not occur. These results document drastic changes in joint behavior based on axial displacements imposed by deformations which can be experienced during seismic events.

The results of these experiments are currently being used to design and implement full-scale, permanent ground rupture experiments on lined and unlined ductile iron pipe specimens. The NEES facility at Cornell University includes a 100 metric ton capacity soil basin with a 50 degree fault located at its
center. One box can displace approximately 1.2 m (48 in.) the respect to the other producing soil displacements similar to those experienced along a fault during an earthquake. Unlined tests consisting of three pipe segments (two joints) have been preformed to characterize the pipe’s behavior without liner. Experiments on lined specimens with the same configuration will be conducted in the near future and results are expected to be available in March of 2012.

In addition to experimental testing, analytical finite element models have been created to replicate each large scale experiment. A three-dimensional joint rotation model will be prepared and validated with strain gage data gathered from forced joint rotation tests. Preliminary fault rupture models have been built to assist in the design of full scale tests. Additional detail will be added to the models as data becomes available, constantly moving toward the goal of producing a complete three-dimensional model of the fault rupture experiment. Once validated, this model has the potential to drastically enhance our understanding and ability to predict the behavior of lined and unlined pipeline systems subject to earthquake induced ground deformations.
EXPERIMENTAL INVESTIGATION ON COMBINED LIVE LOAD AND SEISMIC LOAD EFFECTS ON RESPONSE OF A HORIZONTALLY CURVED BRIDGE

Hartanto Wibowo¹, S.M.EERI, Danielle M. Smith¹, Ian G. Buckle², M.EERI, and David H. Sanders³, M.EERI

1. Graduate Research Assistant, e-mail: hwibowo@unr.edu
2. Foundation Professor and Director of Center for Civil Engineering Earthquake Research, e-mail: igbuckle@unr.edu
3. Professor, e-mail: sanders@unr.edu
Department of Civil and Environmental Engineering, University of Nevada, Reno, MS 0258, Reno, NV, 89557

Abstract

Although earthquake reconnaissance reports have shown that live load is present during earthquake events, design procedures for earthquake-resistant bridges in most countries do not require the simultaneous presence of live load and earthquake load to be considered. This decision is based on two major assumptions. First, it is unlikely that the full design live load will be on the bridge at the time of the design earthquake, and second, the seismic response of a bridge is dominated by its dead load and live load inertial effects are negligible by comparison. However, for bridges in urban areas where congestion is a frequent occurrence, some fraction of the design live load (usually taken as 50%) is now recommended to be included with the dead load when computing gravity load effects, according the current AASHTO Design Specifications. But this recommendation applies only to gravity load effects and not to inertial effects.

The omission of inertial effects in design is the result of a prevailing attitude that the suspension system of a heavy vehicle acts as a tuned mass damper and reduces the motion in the bridge. It is therefore believed to be conservative to ignore these effects. But in fact little is understood about the dynamic interaction between heavy vehicles and bridge systems during strong shaking and there is no hard evidence that the tuned mass damper model is universally applicable. It is equally possible that the added weight increases the inertial loads in the bridge and the corresponding displacements and forces.

Currently, very little research has been conducted to resolve the live load issue. Previous work has shown that live load can either have a beneficial or an adverse effect on the structure during earthquake shaking. However, there are still uncertainties about the reason why this is so and there has been no large-scale experimental work to investigate the effects of live load on the seismic response of bridges prior to this experiment.

For this experiment, the prototype bridge was designed for a rock site in AASHTO’s Seismic Zone 3, with a 1,000-year spectral acceleration at 1.0 sec ($S_1$) of 0.4 g. Under this Design Earthquake (DE), the bridge is expected to be damaged but not collapse. The record selected as the input motion for the experimental studies was the Sylmar record from the 1994 Northridge Earthquake near Los Angeles, scaled to have the same spectral acceleration at 1.0 sec. A scale factor of 0.475 was therefore applied to both the North-South and East-West time histories of ground acceleration from this station.

A three-span, curved bridge model was tested on the NEES Shake Table Array in the Large-Scale Structures Laboratory at University of Nevada, Reno. This 0.4-scale model has a steel plate girder superstructure, single-column reinforced concrete substructures, and seat-type abutments. The bridge model has a total length of 145 ft, a total width of 12 ft, and subtended angle of 104°. Each bent has a single circular column. The column height is 7 ft - 8 in with a diameter of 24 in. The superstructure is a three-span, three-girder steel bridge with concrete deck. The superstructure is supported by fixed
(rotation-only) pot bearings at the bent locations and sliding bearings at the abutments. Moreover, shear keys are provided at the abutments to restrain movement in the radial direction during small amplitude earthquakes, but are designed to fail at higher events to protect the abutment foundations against damage. The closest possible vehicle to match the modeling requirements was found to be the Ford F-250 and six of these vehicles were placed on the bridge deck as the live load for the bridge. The test protocol followed for this experiment started with 10% of the DE and then the motion was increased in successive increments to 20%, 50%, 75%, 100%, 150%, 200%, 250%, 300%, and 350% of the DE. Before each run, a series of white noise excitations were run to characterize the system’s dynamic properties.

The experimental results from this experiment were compared with the results from the experiment without live load. One of the parameters to quantify the effect of live load is the displacement of the columns. From the results and compared to the case without live load, the maximum displacement is less when live load is present. It is also important to note that during the no-live load case, the shear keys at the abutment failed during the 75% DE run, whereas it took a stronger ground motion (100% DE) to fail these keys when live load was present, i.e. the live load reduced the forces in the shear keys at the same level of excitation. This observation shows that at these levels of shaking, the existence of live load caused less demand in the column and reduced the radial shear forces at the abutments. The damage in the column was also found to be minor and not as severe as for the no-live load case. On the other hand, observations from the higher amplitude runs, after the shear keys at the abutments had failed, show maximum displacements that are almost the same in the two cases. At these levels of shaking (and after the keys had failed), the live load exercises the columns to a similar extent and the maximum displacements at the top of the columns became closer to the no-live load case. Furthermore, residual displacements in the columns for the live load case are about double of those without live load. These larger residual displacements indicate greater distress to the columns due to the presence of the live load.

From the experimental results with and without live load, some preliminary conclusions can be drawn. In lower amplitude motions, when the shear keys were still intact, live load gave an apparent beneficial effect. In higher amplitude motions, after the abutments were free to move, the effect due to live load was less significant. This may be due to (1) the deteriorating nature of the bridge under increasing levels of shaking and thus a changing vehicle-to-bridge frequency ratio, or (2) the changed configuration of the bridge when the abutments were released in the radial direction after the shear keys failed, or (3) both of the aforementioned. Studies are continuing to better understand this phenomenon.
Thursday, April 12, 2012
6:00 p.m.

POSTER SESSION: RESEARCHERS/PRACTITIONERS

Azlan Adnan and Hendriyawan
*Development of Peak Ground Acceleration Map of East Malaysia for Design Response Spectra of Bakun Dam*

Yu Bao and Andrew Rietz
*Numerical Simulation and Centrifuge Modeling of Sand Liquefaction*

Mark Benthien
*Great ShakeOut Earthquake Drills: Awareness to Action*

Oliver S. Boyd and Chris H. Cramer
*Estimating Earthquake Magnitudes from Reported Intensities in the Central and Eastern United States*

Chris H. Cramer and Oliver S. Boyd
*Constraints on the 1811-1812 New Madrid Earthquake Magnitudes from a Direct Comparison of Intensity Observations with Known M7 Earthquakes*

Shirley J. Dyke, Bozidar Stojadinovic, Pedro Arduino, Maria Garlock, Nicolas Luco, Julio a. Ramirez, and Solomon Yim
*Future Research Needs in Earthquake Engineering in the U.S.: The 2020 Vision Workshop*

Wael M. Hassan and Jack P. Moehle
*Seismic Vulnerability of Corner Beam-Column Joints in Existing Concrete Buildings*

Tim Huff
*Ground Motion Selection and Modification for Nonlinear analysis of Isolated Bridges in the NMSZ*

Steven C. Jaumé and Norman S. Levine
*Learning from the Earthquakes of Others: The 2010-2011 Christchurch, New Zealand Earthquakes as Analogs for Future CEUS Earthquakes*

Kyrstle S. Miner, Steven C. Jaumé, and Norman S. Levine
*Using New Tools to Learn from an Old Earthquake: Charleston, South Carolina 1886*

Erol Kalkan, Jon P.B. Fletcher, William Leith, and Krishna Banga
*USGS Real-time Structural Health Monitoring of Instrumented VA Medical Center Hospital Buildings in Memphis, Tennessee*

Tracy Kijewski-Correa, Alexandros A. Taflanidis, Dustin Mix, and Ryan Kavanagh
*The 2010 Haiti Earthquake: Seismic Vulnerability and an Empowering Model for Residential Housing Reconstruction*

*PERPETUATE: A European Research Project on the Seismic Protection of Cultural Heritage*

S. Lagomarsino, S. Cattari, and C. Calderini
*A Performance-Based Procedure for the Earthquake Protection of Masonry Historical Structures*

Yun (John) Liao and Jorge Meneses
*Comparison of SEA99 and NGA BA08 GMPEs with Ground Motions from the 2010 El Mayor-Cucapah and 1979 Imperial Valley Earthquakes*
Natasha McCallister, Robert A. Williams, Walter Mooney, and Richard Dart
*U.S. Geological Survey New Madrid Bicentennial Information Products*

Althea Rizzo
*Planning for the Possible, not the Probable, Saves Lives*

Robert Smalley
*Intraplate Earthquakes: How Well does the Elastic Rebound Paradigm Serve to Explain Them*

Ganesh Kumar Venayagamoorthy and Karthikeyan Balasubramaniam
*Impact of Earthquakes on the Electricity Infrastructure*

*The St. Louis Area Earthquake Hazards Mapping Project*

Ivan Wong, Fabia Terra, Douglas Bausch, Jesse Roselle, Paul Morey, Kenneth Rukstales, John Ebel, Laurence Becker, and Edward Fratto
*HAZUS Analyses of Eleven Scenario Earthquakes in New England*
DEVELOPMENT OF PEAK GROUND ACCELERATION MAP OF EAST MALAYSIA
FOR DESIGN RESPONSE SPECTRA OF BAKUN DAM

Azlan Adnan, Professor of Structural Earthquake Engineering, Engineering Seismology and Earthquake Engineering Research (e-SEER), University of Technology Malaysia.
Hendriyawan, Senior Lecturer, Institute of Technology Bandung, Indonesia.

