Sixth National Seismic Conference on Bridges and Highways
Seismic Technologies for Extreme Loads
July 28-30, 2008  •  Charleston, South Carolina
Conference Program
Dear Conference Participants,

It has been a great honor and pleasure to work with our nation’s best researchers and engineers in the structural and seismic fields on the organization of the Sixth National Seismic Conference on Bridges and Highways. This gathering is the sixth in a series, following successful conferences held in San Diego, California (1995), Sacramento, California (1997), Portland, Oregon (2002), Memphis, Tennessee (2004) and San Francisco, California (2006). The theme is “Seismic Technologies for Extreme Loads,” which will allow discussions to include hazards other than earthquakes to help create a synergistic approach to protective systems.

In late 2006, FHWA, in cooperation with MCEER, published the latest “Seismic Retrofitting Manual for Highway Structures.” The manual consists of two volumes: “Part 1 – Bridges,” and “Part 2 - Retaining Walls, Tunnels, Culverts, Slopes and Pavements.” Both are available through FHWA or MCEER. On Sunday July 27, a one-day workshop will be held as part of this conference for participants interested in Part 1 of the manual and new seismic design specifications.

Funded by the National Science Foundation (NSF), the Network Earthquake Engineering Simulation (NEES) system has provided better facilities for advancing seismic engineering technologies and increasing seismic performance. Many technical papers presented at this conference have benefited from NEES support. For example, in cooperation with Japan, FHWA is working together with NSF/NEES, Caltrans, and other State DOTs to conduct a full-scale bridge column test on the world’s largest shake table in Kobe, Japan. We hope that this test will increase our understanding of the impact of scale effects in experimental testing.

Since our 2006 conference in San Francisco, many more deadly earthquakes have occurred around the world. Most recently, the great Wenchuan earthquake struck the Sichuan province of China, where more than 70,000 people died in an 8.0 magnitude earthquake. During the opening ceremonies, I would like to invite you to join me in a one-minute silent prayer to remember the people who have lost their lives in these devastating earthquakes.

I would like to express my sincere appreciation to the Steering Committee, Technical Committee, Local Organizing Committee (SCDOT) and MCEER staff for their guidance and assistance in organizing this conference. Particularly, I appreciate the dedication of Mr. Jerome O’Connor (Conference Coordinator), and Mr. Michael Keever and Ms. Lucero Mesa (co-chairs of the Technical Committee), who have spent a great deal of time working on this conference.

Without them, this conference could not have been successfully accomplished.

My very special thanks go to our honorary chairman, Mr. King Gee, and Mr. Myint Lwin, FHWA’s Chief Bridge Engineer, for their leadership, guidance and support. I would like to express my appreciation to our host agency, South Carolina Department of Transportation and to all the individuals listed on the Acknowledgements page of this program for all their hard work.

I would also like to thank all the presenters, session chairs and exhibitors for their support in helping to make this conference a success. Last, but not least, I thank all the participants who have traveled from near and far to attend this conference. I hope you will all have an excellent time in the Charleston area, while gaining valuable technical knowledge and making lasting friendships through the activities of this conference.

Finally, I am pleased to announce that FHWA is working together with other countries to establish an international bridge seismic engineering committee, and to continue to use this conference as a vehicle to exchange and disseminate up-to-date technology. The next national seismic conference on bridges and highways will expand this international involvement, and is planned for late 2010. The specific date and location will be announced soon.

W. Phillip Yen, Ph.D., P.E.
Office of Infrastructure, R&D
Federal Highway Administration
Acknowledgements

Honorary Conference Chairman
King Gee, Federal Highway Administration, Associate Administrator for Infrastructure

Steering Committee
W. Phillip Yen, Federal Highway Administration (Conference Chairman)
Jerome O’Connor, MCEER, University at Buffalo (Conference Coordinator)
Michael Keever, California Department of Transportation (Technical Committee Co-Chair)
Lucero Mesa, South Carolina Department of Transportation (Technical Committee Co-Chair)
Ian Buckle, University of Nevada, Reno
Genda Chen, Missouri University of Science & Technology
Reginald DesRoches, Georgia Institute of Technology
Jack Hayes, National Institute of Standards and Technology
George C. Lee, MCEER, University at Buffalo
Kristen Lominack, South Carolina Department of Transportation
Stephen Maher, Transportation Research Board
Stephen Mahin, University of California, Berkeley
Ed S. Eargle, South Carolina Department of Transportation
Arun Shirole, Arora and Associates, PC
Kevin Thompson, California Department of Transportation
Ed Wasserman, Tennessee Department of Transportation

Technical Committee
Michael Keever, California Department of Transportation (Co-Chair)
Lucero Mesa, South Carolina Department of Transportation (Co-Chair)
Sreenivas Alampalli, New York State Department of Transportation
Ronald D. Andrus, Clemson University
Juan Caicedo, University of South Carolina
Harry Capers, Arora and Associates, PC
Hannah Cheng, New Jersey Department of Transportation
Jeffrey Ger, Federal Highway Administration
Bryan Hartnagel, Missouri Department of Transportation
Sue Hida, California Department of Transportation
Hossein Ghara, Louisiana Department of Transportation
Hamid Ghasemi, Federal Highway Administration
Ken Johnson, Federal Highway Administration, South Carolina Division
Kornel Kerenyi, Federal Highway Administration
E.V. Leyendecker, United States Geological Survey
Derrell Manceaux, Federal Highway Administration
Richard Pratt, Alaska Department of Transportation
J. Jerry Shen, Federal Highway Administration
Li-Hong Sheng, California Department of Transportation
Paul Somerville, URS Corp.
Daniel H. Tobias, Illinois Department of Transportation
Joe Wang, Parsons Brinkerhoff Quade & Douglas, Inc.
Saiying Zhou, South Carolina Department of Transportation

Previous National Seismic Conference Chairs
Roland Nimis, California Department of Transportation
San Diego, California, 1995 (First Conference)
Sacramento, California, 1997 (Second Conference)
Portland, Oregon, 2002 (Third Conference)
Ed Wasserman, Tennessee Department of Transportation and Paul Sharp, Federal Highway Administration
Memphis, Tennessee, 2004 (Fourth Conference)
W. Phillip Yen, Federal Highway Administration and Kevin Thompson, California Department of Transportation
San Mateo, California, 2006 (Fifth Conference)

Local Organizing Committee
Kristen Lominack, South Carolina Department of Transportation (Co-Chair)
Tina Hembree, South Carolina Department of Transportation (Co-Chair)
Ken Johnson, Federal Highway Administration, South Carolina Division
Lucero Mesa, South Carolina Department of Transportation
Nathalia Rodriguez, South Carolina Department of Transportation
Saiying Zhou, South Carolina Department of Transportation
ACKNOWLEDGEMENTS

TECHNICAL SUPPORT

Administrative Assistant to Conference Coordinator
Joy James, MCEER

Audio-Visual
Daniel Machado, South Carolina Department of Transportation
Lawton Player, South Carolina Department of Transportation
David Bland, South Carolina Department of Transportation

Awards & Professional Development Hours
Ken Johnson, Federal Highway Administration
John Walsh, South Carolina Department of Transportation

Communications
Pete Poore, South Carolina Department of Transportation
Bob Kudelka, South Carolina Department of Transportation

Conference Website
Emily Reese, South Carolina Department of Transportation

Financial Accounting
Jerry Meyers, MCEER

Graphics
Bonnie Cramer, South Carolina Department of Transportation
David Pierro, MCEER

Hotel & on-site coordination
Karen Buchheit, MCEER

On-Line Registration
David Parisi, MCEER

Photography
Rob Thompson, South Carolina Department of Transportation

Proceedings & Program
Jane Stoyle, MCEER
Michelle Zuppa, MCEER

Registration Website
Michelle Zuppa, MCEER

Travel
Patricia Kraemer, MCEER

STUDENT DESIGN COMPETITION

Lucero Mesa, South Carolina Department of Transportation
(Steering Committee Liaison)

Juan Caicedo, University of South Carolina (Event Coordinator)
John Walsh, South Carolina Department of Transportation
Nathalia Rodriguez, South Carolina Department of Transportation
Saiying Zhou, South Carolina Department of Transportation
Genda Chen, Missouri University of Science & Technology
(Judge)

Derrell Manceaux, Federal Highway Administration (Judge)

Stephen Maher, Transportation Research Board (Judge)

SPECIAL EVENTS COORDINATORS

AASHTO T3 Q&A Session
Kevin Thompson, California Department of Transportation

AASHTO T5 Q&A Session
Hossein Ghara, Louisiana Department of Transportation

Companion Activities
Susan Johnson, South Carolina Department of Transportation

Exhibition
Tina Hembree, South Carolina Department of Transportation

On-site Registration
Shirley Jeffcoat, South Carolina Department of Transportation

Poster Session
Reginald DesRoches, Georgia Institute of Technology

Pre-Conference Workshop
Reggie Holt, Federal Highway Administration
Derrell Manceaux, Federal Highway Administration

Technical Boat Tour
Daniel Burton, South Carolina Department of Transportation
Tina Hembree, South Carolina Department of Transportation

Transportation Coordinator
Cal Murray, South Carolina Department of Transportation
A Charleston Landmark!

Parsons Brinckerhoff (PB) was the lead design firm and engineer of record for the design-build team that delivered Charleston’s Arthur Ravenel, Jr. Bridge on behalf of the South Carolina Department of Transportation. PB designed the majestic cable-stayed crossing of the Cooper River to accommodate a 2,500-year seismic event and to withstand ship collisions and hurricane-force winds.

The result is a landmark bridge that is beautiful, functional—and safe.

For career opportunities or more information about Parsons Brinckerhoff (PB), please visit www.pbworld.com
**GENERAL INFORMATION**

**REGISTRATION**
Location: Francis Marion Hotel, Mezzanine Level, one floor up from the lobby

**REGISTRATION HOURS**
Sunday  1:00 pm - 8:00 pm
Monday   7:00 am - 5:00 pm
Tuesday  7:00 am - 5:00 pm
Wednesday 7:00 am - Noon

**ICE BREAKER**
Sunday evening  6:00 pm – 8:00 pm
Location: Colonial Ballroom, just off the lobby
Business casual dress.

**RECEPTIONS**
Monday and Tuesday  5:00 pm – 6:00 pm
Location: Colonial Ballroom, just off the lobby
Business casual dress.

**TECHNICAL EXHIBITS**
With the conference theme *Seismic Technologies for Extreme Loads*, we are fortunate to have twenty companies available to explain the latest technology and services they offer. Please stop by, visit, and leave your business card to receive additional information.

Location: Francis Marion Hotel, Gold Room, Second Floor

**EXHIBIT HOURS**
Monday  7:30 am - 5:00 pm
Tuesday  7:30 am - 5:00 pm
Wednesday 7:30 am - Noon

**CLIMATE AND CLOTHING**
The weather in Charleston can be expected to be clear and sunny during the time of the conference. The average daily high temperature in July and August is 89 °F (32 °C) with a heat index in the mid 90’s. The average daily low temperature in July and August is 71 °F (22 °C). Business casual dress is acceptable for the technical sessions, daytime meetings and social functions. You are encouraged to bring lightweight clothing for touring the city in your free time. Participants of the Technical Boat Tour should take extra precautions to protect themselves from the sun and heat.

**MEALS**
Complimentary *Continental Breakfast* will be served in the Gold Room from 7:00 am – 8:00 am daily.

Complimentary morning and afternoon *coffee breaks* will be served in the Gold Room.

**Lunch** on Monday and Tuesday is included in the conference registration fee. It will be served in the Colonial Ballroom, just off the lobby. Lunch is on your own on Wednesday. Participants of the boat tour will get a box lunch provided as part of the tour.

**Dinners** are on your own. In addition to the restaurant in the hotel, there are numerous moderately priced restaurants within walking distance. Directions and maps are in your registration packet.

**TRANSPORTATION**
Please stop at the registration desk for assistance.

**SOCIAL PROGRAM**
Activities for spouses and companions are available. Please stop in at the registration desk to inquire.

**TECHNICAL BOAT TOUR**
Individuals who have pre-registered for the guided Boat Tour of Charleston harbor and the Ravenel Bridge should be at the front door of the hotel before noon on Wednesday for a 12:00 pm bus departure. The ticket that was provided with your name badge holder at registration will give you admission to the bus, the boat, and entitle you to a box lunch. Since you will be on the water for several hours, be sure to bring appropriate attire (e.g. hat, sunscreen). We expect to be back at the hotel by 4:30 pm.

**PROCEEDINGS**
Conference proceedings are included on a CD which is in the registration packet. The full technical paper associated with each oral and poster presentation is included.
Center for Transportation Infrastructure and Safety

Mission: To advance U.S. technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence.

Theme Areas: Advanced materials including constructed facilities security and the development, manufacture, and application of modern construction materials.

Non-destructive evaluation (NDE) technologies and methods including monitoring and evaluation of new and repaired structures and system components.

Visit our website to learn more about research areas, funding opportunities and educational assistance.