East Malaysia consists of two big states, Sabah and Sarawak located on the east side of the Borneo Island. Sabah is located at the highest seismicity region of the country with Peak ground Acceleration (PGA) values of up to 0.12g for 500 years return period. However, Sarawak is at the moderate level of 0.08g. Bakun dam, which is situated on the Balui River in the most interior area of Sarawak, is a $4.6 billion hydroelectric dam project that will flood an area of virgin rainforest the size of Singapore and generate 2,500 megawatts of power. The objectives of the study are to obtain the PGA level of ground motion and to develop design response spectra of the dam structure. Two levels of ground motion hazard, which are Operation Basis Earthquake (OBE) and Maximum Credible Earthquake (MCE), were evaluated for the site. In this project ground motion level for OBE was analyzed using Probabilistic Seismic hazard Assessment (PSHA) method while MCE level was performed using PSHA and Deterministic Seismic Hazard Assessment (DSHA) methods. In general, the methodology consists of four steps, which are (1) developing the seismotectonic model, (2) selecting appropriate seismic hazard parameters and attenuation relationship, (3) determining the seismic hazard deterministically and probabilistically, and (4) generating time histories. The geometries of the seismotectonic model were constructed based on earthquake spatial distributions and regional tectonic setting of Bakun Dam. The historical earthquake data were compiled from local and international institutions such as Malaysia Meteorological Department (MMD), USGS, ISC, and individual catalogs. The combined catalogs that covers an area from 105°E to 125°E longitude and from 10°S to 10°N latitude, list about 7039 earthquake events occurred during more than 100 years period of observation. All data from earthquake catalogs were processed using statistic principles before it is used to analyze seismic risk. These procedures are performed in order to minimize bias or systematically error and to obtain reliable results. The earthquake catalogues have been declustered in order to separate main shock and accessories shock events using algorithm proposed by Gardner and Knopoff (1974). The algorithm eliminated more than 50% of earthquake data. The completeness analysis was performed in order to assess the completeness level of an earthquake catalog. The seismotectonic models covered for all fault source zones within radius of 500 km from Bakun Dam. The fault sources are Palu-Koro, Sulu, Tarakan Basin, Kutai-Mahakam Basin, and Walanae. The background source was used in this analysis to accommodate uncertainty associated with unknown faults around site region. The background seismicity has been modeled as a fault source with radius of 100 km from Bakun Dam. Analysis of seismic hazard parameters for each source zone used in this analysis were calculated by the least square, Weichert (1980), and Kijko and Sellevoll (1989) methods. The seismicity b-values in this study are within the range 0.7 to 1.2. Based on the comparative study regarding attenuation relationships, three attenuation functions are used in seismic analysis, which are Campbell (2003) attenuation for calculating distant earthquakes and Sadigh et al (1997) and Boore et al (1997) for short distance earthquakes (less than 100 km). Based on the deterministic analysis, the maximum probable PGA is 98.7 gal or 0.099 g produced by Palu-Koro Fault at a distance of 252 km from Bakun. On the other hand, logic trees were used in probabilistic analysis in order to allow uncertainty in selection of models for attenuation, recurrence rate, and maximum magnitude to be considered. The peak ground accelerations at Bakun, calculated for 150, 500, 1000, 2,500, 10,000 year return periods are respectively 30.90, 45.41, 54.50, 66.65, and 86.82 gals. The deaggregation plot shows the most likely magnitude-distance combination to provide the level 150-year return period of motion (the mode), was from an earthquake of Mw 5.25 at a distance 75 km and the mean contribution was from a magnitude, Mw, 5.9 at a distance of 157 km. The deaggregation plot for the 500 and 10,000 year ground motions show the major contribution from the
An earthquake of $M_w$ 5.75 at a distance 75 km. The mean contribution for 500 and 10,000-year ground motions are given by $M_w$, 6.0 at a distance of 158 km and magnitude, $M_w$, 6.5 at a distance 181 km, respectively. Six artificial time histories were produced in this study. The artificial motions were generated by modifying actual ground motion records. The actual ground motions from worldwide earthquakes were selected based on their similarity of their characteristics such as magnitude, distance, and mechanism, and then the spectrums were scaled for matching them with the spectrums from probabilistic analyses. The spectral accelerations from real time-histories data were adjusted within the range 0.5 to 2.0 Hz to the target spectral acceleration. Three time histories data recorded on the bedrock were selected for adjusting the spectrums to spectral accelerations for 150, 500, and 10,000-year return period. Each return period produced two time histories that represent most likely and mean contribution to particular hazard levels. The PGA values from this study were calculated for the bedrock. Local site effects strongly influences the characteristic of ground surface motions, i.e. peak acceleration amplitudes and shapes of response spectra. Geotechnical factors often exert a major influence on damage patterns and loss of life in earthquake events. The local site effects still need to be investigated, in order to predict the effect of the earthquake ground motion at the surface.
NUMERICAL SIMULATION AND CENTRIFUGE MODELING OF SAND LIQUEFACTION

Yu Bao¹ and Andrew Rietz²

1: Assistant Professor, Civil Engineering Technology, Rochester Institute of Technology
2: Research Assistant, Student, Civil Engineering Technology, Rochester Institute of Technology

ABSTRACT

The mechanical behavior of saturated soil is mainly governed by the interaction between the soil skeleton and the pore fluid, and this interaction may lead to significant loss of strength known as liquefaction under seismic loading conditions. This poster presents the application of a kinematic cyclic plasticity model in the simulation of sand liquefaction and the validation of the numerical study by centrifuge-based experimental results. Strong ground motion induces a tendency for volume change and the soil-skeleton dilation/contraction effects cause a progressive pore water pressure build-up as well as cyclic pore pressure variations depending on the drainage condition and soil permeability. The development of excess pore pressures may lead to soil softening, loss of stability and bearing failures. The ability of the constitutive model to predict permanent volume changes during cyclic loading is a major factor in seismic analysis. In this study, a kinematic and cyclic plasticity model based on the concept of fuzzy-set plasticity is implemented to simulate realistic sand behavior during unloading and reloading cycles. The model is not only able to capture the general nonlinear behavior of soil, but also essential soil characteristics, such as confinement dependency, soil skeleton contraction and dilation, critical state soil mechanics features, and pore pressure build-up. The accuracy of numerical analysis needs to be validated. However, due to the difficulty of predicting when and where a major earthquake will occur and the general random nature of these events, most field liquefaction failures have occurred at sites which were not instrumented. The advent of centrifuge modeling that incorporates scaled dynamic events brought to light the development of proper numerical techniques for simulating the consequences of soil liquefaction. Centrifuge testing creates stress conditions in the model that closely simulate those in the full-scale prototype, so that the behavior of the model can approximate that of the prototype. In this research, a servo-controlled electro-hydraulic shake table is mounted on the swing platform of the centrifuge, which could be operated inflight to produce earthquake-like motions. The centrifuge and the shake table are used to test the model of a layer of 10 m thick in a prototype liquefiable soil stratum. The pore water pressure and acceleration at different elevations are measured and the settlement of soil surface is also recorded. The model is constructed at 40-th scale, and the centrifuge is spun at 40 g to simulate appropriate prototype behavior. The model is saturated with a viscous liquid comprising of a metolose solution having a viscosity 40 times greater than the viscosity of water. This ensures appropriate scaling between dynamic and diffusion phenomena of the given g-level. Absorbing boundaries using cork plates in the shaking direction are adopted to simulate the infinite boundary conditions presented in the prototype. Data from centrifuge modeling and numerical simulation are compared. The computed results show good agreement with the experimental results.
Great ShakeOut Earthquake Drills: Awareness to Action

Mark Benthien
Director for Communication, Education, and Outreach
Southern California Earthquake Center

On October 20, 2011, “Great ShakeOut” earthquake drills were held in California, Nevada, Guam, Oregon, Idaho and British Columbia, involving more than 9.5 million participants who practiced how to protect themselves during earthquakes (“Drop, Cover, and Hold On”), and were encouraged to prepare to survive and recover at work, school, and home.

The ShakeOut began in southern California in 2008, as a way of involving the general public in a large-scale emergency management exercise based on a magnitude 7.8 earthquake on the San Andreas fault (the “ShakeOut Scenario,” developed by a team of experts led by Dr. Lucy Jones of the U.S. Geological Survey). The goal was to promote preparedness actions by communicating scientific information and awareness in such a manner that encouraged the whole community to get prepared and to participate in the largest earthquake drill in U.S. history.

The Southern California Earthquake Center (SCEC) developed advanced simulations of this earthquake that were used to estimate potential losses and casualties and also to show the public how the shaking would be throughout the region. In addition to scientific contributions to the ShakeOut Scenario, SCEC also hosted the ShakeOut website (www.ShakeOut.org) and created a registration system where participants could be counted in the overall total. The Earthquake Country Alliance (headquartered at SCEC with members from California science, preparedness, and community organizations) coordinated outreach and recruitment. More than 5.4 million people participated in 2008, with schools for the first time coordinating earthquake drills on the same day.

Soon after the first ShakeOut drill, participant demand convinced organizers to develop the ShakeOut into a statewide, annual event each October that grew to more than 8.5 million participants in 2011. K-12 and college students and staff comprise the largest number of participants, but the ShakeOut also has been successful at recruiting participation by businesses, non-profit organizations, government offices, neighborhoods, and individuals. Each year participants are encouraged to incorporate additional elements of their emergency plans into their ShakeOut drill. Surveys conducted after each drill are being analyzed and results will be presented in this poster and elsewhere in 2012.