Center for Transportation Infrastructure and Safety
A National University Transportation Center
at Missouri University of Science & Technology
220 Engineering Research Laboratory
Rolla, MO 65409

P: 573.341.7848
F: 573.341.6215
ctis@mst.edu
http://utc.mst.edu
### AGENDA

**SUNDAY, JULY 27, 2008**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:00 am – 8:00 am</td>
<td>Pre-Conference Workshop Check-in</td>
<td>Mezzanine Level</td>
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<tr>
<td>8:00 am – 5:00 pm</td>
<td><strong>Pre-Conference Workshop: “Best Practices for Seismic Design &amp; Retrofit of Bridges”</strong></td>
<td>Carolina Ballroom</td>
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<td>(Pre-Registration Required)</td>
<td>Mezzanine Level</td>
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<td></td>
<td>Moderator: Reggie Holt, Federal Highway Administration</td>
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<td>(Breakfast will be provided. Lunch is on your own)</td>
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<tr>
<td>1:00 pm – 8:00 pm</td>
<td>6NSC Conference Registration</td>
<td>Mezzanine Level</td>
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<tr>
<td>3:00 pm – 6:00 pm</td>
<td><strong>Student Bridge Competition Assembly of Bridges</strong></td>
<td>Calhoun Room, Mezzanine Level</td>
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<td>(All welcome)</td>
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<td>Moderator: Juan Caicedo, University of South Carolina</td>
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<tr>
<td>3:00 pm – 6:00 pm</td>
<td><strong>Poster Set-up</strong></td>
<td>Colonial Room, Lobby Level</td>
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<td>(Posters will remain on display until the Poster Session on Tuesday)</td>
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<td>Coordinator: Tina Hembree, South Carolina Department of Transportation</td>
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<tr>
<td>5:00 pm – 9:00 pm</td>
<td><strong>Exhibitor Set-up</strong></td>
<td>Gold Ballroom, Second Floor</td>
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<td>Coordinator: Tina Hembree, South Carolina Department of Transportation</td>
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<tr>
<td>6:00 pm – 8:00 pm</td>
<td><strong>Ice Breaker Reception</strong></td>
<td>Colonial Room, Lobby Level</td>
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**MONDAY, JULY 28, 2008**

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<tr>
<th>Time</th>
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<tr>
<td>7:00 am – 5:00 pm</td>
<td>Conference Registration</td>
<td>Mezzanine Level</td>
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<tr>
<td>7:00 am – 8:00 am</td>
<td>Breakfast</td>
<td>Gold Ballroom, Second Floor</td>
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<tr>
<td>8:00 am – 9:30 am</td>
<td><strong>PLENARY SESSION I</strong></td>
<td>Carolina Ballroom</td>
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<td>Moderator: Jerome O’Connor, MCEER, University at Buffalo</td>
<td>Mezzanine Level</td>
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<tr>
<td>8:00 am – 8:15 am</td>
<td><strong>Welcome</strong></td>
<td>Carolina Ballroom</td>
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<td>W. Phillip Yen, Federal Highway Administration</td>
<td>Mezzanine Level</td>
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<tr>
<td>8:15 am – 8:30 am</td>
<td><strong>Welcome</strong></td>
<td>Carolina Ballroom</td>
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<td>H. B. Limehouse, Jr., South Carolina Secretary of Transportation</td>
<td>Mezzanine Level</td>
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<tr>
<td>8:30 am – 9:00 am</td>
<td><strong>U.S. Highway Infrastructure in the 21st Century</strong></td>
<td>Carolina Ballroom</td>
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<td>King Gee, Federal Highway Administration</td>
<td>Mezzanine Level</td>
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<tr>
<td>9:00 am – 9:30 am</td>
<td><strong>A Summary of FHWA Sponsored Research</strong></td>
<td>Carolina Ballroom</td>
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<td>W. Phillip Yen, Federal Highway Administration</td>
<td>Mezzanine Level</td>
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<tr>
<td>9:30 am – 10:00 am</td>
<td>Break</td>
<td>Gold Ballroom, Second Floor</td>
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**CONCURRENT TECHNICAL SESSIONS: 1A1 and 1B1**

**Track A – Carolina A, Mezzanine Level**

**Session 1A1: SEISMIC ACCELERATED BRIDGE CONSTRUCTION (ABC)**

- **Moderator:** Dan Tobias, Illinois Department of Transportation

  1. **Strategic Implementation Plan for Accelerated Bridge Construction in California**
     - Kevin Thompson, Michael Keever, and Raymond Wolfe
  2. **Pre-Fabricated Bridge Superstructures**
     - Amjad J. Aref, Gordon P. Warn, Petros Sideris, and Andre Filiatrault
  3. **Use of Precast Bridge Members in Areas of High or Moderate Seismicity**
     - Jugesh Kapur and Bijan Khaleghi
  4. **Emergency Repair of Damaged Bridge Columns Using Fiber Reinforced Polymer (FRP) Materials**
     - Ashkan Vosooghi, M. Said Saidi, Jim Gutierrez, and Scott F. Arnold
  5. **Seismic Continuity Performance of Precast Girders Connected to a Cast-in-Place Bent Cap**
     - Kevin Almer and David Sanders

**Track B – Carolina B, Mezzanine Level**

**Session 1B1: NEW GEO-SEISMIC PRACTICE AND GUIDELINES**

- **Moderator:** Paul Liles, Georgia Department of Transportation

  1. **Analysis of Pile Group Under Lateral Loads Using the LRFD Guidelines**
     - Mohamed Ashour and Gary Norris
  2. **Passive Force-Deflection Curves for Abutments with MSE Confined Approach Fills**
     - Luke Heiner, Kyle M. Rollins, and Travis M. Gerber
  3. **SCDOT’s New Geo-Seismic Practice**
     - Nicholas E. Harman, and Eduardo A. Tava
  4. **Proposed AASHTO Specifications for the Seismic Design of Retaining Walls, Slopes and Embankments, and Buried Structures**
     - Donald G. Anderson, Geoffrey R. Martin, I.P. Lam, and J.N. Wang
  5. **Effects of Structural Characterizations on Fragility Functions of Bridges Subjected to Seismic Shaking and Lateral Spreading**
     - Jian Zhang, Yili Huo, Pirooz Kashighandi, and Scott J. Brandenberg

(Continued)
MONDAY, JULY 28, 2008 (Continued)

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<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>11:45 am</td>
<td>Lunch (provided): The Charleston Earthquake, Then and Now</td>
<td>Colonial Room, Lobby Level</td>
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<tr>
<td>1:00 pm</td>
<td>CONCURRENT TECHNICAL SESSIONS: 1A2 and 1B2</td>
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<td>Session 1A2: Emerging Seismic Design and Retrofit Technologies</td>
<td>Track A: Carolina A, Mezzanine Level</td>
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<td>Moderator: Stephen Maher, Transportation Research Board</td>
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<tr>
<td></td>
<td>1. The Development of the FHWA Pushover Analysis Computer Program</td>
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<td></td>
<td>J. Jerry Shen, Linda Kuo-Lin, Jeffrey Ger, and W. Phillip Yen</td>
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<td>2. Calibration of a Model to Estimate the Residual Post-Earthquake Capacity of Circular Bridge Columns</td>
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<td>Vesna Terzic, Kevin Mackie, Bozidar Stojadinovic</td>
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<td>3. Ductility Analysis of Type II Pile Shaft</td>
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<td>Larry Wu and Ray Wolfe</td>
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<td>4. Evaluation of Joint Shear Response for Existing California Bridges</td>
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<td>Fadel Alameddine and Michael Keever</td>
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<td>5. New Seismic 1000 Year Return Period – Impact to Bridge Design Methodologies</td>
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<td>Derrell Manceaux</td>
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<tr>
<td>2:45 pm</td>
<td>Break</td>
<td>Gold Ballroom, Second Floor</td>
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<td>3:15 pm</td>
<td>CONCURRENT TECHNICAL SESSIONS: 1A3 and 1B3</td>
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<td>Session 1A3: Evolving Bridge Seismic Specifications and Its Impact in Design – A State’s Perspective</td>
<td>Track A: Carolina A, Mezzanine Level</td>
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<td>Moderator: Ed Wasserman, Tennessee Department of Transportation</td>
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<tr>
<td></td>
<td>1. AASHTO LRFD Guide Specifications for Seismic Design of Highway Bridges</td>
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<tr>
<td></td>
<td>Roy Imbsen</td>
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<td>Stephanie Brandenberger</td>
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<td></td>
<td>Daniel H. Tobias, Ralph E. Anderson, Chad E. Hodel, William M. Kramer, Riyad M. Wahab and Richard J. Chaput</td>
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<td>4. Updated South Carolina Department of Transportation Seismic Design Specifications for Highway Bridges</td>
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<td>Lucero E. Mesa, Zhugang Amos Liu and Saiying Zhou</td>
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<td>5. Effects of New LRFD Seismic Bridge Design Specifications to a “Normal” Typical Bridge in New York State</td>
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<td>Rajesh Tanega, Mengisteab Debessay and Arthur Yannotti</td>
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<tr>
<td>5:00 pm</td>
<td>Reception and Student Bridge Design Competition (Judging)</td>
<td>Colonial Room, Lobby Level</td>
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<td>6:00 pm</td>
<td>CONCURRENT SPECIAL SESSIONS: T3 and T5</td>
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<tr>
<td>T3: Special Session on AASHTO T3 (Seismic) 2008 Ballot Item: Liquefaction and other Guide-Specification Changes</td>
<td>Track A: Carolina A, Mezzanine Level</td>
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<td>Moderator: Kevin Thompson, California Department of Transportation</td>
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<tr>
<td>T5: Special Session on AASHTO T5 (Loads) 2008 Ballot Item: Coastal Engineering</td>
<td>Track B: Carolina B, Mezzanine Level</td>
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<tr>
<td>Moderator: Hossein Ghara, Louisiana Department of Transportation</td>
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## AGENDA

### TUESDAY, JULY 29, 2008

<table>
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<tr>
<th>Time</th>
<th>Activity</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>7:00 am – 5:00 pm</td>
<td>Conference Registration</td>
<td>Mezzanine Level</td>
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<tr>
<td>7:00 am – 8:00 am</td>
<td>Breakfast</td>
<td>Gold Ballroom, Second Floor</td>
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<tr>
<td>8:00 am – 9:45 am</td>
<td><strong>PLENARY SESSION II</strong>&lt;br&gt;Moderator: George C. Lee, University at Buffalo</td>
<td>Carolina Ballroom&lt;br&gt;Mezzanine Level</td>
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<tr>
<td>8:00 am – 9:45 am</td>
<td>Highway Infrastructure Damage Resulting from Sichuan, China Earthquake of May 12, 2008&lt;br&gt;Guest Speaker</td>
<td>Carolina Ballroom&lt;br&gt;Mezzanine Level</td>
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<tr>
<td>9:45 am – 10:15 am</td>
<td>Break</td>
<td>Gold Ballroom, Second Floor</td>
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<tr>
<td>10:15 am – Noon</td>
<td><strong>CONCURRENT TECHNICAL SESSIONS: 2A1 AND 2B1</strong></td>
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**Track A – Carolina A, Mezzanine Level**

**SESSION 2A1: EMERGING SEISMIC DESIGN AND RETROFIT TECHNOLOGIES**

Moderator: Jugesh Kapur, Washington State Department of Transportation

1. **New Tools Available to Practicing Engineers for the Seismic Design of Bridges**<br>W. Phillip Yen, George C. Lee and Jerome S. O’Connor

2. **The Plastic Hinge Demystified**<br>David W. Taylor, Andy E. Cook and J. Preston Felkel

3. **Damping-Enhanced Strengthening: A Unique Way to Normalize the Seismic Performance of RC Bridges for Multiple Objectives**<br>Genda Chen and Kazi R. Karim

4. **Seismic Retrofit of Highway Bridges in the United States**<br>Glenn Smith

5. **Evaluating the Seismic Stability and Performance of Freestanding Geofoam Embankment**<br>Steven F. Bartlett and Evert C. Lawton

**Track B – Carolina B, Mezzanine Level**

**SESSION 2B1: SOIL-STRUCTURE INTERACTION AND FOUNDATIONS**

Moderator: Bryan Hartnagel, Missouri Department of Transportation

1. **Soil-Foundation-Structure Interaction of Long-Span Bridge Structures**<br>Anoosh Shamsabadi, Hubert Law and Amir Zand

2. **The Golden Ears Bridge Design-Build Project: Foundation Design for Segment 4 Approach Structures**<br>King Sampaco, Ha Pham, and Donald Anderson

3. **Effect of Nonlinear Pile Stiffness on Bridge Seismic Response**<br>Jin-Xing Zha

4. **Effect of Shallow Foundation Rocking on Dynamic Response of Bridges**<br>Andres Espinoza and Stephen Mahin

5. **Developing Spectra For Type F Soils For Two Bridge Sites Near Salt Lake City**<br>Zia Zafir and James Higbee

| Noon – 1:00 pm | Lunch (provided):<br>Presentation of Awards for Student Competition, Best Papers<br>By John Walsh, South Carolina Department of Transportation | Colonial Room<br>Lobby Level |

(Continued)
## Agenda

**Tuesday, July 29, 2008** (Continued)

### 1:00 pm – 2:45 pm  
**Concurrent Technical Sessions: 2A2 and 2B2**

<table>
<thead>
<tr>
<th>Track A – Carolina A, Mezzanine Level</th>
<th>Track B – Carolina B, Mezzanine Level</th>
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</table>
| **Session 2A2: Design and Analysis of Major Bridges in Areas of High or Moderate Seismicity**  
Moderator: Stephanie Brandenberger, Montana Department of Transportation  
1. Seismic Detailing on the Stono River Bridge in South Carolina  
   Robert Fish and Ernie Dozzi  
2. Seismic Evaluation of the I-155 Bridge Over the Mississippi River  
   Mark R. Capron  
3. Seismic Analyses and Evaluation for Retrofit of the Suspended Spans of the Bronx-Whitestone Bridge  
   Ruben B. Gajer, David Rubin, Adam Hapij, Fangyin Zhang, Christopher Mauch and Mohammed Etienne  
4. Lake Natoma Crossing: Combining High Performance Requirements for Seismic, River Flow, and Scour with a High Aesthetics Demand  
   Robert Fish  
5. Development of Seismic Design Criteria for the Dumbarton and Antioch Toll Bridges, California  
   Hubert K. Law, Ignatius Po Lam, Brian Maroney, and Saba Mohan | **Session 2B2: Seismic Instrumentation and Monitoring Systems**  
Moderator: Rajesh Taneja, New York State Department of Transportation  
1. Evaluation of Damage Identification Algorithms applied to a 4-span Concrete Bridge Subjected to Near Source Ground Motions Using Nonlinear Finite Element Method  
   Amirhossein Irmaneshe, Seyed A. Bassam and Farhad Ansari  
2. Changes in Modal Frequencies of a Highway Bridge  
   Marvin W. Halling, Shutao Xing, Paul J. Ban, Zachary C. Hansen  
3. Rion-Antirion Monitoring System  
   Aris Vlamis-Stathopoulos, Gilles Hovhanessian and Benoit Kroely  
4. Energy Based Approach for Post Seismic Structural Health Monitoring of a Four Span Bridge  
   Seyed A. Bassam, Amirhossein Irmaneshe and Farhad Ansari  
5. Development of Rocking Column Systems  
   Matthew J. Tobolski and José I. Restrepo |