Because of the success of the ShakeOut in California, several other regions (www.ShakeOut.org/history) have created ShakeOut drills, with websites managed by SCEC. In addition to the areas listed above, the Central U.S. has held ShakeOut drills in 2011 and 2012, the first Tokyo Shakeout is planned for March 9, 2012, Utah is holding its first ShakeOut on April 17, 2012, and New Zealand is planning a nationwide ShakeOut in September, 2012. In October 2012 the “west coast” ShakeOuts listed above will be joined by Puerto Rico, a regional drill in the Southeast U.S., and possibly other regions. Washington State, Alaska, Hawaii, and several countries (Turkey, Chile, China, and more) have also expressed interest.
ESTIMATING EARTHQUAKE MAGNITUDES FROM REPORTED INTENSITIES IN THE CENTRAL AND EASTERN UNITED STATES

Oliver S. Boyd, U.S. Geological Survey, Memphis, TN
Chris H. Cramer, University of Memphis, Center for Earthquake Research and Information, Memphis, TN

We develop an intensity-attenuation relation for the central and eastern United States (CEUS) and estimate the magnitudes of the 1811–1812 New Madrid, MO and 1886 Charleston, SC earthquakes. We constrain the relation with two large modified Mercalli intensity (MMI) datasets and North American census data. The National Oceanic and Atmospheric Administration (NOAA) modified Mercalli intensity dataset contains responses to questionnaires for earthquakes between 1924 and 1985. The USGS ‘Did You Feel It?’ (DYFI) dataset is obtained for responses from 2000 through April, 2011. The combined dataset has more than 250,000 felt reports for 857 earthquakes with magnitude between 3 and 7.3.

We assume that distances for a given intensity are log-normally distributed and seek a relationship predicting the mean of the log normal distribution of reported intensities as a function of MMI and magnitude in order to estimate the magnitude of sets of reported MMI having unknown magnitude. To properly estimate the mean of the log-normal distribution, the population density must be accounted for. For each earthquake and MMI in the combined dataset, a log-normal distribution of felt reports is simulated. In the simulation, the number of reports at each point on a uniform grid is proportional to the population density, where the historic population density is taken from the decadal census made available by the National Historical Geographic Information System (www.nhgis.org). The parameters of the log-normal distribution and fraction of population that generates a felt report are varied until they match the observed data.

We generally find that the fraction of population at a given location to report having felt the earthquake is proportional to MMI; larger MMI is correlated to a larger fraction reporting having felt the earthquake. We also find a positive correlation between the mean log-normal distance and the standard deviation of the log-normal distribution.

An inversion is performed to determine the coefficients of a bilinear function relating the mean log-normal distance, MMI and magnitude. Each data point is weighted by its uncertainty, which we assume to be proportional to the inverse of the square root of the number of observations.

To find the magnitude for the older 1811–1812 New Madrid and 1886 Charleston datasets, we begin with the procedure described above. The distribution of the number of felt reports versus distance for each dataset and MMI is simulated to find the mean log-normal distance. The bilinear function is then solved for magnitude.
and the magnitudes determined for each MMI are averaged, weighted by their uncertainty.

We find that the new relation leads to similar or slightly smaller magnitude estimates for the New Madrid earthquakes than have been determined by previous studies. Depending on the modified Mercalli intensity dataset used, the new relation results in estimates for the moment magnitudes of the December 16th, 1811, January 23rd, 1812, and February 7th, 1812 mainshocks and December 16th dawn aftershock of 6.8–7.1, 6.9–7.4, 7.3–7.6, and 6.8–7.3, respectively, with a magnitude uncertainty of ±0.4–0.5. We estimate a magnitude of 7.2±0.4 for the 1886 Charleston, SC earthquake.
Constraints on the 1811–1812 New Madrid Earthquake Magnitudes from a Direct Comparison of Intensity Observations with Known M7 Earthquakes

Chris H. Cramer and Oliver S. Boyd

Abstract

Uncertainty in the magnitudes of the 1811–1812 New Madrid mainshocks contributes significantly to the uncertainty in the seismic hazard in the central United States. A direct comparison of intensity observations between these historic and more recent M7 stable continental region earthquakes provides new constraints on the magnitudes of the 1811–1812 New Madrid mainshocks. Evernden (1975) suggested proximal large-intensity values are influenced by magnitude, source depth, and other factors; however, distant lower-intensity values are influenced mostly by the magnitude of the earthquake. We confirm this by fitting intensity observations for each of the four largest 1811–1812 New Madrid earthquakes, the 1929 M7.2 Grand Banks earthquake, and the 2001 M7.6 Bhuj, India earthquake. We compare the mean Modified Mercalli Intensity (MMI) curve vs. distance and its 95% confidence interval for each New Madrid event from several interpretations of the intensities with those of the Grand Banks and Bhuj, India, earthquakes at distances greater than 1000 km.

Potential biases affecting the direct comparisons include the following:

(1) The method of assigning intensities to observations mainly affects the proximal large-intensity values. The distant lower-intensity values tend to be more in agreement among the assignment methods as shown by the convergence at larger distances of the mean intensity curves for the same event and hence suggest the same magnitude.

(2) Limited sampling of intensity in number (fewer overall observations) and space (not sampled well at large distances) for the 1811-1812 New Madrid earthquakes increases uncertainty in the estimate of the mean intensity curves. But we fit the mean intensity curves with MMI as the dependent variable, which provides robust comparisons and essentially the same results both with truncations of the MMI dataset in maximum distance and minimum MMI.

(3) Source effects are more important at sites proximal to the event as indicated by ground motion prediction equations. Large differences in the stress drop could be important at all distances, but estimates of stress drop for the 2001 Bhuj, India earthquake and earthquakes in the source region of the 1929 Grand Banks, Canada earthquake are similar to the published mean stress drop for eastern North America (ENA) earthquakes. Directivity effects have been observed in the 1988 Saguenay, Canada and 2011 Mineral, Virginia intensities and ground motions data sets. But ground motion observations beyond 200 km for these earthquakes show at most a factor of two average increase in ground motions, which only corresponds to a 1/3 MMI increase and is not particularly significant at these distances.
(4) Differences in seismic attenuation between cratonic India and ENA are significant, but the 2001 Bhuj intensities have been corrected to ENA intensity attenuation using published intensity prediction equations for each region. The Grand Banks continental margin has been shown to be ~30 km thick Appalachian province crust by both marine and land reflection/refraction surveys. The Appalachian province is part of the ENA stable continental region. Observations of Q in the Appalachian province show typical ENA values. Thus, the paths to the intensity observation sites for the Grand Banks earthquakes are essentially ENA in their seismic properties, indicating that it is reasonable to compare intensity observations from the Grand Banks earthquakes with other ENA earthquakes’ intensities. Additionally, crustal structure may preferentially focus and increase intensity and ground motion observations, particularly for the 2011 Virginia and 1811–1812 New Madrid earthquakes. But at large distances, as cited above, the Virginia earthquake shows that this effect combined with directivity is not more than a factor of 2 in ground motion and 1/3 MMI unit in intensity, which is not particularly significant in our comparisons. Additionally, the 1929 Grand Banks intensities also show preferential increases in MMI along the structural trend parallel to the Atlantic coast that suggest similar effects in that dataset too, reducing the possibility of bias in comparisons with the 1811–1812 New Madrid intensities.

(5) Site effects from soils are important close in due to the presence of thick soils such as those in the Mississippi embayment and the Gulf and Atlantic coastal plains. Even the soils in the Ohio River Valley are only a few hundred kilometers from New Madrid and are not present beyond ~500 km. But at greater distances, the site conditions are typical ENA thin to no soils and thus not a source of bias in the direct comparisons at those distances.

Hence, all sources of bias in our direct comparisons are minimal and not significant, suggesting that our direct comparisons can provide constraints on the magnitude of the 1811–1812 New Madrid earthquakes. Our direct comparison of mean intensity curves beyond 1000 km suggests M~7.6, M7.2–7.6, and M>7.6 for the three 1811–1812 New Madrid mainshocks, and M~7.0 for the December 16, 1811, New Madrid “dawn” aftershock. Our estimates are consistent with those of Bakun and Hopper (2004) and higher than those of Hough and Page (2011), even using their MMI interpretations.
Future Research Needs in Earthquake Engineering in the U.S.: The 2020 Vision Workshop

Shirley J. Dyke, Purdue University
Bozidar Stojadinovic, University of California, Berkeley
Pedro Arduino, University of Washington
Maria Garlock, Princeton University
Nicolas Luco, U.S. Geological Survey
Julio A. Ramirez, Purdue University
Solomon Yim, Oregon State University

This poster will provide a summary of the outcomes of the workshop, Vision 2020: An Open Space Technology (OST) Workshop on the Future of Earthquake Engineering. Vision 2020 was established to formulate a vision of where Earthquake Engineering in the US needs to be in 2020 to vigorously address the grand challenge of mitigating earthquake and tsunami risk going forward. The objectives of the workshop were: 1) to chart the principal new directions in earthquake engineering research, practice, education and outreach for the earthquake engineering community over the next 10 years, and to postulate the needs beyond 2020; and 2) to reflect on the role of the current NSF NEES facilities in meeting the research needs of the earthquake community and to elucidate what new facilities would facilitate rapid progress along these new directions. A total of 78 participants attended, representing a diverse cross-section of researchers and practitioners from the earthquake engineering community. Using Open Space Technology, the workshop participants generated a set of 40 diverse topics during the first day. These topics were discussed in terms of their potential for having an impact on how our society responds to earthquakes and other hazards. During the second day of the workshop, these topics were refined to formulate the overarching goal and the principal research directions that should be undertaken to advance the earthquake engineering community by 2020.
SEISMIC VULNERABILITY OF CORNER BEAM-COLUMN JOINTS IN EXISTING CONCRETE BUILDINGS

Wael M. Hassan, Ph.D., S.E. and Jack P. Moehle, Ph.D., P.E.

Earthquake reconnaissance has reported the substantial damage that can result from inadequate beam-column joints. In some cases, failure of older-type corner joints appears to have led to building collapse. Beam-column joints in concrete buildings are key components to ensure structural integrity of building performance under seismic loading. Since the 1960s, many advances have been made to improve seismic performance of building components, including beam-column joints. New design and detailing approaches are expected to produce new construction that will perform satisfactorily during strong earthquake shaking. Less attention has been focused on beam-column joints of older construction that may be seismically vulnerable. Concrete buildings constructed prior to developing details for ductility in the 1970s normally lack joint transverse reinforcement. The available literature concerning the performance of such joints is relatively limited, but concerns about performance exist.

Many tools have been developed to predict shear strength and to numerically model joints with ductile details. However, much fewer guidelines and analytical models are claimed to be applicable to joints that lack transverse reinforcement.