### 2:45 pm – 3:15 pm  
Break

### 3:15 pm – 5:00 pm  
**Concurrent Technical Sessions 2A3 and 2B3**

<table>
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<tr>
<th>Track A – Carolina A, Mezzanine Level</th>
<th>Track B – Carolina B, Mezzanine Level</th>
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| **Session 2A3: Earthquake Strategies for Protection Against Other Hazards**  
Moderator: Hossein Ghara, Louisiana Department of Transportation  
1. Developing a Methodology for Comparison of Extreme Hazards for Highway Bridge Design  
   George C. Lee, Sangyul Cho, Mai Tong and W. Phillip Yen  
2. Multiple Hazard Research Needs and AASHTO Code Development Activities  
   Harry A. Capers, George C. Lee, and Jerome S. O’Connor  
3. Seismic Hazard Considerations within a Multihazard Environment  
   Mohammed Etienne and Sreenivas Alampalli  
4. Beneficial Aspects of a Multi-Hazard Approach to Design of Highway Bridges  
   M. Ala Saadeghvaziri and Bakhtiar Feizi  
5. Large-Scale Wave Flume Experiments on Highway Bridge Superstructures Exposed to Hurricane Wave Forces  
   Thomas Schumacher, Christopher Higgins, Christopher Bradner, Daniel Cox, and Solomon Yim | **Session 2B3: Seismic Risk Assessment of Highway Networks**  
Moderator: Ken Johnson, Federal Highway Administration  
1. Experiences in Creating a Seismic Risk Model of the Oregon Highway Bridge Network Using REDARS2  
   Peter Dusicka, Michael Glickman, Helen Oppenheimer and Holly Winston  
2. Seismic Risk Assessment of the Transportation Network of Charleston, South Carolina  
   Reginald DesRoches, Jamie Padgett, and Emily Nilsson  
3. Effects of Retrofits on Seismic Fragility of Multi-Span Continuous Steel Highway Bridges in New York State  
   Anil K. Agrawal, Ying Pan and Sreenivas Alampalli  
4. Seismic Risk Assessment of Priority Bridges along I-24 in Western Kentucky  
   Wael Zatar, Issam Hark, Wei-Xin Ren, and Tong Zhao  
5. Probabilistic Damage Control Approach (PDCA) and Performance-Based Design of Bridges  
   Abbas M. Tourzani, Amir M. Malek, Sam Ataya, and Mark Mahan |

### 5:00 pm – 6:00 pm  
Reception and Poster Session (with an award for Best Poster)  
Moderator: Reginald DesRoches, Georgia Institute of Technology  
Colonial Room  
Lobby Level
AGENDA

WEDNESDAY, JULY 30, 2008

7:00 am – Noon  Conference Registration  Mezzanine Level
7:00 am – 8:00 am  Breakfast  Gold Ballroom, Second Floor
8:00 am – 9:45 am  PLENARY SESSION III  Carolina Ballroom Mezzanine Level
Moderator: Myint Lwin, Federal Highway Administration
8:00 am – 8:45 am  Displacement Based Seismic Design of Bridges  Carolina Ballroom Mezzanine Level
Gian Michele Calvi, University of Pavia, Italy
8:45 am – 9:30 am  Reconstruction of Ica, Pisco, Chincha and Cañete, Peru, Based on Updated Hazard  Carolina Ballroom Mezzanine Level
Maps  Julio Kuroiwa, National University of Engineering, Lima, Peru
9:30 am – 9:45 am  Closing Remarks  Carolina Ballroom Mezzanine Level
W. Phillip Yen, Federal Highway Administration
9:45 am – 10:15 am  Break  Gold Ballroom, Second Floor
10:15 am – Noon  CONCURRENT TECHNICAL SESSIONS: 3A1 AND 3B1  Carolina Ballroom Mezzanine Level
Track A – Carolina A, Mezzanine Level
Track B – Carolina B, Mezzanine Level
SESSION 3A1: INTERNATIONAL TECHNOLOGIES AND PRACTICES  Moderator: Juan Caicedo, University of South Carolina
1. Extreme Wind Loads  Dorian Janjic
2. Advanced Seismic Design Considerations for Highway and High Speed Railway Bridges in Spain  Jose-Luis Sanchez Jimenez
3. Expected Behavior of the Infrenillo II Bridge in Mexico  José M. Jara, Manuel Jara and Hugo Hernández
4. Experimental Investigations of Precast Segmental Bridge Columns Seismically Isolated with Lead-Rubber Bearings  Yu-Chen Ou, Mu-Sen Tsai, Ping-Hsiung Wang, Kuo-Chun Chang, and George C. Lee
5. Seismic Performance of Skewed Bridges with Sliding Rubber Bearings  Kevin Lui and Kuo-Chun Chang
Noon – 4:30 pm  Technical Boat Tour  Meet bus at hotel door
(Pre-registration required. Box lunch provided)
Presenter: Daniel Burton, South Carolina Department of Transportation
SESSION 3B1: EFFECTS OF NEAR-FIELD EARTHQUAKES ON BRIDGES  Moderator: Derrell Manceaux, Federal Highway Administration
1. Simplified Analysis of Bridges Crossing Fault-Rupture Zones  Rakesh K. Goel and Anil K. Chopra
2. Study of Pulse Effects of NFGM on the Dynamic Response of Bridge Structures  Ajit C. Khanse and Eric M. Lui
3. Effects of Near-field Earthquakes on Bridges with Tall Bearings  Monique C. Hite, Siddharth Srivastava, Reginald DesRoches, and Roberto T. Leon
4. Development of a Biaxial Hysteretic Model for Reinforced Concrete Structures  Shu-Hsien Chao and Chin-Hsiung Loh
5. The Influence of Vertical Earthquake Motion and Pre-Earthquake Stress State on the Seismic Response of Precast Segmental Bridge Superstructures  Mark Veletzos and José I. Restrepo

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To Order, Visit:
http://mceer.buffalo.edu/publications/Bridge_and_Highway_Reports/Bridge_Manuals.asp
**Program at a Glance**

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<tr>
<th>Sunday</th>
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<th>Tuesday</th>
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<td>Registration:</td>
<td>7:00 am - 5:00 pm</td>
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<tr>
<td>Pre-Conference Workshop:</td>
<td>Plenary Session</td>
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<tr>
<td>&quot;Best Practices for Seismic Design &amp; Retrofit of Bridges&quot;</td>
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<td>Carolina</td>
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<td>Ice Breaker</td>
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<tr>
<td>Reception &amp; Judging of Student Competition</td>
<td>2 Concurrent Sessions</td>
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<td>5:00 pm - 6:00 pm</td>
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<td>Concurrent Sessions on 2008 AASHTO T3 &amp; T5 Ballot Items</td>
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<td>6:00 pm - 7:30 pm</td>
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**Notes:**
- The conference registration desk is on the Mezzanine Level, at the top of the stairs, one floor up from the Lobby.
- All technical sessions are in the Carolina Room on the Mezzanine Level.
- Exhibitors, breakfast, and all breaks are in the Gold Ballroom.
- Exhibitor set up is Sunday 5:00 - 9:00 pm in the Gold Ballroom. Take-down is Wednesday 10:15 - Noon.
- All are invited to watch the assembly of bridges for the student competition Sunday 3:00 - 6:00 pm in the Calhoun Room.
- Student Bridge Competition to be judged during the reception Monday 5:00 - 6:00 pm in the Colonial Room.

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This exhibit provides information for researchers that lead the way in developing the building blocks for enhancing the performance of our transportation infrastructure, for academia who educate and prepare future engineers, and for industry partners who must assure quality in the constructed projects.

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University of Buffalo
Red Jacket Quad
Buffalo, NY 14261-0052 USA
Phone: (716) 645-3391
Fax: (716) 645-3399
E-mail: mceer@buffalo.edu
Website: http://mceer.buffalo.edu/

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Contact: Karen Odash
14000 Technology Drive
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TRC provides a full range of consulting engineering services in support of the transportation industry. TRC’s capabilities include structural, civil, and transportation engineering; construction administration; and much more. TRC encompasses all phases of transportation design, including planning studies, complete plans, specifications and estimates (PS&E), design reviews and construction phase services and is especially noted for its innovations in earthquake engineering including seismic analysis and design of highway structures. TRC also maintains, markets and supports its own line of bridge and structural engineering design software.

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Mr. Limehouse, also known as “Buck,” received a Bachelor of Arts degree from The Citadel. In May 1995, he was awarded an honorary Doctorate Degree in Hospitality management from the prestigious Johnson & Wales University. The Citadel awarded him an Honorary Doctorate of Business in May 1997. Among his numerous honors, he was named “Transportation Advocate of the Year” in 1995 by the South Carolina Transportation Policy Council, and he received the Order of the Palmetto from Governor Campbell in 1995 and a second Order of the Palmetto from Governor Beasley in 1999. He is listed in “Who’s Who in America” and “Who’s Who in the World.”

Harry B. Limehouse, Jr., South Carolina
Secretary of Transportation

8:15 am
Welcome

Harry B. Limehouse, Jr. was recently appointed by Governor Mark Sanford as the first Secretary of Transportation in the history of South Carolina. Previously, Mr. Limehouse served as a Commissioner, Chairman of the Commission, Executive Director and a member of the State Transportation Infrastructure Bank Board. Mr. Limehouse has served as a consultant to the Georgia Department of Transportation and was nominated by the Florida Department of Transportation Commission for the post of Secretary of Transportation in that state.

Mr. Gee has received a number of performance and honor awards including the FHWA Administrator’s Award for Superior Achievement, and the Presidential Rank Meritorious Executive Award.
His current and past professional affiliations include the American Geophysical Union, Seismological Society of America, Earthquake Engineering Research Institute, Geological Society of America, and the United States Committee on Large Dams, among others.

His current and past research activities include the study of prehistoric and current seismic activity and seismic hazard analysis in South Carolina; the 1886 Charleston earthquake—its history, causes, mechanisms, seismotectonics, etc. He was involved in reevaluation of seismic hazards in the South Carolina Coastal Plain for the South Carolina Department of Transportation, and the seismic hazard evaluation of the new Cooper River Bridge. His other research interests include the study of reservoir induced seismicity, fluid pressure flow in fractures, the study of paleoliquefaction features to obtain the recurrence time of prehistoric earthquakes, and the measurement of geodetic strain in the Charleston area. Together with his students, he has given more than 400 technical talks and published more than 100 research papers.

Among his professional honors are being elected as a Fellow of the Geological Society of America, the Seismological Society of America’s Eastern Section JSA Award for Contributions to Observational Seismology, and the 2008 Richard Russell Research Award for Science, Mathematics and Engineering, the highest research award given at USC.

Plenary Session III
Wednesday, July 30, 2008, 8:00 - 9:45 am

Gian Michele Calvi, University of Pavia, Italy

8:00 am
Displacement Based Seismic Design of Bridges

Gian Michele Calvi is professor of Structural Design at the Università degli Studi di Pavia and Director of the Centre of Research and Graduate Studies in Earthquake Engineering and Engineering Seismology (ROSE School), Istituto Universitario di Studi Superiori (IUS) of Pavia. He received his Master of Science from the University of California, Berkeley and his Ph.D. from the Politecnico di Milano.

Dr. Calvi serves as Associate Editor of the “Journal of Earthquake Engineering.” He is also the author of more than 200 publications, among them the book “Seismic Design and Retrofit of Bridges,” written together with M.J.N. Priestley and F.
Seible and published in 1996 by John Wiley, which has been translated into Japanese and Chinese. More recently, he has co-authored the book “Displacement-Based Seismic Design of Structures” (with M.J.N. Priestley and M.J. Kowalsky, IUSS Press, Pavia, 2007, 721 pp.), whose review for a major journal, written by G. Powell, Emeritus of the University of California, Berkeley, starts with this sentence: “It is rare for a book on structural engineering design to be revolutionary. I believe that this is such a book.”

His research interests are related to design and assessment of bridges and buildings, with emphasis on either experimental and numerical aspects. He is coordinating several international research projects on these subjects. He has been involved in the seismic design or verification of several hundred buildings and bridges, has been a member of the checker team for the Rion-Antirion cable stayed bridge (2883 m, in Greece) and the designer of the strengthening intervention of the Bolu viaduct (119 spans, in Turkey).

JULIO KUROIWA, NATIONAL UNIVERSITY OF ENGINEERING, LIMA, PERU

8:45 am
Reconstruction of Ica, Pisco, Chincha and Cañete, Peru, Based on Updated Hazard Maps

Julio Kuroiwa, Professor Emeritus of the National University of Engineering (UNI), Lima, Peru, has been a consulting engineer for 35 years, and is the author of 100 papers on natural and technological disasters presented at world conferences and national and international seminars and congresses. He has written four books on disaster prevention and risk reduction.

Professor Kuroiwa has carried out investigations on natural disasters in the Americas for more than 30 years, developing methods and techniques for microzonation, urban planning, and earthquake-resistant buildings, among other studies. In 1980-84 and again in 1984-88, he was Director of the International Association of Earthquake Engineering with headquarters in Tokyo, Japan. In 1990, the United Nations Sasakawa-UNDRO Disaster Prevention Award, among other distinctions, was awarded to Professor Kuroiwa for his contributions. He was a member of the Advisory Committee of the United Nations Center for Regional Development, Nagoya, Japan from 1998 to 2000. He was also the Chief Technical Advisor to the United Nations Disaster Mitigation Program in Colombia (1988-91) and Peru (1992-95), and the Chief Technical Advisor to the Sustainable Cities Program in Peru (1999-2007). He has conducted many study missions to countries in Central and South America for several United Nations (UN) and Organization of American States (OAS) agencies. At present, he is Chief Technical Advisor of the Reconstruction Program/Sustainable Cities advising the Peruvian Government under contract with United Nations Development Program (UNDP).

His biography is included in the “Who’s Who in the World” 1997, 1999 and 2001 editions; and “Who’s Who in Science and Engineering” 1985, 2000 and 2001 Millennium editions, published by Who’s Who in America. The directory of the Biographical Institute of the United States recognizes Professor Kuroiwa as one of the 500 Leaders of Influence in the years 2001 and 2003, and he has been considered by the International Biographical Centre of Cambridge, England as one of the 2,000 most outstanding scientists of the 20th century and international scientist of the year in 2004. He has been an Honorary Member of the International Association for Earthquake Engineering since 2004.
JAMES COOPER BEST PAPER AWARDS

The James Cooper Best Paper Awards will be given to the authors of the papers with the greatest potential impact, contribution to society and best overall quality. Two awards will be presented – one to the authors of a structurally-oriented paper and the other to the authors of a geotechnically-oriented paper.

James D. Cooper was an internationally recognized structural engineer and leader in the field of bridge engineering, with a specialty in earthquake engineering. He died on November 23, 2005.

Mr. Cooper, who retired from the Federal Highway Administration in 2003 as Director of the Office of Bridge Technology, served as a bridge engineer for over three decades. As Director, he provided national leadership in the development of policies, standards, and criteria for the location, design, construction, management, and maintenance of bridges and other highway structures, along with leadership on the Federal Aid Highway Bridge Program. He championed the development of advanced technologies and fostered their implementation in practice. These efforts were instrumental in the development and delivery of new technology for structures, including the application of high performance materials and in the success of the FHWA Innovative Bridge Research and Construction program.