The current study aimed to experimentally improve understanding and assessment of seismic performance of unconfined exterior and corner beam-column joints in existing buildings and to improve analytical tools for nonlinear simulation. Four full-scale three dimensional corner beam-column joint subassemblies, with concrete slab included, were tested under alternating unidirectional and simultaneous bidirectional cyclic loading that incorporated varying axial loads to simulate overturning seismic moment effects. The axial loads varied between tension and high compression loads reaching about 50% of the column axial capacity. The test parameters are axial load level, joint aspect ratio, loading history, and beam reinforcement ratio. The main performance measures assessed in this study are shear strength and ductility, failure modes, stiffness and strength degradation, shear deformations, and axial failure potential following shear failure of unconfined corner joints.

Test results have proven the potential for early shear failure and degradation of unconfined corner joints. Two distinct joint failure modes were identified based on reinforcement ratio and joint aspect ratio. Joint aspect ratio is inversely proportional to joint shear and axial capacities. Axial load effect on shear strength and deformation capacity varies based on joint failure mode. Axial failure of shear damaged joints appears to be unlikely within the practical drift range of older buildings. Elliptical shear strength interaction proved to be suitable for bidirectionally loaded joints. Tests revealed the inaccuracy of shear strength provisions of available existing building assessment documents. An exterior joint simplified shear strength models were developed and accurately predicted the strength of the test specimens.

A new nonlinear macro model is developed to predict the test observed seismic performance of unconfined joints. The model incorporates new expressions for joint performance including shear strength and axial capacity of beam-column joints. In addition, the effects of axial load level, joint aspect ratio and mode of joint failure on the constitutive cyclic backbone curve of unconfined joints. Cyclic strength and stiffness degradation and pinching parameters along with bond-slip expressions are suggested for advanced simulation of joint cyclic performance. The model successfully captured the experimental cyclic performance of unconfined exterior and corner joints and offered an alternative means to the existing recommendations of nonlinear modeling of unconfined joints, which were shown in the paper to be substantially conservative.

1Professional Structural Engineer, Skidmore, Owings & Merrill LLP (SOM), San Francisco, California, USA 
   Email: wael.hassan@som.com
2Professor of Structural Engineering, University of California, Berkeley, California, USA 
   Email: moehle@berkeley.edu
GROUND MOTION SELECTION AND MODIFICATION FOR NONLINEAR ANALYSIS OF ISOLATED BRIDGES IN THE NMSZ

Tim Huff1
Dr. James A. Mason2

Abstract

Current design philosophy for bridge structures in the NMSZ relies primarily upon plastic hinging in substructures. An available, yet seldom considered, alternative is seismic isolation.

The Hernando De Soto Bridge – Interstate 40 over the Mississippi River – is currently being retrofitted and seismic isolation has been incorporated into the design. Both Lead-Rubber-Bearing (LRB) and Friction-Pendulum-System (FPS) devices have been installed and other retrofit modifications are still being constructed.

Perhaps isolation should be considered, not only for major structures like the De Soto Bridge, but also for typical, more common bridge types in the NMSZ.

One of the first steps in the design of an isolation system for bridges is the selection and modification of ground motion records for nonlinear time history analysis of the isolated bridge.

The purpose of the study is to define a suite of code-compliant ground motion records for the nonlinear dynamic time history analysis of bridges in the New Madrid Seismic Zone. The records are to be used in future work to study the feasibility of isolation as a design strategy for routine bridges in the NMSZ.

Ground motion selection and scaling strategies for two sites in West Tennessee – one in Shelby County and another in Lake County – are discussed. Site No. 1, in Shelby County, Tennessee near densely populated Memphis, consists of soils in the upper 100 feet indicative of AASHTO Site Class “E” conditions. Site No. 2, in Lake County, Tennessee and one of the most vulnerable locations in the state in terms of seismic hazard, is characterized by AASHTO Site Class “D” soil conditions.

With limited strong motion recordings available for high magnitude, intra-plate events, the process of selecting appropriate ground motions is not a trivial one. Scenario events from USGS deaggregations at the two sites are established. Eight sources of data are queried to establish approximately 600 ground motion record pairs from 23 appropriate magnitude, historic events to be used as initial candidates for the two sites. Further screening of the records is based on available data for distance and site class conditions.

Artificial accelerograms are developed to complement the historic records. Amplitude scaling and spectral matching are employed to modify the motions. Target spectra are developed using code-based, uniform hazard criteria, risk-targeted criteria, conditional criteria, and by empirical methods.

Issues related to the range of periods across which spectral matching and scaling should be applied are discussed.

1Civil Engineering Manager, Tennessee Department of Transportation; Ph.D. Student, Civil and Environmental Engineering Department of the University of Tennessee, Knoxville
2Research Assistant Professor, Civil and Environmental Engineering Department, the University of Tennessee, Knoxville
A series of large and moderate earthquakes has struck the Christchurch, New Zealand region, causing massive damage and the 2nd largest loss of life in an earthquake in New Zealand’s history. This earthquake sequence started with an \( M_w 7.0 \) event in September 2010 and damaging aftershocks have continued up to December 2011 (i.e., \( M_w 5.9 \)). We believe Christchurch shares many features in common with US cities, particularly in the central and eastern US (CEUS) that make it a good analog for the impact of future damaging earthquakes in the CEUS. We will present examples of damage and other impacts from the 2010-2011 Christchurch earthquake sequence and compare them to the impact of the 1886 Charleston, South Carolina earthquake, using this to argue that the Christchurch experience should be mined by those involved in earthquake mitigation efforts in the CEUS.

Christchurch, New Zealand is a city of ~400,000 people on the South Island of New Zealand. It is similar to many cities in the CEUS, where historic unreinforced masonry (URM) buildings co-existed with steel and reinforced concrete buildings of several generations and building codes in the central business district (CBD). The Christchurch CBD is itself surrounded by suburban bedroom communities, much like most modern American cities. While New Zealand has a high level of earthquake activity, Christchurch is distant from the major plate boundary faults and its pre-2010 earthquake hazard estimates were similar to hazard levels estimated for the New Madrid and Charleston regions in the CEUS. Christchurch also lies on a coastal plain underlain by several hundred meters of sediment, which makes it geologically similar to Southeast/Gulf coastal plain (e.g., Charleston, SC) and Mississippi Embayment (e.g., Memphis, TN) regions in the CEUS. The extended nature of the Christchurch earthquake sequence is also similar to the extended 1811-1812 New Madrid sequence. These similarities in the built and geological environments argue that the impact of future damaging CEUS earthquakes will bear substantial similarities to the 2010-2011 Christchurch experience.

Several (but not all) aspects of the 2010-2011 Christchurch earthquake sequence we believe should studied closely are: a) damage as a function of changing building codes through time, b) effectiveness of URM retrofit measures (a number of Christchurch URM’s were retrofitted prior to the earthquakes), c) impact of multiple liquefaction events on lifelines, particularly underground pipelines, and d) impact of the extended earthquake sequence on recovery and rebuilding efforts. A number of parallels already exist between these aspects and locations impacted by historic CEUS earthquakes. Many historic URM buildings in Charleston, South Carolina have been retrofitted as part of preservation efforts – how well will they work? Severe liquefaction occurred during the 1755 Cape Ann, MA, 1811-1812 New Madrid and 1886 Charleston, SC earthquakes – what impact would such widespread liquefaction have today? Temporary population displacements occurred as a result of the 2010-2011 Christchurch, NZ, 1811-1812 New Madrid and 1886 Charleston, SC earthquakes – how will this impact recovery efforts?
The August 31, 1886 M~7 Charleston earthquake is the best-documented large damaging central and eastern US (CEUS) earthquake, particularly with respect to its impact on the built environment. Our goal is to take historic information, combine it with modern geological and geotechnical data, and “reconstruct” the role of geological site conditions in the distribution of damage during the 1886 earthquake. This will allow us to use the 1886 earthquake as a calibration event for site condition maps included in HAZUS damage estimates, and thus better estimate the impact of future earthquakes in Charleston, South Carolina.

Numerous photographs from the 1886 earthquake exist, many of them annotated with location information, that document damage to both public and private buildings. An insurance report, keyed to 1884 Sanborn fire insurance maps (also available), describes damage and in some cases estimated repair costs to nearly 7000 buildings. Other historical documents, such as the first U.S. Geological Survey scientific report on an earthquake (Dutton, 1889), are also available. Much of this information has already been digitized (e.g., photographs and Sanborn maps are available via the Lowcountry Digital Library; http://lowcountrydigital.library.cofc.edu/), allowing us to locate the type and severity of building impact from this historic earthquake within a modern geographical coordinate system.

Modern data in this study include digitized surface geology and soil maps of the Charleston region. We also have access to geotechnical borehole data (SPT, CPT and SCPT) and estimates of shallow shear wave velocities from surface seismic studies (i.e., shear wave refraction and refraction microtremor). More recently, we have also completely an ambient seismic noise survey to estimate frequencies and relative amplitudes of site resonance in Charleston. We are combining the modern geological/geotechnical information together with the historic building damage into a GIS product that will allow us to document the influence of site conditions on building impact at a level of unprecedented detail for a historic earthquake event.