Prior to serving as Director, Mr. Cooper held a variety of positions at FHWA during his tenure, which began in 1973. He served as Division Chief, responsible for the administrative leadership and technical guidance of a broad structures research program. Following a major FHWA reorganization in the mid-1990s, he was appointed Technical Director for all bridge related research and development (R&D) activity. It was during this time that Mr. Cooper coined the phrase “find it and fix it” to represent the primary focus of the FHWA structures research program.

Mr. Cooper has been recognized by many organizations and agencies both nationally and internationally. Among the most significant was the 2004 ASCE Charles Martin Duke award, for his lifelong contributions and achievements in the field of lifeline earthquake engineering.

BEST POSTER AWARD

This award will be given to the authors of the poster that is judged to best communicate the concepts presented in their technical paper and make a significant contribution to extreme event engineering.

STUDENT BRIDGE DESIGN COMPETITION

An award will be given to the team of undergraduate engineering students that scores the highest according to the rules established for the competition. Each team attending has prepared a technical paper that was submitted for review, constructed a model bridge according to their design, and will have their model judged and subjected to physical load in an earthquake simulator test during the Monday afternoon reception.

The goal of this competition is to provide an environment for undergraduate engineering students to explore the effects of earthquakes on bridges. With this competition the organizers hope to increase awareness of the catastrophic effect of earthquakes on bridges and the importance of earthquake design. Juan Caicedo, University of South Carolina, conceived of and managed all aspects of the program.
**SESSION 1A1: SEISMIC ACCELERATED BRIDGE CONSTRUCTION (ABC)**

**MODERATOR: DAN TOBIAS, ILLINOIS DEPARTMENT OF TRANSPORTATION**

**Paper No. 1A1-1**

**Strategic Implementation Plan for Accelerated Bridge Construction in California**

*Kevin Thompson, Michael Keever and Raymond Wolfe, California Department of Transportation*

Strong leadership from the Federal Highway Administration (FHWA) has challenged traditional construction techniques and compelled designers to contemplate accelerated bridge construction methods in the context of their designs. The potential benefits realized by system users are tremendous: reduced traffic delays, safer construction worksites resulting from compressed on-site construction schedules, enhanced quality, etc. While several states have completed associated pilot projects with positive results, issues with connection details in seismic regions remain unresolved. Recognizing this, the California Department of Transportation (Caltrans) has taken a leading role to resolve these problems. This paper will outline the strategic implementation plan developed by Caltrans as a result of an October 2007 workshop. Parallels and extensions to the associated developing national implementation plan will be explored.

**Paper No. 1A1-2**

**Pre-Fabricated Bridge Superstructures**

*Amjad J. Aref, Gordon F. Warn, Petros Sideris and Andre Filiatrault, Department of Civil, Structural and Environmental Engineering, University at Buffalo*

In the past thirty years, the number of applications of precast segmental bridge construction has increased substantially both in the United States and around the world. However, most of the applications have been in regions of low seismicity. The increasing number of applications can be attributed to the advantages that precast segmental construction offers over more traditional cast-in-place construction techniques. These advantages include: a higher quality of construction, accelerated bridge construction and construction that does not require falsework. Despite the apparent advantages of precast segmental bridge construction over traditional cast-in-place construction, there exist some concerns about the performance of such systems in regions with moderate to high seismicity. This paper summarizes the development and verification of Finite Element (FE) models used to assess the seismic vulnerabilities of segmental bridge superstructures.

**Paper No. 1A1-3**

**Use of Precast Bridge Members in Areas of High or Moderate Seismicity**

*Jugesh Kapur and Bijan Khaleghi, Bridge and Structures Office, Washington State Department of Transportation*

Prefabricated bridge components are in increasing demand for accelerated bridge construction. Precasting eliminates the need for forming, casting, and curing of concrete in the work zones, making bridge construction safer while improving quality and durability. Precast bridges consisting of pretensioned girders, post-tensioned spliced girders, trapezoidal open box girders, and other types of superstructure members are often used for accelerated bridge construction; however, bridge engineers are concerned with the durability and performance of bridges made of precast members in areas of high or moderate seismicity. This paper examines the applicability of the AASHTO LRFD Specifications to precast prefabricated bridges in areas of high or moderate seismicity, discusses the different seismic design methodologies, and provides guidance in their application to precast bridges. It provides an overview of WSDOT design criteria and recent research and bridge projects using the accelerated bridge construction technique in Washington State.

**Paper No. 1A1-4**

**Emergency Repair of Damaged Bridge Columns Using Fiber Reinforced Polymer (FRP) Materials**

*Ashkan Vosooghi and M. Saidi Saidi, Department of Civil and Environmental Engineering, University of Nevada, Reno; Jim Gutierrez, California Department of Transportation; Scott F. Arnold, Fyfe Co.*

The middle bent of a large-scale two-span bridge model, which was damaged to the highest repairable level (visible bars, initial buckling in some longitudinal bars, and initial concrete core damage) in the previous tests, was repaired using CFRP wrapping and retted to evaluate the repair performance. Damaged concrete was repaired by removing loose unsound concrete and using a fast set grout and epoxy injecting adjacent cracks. The columns were then wrapped with carbon fiber reinforced polymer sheets which were subjected to an accelerated cure procedure and allowed to cure for only 54 hours before testing. The specifications call for 7 day curing but the objective here was to determine the effectiveness of the rapid repair method for emergency repair. The tests showed that the plastic base shear capacity, service stiffness, and ductility capacity of the bent had been restored after repair. The material tests showed that the used CFRP and epoxy and curing process were efficient for an emergency repair.

**Paper No. 1A1-5**

**Seismic Continuity Performance of Precast Girders Connected to a Cast-in-Place Bent Cap**

*Kevin Almer and David Sanders, Department of Civil and Environmental Engineering, University of Nevada, Reno*

A common bridge system in high seismic regions includes a continuous cast-in-place concrete superstructure with an integral substructure. The typical cast-in-place superstructure construction requires falsework over traffic lanes creating significant construction delays and potentially unsafe conditions for both public and construction workers. Using a precast superstructure eliminates a need for excess falsework; thereby minimizing time delays and potential hazards. It is critical in high seismic regions to have full connectivity between the girders and the support columns to transfer the high seismic forces. The purpose of this study is to develop and examine integral connection details between precast U-girders and cast-in-place substructures subjected to longitudinal seismic loading. Analytical and experimental results show benefits to longitudinal post-tensioning in respect to joint detailing and system continuity which aren’t considered in current design methods. Design and analysis recommendations will be provided along with experimental and analytical results.

**SESSION 1B1: NEW GEO-SEISMIC PRACTICE AND GUIDELINES**

**MODERATOR: PAUL LILES, GEORGIA DEPARTMENT OF TRANSPORTATION**

**Paper No. 1B1-1**

**Analysis of Pile Group Under Lateral Loads Using the LRFD Guidelines**

*Moahmed Ashour, Civil Engineering Department, West Virginia University Institute of Technology; Gary Norris, Department of Civil and Environmental Engineering, University of Nevada, Reno*

The NHI’s (National Highway Institute) Load & Resistance Factored Design (LRFD) manual established particular guidelines to calculate the values of the loads applied on the bridge pile foundations and the resulting response. Such guidelines require specific characterization and classification for the loads transferred from the bridge superstructure down to the bridge pile foundations. To implement such procedures, specific formulas should be used to account for the effect of the different types of loads that may act simultaneously on the pile foundations. The application of such design procedure using the concept of the p-multiplier for the analysis of the laterally loaded pile group is very lengthy and carries a level of uncertainty. The use of (the recently updated version of) the Strain Wedge Model to analyze the pile groups under lateral loads reduces the calculation process and
the level of uncertainty significantly. No p-multipliers are required in such analysis. The interaction among the piles in a group is evaluated based on the pile spacings in both directions (front and side), level of loading, soil profile (geotechnical site conditions), and soil and pile properties.

Paper No. 1B1-2
Passive Force-Deflection Curves for Abutments with MSE Confined Approach Fills
Luke Heiner, Kyle M. Rollins, and Travis M. Gerber, Department of Civil and Environmental Engineering, Brigham Young University

Approach fills behind bridge abutments are commonly supported by wrap-around mechanically stabilized earth (MSE) walls. In contrast to a sloped fill, the vertical MSE wall face would tend to reduce the passive resistance provided by the abutment wall. However, the reinforcing strips provide confinement to the approach fill which would increase the passive resistance. This paper describes the first large-scale tests to evaluate passive force-deflection curves for abutments with MSE side walls. A test was also performed with fill extending beyond the edge of the abutment wall for comparison. The abutment wall was simulated with a pile supported cap 5.58 ft high, 11 ft wide, and 15 ft long in the direction of loading backfilled to 5.5 ft. The backfill behind the pile cap consisted of clean sand compacted to 96% of the modified Proctor maximum density. During lateral loading, the MSE wall panels moved outward 1.4 inches when the ultimate passive force developed. However, the passive force was still 76% of the resistance provided by the cap with fill extending beyond the edges. The normalized passive force-deflection curves for the tests with and without the MSE walls were similar and reached an ultimate at deflections of 3.8% and 4.2% of the wall height for the MSE wall confined and unconfined backfills, respectively. The measured ultimate passive force is compared to the computed ultimate passive force for the Rankine, Coulomb, log spiral and Caltrans methods. The log spiral method underestimated the ultimate passive resistance by 36% while the Caltrans method provided an excellent estimate.

Paper No. 1B1-3
SCDOT’s New Geo-Seismic Practice
Nicholas E. Harman, South Carolina Department of Transportation, Eduardo A. Taverna, GeOEngineers, Inc.

August 31, 1886 was an important date in the history of South Carolina. It was on this date that an earthquake with a moment magnitude of 7.2 – 7.5 struck the Charleston metropolitan area with devastating results to the local communities. While the motion of this earthquake has long since stopped, South Carolinians and the surrounding states today are still feeling the effects of this earthquake. Modern buildings, bridges, and other structures must be designed to resist the anticipated loadings from a seismic event of similar magnitude. To accomplish this, the South Carolina Department of Transportation (SCDOT) adopted in 2000 Seismic Design Specifications for bridges. SCDOT has recently updated the Seismic Design Specifications while concurrently developing a Load and Resistance Factor Design (LRFD) “Geotechnical Design Manual” (GDM) that will assist in establishing a Geo-Seismic state-of-practice that promotes communication between the structural and geotechnical engineers. A major component of the GDM is the emphasis on geotechnical performance based design for all Limit States (including seismic). This paper will highlight the major Geo-Seismic aspects of integrating geotechnical engineering and geotechnical earthquake engineering with the structural design through the use of LRFD design methodologies. If the performance limits presented in the GDM are exceeded, it is the intention of the authors as well as SCDOT that the geotechnical and bridge engineers will work closely to provide the South Carolina traveling public with a safe and cost effective transportation infrastructure network.

Paper No. 1B1-4
Proposed AASHTO Specifications for the Seismic Design of Retaining Walls, Slopes and Embankments, and Buried Structures
Donald G. Anderson, CH2M HILL; Geoffrey R. Martin, Department of Civil and Environmental Engineering, University of Southern California; J.P. Lam, Earth Mechanics, Inc.; J.N. Wang, Parsons Brinckerhoff

Current AASHTO LRFD Bridge Design Specifications provide guidance for seismic design of retaining walls, but no guidance for seismic design of slopes and buried structures. Guidance for retaining walls relies on the Mononobe-Okabe (M-O) equations for seismic active and passive earth pressure determination. Designers have found that the M-O equations have limitations. Specifically, the M-O equation for seismic active earth pressure results in unrealistically high pressures for some combinations of ground motion and wall geometry, as well as uncertainties where soils are not homogeneous and cohesionless. For passive earth pressures the M-O equation is based Coulomb failure theory which is believed to be inaccurate for some loading conditions. Realizing the limitations in the M-O equations and the absence of guidance for seismic design of slopes and buried structures, NCHRP Project 12-70 was conducted to update current design methods. The NCHRP 12-70 Project focused on free-standing retaining walls, cut and fill slope designs, and small-diameter buried structures used for drainage and for pedestrian access. The products of the Project included developing (1) recommendations on design ground motions, including effects of wave scattering, (2) an updated method for estimating permanent ground movement, (3) charts for including effects of cohesion in seismic earth pressure calculations, and (4) a generalized limit equilibrium approach for evaluating seismic active earth pressures for sites involving cohesive soils and complex site geometries. Draft specifications describing methods to follow during seismic design of retaining walls, slopes and embankments, and buried structures were also developed. This paper summarizes Project accomplishments.

Paper No. 1B1-5
Effects of Structural Characterizations on Fragility Functions of Bridges Subjected to Seismic Shaking and Lateral Spreading
Jian Zhang, Yili Huo, Pirooz Kachroo and Scott J. Brandenberg, Department of Civil and Environmental Engineering, University of California, Los Angeles

Bridges are one of the most vulnerable components of highway transportation systems. Following major earthquakes, bridges often suffered various levels of damages due to strong shaking or liquefaction induced lateral spreading. This paper evaluates seismic vulnerability of different classes of typical bridges in California when subjected to seismic shaking or liquefaction induced lateral spreading. The detailed structural configurations in terms of column detailing, superstructure type, material, connection, continuity at support and foundation type etc., render different damage resistant capability. Four classes of bridges are established based on their anticipated failure mechanisms under earthquake shakings. The numerical models that are capable of simulating the complex soil-structure interaction effects, nonlinear behavior of columns and connections are developed for each bridge class. The dynamic responses are obtained using nonlinear time history analyses for a suite of 250 earthquake motions with increasing intensity. A static pushover procedure is also implemented to evaluate the vulnerability of the bridges when subjected to liquefaction induced lateral spreading. Fragility functions for each class of bridges are derived and compared for both seismic shaking (based on time history analyses) and lateral spreading (based on static pushover procedure) for different performance states. The study finds that the fragility functions of bridges subjected to ground shakings show significant correlation with the structural characterization while the fragility functions of bridges under liquefaction induced lateral spreading show similar response independent of the structural characterization for the load cases analyzed and the assumed soil profile, probably because the soil properties are the dominant factor. Structural properties that will mostly affect the bridges’ damage resistant capacity are also identified through a parametric study.
The Development of the FHWA Pushover Analysis Computer Program

J. Jerry Shen, Linda Kuo-Lin, Jeffrey Ger and W. Phillip Yen, Federal Highway Administration

The AASHTO has recently adopted the pushover analysis as one of the methods for design with high seismicity in the LRFD guidelines. It has also been prescribed in the new FHWA Seismic Retrofitting Manual as a structural capacity/demand analysis method for the upper level earthquake. These latest developments have made the pushover analysis a necessary capability of all government bridge engineers. A simple and reliable computer program customized for pushover analysis of bridges was developed. This program incorporates four different nonlinear structural stiffness formulation methods, including Bilinear Interaction Axial-Moment, Plastic Hinge Length, Finite Segment-Finite String, and Finite Segment-Moment Curvature methods, covering from the simplest to the most sophisticated stiffness formulation approaches. The program will be provided to bridge designers as a supporting effort in implementing the latest bridge seismic design methodology. Several examples are included in the paper to demonstrate the functions of this program and how it fits into the context of the seismic design and analysis of bridges.

Calibration of a Model to Estimate the Residual Post-Earthquake Capacity of Circular Bridge Columns

Vesna Terezic and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley; Kevin Mackie, Department of Civil and Environmental Engineering, University of Central Florida

The residual post-earthquake load-carrying capacity of a bridge depends on the remaining capacity of the bridge columns. An experimental study was conducted to investigate the relationship between earthquake-induced damage in circular bridge columns and their residual axial, shear, and bending capacity. One-third scale models of the prototype column, typical of California bridges, were designed for testing in the cantilever configuration. Five column specimens were tested following a two-stage testing procedure. In the first stage, a constant axial load ratio of 10% was applied, followed by a bi-directional incremental lateral displacement protocol applied in a quasi-static manner. The bi-directional loading was applied up to a prescribed level of displacement ductility that was incrementally increased across the five column specimens. In the second stage, the damaged columns were subjected to a monotonically increasing axial force to determine the residual axial load-carrying capacity remaining after the specified lateral ductility demands. A theoretical model, derived from the Total Capacity Model proposed by Elwood and Moehle, was calibrated using the combined results from the lateral load and axial load tests. This model is used to predict the capacity of a bridge to carry self-weight and traffic load after an earthquake.

Ductility Analysis of Type II Pile Shaft

Larry Wu and Ray Wolfe, California Department of Transportation

Large diameter CIDD pile shafts have been widely used to support bridge columns due to the significant cost savings. Two types of pile shafts are classified in the Caltrans Seismic Design Criteria. Type I shafts may have a plastic hinge formed below ground in the pile shaft. Type II shafts are usually enlarged and the plastic hinge forms at the shaft/column interface. Based on the ductility response and capacity design concept, it is very important to have a plastic hinge formed in the column, not in the foundation system in order to avoid the difficulty of post-earthquake inspection and the high cost associated with repair of the damaged foundation system. Therefore, Type II pile shafts should be a preferred alternative. Since Type II shafts are much stronger than columns, the assumption of a “fixed” base at the interface between column and shafts is widely adopted in engineering practice. In this paper, a procedure that incorporates surrounding soil properties into the ductility analysis of Type II pile shafts is developed. The interactions between soil and shafts are represented by the Beam-on-Winkler-Foundation model. The Capacity Spectrum Method is introduced to calculate the ductility of the column-shaft system. The influences of soil-pile interaction are evaluated through the examples.
Retrofitting Bridge SR167/112W for Liquefaction-Induced Settlements

Yang Jiang and Gerald Dam, HNTB Corp.

This paper describes the methodologies investigated to retrofit Bridge SR167/112W near Seattle, Washington for liquefaction-induced ground settlements. Bridge SR167/112W is a 5-span prestressed girder bridge that will be widened to provide additional traffic lanes and retrofitted for seismic events. The existing bridge has been identified as being susceptible to liquefaction-induced settlements and downdrag forces. The estimated liquefaction-induced settlements are 2 inches at the abutments and as high as 12 inches at the piers. In addition, the differential settlement along a single pier could be on the order of half of the total settlement. The analyses have shown that the seismic deficiencies are primarily a result of anticipated settlement and downdrag caused by the liquefying and settling soils under each of the piers of the existing structure during a seismic event. The key to mitigate the potential bridge collapse is to prevent or minimize the ground settlement and downdrag by either geotechnical means – ground or foundation improvement, or structural means - design the structure using structural elements. Six retrofit alternatives were found feasible: 1 - Ground improvement; 2 - Micropiles for foundation retrofit; 3 - Pier wall retrofit; 4 - Grade beam retrofit; 5 - Bridge replacement; and 6 - No retrofit and widening only. Advantages and disadvantages of each alternative are discussed. Alternative 4 was recommended for adoption.
Paper Abstracts

Session 1A3: Evolving Bridge Seismic Specifications and Its Impact in Design – A State’s Perspective

Moderator: Ed Wasserman, Tennessee Department of Transportation

Paper No. 1A3-1

AASHTO LRFD Guide Specifications for Seismic Design of Highway Bridges
Roy A. Imbsen, Imbsen Consulting

AASHTO recently adopted a new LRFD Guide Specification for Seismic Design of Highway Bridges. This Guide Specification was developed under the guidance and support of the AASHTO T-3 Committee on Seismic Design and several participating member and volunteer states. The Guide Specification and new seismic hazard for a 1000 year return period were adopted unanimously by AASHTO at the yearly meeting on July 12, 2007. This paper will give a brief history and background on the development of the Guide Specifications to meet the expectations of the T-3 Committee. The presentation will also include an overview of the new specification. The Guide Specifications were developed specifically for ordinary, girder and slab type bridges, using a Displacement Based Approach with design factors calibrated to prevent collapse and reflect both the inherent reserve capacity to deform under imposed seismic loads and to accommodate relative displacements at the supports and articulated connections. A new seismic hazard map was developed by USGS for 7% probability of exceedance in 75 years (i.e. approximately a 1000 year return period) specifically for AASHTO and is now under the control of AASHTO. The selected hazard for design was made considering large historical earthquakes, without compromising collapse prevention, using calibrated design factors. Uniform hazard design spectra are constructed using the Three Point Method with the new AASHTO/USGS Maps for the PGA, 0.2 second, and 1.0 second horizontal ground accelerations and corresponding NEHRP Site Class Spectral Acceleration Coefficients. To assist the designer in the seismic design process, the new Guide Specifications include detailed flow diagrams with reference to the applicable Articles in the specifications for each of the three designated Global Seismic Design Strategies and Seismic Design Category (SDC).

Paper No. 1A3-2

Comparison of Bridge Designs using AASHTO Guide Specifications and Seismic Provisions in LRFD Specifications for Montana
Stephanie Brandenberger, Montana Department of Transportation

The American Association of State Highway Transportation Officials (AASHTO) recently approved two significant changes in the seismic design of bridges. First is the modification of seismic provisions in the current Load and Resistance Factor Design (LRFD) Bridge Design Specifications to increase the return period of the design earthquake from 475 years to approximately 1000 years, in addition to several updates reflecting recent refinements to the force based seismic design methodology. The second development is completion of the Guide Specifications for LRFD Seismic Bridge Design. The Guide Specifications are an alternate set of provisions specifically focusing on the ductility and displacement capacity of a structure, and as such is referred to as a displacement based approach. The purpose of this paper is to compare the designs of a representative case study bridge using both the “force based” and “displacement based” specifications and assess the impact to the Montana Department of Transportation (MDT) bridge design and construction program.

Paper No. 1A3-3


In 2006, the possible implications for Illinois of new AASHTO seismic bridge design guide specifications and revised code provisions were explored at the 5th National Seismic Conference on Bridges and Highways. In the summer of 2007, the AASHTO Guide Specifications for LRFD Seismic Bridge Design (Guide Specifications) and updated seismic provisions in the AASHTO LRFD Bridge Design Specifications (LRFD Code) were formally adopted by AASHTO with publication slated for 2008. Illinois was a contributing member of the AASHTO Technical Committee T-3 (Seismic Design) during the development of these documents. Partly due to this participation, the Illinois Department of Transportation (IDOT) was able to simultaneously develop and begin to finalize implementation plans for these new and revised seismic bridge design criteria prior to publication. The paper describes how IDOT has implemented and interpreted the new Guide Specifications and updated LRFD Code for Illinois. Explored themes focus on the performance criteria, practicality and economics of a developed Earthquake Resisting System (ERS) strategy for Illinois.

Paper No. 1A3-4

Updated South Carolina Department of Transportation Seismic Design Specifications for Highway Bridges
Lucero E. Mesa and Saiying Zhou, South Carolina Department of Transportation; Zhugang Amos Liu, STV/ Ralph Whitehead Associates

South Carolina is located in the most active seismic region on the east coast of the United States. In order to address seismic design needs, the South Carolina Department of Transportation (SCDOT) developed and implemented the Seismic Design Specifications for Highway Bridges in 2001. Since then, SCDOT has gathered input from bridge designers, geotechnical engineers, contractors and other government agencies. Based on this input, SCDOT is incorporating recent research results and newly developed seismic design methodologies to update the Specifications to fulfill SCDOT needs and standard practices of the State, including the SCDOT Seismic Hazard Maps Study, and standard construction details. Efforts have been made to attain consistency of the Specifications with SCDOT geotechnical engineering practice, and the newly developed Geotechnical Design Manual, to achieve the seismic performance requirements of the Specifications. The updated Specifications continue to require performance based design considering functional evaluation and safety evaluation levels of earthquake ground motions. This paper describes the SCDOT seismic design criteria, new findings since its implementation and the need for more research.

Paper No. 1A3-5

Effects of New LRFD Seismic Bridge Design Specifications to a ‘Normal’ Typical Bridge in New York State
Rajesh Tanega, Mengisteab Debessay and Arthur P. Yannotti, New York State Department of Transportation

In July 2007, AASHTO Subcommittee on Bridges and Structures adopted revised seismic provisions for LRFD Bridge Design Specifications and a new AASHTO Guide Specifications for LRFD Seismic Bridge Design. The design earthquake return period has increased from 500 to 1000 years. Base LRFD specifications are founded on a ‘Force-Based’ approach while the Guide Specifications are founded on a ‘Displacement-Based’ approach. For the new design of an ordinary (non-critical) bridge in a low seismic zone such as in the State of New York, a New York City location is chosen. Typical multi span bridges with fixed bearings at a pier and expansion bearings at abutments and at remaining piers are selected and are classified as ‘Other (Normal) Bridges.’ This paper presents an overview of the application of the two new seismic specifications, Base and Guide Specifications, and discusses the similarities and the differences of the two specifications when applied to the selected bridges in a low seismic Eastern United States Zone. This paper also lists some discrepancies of the two specifications as compared to the past AASHTO Division IA Standard Specifications. In January 2006, FHWA released a new ‘Seismic Retrofitting Manual.’ Bridge examples in the same geographical location are screened and assessed as per the retrofitting manual.
SESSION 1B3: LESSONS LEARNED FROM RECENT EARTHQUAKES AND OTHER EXTREME EVENTS

MODERATOR: RICHARD PRATT, ALASKA DEPARTMENT OF TRANSPORTATION

Paper No. 1B3-1
An Assessment of Damage to Peru’s Highway System after the M8.0 Pisco Earthquake
Jerome S. O’Connor, MCEER, University at Buffalo; Lucero E. Mesa, South Carolina Department of Transportation; Monique Nykamp, Shannon & Wilson, Inc.
The performance of Peru’s highway system in this M8.0 earthquake is relevant since the infrastructure was built using AASHTO specifications. The Pisco earthquake of July 2007 was a strong and unusually long-period earthquake. Soil conditions and ground water levels led to widespread liquefaction contributing to more highway damage than ground shaking did. This reconnaissance survey illustrates why geotechnical considerations are paramount. Because some bridges were subject to secondary hazards such as rockfall, there is also a case for consideration of multiple hazards during the design or retrofit of bridges.

Paper No. 1B3-2
Hurricanes Katrina and Rita - Louisiana’s Response and Recovery
Ray Murphrey and Hossein Ghara, Louisiana Department of Transportation and Development
Louisiana’s transportation and hurricane protection system took a tremendous blow from two major hurricanes that struck the coast of Louisiana in 2005, hurricanes Katrina and Rita. This presentation will introduce the audience to the transportation infrastructure damage Louisiana experienced as a result of these two storms and will describe how Louisiana is responding to the disasters and our road to recovery.

Paper No. 1B3-3
Replacement of Caminada Bay Bridge in Louisiana Coastal Engineering Study and Support for Design
Zhengzheng “Jenny” Fu, Arthur D’Andrea and Hossein Ghara, Louisiana Department of Transportation and Development
The 0.8 mile Caminada Bay Bridge on LA 1, owned and operated by Louisiana Department of Transportation and Development (LADOTD), is a critical structure connecting Grand Isle and Louisiana's mainland. The bridge was in poor condition due to serious corrosion and was scheduled for replacement under the Federal Bridge Replace Program before Hurricane Katrina. As a result of Hurricane Katrina, the bridge experienced additional damages that required emergency repair prior to reopening the bridge to traffic. The bridge is now scheduled for reconstruction in the fall of 2008. To assist with the design, a coastal engineering study from Coast & Harbor Engineering was acquired by LADOTD to investigate the vulnerability of the bridge to wave impacts from extreme hurricane events. The study includes development of the design hurricane event, numerical modeling of hurricane propagation to the project site (bridge), storm surge analysis, and computation of hurricane wave forces on the bridge spans. This study is also a test drive of the AASHTO Guide Specification for Bridges Vulnerable to Coastal Storms.

Paper No. 1B3-4
Assessment of Blast Resistance of Seismically Designed Bridges
Jason Fang, Paul Chung, Ray W. Wolfe and Michael Keever, California Department of Transportation
This paper addresses analytical method of assessing the adequacy of the bridge column subjected to the blast loads, which includes the detail method for modeling an equivalent single-degree-of-freedom (SDOF) system, linear and nonlinear analysis of the blast loaded bridge column, the pressure-impulse (P-I) diagram approach of capacity evaluation. A numerical example of assessing the blast adequacy of the seismically designed bridge column is given for illustrating the proposed method and procedure. The analysis shows that the bridges designed complying with current seismic criteria would provide high level protection to against terrorism air blast attacks.