The ultimate aim of this project is to make the 1886 earthquake a “calibration event” for site condition maps used as input for HAZUS estimates of damage from future earthquakes in the Charleston, South Carolina region. This will allow more accurate predictions of damage in future large earthquakes, which can be used for land use planning, updating emergency response plans and other earthquake mitigation measures.
USGS Real-time Structural Health Monitoring of Instrumented VA Medical Center Hospital Buildings in Memphis, Tennessee

Erol Kalkan¹, Jon P. B. Fletcher¹, William Leith², and Krishna Banga³

(¹) U.S. Geological Survey, Menlo Park, CA, USA
(²) U.S. Geological Survey, Reston, VA, USA
(³) U.S. Department of Veterans Affairs, Washington D.C., USA

Memphis sits squarely in the damage range of the New Madrid Fault Zone, the most active fault zone in the south and midwest of the United States, caused a series of major earthquakes during 1811-1812. Today, the dense urbanization in the New Madrid Fault Zone area increases the earthquake hazards. Major earthquakes near urban centers such as Memphis can cause catastrophic structural damage and life losses. For a nation’s critical infrastructure such as hospitals, fire stations, emergency operation centers, major bridges, nuclear power plants, off-shore platforms and airports, it is imperative to assess their structural integrity immediately after a major catastrophic event. Such efforts may (i) protect human lives and prevent injuries, (ii) minimize economic losses (structural and non-structural damage), (iii) maintain vital services and minimize operation/production interruptions, and (iv) protect the environment. To date, the U.S. Geological Survey (USGS) National Strong Motion Project (NSMP) works closely with the Department of Veterans Affairs (VA) to monitor earthquake shaking in more than 70 VA medical centers in seismically active regions in the continental U.S., Alaska and Puerto Rico. One of the significant potential uses of data recorded by the seismic arrays installed in structures is monitoring their structural health. This effort helps to increase pace of progress in safeguarding the VA’s building inventory against future earthquake losses. Recently, USGS/NSMP has instrumented two hospital buildings at the Tennessee VA Medical Center in Memphis. Real-time structural health monitoring system installed in the 5-story Bed Tower building and 3-story Spinal Injury building is one of the most sophisticated monitoring systems in the country. The seismic monitoring system within these buildings is designed to record (1) lateral swaying, (2) twisting, (3) wave travel time, and (4) drift (displacement) between each pairs of adjacent floors and average drift between any number of floors. The buildings sensors are complemented by three-component sensors located in a reference site distant from the buildings to monitor ground shaking without interference with buildings’ responses. The data from the reference site provide the input signal of the seismic waves that shake the buildings. This dense array of seismic sensors in buildings and reference site is the main component of a sophisticated real-time structural health monitoring system of the Tennessee VA Medical Center, which could led authorities making the informed decisions on utilizing the hospital buildings in the aftermath of an earthquake.
On January 12 2010, at 4:53 pm local time, a magnitude 7.0 earthquake struck the Republic of Haiti. The epicenter of the earthquake was 25 km southwest of the capital Port-au-Prince, close to the city of Léogâne. Although Haiti has experienced frequent weather-related disasters in recent years, this earthquake dwarfed these earlier events, in both lives lost and damage inflicted. It is estimated that in excess of 300,000 people were killed, hundreds of thousands more were injured, and approximately 1.3 million people were left homeless due to the failure of the majority of the building stock in the affected regions. In particular, Léogâne, a city of 130,000 people and one of Haiti’s 140 communes, was completely devastated by the earthquake, with estimated damage to 93% of its buildings, the majority of which collapsed.

This level of devastation can largely be attributed to the many political and economic issues that have faced this nation, whose struggles with education, government oversight of civil works, and general lack of resources have historically prohibited the establishment of reliable civil infrastructure. Additionally, although Haiti is situated in a seismically active region, prior to the January 2010 earthquake, it had experienced no significant seismic event since 1846. Due to this long period of seismic inactivity, Haitians were not truly cognizant of the threat of major earthquakes; a situation that is similar to the current conditions in the central United States, with respect to the New Madrid Fault. As such, Haitian housing prior to the quake was predicated on environmental requirements (capacity to withstand the frequent tropical storms) and cultural preferences towards privacy and security, subject to practical constraints related to the lack of native resources, income, education, and government oversight. Due to the lack of wood for use as either formwork or as a partitioning alternative, and the high cost of steel, Haitians construct structures with heavy masonry walls made of hand-pressed, unreinforced concrete masonry units (CMUs) and lightly reinforced, undersized concrete columns. The structural system frequently has no beams, leading to systems with inadequate strength and ductility. This combination created systems that actually performed well under strong winds common to the Caribbean, but were proven to be extremely vulnerable to earthquakes, with most failing through brittle collapse modes. The pre-existing factors that led to the vulnerabilities exposed so harshly during the earthquake are deeply rooted structural issues of the country that subsist today, creating what may be the most difficult reconstruction effort following any major disaster of modern times.
Two years after the earthquake, despite the millions of dollars pledged through foreign aid and well-intended efforts of the international community, the sad reality is that the majority of the families displaced due to the earthquake [over 600,000 Haitians] are still waiting in transitory shelters, without a clear roadmap towards safe permanent housing they will be able to call “home”. Recent surveys have found that 34% of Haitians reported leaving the Internally Displaced People (IDP) camps due to forced evictions, without any financial or housing assistance. Most have been unable to find a permanent, reliable housing solution, forcing them into similar, if not worse, living conditions experienced in the IDP camps. Lack of advancement of a permanent housing solution has led to a situation where international aid is continually walking the line between relief and reconstruction, a phenomenon seen throughout other parts of the world such as Africa, leading to imported solutions that are temporary in nature and unsustainable after the non-governmental organizations (NGOs) withdraw from the country. The lack of a precedent for a disaster whose victims are trapped in such dire economic straits has left the Civil Engineering community at a loss, with many failing to understand Haiti’s unique constraints and how well intentioned rebuilding efforts can actually perpetuate vulnerabilities in the long run. It is apparent, with the current state of housing two years after the earthquake, that providing long-term, resilient housing is not as simple as importing “first world” solutions, and in fact, doing so creates a long-term dependence on foreign aid. Housing is a often a privately funded and supervised endeavor, especially in a country with a weak governing structure, and therefore, solutions must be predicated on transforming good intentions of the international community from implementation of foreign solutions into creating a new Haitian housing paradigm that empowers those at the bottom of the pyramid.

The authors’ attempt to contribute to this recovery has been marked by four trips to Léogâne over the last two years [more information on these trips may be found at http://www.engineering2empower.org/]. The first (March 2010) focused on post-quake reconnaissance and identification of the vulnerabilities that contributed to the extensive structural collapses. The second (August 2010) focused on surveying cultural preferences in urban housing as well as the local construction materials and practices. The third (March 2011) was devoted to a Community Planning Workshop for Léogâne, and the fourth (December 2011) was dedicated to gathering labor and material pricing and surveying cultural preferences to support new housing paradigms. These experiences have reminded the authors of the vulnerabilities created when construction practices driven by economic constraints neglect infrequent hazards, a situation similar to the current practice related to aseismic design in the Central US, and the associated devastation such practices can result in. Of equal importance is the legitimate danger that the desperation and the demand to meet basic human needs during the reconstruction process will lead to a reliance on heavily subsidized and imported engineered designs that are well beyond the financial reach of most Haitian families.

This poster reviews the experiences of the authors from all these trips. It initially discusses the seismic vulnerabilities exposed in Haiti during the 2010 earthquake, focusing on lessons learned when operating in such unique resource-constrained environments. It then presents the efforts of the authors to offer an alternative housing paradigm, based on the principle of empowering the Haitian people. To do so requires innovations in technologies and processes that treat, with equal importance, resiliency, feasibility, sustainability, and cultural viability. The authors’ experiences in post-quake Haiti have demonstrated that such pathways to empowerment can indeed be discovered, first and foremost by listening to the community being served, but require the commitment and patience to follow what inevitably is a long, arduous, and at many times uncertain path to recovery. This process requires continuous feedback from the population being served and frequent re-evaluation of priorities and proposed solutions. This is an important lesson that must be learned from this disaster, not only for the people of Haiti, but also for the millions of disadvantaged people throughout the world.
The poster provides a general overview of the research project PERPETUATE: PERformance-based aPproach to Earthquake proTection of cUlturAl heriT age in European and mediterranean countries. This research is funded by the Seventh Framework Programme (Theme ENV.2009.3.2.1.1) and the consortium includes 6 Universities, 2 Public Institutions and 3 Small-Medium Enterprises. Five European Countries (France, Greece, Italy, Slovenia, United Kingdom) and one International Cooperation Partner Country (Algeria) are represented.

The main motivations of this research project are the followings: i) application of the performance-based assessment to monumental structures; ii) the conservation of cultural heritage and the safety of people should be considered in an integrated approach; iii) definition of proper performance levels and acceptable criteria for cultural heritage buildings, as well as for the contained artistic assets; iv) proposal of models for a reliable hazard assessment and an accurate vulnerability analysis in order to adopt a minimum intervention, for the sake of conservation.

According to these motivations, the three main points of this research programme are: 1) increasing of knowledge on the cultural assets and on the peculiar intensity measures of the seismic hazard; 2) improving of modelling strategies of the ground, the foundation system, the structure and the materials; 3) design of innovative, low-impact and reliable strengthening interventions.

In particular, in order to face these hard issues, the methodology proposed in PERPETUATE uses a displacement-based approach for the vulnerability evaluation and the design of interventions [1]. According to recent trends in the field of seismic assessment, the use of safety verification in terms of displacement, rather than strength, orients to new strengthening techniques and helps in the comprehension of the interaction between structural elements and unmovable artistic assets. The procedure is based on the following fundamental steps: 1) definition of performance limit states, specific for the cultural heritage assets (considering both architectonic and artistic assets); 2) evaluation of the seismic hazard and of the soil-foundation interaction; 3) construction knowledge (historical analysis, survey, non-destructive testing, material parameters, structural identification); 4) development of structural models for the seismic analysis of masonry structures and artistic assets, in the actual state and for the design of interventions.

Two main scales are considered: a) the assessment of a single historic building or artistic asset; b) the evaluation of the seismic risk to cultural heritage assets in a wide territorial area, in order to plan...
mitigation strategies. Final aim of the project is to develop European Guidelines for evaluation and mitigation of seismic risk to cultural heritage assets.

The poster focuses the attention on the application of the PERPETUATE procedure to several case studies, aimed to validate the methodology, selected in different countries (Italy, Greece, Algeria, Slovenia): 1) the Casbash, the Citadel and Great Mosque in Algiers; 2) some monuments in the historical centre of Rhodes (Greece); 3) Kolizej Palace in Ljubljana (Slovenia); 4) Santa Maria Paganica Church and Ardinghelli Palace in L’Aquila (Italy); 5) St. Pardo Cathedral in Larino (Italy). Each case study provides an exclusive occasion to face the problem of seismic protection of cultural heritage at different scales (single asset or group of buildings in town) and conditions (seismic prevention or reconstruction after an earthquake). Moreover in most of cases, relevant artistic assets are present, allowing us to test results provided by the project also for these “non structural” elements.

In particular, the Casbah of Algiers and the historical centre of Rhodes (both in the UNESCO list of the World Cultural Heritage) are made up of a complex aggregation of historical buildings, which represent a cultural heritage asset as a whole but also contain a wide number of single important monuments. The Casbah of Algiers constitutes a relevant occasion to test the proposed procedure at territorial scale: available models have been updated to take into account the peculiarities of these buildings. In case of Rhodes, the procedure will be applied in a well documented sample of typical and important monumental buildings and residential structures, representative of different periods and morphologies. In both cases, in-situ microtremors survey and array measurements have been performed, oriented to both the structural identification and the soil characterization.

The Kolizej Palace in Ljubljana has been a very exclusive occasion to apply several diagnostic techniques (either destructive or not) as its complete demolition was planned by Authorities.

Santa Maria Paganica Church and Ardinghelli Palace in L’Aquila have been strongly damaged by the Abruzzo earthquake on April 6, 2009. Starting from the damage survey, fundamental step to understand the actual seismic behaviour, proper modelling strategies have been adopted for the seismic assessment, in order to decide about the restoration works (due to the high level of damage, many options have been considered: conservation as a ruin, reconstruction with the same or new materials and technologies).

Finally, St. Pardo Cathedral in Larino was slightly damaged by the earthquake in Molise Region, 2002; it is worth noticing that damage was concentrated in those parts that were previously retrofitted. Thus in this case the application of PERPETUATE procedure aims to design the technical solutions more appropriate for the seismic improvement of the monument.

Some preliminary documents delivered by the project may be found in www.perpetuate.eu.

References

A performance-based procedure for the earthquake protection of masonry historical structures

S. Lagomarsino, S. Cattari and C. Calderini

Dept. of Civil, Environmental and Architectural Engineering, University of Genoa, Italy

The damage assessment to historical masonry buildings after past and recent earthquakes has shown their high seismic vulnerability. In 2009 L’Aquila earthquake, in Italy, severely struck a large number of monumental buildings, such as churches, towers, palaces and ancient urban aggregates; this confirms the need of proper procedure for the conservation of cultural heritage in seismic prone areas.

Differently from the case of ordinary buildings, concepts related to the protection of the cultural heritage should be added to requirements strictly associate d to the safety of people and to operational and economic aspects (usually related to the actual reparability of damage). Moreover, since the behaviour of masonry structures is strongly non linear, it is necessary that seismic assessment refers to a displacement-based approach rather than a strength one: thus, according to all recent codes and recommendation documents, the most suitable choice seems working in the context of performance-based assessment (PBA). Despite the need of considering modelling strategies able to properly simulate the non linear response, the great variability and complexity of masonry historical buildings makes difficult to propose well established approaches, as in codes for the case of new buildings, to be adopted as reference.

The poster describes the performance-based assessment procedure developed for masonry cultural heritage structures by PERPETUATE project (funded by the European Commission in the Seventh Framework Programme - www.perpetuate.eu). Even if the importance and uniqueness of monuments may advise to face the problem of their seismic vulnerability by a detailed analysis of each single building, the large number of monuments present in seismic areas requires anyhow a territorial scale approach, addressed to plan preventive risk mitigation policies and to optimize the use of economic resources. To this aim, the proposed procedure considers both scales of the single asset and the territorial one, with different degree of accuracy in all steps of procedure. Moreover, it considers different stages and conditions in which this procedure should be applied; indeed results of the seismic assessment should provide useful data for rehabilitation decisions to be carried out both before, as a seismic prevention action, or after, to orient choices on repair and reconstruction, the occurrence of an earthquake.

As known, PBA is based on the fulfillment of selected rehabilitation objectives, that are defined by specific performance levels (PL) in correspondence to earthquake hazard levels (associated to selected probabilities of exceedance in a reference time or return periods).

In case of historical buildings PL have to be linked also to cultural relevance concepts: thus, the use and safety of people, the conservation of the building and the conservation of artistic assets (if present) should be considered in an integrated approach. Once the safety and conservation requirements have been defined from a conceptual point of view, proper acceptance criteria have to be established in order to verify if the structure is able or not to satisfy the required PL. In particular, the acceptance criteria require: 1) the definition of proper parameters measuring damage (and the reference limit values), correlated to building seismic response, which allow us to check the performance levels; 2) proper mechanical models, able to evaluate these parameters for a given seismic action. In case of masonry ordinary buildings, the parameter usually adopted as reference is the drift (both the interstory drift or that in each single masonry panel); however, for other monumental structures (e.g. towers, churches, stone columns, etc.) different parameters need to be introduced.
Moreover, the complexity of cultural heritage structures requires referring to various proper modelling strategies. To this aim, a damage and typological classification of cultural heritage asset represents one of the first results of PERPETUATE project: this classification has to be considered as strictly “mechanical”, since the occurrence of different types of damage are closely related to building morphology (architectural shape, dimensions) and technology (type of masonry, characteristics of horizontal diaphragms, effectiveness of wall-to-wall and floor-to-walls connections). According to the identified damage modes and asset types, models are classified following two criteria: scale of discretization (whether material or structural element one) and constitutive modelling of masonry (whether continuous or discrete). Four types of models are identified: 1) Continuum Constitutive Laws Models [1], 2) Structural Element Models [2], 3) Interface Models, 4) Macro-Blocks Models. The use of these different modelling strategies is discussed with respect to both the classes of heritage buildings (churches, palaces, towers, defensive walls,…) and their use in the seismic analyses.

Regarding the analysis and safety verification methods, particular attention is paid to non-linear static and dynamic procedures. Both global seismic response of the structure (mainly associated to the in-plane response of walls and to the activation of a box type behaviour) and local response of single parts (usually subjected to out-of-plane mechanisms, as discussed in [3]) are considered. Moreover also soil structure interaction and foundation problems are considered in the analysis (if relevant). In case of non linear static analyses, a multi-criteria approach to define performance levels on the capacity curve is proposed by considering damage at the scale of structural element (local damage), mechanisms in architectonic elements (macrolelement pushover curve), global behaviour (pushover curve of the whole building).

In case of existing buildings, as known, the seismic safety assessment is affected by more uncertainties than the one related to the design of a new building; in fact, uncertainties related to the incomplete knowledge of the asset (epistemic uncertainties) add up to the statistical ones. In order to reduce these uncertainties, the knowledge investigations represent a preliminary but fundamental step of the assessment. The approach proposed in PERPETUATE project is based on the use of confidence factors, which are in this case defined after a sensitivity analyses to identify the parameters that mostly affect the structural response; this approach seems to be very effective in order to optimize the plan of in-situ investigations and testing to be performed.

Finally, as PBA requires to compare the “structural capacity” and the “seismic demand”, the hazard definition represents the fundamental step to close the procedure. On one hand, the return period of the hazard can be modified in order to take into account the different cultural relevance and use of each cultural heritage asset. On the other hand, some classes of historical buildings require specific hazard characterization: as an example, some architectonic classes (such as single stone columns) are characterized by very long period of vibration (rocking behavior) and require a reliable definition of the input acceleration-displacement response spectrum also for long periods of vibration (this is usually not necessary for rigid structures as palaces). Moreover, in some cases, the adoption of the non linear dynamic analysis seems preferable to the static one: thus, the hazard must be defined by a proper set of recorded accelerograms, instead of acceleration-displacement response spectra.

References

The Salton Sea region is a very seismically active region. Among the earthquakes occurred in the area, the 2010 Mw 7.2 El Mayor-Cucapah earthquake and the 1979 Mw 6.5 Imperial Valley earthquake bear many similarities. The El Mayor-Cucapah earthquake occurred across on a series of faults, with a strike of N130°E very similar in orientation to the Imperial fault which has a strike of N143°E. Both earthquakes occurred on strike-slip faults. Observed spectral accelerations during both earthquakes are compared to the predictions by the Next Generation Attenuation (NGA) Boore and Atkinson (BA08) ground motion prediction equation (GMPE) and the SEA99 GMPE.

Ground motion records within the United States from the El Mayor-Cucapah earthquake are downloaded from the Center for Engineering Strong Motion Data (http://www.strongmotioncenter.org). These records were filtered with a 0.07 – 40 Hz band-pass filter and baseline corrected. Ground motion records obtained in Baja California, Mexico were downloaded from the CI CESE website (CICESE, 2010). These records were baseline corrected and filtered with corner frequencies between 0.1 and 25 Hz. All these records obtained in both California and Baja California had not been processed following the protocols of the NGA project. Ground motions from the 1979 Imperial Valley earthquake are downloaded from the PEER Ground Motion Database. These ground motions have been processed following the protocols of the NGA project.

In general, both the BA08 and the SEA99 GMPEs predict spectral accelerations that show a trend of positive intra-event residuals at site-to-source distances between about 10 to 50 km and negative residuals from about 50 to 100 km for ground motions from the 2010 El Mayor-Cucapah earthquake. However, such a trend is not observed for the 1979 Imperial Valley earthquake for both the SEA99 and the BA08 GMPEs. It is also observed that the intra-event residuals predicted by both SEA99 and BA08 GMPEs show larger scattering for the 2010 El Mayor-Cucapah earthquake than the 1979 Imperial Valley earthquake. Overall, the SEA99 and the BA08 GMPEs perform similarly well in predicting spectral accelerations for PGA, 0.3, 1.0, and 2.0 second periods.
Several of the largest historical earthquakes to strike the continental United States occurred in the winter of 1811-1812 along the New Madrid seismic zone (NMSZ), which stretches from near Memphis, Tennessee into southern Illinois. This earthquake sequence produced hundreds of aftershocks. These earthquakes were felt across the U.S. and from the Gulf of Mexico to Canada. The area that was strongly shaken by the three main shocks was 2 to 3 times larger than the strongly shaken area of the 1964 M9.2 Alaskan earthquake, and 10 times larger than the 1906 M7.8 San Francisco earthquake. The 1811–1812 New Madrid earthquake sequence was preceded by at least two other similar sequences in about A.D. 1450 and A.D. 900. Research also indicates that other large earthquakes have occurred in the region surrounding the main New Madrid seismicity trends in the past 5,000 years. For the Bicentennial of these earthquakes the U. S. Geological Survey (USGS) has produced several information products for the general public and scientific communities that discuss these sequences, central U.S. earthquake hazard, emergency preparedness, and mitigation.

The USGS Fact Sheet (2010) “Earthquake Hazard in the New Madrid Seismic Zone Remains a Concern” gives a brief yet comprehensive description of the 1811-1812 earthquake sequence, sequences of other pre-historic earthquakes, and the possible consequences of future earthquakes. Several thousand copies of “Putting Down Roots in Earthquake Country” (central U.S. version) were distributed during 2011-2012. This document is modeled on similar versions used in California and Utah and provides the general public with history, science, and emergency preparedness (before, during and after an event) information for the central U.S. Much is known about the threat of earthquakes in the central United States and what can be done to reduce losses from future earthquakes, but not enough has been done to prepare for future earthquakes. The handbook describes such preparations that can be taken by individual residents before an earthquake to be safe and protect property.