Paper No. 1B3-5
Blast Resistance of Seismically Designed Highway Bridge Piers
Shuichi Fujikura and Michel Brunou, Department of Civil, Structural and Environmental Engineering, University at Buffalo
The issue of protecting infrastructure against multiple extreme events is gaining interest in civil engineering. The authors previously presented the development and experimental validation of a multi-hazard bridge pier concept, i.e., a bridge pier system capable of providing an adequate level of protection against collapse under both seismic and blast loading. The proposed concept was a multi-column pier-bent with concrete-filled steel tube (CFST) columns. The columns turned out to be effective for blast loadings because breaching and spalling of concrete are prevented to occur in the CFST columns. While CFST columns perform excellently in a multi-hazard perspective, they have not been commonly used in bridge engineering practice. Questions arose as to whether conventional columns designed to perform satisfactorily under seismic excitations would possess adequate blast resistance. Two commonly used systems to provide ductile performance of reinforced concrete (RC) columns in seismic regions were considered in this project; first, RC columns with closely spaced stirrups in compliance with latest seismic provisions, and second, non-ductile reinforced concrete columns retrofitted with steel jackets. This paper presents the findings of research to examine seismically resistant bridge piers that are designed according to current seismic knowledge and that are currently applied in typical highway bridge designs. A series of experiments were performed on 1/4 scale typical seismically detailed ductile RC columns and non-ductile RC columns retrofitted with steel jacketing. The standard RC and steel jacketed RC columns, known to exhibit satisfactory seismic behavior, failed in shear at the base of the column under blast loading.
Damping-Enhanced Strengthening: A Unique Way to Normalize Seismic Performance of RC Bridges for Multiple Objectives

Genda Chen and Kazi R. Karim, Department of Civil, Architectural and Environmental Engineering, Missouri University of Science and Technology

A damping-enhanced strengthening methodology can be implemented by integrating viscoelastic damping into a fiber-reinforced polymer jacket for normalized performance objectives under various earthquakes. This methodology was applied to the Old St. Francis Bridge near the New Madrid Seismic Zone. A damping layer was represented by a series of discrete and complex springs in the finite element model of bridge columns. Numerical results indicated that a damping layer of 2.38 mm can effectively reduce the accelerations and displacements of the bridge. For the same amount of damping materials, retrofitting one end of the columns is more efficient than retrofitting both ends. The damping component ensures the operational level under moderate earthquakes and the strengthening component ensures the safety level under strong earthquakes. Together, they meet the multiple performance objectives under earthquakes of various intensities and can lead to an optimum performance design of the bridge.

Seismic Retrofit of Highway Bridges in the United States

Glenn Smith, Federal Highway Administration

In light of the public's concern over the viability of our bridge system after the I-35W bridge collapse, an inquiry was made through FHWA's Divisions to assess the states' seismic retrofit needs. While California has an in-depth understanding of their seismic retrofit problems, both statewide and locally, most states have gaps in their knowledge for planning purposes. In the year 2000, MCEER completed a program of basic research to support a bridge seismic retrofit manual. The manual was expanded to be more user-friendly and was finally shared with the bridge community in 2006. With adoption of LRFD seismic design provisions and a guide specification in July 2007, AASHTO has changed requirements for seismic design of new bridges. To facilitate better assessment of seismic vulnerability and retrofit needs, guidance is provided on using the FHWA retrofit manual with the AASHTO design documents (including the AASHTO 2007 Ground Motion CD); using 2007 USGS Preliminary Ground Motion Data from the internet; obtaining training material developed for and by FHWA on seismic retrofit of bridges; and availability of publications and training materials developed for FHWA to facilitate planning seismic retrofit (i.e., truss bridges, seismic isolation, and network analysis).
Paper Abstracts

Session 2B1: Soil-structure Interaction and Foundations

Moderator: Bryan Hartnagel, Missouri Department of Transportation

Paper No. 2B1-1

Soil-Foundation-Structure Interaction of Long-Span Bridge Structures
Anoosh Shamsabadi, California Department of Transportation; Hubert Law and Amir Zand, Earth Mechanics, Inc.

The Soil-Foundation-Structure Interaction (SFSI) effects considering a kinematic condition have been implemented during the retrofit evaluation of the Dumbarton and Antioch bridges in California. These are long-span bridge structures supported on pile foundations, and seismic ground excitation will vary with depth along the pile length. The effects of depth-varying ground motion were rigorously addressed in the analysis. Substructure models were used to reduce the number of degrees of freedom of the bridge model. This approach employs a bridge model without explicit foundation and yet it takes into account the effects of depth varying ground motions. The foundation substructure in the bridge model was represented by a linear 6x6 stiffness matrix representing the entire soil-pile system and a set of kinematic ground motion representing effective shaking arising from the depth-varying motions acting along the pile.

Paper No. 2B1-2

The Golden Ears Bridge Design-Build Project: Foundation Design for Segment 4 Approach Structures
King Sampaco, Ha Pham and Donald Anderson, CH2M HILL

This paper discusses the foundation design concept for Segment 4 approach structures of the Golden Ears Bridge (GEB) Design-Build project being constructed east of Vancouver, British Columbia as part of infrastructure improvements for the 2010 Winter Olympics. The design concept involves the use of a disconnected spread footing (DSF) to meet settlement limits and seismic loading demands. The DSF foundation concept uses conventional spread footing and columns to support the bridge. The footing transfers loads to a group of long-slender, precast square concrete piles (LSP). The LSPs have a dimension of 0.35 m by 0.35 m and are typically 36 m in length. These piles are not attached to the pile cap and, therefore, are designed to handle minimal tension, shear, and bending. The LSPs are used to transfer axial loads from the bridge to the underlying, more competent material and to reduce long-term settlements of the underlying clay. Short shear drilled shafts (SSDS) are used to increase the shear capacity of the foundation. The resisting forces from the SSDS add to shear resistance developed from the passive soil resistance in front, and the friction along the sides, of the pile cap. These shafts are fixed to the pile cap, and are 0.9 m in diameter and 5 m long. Under extreme seismic loading, the DSF concept has significant advantages relative to a more conventional pile group. This presentation discusses the geotechnical design aspects of the DSF foundation concept and the methodology adopted for modeling and design of this concept.

Paper No. 2B1-3

Effect of Nonlinear Pile Stiffness on Bridge Seismic Response
Jin-Xing Zha, California Department of Transportation

Nonlinear seismic soil-pile-structure interaction analyses are performed for a steel girder bridge supported by two-column bents founded on pile footings using a finite element program. The pile-soil interaction is modeled with a 6x6 stiffness matrix that is input into the program either in a linear or nonlinear format. If a linear stiffness matrix is used, it has to be revised each time when an iterative bridge response is obtained until it is compatible with the displacements of the pile caps. In the case of the nonlinear stiffness matrix input, the nonlinear soil-pile behavior is governed by “decoupled” nonlinear load versus displacement curves for vertical, horizontal, rotational, and torsional loading modes. This paper presents procedures to construct the pile stiffness matrix in both a linear and a nonlinear format. A numerical study is carried out to demonstrate how each of the two stiffness matrix input formats is incorporated into a FEA model for nonlinear seismic soil-pile-structure interaction analysis.

Paper No. 2B1-4

Effect of Shallow Foundation Rocking on Dynamic Response of Bridges
Andres Espinoza and Stephen Mahin, Department of Civil and Environmental Engineering, University of California, Berkeley

Rocking as an acceptable mode of seismic response has been extensively studied and has been shown to potentially limit local displacement demands. Rocking can act as a form of isolation, reducing displacement and force demands on a bridge, thereby allowing for design of smaller footings and members. As part of a collaborative effort to develop guidelines for the design of bridges supported on rockers that rock on their foundations a series of shake table tests of a simple ¼ scale inverted pendulum reinforced concrete bridge column was conducted. These tests are among the first to consider three components of excitation. Testing levels included design and maximum credible earthquake scenarios that created an inelastic response in the test specimen. Concurrent centrifuge testing to determine the inelastic response of soil when similar to-scale systems were allowed to rock developed data which could be used with the shake table tests to create and validate analytic models of the complete rocking response. Analysis shows that full-scale systems allowed to rock on their foundations reduce displacement and force demands without creating a global instability. Analytic models show that short period fixed bases systems tend to have amplified displacements when allowed to rock for a variety of soil profiles.

Paper No. 2B1-5

Developing Spectra For Type F Soils For Two Bridge Sites Near Salt Lake City
Zia Zafar, Kleinfelder; James Higbee, Utah Department of Transportation

Presence of potentially liquefiable soils beneath two proposed bridge (overpass) sites along Legacy Parkway north of Salt Lake City required site response analyses to develop site-specific horizontal and vertical response spectra for the design of the bridges per the criterion established by Guidelines for the Seismic Design of Highway Bridges (MCEER/ATC-49, 2003) document. A site response analysis involves development of target spectrum for rock-like condition, selection and scaling or spectra-matching a suite of time histories, performing equivalent linear and/or nonlinear site response using the scaled or spectra-matched time histories, and finalizing the design response spectrum using the results of site response. This paper presents the results of site response analyses and discusses the effects of the following variables on the site response using equivalent linear method: (a) selection and number of time histories for site response and (b) scaling or spectra-matching time histories. Results of our analyses indicate that a sufficient number of time histories are generally needed to understand the seismic response of a site and variability between the time histories can be significantly reduced if the time histories are spectrally matched.
Seismic Evaluation of the I-155 Bridge Over the Mississippi River
Mark R. Capron, Jacobs Engineering
This paper presents a seismic evaluation of a 7,100 foot long bridge located near the New Madrid Seismic Zone in southeastern Missouri. The main span features a two-span asymmetric cantilever truss. Foundations are supported in dense sands and bedrock is located about 2,700 feet below the surface. The objectives of this evaluation are to extend previous studies using current engineering practice, and to develop a range of retrofit alternatives. A site specific seismic study was performed to develop response spectra and ground motions for 500, 1,000, and 2,500 year return period earthquakes. Evaluation of liquefaction potential showed that widespread liquefaction is expected in the upper 40 to 65 feet of soil and a recommended mitigation approach was developed that includes compaction grouting and vertical drains along the entire length of the bridge. The primary focus of this paper is the structural evaluation using Method D2, Structure Capacity/Demand – Pushover from FHWA HRT-06-032. The evaluation includes the existing structure, and the structure retrofit with steel column jackets, cap-beam modifications, and seismic isolation bearings in the main spans. The results of this evaluation show that the existing structure has 30% to 40% of the displacement capacity required for the 500 year design level, and significantly less than required for the 1,000 and 2,500 year levels; that column, cap-beam, and other retrofits can improve performance to the 500 year level, provided that damage beyond the first component reaching capacity is accepted; and that isolation bearings can improve performance of the main spans.

Seismic Analyses and Evaluation for Retrofit of the Suspended Spans of the Bronx-Whitestone Bridge
Ruben B. Gajer, David Rubin, Adam Haji, Fangyin Zhang, Christopher Mauch and Mohammed Ettouney, Weidlinger Associates, Inc.
The Bronx-Whitestone Bridge was opened in 1939. By the mid-90’s, when the suspended span deck system had reached its useful life limit, a seismic evaluation showed that certain bridge components would require retrofit: the stiffening girders, cable anchorages, lateral bracing, and the concrete strut connecting the pedestals between tower shafts. In a 2000 study, Weidlinger Associates selected an orthotropic deck scheme as the optimum replacement strategy, which also help in reducing the seismic demands on the bridge. During the final design phase, seismic analyses were performed to mitigate all the vulnerabili- ties related to the redecking; innovative design using Low Yield Point Steel (LYP) was introduced to modify the behavior of the structure at the anchorage-deck connections, dissipate energy and eliminate the vulnerabilities at the stiffening girders and lateral bracing. In a current contract, additional analyses and evaluations were performed to evaluate the need of mitigating the vulnerabilities related to the anchorages and tower caisson struts. Global Nonlinear Time History Analyses of the bridge were performed. The seismic motions and dynamic soil-foundation springs were derived from local transient and harmonic analyses at each soil-foundation system. This paper focuses on the technical challenges of the seismic analyses and the design issues addressed to mitigate the vulnerabilities.

Lake Natoma Crossing: Combining High Seismic, River Flow, and Scour Demands with a High Aesthetics Requirement
Robert Fish, Lim and Nascimento Engineering Corporation
This paper discusses pre-design, design, and construction of a 2,264-foot (690meter) long bridge structure consisting of two structural light-weight concrete box frames on seismic isolation bearings. The lake crossing (frame one) consists of three 328 foot (100meter) spans with 181 foot (55meter) back spans of dual single cell, prestressed concrete, hunched box girders, with a continuous 110 foot (33.6meter) wide deck. The foundation is large diameter drilled shafts. Seismic Resistance: Combined with an efficient box girder design and lightweight concrete, using seismic isolation bearings provided the additional seismic protection the Owner (City of Folsom, CA) required for this lifetime structure. A two-level seismic performance criteria as described in the Applied Technology Council (ATC) 32,”Improved Seismic Design Criteria for California Bridges: Provisional Recommendations” was applied. Scour Resistance: The geometry of the project area required the bridge to be scour resistant up to 46 feet (14meters). Seismic design had to incorporate a solution that worked for both scour and non-scour scenarios. Using deep shafts and including steel casings as a permanent composite part of the shaft accomplished this goal. Architectural Elements: Using architectural elements mitigated the impact of putting a new structure in a scenic valley amidst a populated area. Part of the solution was to add “fake” arches. The six arches are fully prestressed large concrete box cells 10foot (3meter) wide and vary in depth from 5foot (1.5m) at the spring-line to 2.5foot (3/4m) at the crown.

Development of Seismic Design Criteria for the Dumbarton and Antioch Toll Bridges, California
Hubert K. Law and Ignatius Po Lam, Earth Mechanics, Inc.; Brian Maroney and Saba Mohan, California Department of Transportation
The authors have been involved in seismic evaluation of two toll bridges in California; Dumbarton Bridge and Antioch Bridge. They are the last two remaining major toll bridges to be seismically retrofitted as part of the Seismic Safety Program undertaken by the California Department of Transportation. Ground motion criteria have been developed for both bridges employing the latest developments from the seismological community including the updated USGS seismic source model and the Next Generation Attenuation (NGA) relations. In addition, soil-structure interaction and experience gained from seismic retrofits and new designs of other toll bridges in California for the last 15 years were considered in the development of the earthquake design criteria. Since response spectrum and non-linear time history analyses of the bridges will be conducted for seismic performance evaluations, both design ARS curves and acceleration time histories were developed. To support the ground motion study, a major site investigation program involving over-water drilling, cone penetration, and seismic velocity measurements was performed at each bridge.
**PAPER ABSTRACTS**

**SESSION 2B2: SEISMIC INSTRUMENTATION AND MONITORING SYSTEMS**

**MODERATOR: RAJESH TANEJA, NEW YORK STATE DEPARTMENT OF TRANSPORTATION**

**Paper No. 2B2-1**

Evaluation of Damage Identification Algorithms Applied to a 4-span Concrete Bridge Subjected to Near Source Ground Motions Using Nonlinear Finite Element Method

Amirhossein Irannanesh, Seyed A. Bassam, and Farhad Ansari, Department of Civil and Materials Engineering, University of Illinois at Chicago

This study reports on the analysis of results acquired from shaking table tests of a large scale 4-span bridge subjected to progressively increasing amplitudes of seismic motions recorded during the Northridge earthquake. Through an analytical approach, a finite element model was developed using OpenSees program to simulate the response of the bridge and the abutments. Nonlinear dynamic analyses were conducted using the shaking table motions during each event of the test. The model was calibrated and modified to predict the bent displacements of the modeled bridge in an acceptable consistency with the measured bent displacements obtained from experimental analysis results. The objective was to evaluate the global damage index of the bridge following each seismic event due to reduction in structural strength, reflected in the time evolution of the tangential stiffness matrix KT. Virtual-energy-based damage indicators have been already defined to estimate this information. The global structural damage of the bridge was assessed on the basis of Virtual-energy-based damage indicators calculated from modal analysis on the nonlinear finite element model. The results were compared with minor damage indicators obtained from low cycle fatigue analysis on the test results.

**Paper No. 2B2-2**

Changes in Modal Frequencies of a Highway Bridge

Marvin W. Halling, Shutao Xing and Paul J. Barr, Department of Civil and Environmental Engineering, Utah State University; Zachary C. Hansen, ARW Structural Engineers

Instrumentation has been used to record seismic motions of the ground, buildings, and bridges for many years. More recently, interest has grown in using this instrumentation for monitoring the state of health of a structure without the need for a “triggering seismic event.” Structural damage will result in permanent changes in dynamic structural properties such as stiffness. These changes may be detected through structural monitoring. The use of vibrational monitoring is a field of structural analysis that is capable of assisting in both detecting and locating structural damage. This work is focused on increasing the understanding of the variability in dynamic properties so that structural changes can be correctly interpreted if outlying data is recorded.

**Paper No. 2B2-3**

Rion-Antirion Monitoring System

Aris Vlamis-Stathopoulos, GEYFRA; Gilles Hovhanessian and Benoit Kroely, Advitam Inc.

VINCI group, is the largest worldwide construction and concession group, and operates exceptional structures and long span bridges such as Confederation Bridge in Canada, Vasco de Gama Bridge in Portugal, Severn Crossing bridges in the UK, and more recently, Rion-Antirion Bridge in Greece. European concession contracts commonly last over periods ranging from 20 to 70 years. Preventive inspections and structural maintenance represents significant challenges which occur over such periods. In the case of Gefyra, Operation Company of the Charilaos Trikoupis Bridge, also called Rion-Antirion Bridge, the concession period is 35 years. Therefore, Gefyra decided to work with Advitam to build methodologies and system to optimize structural inspection & the maintenance process. This includes: A structural health monitoring system which provides real time monitoring of the bridge and automatic alarm management. The monitoring system is designed to monitor all critical elements of the bridge in order to detect abnormal behavior. It provides in particular automatic traffic management in case of earthquakes and high winds, which are common events in this part of the Gulf of Corinth. A very detailed Inspection & Maintenance manual, covering all aspects of long term maintenance: description & design of the project; periodic inspections; special event and post incident reaction plans; and preventive maintenance & heavy maintenance. A computerized inspection & maintenance system which improves quality and cost efficiency of the global process, as well as provides to the Greek authorities full quality control. The final article will briefly describe the methods and system involved, but will mainly focus on the benefits for the Concession Company and the Greek authorities.

**Paper No. 2B2-4**

Energy Based Approach for Post Seismic Structural Health Monitoring of a Four Span Bridge

Seyed A. Bassam, Amirhossein Irannanesh and Farhad Ansari, Department of Civil and Materials Engineering, University of Illinois at Chicago

This study reports on the development of a structural health monitoring methodology for detection of various stages of damage in bridges following earthquakes. The results are acquired from shaking table tests of a 4-span large Scale Bridge subjected to progressively increasing amplitudes of seismic motions recorded during the Northridge earthquake. Development of an efficient monitoring system included high resolution long gauge displacement fiber optic sensors which were designed for post-seismic evaluation of typical concrete highway bridges in seismic zones. An energy based damage evaluation technique was developed for the evaluation of the bridge integrity at various amplitudes of seismic motions to gauge the damage assessment capability of the method. Following each seismic motion, the structural integrity of the bridge was investigated by the energy based method. Results from this study indicated that it is possible to detect damage at early stages of development through a combination of high resolution sensors and advanced structural health monitoring methodologies.

**Paper No. 2B2-5**

Development of Rocking Column Systems

Matthew J. Tobolski and Jose I. Restrepo, Department of Structural Engineering, University of California San Diego

Current seismic bridge design practices rely on the development of damage and the potential for residual deformations following a seismic event due to the formation of a flexural plastic hinge. Improved response can be realized through the use of rocking column systems that employ a combination of unbonded post-tensioning and bonded mild reinforcement. Rocking column systems can produce significantly less damage and residual displacements when compared to a traditional cast-in-place concrete column. As a part of a broader research program investigating seismic accelerated bridge construction, a total of three rocking column systems are being studied both analytically and experimentally. The first specimen is a conventional system employing tightly spaced spiral reinforcement to provide confinement at the column base. The second specimen uses a concrete filled steel tube for confinement and flexural reinforcement. Mild reinforcement only passes across the joint and develops in the column and is then terminated. The third specimen is a hollow column that used two shells as confinement and lateral resistance. Again the mild reinforcement only passes across the joint and develops in the column and is then terminated. The third specimen is a hollow column that used two shells as confinement and lateral resistance. Again the mild reinforcement extends only a short distance into the column to allow for development. This paper presents the basic design requirements that must be satisfied to ensure the benefits of a hybrid system are achieved. Basic results of the testing of the first two specimens are also included.
Paper No. 2A3-1

Developing a Methodology for Comparison of Extreme Hazards for Highway Bridge Design

George C. Lee and Sangyul Cho, Department of Civil, Structural and Environmental Engineering, University at Buffalo; Mai Tong, Federal Emergency Management Agency; W. Phillip Yen, Federal Highway Administration

Load combination and load factors of extreme event limit states have not been properly calibrated in the current AASHTO LRFD specifications for a uniform reliability target. Bridge collapses and damage in recent extreme hazard events have elevated the need to carefully examine these hazard loads for design purposes. This paper is a progress report of a research project, sponsored by the Federal Highway Administration, to develop a methodology to compare hazards by exploring commensurable criteria across extreme events to establish quantifiable measurements for bridge structural design to protect against extreme events. In consideration of the uncertainties of extreme hazards and the different design concepts for individual hazards, “collapse hazard intensity” is conceptually selected as a preferable comparison reference vis-à-vis code-specified design hazard intensity. However, the collapse intensity has yet to be carefully established for each extreme hazard. To illustrate the methodology, this paper uses a temporary substitute measure called “uniform comparison hazard intensity” in place of “collapse hazard intensity” in the examples of three selected extreme hazards: earthquake, wind and vessel collision. The results of this pilot study are presented and discussed to explain the approach pursued in this research project to establish a platform of comparison for different extreme hazards.

Paper No. 2A3-2

Multiple Hazard Research Needs and AASHTO Code Development Activities

Harry A. Capers, Arora and Associates, P.C.; George C. Lee, Department of Civil, Structural and Environmental Engineering, University at Buffalo; Jerome S. O’Connor, MCEER, University at Buffalo

Recent history in the U.S. has repeatedly shown that our transportation infrastructure can be severely damaged by hazard loadings far exceeding our expectations. Storm surge, vehicular collision, and terrorist acts are hazards that are not addressed in the current bridge specifications despite resulting in severe damage to bridges throughout the country. While it is impractical to think that all bridges can be designed to sustain the worst of all possible hazards, or a simultaneous occurrence of numerous hazards, recent bridge failures should cause bridge owners to re-examine the approach used to deal with extreme events. AASHTO load cases assume simultaneous application of loads that must be resisted. In reality, structures are seeing multiple and cascading events. Structures that have sustained damage from one event (or are already weakened from a preexisting condition like scour or corrosion), are expected to resist additional loads inflicted by a subsequent event. Many other fields, such as aviation and nuclear engineering address the possibility of multiple hazards. The highway transportation industry needs to deal with these real possibilities and follow their lead. The collapse of bridges must be avoided to insure life safety. However, since bridges are a crucial link in the transportation network, owners also need to insure that the most important bridges remain functional after an event so that the social and economic needs of a region are met and must be given tools to enable them to use their own judgment in setting performance standards and assessing risk they can tolerate in the design of their bridges. Data and experience from recent events should be used to develop new standards that account for multiple hazards and will provide for bridge designs that perform to reasonable expectations.

Paper No. 2A3-3

Seismic Hazard Considerations within a Multihazard Environment

Mohammed Ettouney, Weidlinger Associates; Sreenivas Alampalli, New York State Department of Transportation

Multiple hazards affect the stability and service life of structures and should be considered during design and analysis of structures such as bridges and buildings. Due to recent events, design of structures for blast and impact are also becoming very important among other hazards, such as earthquakes, floods, and fire. It is anticipated that multihazard design considerations will result in overall cost reduction while maintaining the needed safety levels. This paper briefly describes the application of the theory of multihazards considering life-cycle costs for making appropriate retrofit decisions. Specific differences of designing and analyzing for seismic vs. other hazards, such as wind, blast, flood, and fatigue are presented. Structural Health Monitoring (SHM) considerations of the interaction of seismic hazard with other hazards are also discussed.

Paper No. 2A3-4

Beneficial Aspects of a Multi-Hazard Approach to Design of Highway Bridges

M. Ala Saadeghiazari and Bakhtiar Feizi, Department of Civil and Environmental Engineering, New Jersey Institute of Technology

Transportation infrastructure is vital to economic development and critical to response and recovery after extreme events. However, they are also quite vulnerable to natural and man-made hazards such as earthquakes, storm surge, fire and terrorist threats; especially highway bridges. Therefore, there is a need to move toward multi-hazard design of highway bridges. This paper will highlight beneficial aspects of such an approach. Multi-hazard approach to design of highway bridges will require emphasis on vertical strength and stability to ensure collapse prevention. Consequently, elements such as superstructure response in the vertical direction and connections details will require special consideration. Collapse of an intermediate support (due to fire or terrorist acts) or buoyancy pressures from an storm surge (such as Hurricane Katrina) or vertical motion of earthquake ground motion all exert demands on bridge superstructure, bearings, and load transfer mechanism to the foundation that are not considered within the existing design guidelines. This paper discusses such commonality among various hazards and through a simple example some of the parameters are highlighted in quantifiable terms. It is shown that multi-hazard approach will require providing additional rotation capacity at the bearings to ensure development of catenary action and to prevent progressive collapse. Furthermore, integrity reinforcements, or more generally multi-hazard reinforcements, must be provided in the deck to account for higher and/or reversed flexural and shear demands on the deck. Robust mechanism to transfer large catenary action forces at the abutments is yet another factor to consider within a multi-hazard framework to design of highway bridges.

Paper No. 2A3-5

Large-Scale Wave Flume Experiments on Highway Bridge Superstructures Exposed to Hurricane Wave Forces

Thomas Schumacher, Christopher Higgins, Christopher Bradner, Daniel Cox and Solomon Yim, School of Civil and Construction Engineering, Oregon State University

Recent failures of US coastal highway bridges during hurricane events have shown the need for improved modeling and analysis of storm induced wave forces. Failures mostly consisted of bridge superstructures being partially or in some cases completely removed from the supporting elements. Damage was attributed to elevated storm surges that enabled larger waves to reach the superstructure and to inadequate connection designs. Previous research on wave forces for bridge structures used small-scale experiments on the order of 1:15 to 1:20 with essentially rigid bridge models (neglecting realistic fluid-structure interaction). A new innovative large-scale laboratory setup has therefore been developed that enables realistic simulation of storm-induced wave forces on bridge superstructures. The experiment
SIXTH NATIONAL SEISMIC CONFERENCE ON BRIDGES & HIGHWAYS

PAPER ABSTRACTS

Paper No. 2B3-1
Experiences in Creating a Seismic Risk Model of the Oregon Highway Bridge Network Using REDARS2
Peter Dusicka, Michael Glickman and Helen Oppenheimer, Department of Civil and Environmental Engineering, Portland State University; Holly Winston, Oregon Department of Transportation

A seismic risk model was developed for an Oregon highway network using REDARS2, a seismic risk analysis tool recently released after 12 years of primarily FHWA sponsored research and development. This paper outlines some of the successes, issues and observed limitations encountered in developing the model and in conducting seismic risk analyses for Oregon highway bridges along major truck routes. The Oregon model represented one of the first applications of REDARS2 outside of the original development team, offering a unique perspective on the tool’s implementation. When compared to previous demonstration studies, the Oregon highway network model consisted of a larger number of bridges spread across a larger geographic area and also for the first time attempted to consider liquefaction risk for majority of the bridges. Key challenges in implementing the model included data import incompatibilities, limited troubleshooting feedback and restricted model modification capability. Once fully implemented, the Oregon highway network model will provide an excellent analysis basis and will be a good framework for more detailed evaluation in the future, which needs to incorporate a more appropriate seismic hazard characterization capability in REDARS2 for the Pacific Northwest and refine the traffic input data for the Oregon data.

Paper No. 2B3-2
Seismic Risk Assessment of the Transportation Network of Charleston, South Carolina
Reginald DesRoches and Emily Nilsson, School of Civil & Environmental Engineering, Georgia Institute of Technology; Jamie Paddock, Department of Civil and Environmental Engineering, Rice University

The functionality of the transportation network following an earthquake event is critical for post-earthquake response and long-term recovery. The likely performance of a transportation network can be evaluated through a detailed seismic risk assessment. This paper presents an assessment of the seismic risk to the transportation network in Charleston, SC and the surrounding counties to support emergency planning efforts, and for prioritizing retrofit. This study includes an inventory analysis of the approximately 375 bridges in the Charleston area, and convolution of the seismic hazard with fragility curves analytically derived for classes of bridges common to this part of the country. Damage-functionality relationships, and replacement cost estimates based region-specific data are used to obtain economic loss and functionality estimates. Using state-of-the-art tools, the distribution of potential bridge damage and functionality is evaluated for several scenario events in order to aid in the identification of emergency routes and assess areas for investment in retrofit. Initial estimates of economic losses are assessed and preliminary recommendations for emergency routes and prioritized retrofitting are presented.