The USGS collaborated with the National Park Service to produce the poster “Bicentennial of the 1811-1812 New Madrid Earthquake Sequence December 2011-2012”. The poster presents an overview of some of the hundreds of compelling personal accounts of the people living in the New Madrid area as well as experiences of those on the east coast of the U.S.

“20 Cool Facts about the New Madrid Seismic Zone: Commemorating the Bicentennial of the New Madrid Earthquake Sequence December 1811-February 1812” poster summarizes a few of the more significant facts about this series of large earthquakes that struck the region and is suitable for a classroom setting.

The USGS, in conjunction with state and local agencies, also produced several videos about earthquakes in the New Madrid seismic zone, earthquake hazards, preparedness, research, ground shaking effects, historical accounts, and research projects. These videos can be seen at http://www.youtube.com/user/NewMadrid2011.

The 2011 FEMA-led National Level Exercise (NLE) simulated the catastrophic nature of a major earthquake in the central United States region of the New Madrid seismic zone. NLE 2011 utilized scenarios for a similar sized earthquake (magnitude 7.7 for the scenario) as the 1811-1812 sequence main shocks and a similar aftershock (M6.0). PAGER and ShakeMap reports were issued for the two simulated earthquakes. The PAGER and ShakeMap tools played a vital role in initiating the drill as well as helping to provide a better understanding of the effects of a major earthquake to all of the organizations that participated.
As part of a State series of earthquake history maps new seismicity maps for Mississippi and Arkansas were produced. Each summarizes several hundred years of earthquake historic activity. Links to these maps can be found at the New Madrid Bicentennial website. The site commemorates the earthquake sequence and connects people to information, events, announcements, news, and educational products. Visit http://newmadrid2011.org/ for more information.

The USGS supported the implementation of the 2011 Great Central U.S. ShakeOut. This award-winning and highly successful program was led by the Central US Earthquake Consortium (CUSEC) and modeled on previous ShakeOut programs from California. The event encourages businesses, schools, response agencies, state and local governments, and the general public to learn about earthquake hazard and engage in activities that improve community resilience. The Great Central US ShakeOut website provides information on earthquake preparedness, events, and educational resources. Participants may register for future ShakeOut events online at http://www.shakeout.org/centralus/.
PLANNING FOR THE POSSIBLE, NOT THE PROBABLE, SAVES LIVES
Althea Rizzo, Ph.D.
Geologic Hazards Program Coordinator
Oregon Office of Emergency Management

Despite having the possibility of a subduction zone earthquake capable of rivaling both the Andaman and Japan Trench in devastating consequences, U.S. planning efforts still rely on premises that under-estimate the level of risk. Japanese emergency planners’ reliance on underestimated risk led to mistakes which caused loss of life, property, and a nuclear disaster. Emergency planners in the U.S. can learn from these past disasters and plan for the possible, not the probable.

Japanese seismologists and geologists, such as Yukinobu Okamura, called attention to a higher seismic risk than was accepted by the Japanese government for planning purposes. This led to under-engineering of seawalls and other built environment measures. In addition, public education and warning capability were based on the incorrect lower hazard.

Future emergency planning on the West Coast of the U.S. must take proper understanding of what is possible, and not base decisions solely on what is probable. This “planning for the possible, not the probable” is especially important for critical infrastructure and facilities such as first responders, hospitals, and schools. This message is brought home to emergency managers by the example of the community Minamisanriku, whose EOC was overtopped by the March 11 tsunami, killing most of the staff. We do not know how much time we have to prepare for the next Cascadia Subduction Zone earthquake and tsunami, and we will only have one chance to get it right.

References:


Sawai, Y. et al. (2008) Marine incursions of the past 1500 years and evidence of tsunamis at Suijin-numa, a coastal lake facing the Japan Trench. The Holocene 18, (4) 517–528

INTRAPLATE EARTHQUAKES: HOW WELL DOES THE ELASTIC REBOUND PARADIGM SERVE TO EXPLAIN THEM?

Dr. Robert Smalley, Jr., Research Professor

Center for Earthquake Research and Information, The University of Memphis, Memphis, TN 38152

An important component of estimating seismic hazard is an understanding of the physical processes that cause earthquakes. Knowing the basic physics of earthquakes and the state of Earth’s crust one can then produce estimations of future behavior of faults such as the rate and size of earthquakes it might generate. These estimations contribute as a fundamental input to the estimation of seismic hazard. Recent results from GPS geodesy in the New Madrid seismic zone, interpreted using a plate boundary earthquake model, have been used to suggest that seismic hazard there has been overestimated. Observed crustal deformation in non-plate boundary settings, determined by GPS, suggests that the standard model of earthquake occurrence is in need of modification when applied to earthquakes away from plate boundaries. Worldwide GPS observations away from plate boundaries, when combined with paleoseismic data for the New Madrid seismic zone, indicate that the current seismic hazard estimate for the New Madrid seismic zone does not need to be modified in light of the GPS results.

Reid’s elastic rebound theory of earthquakes has been very successful in describing the cycle of elastic energy storage and release, especially for earthquakes along transform plate boundaries. It is also generally accepted that it explains the earthquake cycle in compressive plate boundaries, although being a purely elastic description it completely misses the accumulation of permanent deformation driven by the plate boundary, but associated with crustal earthquakes on faults that are not part of the boundary, in compressional mountain belts such as the Andes.

In the elastic rebound theory, although they occur at very different rates, the interseismic strain signal is simply the negative of the co-seismic signal. One elastically stretches and releases a spring; there is no permanent deformation. This works very well for transform/strike-slip plate boundaries where the faults, while they can be quite long, are limited in width to the thickness of the crust. Whether one uses a plate or a half-space model for strike-slip faults the volume participating in the elastic storage and release of elastic strain energy is relatively small compared to the volume of tectonic plates. Both traditional and GPS crustal deformation measurements observe and model the complete cycle very well. At convergent margins the region of deformation associated with the elastic rebound theory is much larger due to the dipping geometry of the faults combined with thicker crust, or possible continuation of the faults into sub-crustal lithosphere, that result in much larger faults. The volume of energy storage and release is therefore much greater and convergent plate margins produce the largest earthquakes. The horizontal deformation associated with both the co-seismic and interseismic components of the earthquake cycle at convergent margins is not detectable by traditional surveying due to the much larger region involved, resulting in small strains, and the fact that the boundary itself, where the maximum deformation is concentrated, cannot be observed because it is underwater in the trench. The advent of GPS geodesy, which provided a two order of magnitude increase in the precision of horizontal surveying, allows the observation of crustal deformation data that
supports the elastic rebound theory at the plate tectonic scale within the precision of the data. Looking in more detail at earthquakes in the deforming region, but off the plate boundary, however, we notice that only the co-seismic component of elastic rebound is observed. This is also true for intraplate earthquakes in regions with no GPS detectable interseismic deformation. The elastic rebound model requires both far field displacements and focused interseismic elastic strain accumulation on the fault that will eventually rupture (the fault is therefore “pre-identified” as it is on the plate boundaries). To date no interseismic or pre-seismic deformation signals associated with the interseismic component of elastic rebound have been observed around any non plate boundary faults that have ruptured. Earthquakes that have occurred in deforming regions have not been considered to challenge elastic rebound because elastic strain energy is being stored by the deformation, even though they do not display the interseismic signal. Even on plate boundaries, where we claim to understand the process, pre-event changes in the deformation pattern of future rupture areas of earthquakes, such as accelerations or decelerations in the rate of strain accumulation, have not been observed.

We need to examine alternate models for maintaining and modifying the stresses that exist off the plate boundaries. The elastic rebound model is a half-space model, with far field motions and slipping faults that allow stress to build up on the locked fault, that does not take into account the fact that the lithosphere is a stress guide and can transmit stresses over very long distances. In the elastic rebound model the far field plate can be stress free and elastic energy only builds at the plate boundary where earthquakes periodically remove all of the elastic strain energy that is found and stored only at the boundary. In plate interiors and deforming regions such as the eastern Andes elastic strain energy can be both very high and widely distributed. The mechanism and speed of stress changes and postseismic stress recovery is completely unknown. Intraplate earthquakes may not relieve the stress significantly, except in the very immediate vicinity of the earthquake. How the stress evolves immediately after an earthquake is also completely unknown.

GPS and other geodetic techniques measure changes in the strain and infer changes in the stress, they do not measure absolute strain and stress. Modern geodetic measurements away from plate boundaries are providing data that is in agreement with the tenets of plate tectonics that hold that the interiors of plates are rigid and non-deforming. This does not mean that the plate interiors are free of stresses and associated strains. While plate interiors are less active seismically that plate boundaries, they do have earthquakes. Observation trumps a theory that does not agree with the observations. Rather than use GPS results to argue that lack of measurable deformation implies a lack of the stresses needed to produce earthquakes, we need to discover how stresses evolve and behave in both plate interiors and the large deforming regions associated with plate boundaries. As the stress levels and the processes acting at in plate interiors can be quite different from those at plate boundaries we need to develop a model for how these stresses generate earthquakes.
IMPACT OF EARTHQUAKES ON THE ELECTRICITY INFRASTRUCTURE

Ganesh Kumar Venayagamoorthy and Karthikeyan Balasubramanium
Real-Time Power and Intelligent Systems Laboratory
Holcombe Department of Electrical and Computer Engineering
Clemson University, Clemson, South Carolina 29634, USA
gkumar@ieee.org

According to North American Electric Reliability Council’s disturbance analysis working group database, 1.6% of all blackouts during the year 1984-2006 is due to earthquakes, for events affecting more than 50,000 customers. Average number of customers with loss of power is more than 500,000 and average loss of generation is over 1000 MW [1]. These numbers indicate the fact that although earthquakes are less frequent than other events that initiate blackouts, they cause large scale damage due to component failure. Porcelain components such as insulators, bushings, and support columns often fail. Damage to other equipment components and busses is caused by inadequate slack between elements connected by wires, or by bumping because of inadequate clearance [2]. Typically, failure of major equipment components such as transformers and circuit breakers are caused by breakage of porcelain components such as bushings and support columns. High-voltage equipment is generally more vulnerable than lower-voltage equipment because of greater clearance requirements. Leaking gaskets is another frequently observed form of transformer damage. This results in loss of cooling fluid which in turn causes transformer failure [2].

Substation elements with ceramic columns supporting circuit breakers, bus-support structures, disconnect switches, and bushings and radiators of transformers are also vulnerable [2]. Transmission towers are not very vulnerable; however damage occurs due to secondary disturbance such as landslides. Distribution systems are generally more rugged than high voltage transmission systems and the poles and lines are not very susceptible to damage. However, damage can occur due to failure of adjacent structures and distribution wires may become entangled and burn before circuit breakers can cut off current through the lines [2].

Countries such as Japan, which is regularly pummeled by earthquakes have made structural and operational changes to their electric industry. Tokyo straddles three tectonic plates- the Eurasian plate, Philippine seat plate and pacific plate. However, in the ten year period from 1992-2001, customers of Japan’s largest power supplier, Tokyo Electric power co. (Tepco), suffered an average outage of less than 5 minutes in any given year [3]. By comparison, customers of 65 power utilities across 24 states in United States had sustained power interruptions totaling 107 minutes on average in any one year during the same period, according to US Electric Power Research Institute (EPRI). The Tachikawa system load dispatching office building is decoupled from its foundation by interposing laminated rubber bearings. This allows the structure to sway horizontally and survive a 7.3 magnitude earth quake. Should an earthquake disrupt the network, vehicles equipped with satellite communications equipment and wireless telephone exchanges will take over and maintain the communication needed. There are also fleets of vehicles equipped with high- and low-voltage generators and mobile transformers [3].

Security of service level in transmission system is generally measured via the use of N-1 criteria. The N-1 criteria or single contingency criteria used in planning and operation of power systems throughout the world, allows the system to operate normally in front of any outage on equipment or facilities, either a line circuit or a generating unit, without a cascade propagation on the rest of the system facilities [4]. However, a cascading failure is possible and when one such event emanating from an earthquake occurs, blackout might spread across a big portion of the grid. Such an event occurred during Marmara blackout of turkey in 1999. This resulted in more than one third of the load being dropped [5]. Part of smart grid approach is to make the grid more observable, this enables local controllers to make informed decisions based on system wide information and hence mitigate cascading failures. Enhanced observability also results in better partitioning during ‘island mode’ operation. This reduces chances of voltage collapse.
There have been suggestions in literature as to how to extend fault tolerant capabilities of internet to power grid [6]. The discussion revolves around distributed and autonomous control; diverse information routing and redundant data or application storage; and performance degradation instead of full failure. During contingency conditions such as earthquakes, loss of power supply can result from generation loss, damage to transmission system, damage to distribution network and difficulties in system operation such as loss of communication channel. Under such conditions, in traditional power grids, parts of the interconnect goes into island mode of operation i.e. disconnect themselves from the rest of the grid, this way operation in the disconnected area is carried out by matching demand and supply within the island area. The downside is load shedding, if generation is not enough to match demand.

A smart grid which incorporates distributed generation or microgrids has the following advantages over traditional grid during contingency situations. Microgrids can be disconnected from the grid and operated in islanded mode to serve local customer base. Under such conditions, local controllers will dispatch power to ‘island’ region using local generation such as wind, solar power. Intermittent nature of renewable energy sources could be overcome with the use of energy storage such as pumped hydro, compressed gas, flywheels or battery storage banks. Smart grids in general allow for better integration of energy generation and storage, including plug-in electric vehicles. This helps in better load following. The difference between microgrids in islanded mode of operation and parts of the network separated from grid and operating in islanded mode as explained in the previous paragraph is essentially the size of service area. During contingency, a decentralized approach such as microgrids potentially offers a better solution because of the smaller service area. Smaller service area presents a lesser constrained optimization problem than the case of larger service area.

Damage to transmission lines does not disrupt service in microgrids. However, damage sustained by distribution networks during earthquakes impose limits on microgrid operation. Redundancy of distribution lines is a desired factor under these conditions as they allow for power to be re-routed. Even with minimal to no change in distribution networks, microgrids can minimize blackout size. Microgrids can operate with lesser constraints with regards to operating conditions, for example a higher tolerance level for operating frequency can be employed than in an interconnected system as there is no risk of losing synchronism with the rest of the grid. Furthermore, power flow in lines can be controlled by using controllable network transformers and flexible AC transmission lines, and this will alleviate line congestion. Difficulties in system operation such as damage to SCADA or loss of communication channel affect microgrids only in a minimal way as the operational area is much smaller.

Smart grid technologies [7, 8] during earthquakes are expected to provide resiliency to the parts of the network not in the earthquake zone unlike the traditional power system. Besides, response of the electricity infrastructure to earthquakes will be enhanced to maintain stability and cascaded blackouts will be minimized.

References
THE ST. LOUIS AREA EARTHQUAKE HAZARDS MAPPING PROJECT

R.A. Williams¹, C.H. Cramer², J.D. Rogers³, R.A. Bauer⁴, J. Chung³, J. Prewett³, G.L. Hempen⁶, P.J. Steckel⁷, D. Hoffman³, C.M. Watkins, O.S. Boyd¹, and N.S. McCallister¹

¹U.S. Geological Survey, ²University of Memphis, ³Missouri University of Science and Technology, ⁴Illinois State Geological Survey, ⁵Missouri Division of Geology and Land Survey, ⁶URS Corporation, ⁷Earthquake Insight LLC

The St. Louis Area Earthquake Hazards Mapping Project is an urban hazard mapping effort supported by the U.S. Geological Survey (USGS) Earthquake Hazards Program. The goal of the project is to provide urban seismic and liquefaction hazard maps for the St. Louis region in Missouri and Illinois that can be used in land-use planning and private sector decision making. We use the 2008 USGS National Seismic Hazard Map hazard model as a foundation for our hazard calculation, but a significant difference is that this urban seismic hazard map includes the effects of local geology. The project includes a database of subsurface geological, geophysical, and geotechnical information to form a three-dimensional model of the surficial soft sediments over Paleozoic rock. In 2011 we completed an update of this 3-D model and generated 24 new reference soil profiles from shear-wave velocity (Vs) measurements for several soil type variations of the uplands (loess/till) and lowlands (alluvial). Site amplification ranges (distributions) are then generated by the randomization of the Vs profile, dynamic properties, and input ground motions and then used to produce probabilistic and scenario ground motion hazard maps. For peak ground acceleration and 0.2-second spectral acceleration (Sa), the resulting urban hazard maps show increased ground motion hazard in the uplands, which are covered by thinner loess/till deposits compared to the lowlands. We find similar ground motion hazard in the 30-50-meter thick alluvium lowlands relative to the 2008 USGS national seismic hazard maps. For 1.0 second Sa, the urban seismic hazard maps show a reversed pattern of greater amplification on lowlands alluvium than upland loess and till. Previous studies of earthquake recordings in the project area show that the high impedance between the lowland alluvial cover and the underlying Paleozoic rock can also generate strong S-wave resonances that could impact structures with similar resonant frequencies.
HAZUS ANALYSES OF ELEVEN SCENARIO EARTHQUAKES IN NEW ENGLAND


Earthquake losses were estimated for 11 New England scenario earthquakes by the New England Shake Map/HAZUS Working Group. The following scenario earthquakes were selected.

- 1727 Newburyport, MA M 5.8
- Moodus, CT M 5.3
- Littleton, MA M 5.0
- Rumford, ME M 5.5
- 1755 Cape Ann Offshore, MA M 6.5
- 1663 Charlevoix, Canada M 7.5
- 1638 Central New Hampshire M 6.5
- 1904 Passamaquoddy Bay, ME M 6.2
- 1732 Montreal, Canada M 6.2
- 1983 Goodnow, NY M 5.8
- 2002 Plattsburgh, NY M 5.8

The scenarios are distributed throughout New England and were generally selected based upon a prior historical earthquake. Most of the earthquakes occur on blind or unknown faults and so there is no known causative fault for the majority of events.

A Level 2 analysis was performed using HAZUS-MH version 2.0 that included incorporation of new/modified inventory of essential facilities, updating the demographic information to using the Homeland Security Infrastructure Program (HSIP) data from 2010, and the addition of imported ShakeMaps produced by the USGS. Losses were only calculated for the U.S. and so losses in Canada are not accounted for.

A comprehensive summary packet that included a set of 11 multi-risk maps was developed for each earthquake scenario. These maps include:

- Estimated Building Inspection Needs
- Estimated Building Economic Loss by County
- Displaced Households
- Electrical, Natural Gas and Oil Facility Damage
- Estimated Concrete, Steel Debris
- Estimated Highway Infrastructure Damage
- Impaired Hospitals (Day 1)
- Injuries Requiring Hospital Treatment 2 p.m.
- Potential Search and Rescue Needs 2 p.m.
- Short Term Shelter Public Needs
- Estimated Potable Water Needs by County

The greatest losses are those associated with a repeat of the 1638 M 6.5 Central New Hampshire earthquake with total fatalities of about 100 people, 2,000 injuries (2 p.m.), and $8.3 billion in total
economic losses including building and lifeline-related losses. This event is the largest onshore earthquake other than the M 7.5 Charlevoix earthquake and so the losses are expected.

The next most significant losses are sustained in a future M 5.8 Newburyport earthquake. Despite its moderate size, its occurrence in a highly populated area explains the high losses of 10 fatalities, 500 injuries, and $4.8 billion total economic loss. An offshore M 6.5 Cape Ann earthquake would result in only few deaths, about 200 injuries, and 200 extensively damaged buildings. Total economic losses are estimated to be about $3.2 billion.

The above estimates are probably low particularly for the Cape Ann earthquake because the extensive inventory of URM (unreinforced masonry) buildings has been underestimated, particularly for the Boston area. Fill and alluvial areas along the waterfronts in Boston have also not been accounted for in the NEHRP site class map. The losses should be considered preliminary first-order estimates that can be improved with future improvements in the NEHRP incorporation of a site class map and building inventories. Such improvements would include incorporating (1) detailed NEHRP site class and liquefaction potential maps for the greater Boston area based on a surficial geological map; (2) improved building inventories including URM buildings for Boston; and (3) 2010 census information.