Paper No. 2B3-3
Effects of Retrofits on Seismic Fragility of Multi-Span Continuous Steel Highway Bridges in New York State
Anil K. Agrawal, Department of Civil Engineering, The City College of New York; Ying Pan, Gilanz Murray Stetefcek; Sreenivas Alampall; New York State Department of Transportation

Various strategies such as fiber-reinforced plastics (FRP), Elastomeric and LRB bearings and fluid dampers are being used increasingly for seismic retrofits of bridge piers. In this paper, effectiveness of these retrofit options in improving seismic resistance of bridge piers is investigated by carrying out fragility analysis of bridges with and without retrofits. The structural type and topological layout of this multi-span I-girder bridge have been identified to be most typical of continuous bridges in New York State. The structural details of the bridge are designed as per New York State bridge design guidelines. Uncertainties associated with the estimation of material strength, bridge mass, friction coefficient of expansion bearings and expansion-joint gap size are considered. The uncertainties of capacity and demand are considered simultaneously by using the ratios of demands to capacities at different limit states to construct seismic fragility curves as a function of PGA. The fragility curves from this analysis demonstrate comparative advantages of different retrofit options. The results presented in this paper can be used to seismic effective retrofit measures to improve seismic resistance.

Paper No. 2B3-4
Seismic Risk Assessment of Priority Bridges along I-24 in Western Kentucky
Wael Zatar, College of Engineering, Marshall University; Issam Hanik and Tong Zhao, Department of Civil Engineering, University of Kentucky; Wei-Xin Ren, Department of Civil Engineering, Fuzhou University

Interstate-24 (I-24) in western Kentucky lies just east of the New Madrid Seismic Zone. Seismologists believe that there is a high probability of a major earthquake event to hit the area in the near future. I-24 is a high priority and emergency route that has to remain functional and operational during major earthquake events. Two parallel long span bridges lie along I-24 in western Kentucky and cross the Tennessee River. Two other parallel bridges lie along I-24 in western Kentucky and cross the Cumberland River. Due to the importance of the four existing bridges, it was decided to carry out seismic evaluation and risk assessment studies. The bridges were evaluated for the 250-year and the 500-year seismic events. The following tasks were carried out to judge the structural integrity and the seismic vulnerability of the bridges: (1) field testing of the main long spans; (2) finite element modeling and calibration; (3) time-history seismic response analysis; and (4) seismic evaluation for the main spans and the approach spans. Deficiencies of the seismic performance of the four bridges at the Tennessee River and at the Cumberland River crossings were identified, and retrofit recommendations were provided.

Paper No. 2B3-5
Probabilistic Damage Control Approach (PDCA) and Performance-Based Design of Bridges
Abbas M. Tourzani, Amir M. Malek, Sam Ataya and Mark Mohan, California Department of Transportation

Performance-based design objectives are applied through the use of performance and hazard levels in design. Performance-Based Design procedure for bridges is not just for seismic event but all events that may cause major damages; however, in this paper only seismic event is considered. Probabilistic Damage Control Approach is a “capacity design” procedure to predict performance of the bridge column under specific potential hazard level and is an important step of Performance-Based Design of Bridges. The Probabilistic Damage Control Approach is a proposed procedure for designing and evaluating bridge column based on predefined or expected performance level. In Probabilistic Damage Control Approach, performance of column is measured through application of damage index. In this paper application of Probabilistic Damage Control Approach in performance-based design will be illustrated and a design example will be presented to show the practical application of this approach.
SESSION 3A1: INTERNATIONAL TECHNOLOGIES AND PRACTICES

MODERATOR: JUAN CAICEDO, UNIVERSITY OF SOUTH CAROLINA

Paper No. 3A1-1

Extreme Wind Loads
Dorian Janjić, Bentley Systems, Inc.

In the last decades, increased emphasis is put on thorough investigation of dynamic wind effects on long span bridges. This has become necessary mainly for two reasons: On the one hand, there are increasing span lengths, which makes the construction more susceptible for oscillations. On the other hand, the used cross sections cause often very low static loads while dynamic loads due to turbulent wind are a magnitude higher. Consequently, it is not sufficient to approximate dynamic effects by additional factors for the static load in such cases. Instead, sophisticated calculation methods must be applied to account for the time dependent wind forces. These calculations must be based on a detailed statistical description of the wind events as well as an accurate aerodynamic characterization of the cross sections. To estimate the full range of dynamic effects, a software tool was developed to calculate: steady state and flutter coefficients (CFD); static wind load; dynamic wind loads within a modal approach (buffeting analysis); and wind design checks for vortex shedding, across wind galloping, torsional divergence, classical and torsional flutter. In this contribution, the theoretical background of the implemented calculations and checks is outlined and practical examples are presented.

Paper No. 3A1-2

Advanced Seismic Design Considerations for Highway and High Speed Railway Bridges in Spain
José-Luis Sanchez Jimenez, Department of Structural Engineering, TYPISA

Spain, in the south west of Europe, has a moderated seismic hazard, caused by the proximity of the Azores and the Mediterranean Faults, with basic seismic acceleration under 0.25g. The great development reached in the last fifteen years, specially involving highway and high speed railway infrastructures, has forced to improve the technology, the constructive procedures and, also, specific considerations for the seismic actions. The communication gives an overview of the Eurocode and Spanish regulations, insisting on the ductility prescriptions. It will be presented several highway bridges, designed by TYPISA with the capacity method, showing the control of the ductility required versus available and other factors involved. Special interest has the case of long high speed railway viaducts. In order to control the braking forces avoiding multiple rail dilatation devices, usually the deck is anchored at one fixed point, typically one of the abutments. When the seismic event must be considered, the induced seismic forces could reach high levels. Two HSR viaducts are discussed, designed by TYPISA with isolating and damping devices, combined with shock transmission units (adjusted to assume the braking forces), without increasing the costs.

Paper No. 3A1-3

Expected Behavior of the Infreprillo II Bridge in Mexico
José M. Jara, Manuel Jara and Hugo Hernández, Civil Engineering School, University of Michoacán, Mexico

The 525 meters long Infreprillo II bridge crosses the Infreprillo Dam and it is the first isolated bridge built in Mexico. It is situated in the Morelia-Lazaro Cardenas highway that connects central cities of the country to the Pacific Coast. Arch steel trusses compose the superstructure of the five simple supported spans. The substructure consists of reinforced concrete piles and abutments. The bridge was subjected to an assembly of real strong motion movements recorded close to the Pacific Coast in Mexico. The study started calibrating the proposed analytical model, by using the results of environmental vibration measurements previously taken. Results show the importance of the dynamic characteristics of the isolators employed on the expected seismic behavior of the bridge and special emphasis is dedicated to analyze the effectiveness of the isolation system for avoiding concentration of ductility demands due to the substructure stiffness irregularity.

Paper No. 3A1-4

Experimental Investigations of Precast Segmental Bridge Columns Seismically Isolated with Lead-Rubber Bearings
Yo Chen Ou and George C. Lee, Department of Civil, Structural and Environmental Engineering, University at Buffalo; Mu-Sen Tsai and Kuo-Chun Chang, Department of Civil Engineering, National Taiwan University; Ping-Hsiung Wang, National Center for Research on Earthquake Engineering, Taipei

This paper presents a US-Taiwan cooperative research project on seismic performance of segmental bridge columns for accelerated bridge construction, jointly supported by the US FHWA and NCREE in Taiwan. Precast segmental bridge column construction is an effective approach in accelerating on-site bridge construction. However, in the current design practice of segmental bridge columns, mild steel longitudinal reinforcement is normally discontinued at the segment joints for ease of on-site erection. This leads to columns with significantly lower lateral strength and hysteretic energy dissipation capacity than conventional monolithic columns for a given column size. To address this issue, we examine the use of seismic isolation bearings in segmental bridge columns to decrease the seismic demand. Among typical seismic isolation bearings, the use of lead-rubber bearings is first investigated. Large-scale specimens of segmental bridge columns seismically isolated with lead rubber bearings will be tested to investigate their seismic performance. The tests will include quasi-static cyclic loading and bi-directional pseudo-dynamic loading with a spectrum-compatible earthquake. The experimental program is in progress and expected to be completed by the end of 2008.

Paper No. 3A1-5

Seismic Performance of a Skewed Bridge with Sliding Rubber Bearings
Kevin Liu and Kuo-Chun Chang, Department of Civil Engineering, National Taiwan University

Design concept of plastic hinge has been utilized in the design specification for decades. However, investigations from 1999 Chi-Chi earthquake showed construction practice of unbolted elastomeric rubber bearings, which providing a sliding function as a semi-fixed bearing, is one of the reasons in controlling the failure mechanism of the bridge. Though bridge column was protected by only dissipating friction force from bearings, large displacement on the superstructure can also be observed, if this resistance is small; evermore, the bridge is skewed. Therefore, parametric study of one bridge with 20 degrees skew angle was performed. Variables include bearing type, friction coefficient, and input intensity of ground motions. It is found for the case with ideal hinge and roller support, compared to those in straight bridge; the moment and torsion in the column of skewed bridge are rapidly increasing due to skew-induced bilateral effect. Moreover, for the case with sliding rubber bearing and low friction coefficient, not only the displacement of girder should be considered in the longitudinal direction, but the one along the transversal direction should be pay attention to, so that the design of displacement-restrained device can be optimized to prevent superstructure from unseating and mitigate the unexpected impact force.

SESSION 3B1: EFFECTS OF NEAR-FIELD EARTHQUAKES ON BRIDGES

MODERATOR: DERRELL MANCEAUX, FEDERAL HIGHWAY ADMINISTRATION

Paper No. 3B1-1

Simplified Analysis of Bridges Crossing Fault-Rupture Zones
Rakesh K. Goel, Department of Civil and Environmental Engineering, California Polytechnic State University; Anil K. Chopra, Department of Civil and Environmental Engineering, University of California, Berkeley

Rooted in structural dynamics theory, a simplified procedure, denoted as static analysis procedure, is presented for estimating seismic demands for bridges crossing fault-rupture zones and deforming into their inelastic range. This procedure estimates the total seismic demand by superposing peak values of quasi-static and dynamic parts. The peak quasi-static demand is computed by nonlinear static analysis of the

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bridge subjected to peak values of all support displacements applied simultaneously whereas the peak dynamic demand is estimated by linear static analysis of the bridge due to lateral forces appropriate for bridges crossing fault-rupture zones. This procedure is shown to provide estimates of seismic demands that are accurate enough to be useful for practical applications. Application of the static analysis procedure is illustrated through example. Comments on a procedure currently being used by practicing engineers are also provided.

Paper No. 381-1

Study of Pulse Effects of NFGM on the Dynamic Response of Bridge Structures
Ajit C. Khansne and Eric M. Lui, Department of Civil and Environmental Engineering, Syracuse University

Low-frequency near-fault ground motions (NFGM) occur as a result of source effects of rupture directivity. Because of path effects, large subduction-zone earthquakes as well as moderate to large crustal earthquakes can generate far-source low-frequency ground motions in distant sedimentary basins. These effects are important design considerations because they often impose large demands on long-period structures like bridges. By using discrete-time signal processing method in which a low-pass filter at a suitable cut-off frequency is applied to the Fourier transforms of the processed acceleration and velocity time history records, low-frequency contents for acceleration, velocity and/or displacement time histories can be isolated from which directivity or path effects can be identified. By using the acceleration pulse as the excitation force, it is shown that the displacement response of a linearly elastic single degree-of-freedom (SDF) system with natural period exceeding a certain value referred to as the cut-off period is quite comparable with that due to the original ground excitation. The displacement response characteristics of a linearly elastic SDF system like a bridge bent when it is subjected to pulse-like excitation is studied qualitatively and quantitatively. Qualitatively, the effects of three types of pulses - monotonically increasing, ripple and resonance - on the system displacement response are identified. Quantitatively, these three pulse types are identified though a modified displacement response factor. Because values of can be as high as 10 to 25 for resonant pulses acting on an undamped system, it can be concluded that such pulses are the most devastating.

Paper No. 381-3

Effects of Near-field Earthquakes on Bridges with Tall Bearings
Monique C. Hite and Siddharth Srivastava, Department of Civil Engineering, Texas A&M University; Reginald DesRoches and Roberto T. Lean, School of Civil and Environmental Engineering, Georgia Institute of Technology

Seismically induced pounding of bridge decks may generate significant forces from large accelerations of near-field ground motions, resulting in bridge damage. Previous studies have used various contact elements and energy methods to focus on the effects of bridge pounding with limited attention to the transfer of loads from the bridge deck to the columns via bearings. This preliminary analytical study investigates the effects of pounding on bridges with tall bearings, where the distribution and redistribution of forces is paramount when subjected to near-field earthquakes. Tall bearings such as steel pedestals (19" to 33") may not have the capacity to resist the large lateral forces generated from earthquake excitation coupled with pounding of the bridge decks and abutments. Consequently, these tall bearings may become unstable as energy is dissipated when subjected to synthetic time histories developed for 10% and 2% probabilities of exceedance (PE) for Charleston, South Carolina. Particular emphasis is placed on modeling the nonlinear behavior of the bridge columns, localized impact at the expansion joints, and bearing behavior, where the hysteretic force-displacement behavior of the tall bearings is uniquely modeled using experimental test results. Therefore, the objective of this study is to gain more insight as to the seismic vulnerabilities of tall bearings in a generic bridge with expansion joints, where the effects of pounding induced by near-field synthetic ground motions for Charleston, South Carolina are analyzed using nonlinear time history analysis.

Paper No. 381-4

Development of a Biaxial Hysteretic Model for Reinforced Concrete Structures
Shu-Hsien Chao and Chin-Hsiung Loh, Department of Civil Engineering, National Taiwan University

The objective of this study is to develop a biaxial hysteretic model to simulate the structural non-linear inelastic response with strength, stiffness deterioration and pinching phenomenon. The concept of zero force point is proposed in this study. The biaxial hysteretic model can be derived from any types of the uniaxial one by using the concept of zero force point. Two non-linear inelastic springs and one elastic spring are connected in parallel connection to define the cyclic behavior of the proposed uniaxial and biaxial hysteretic model. The proposed biaxial hysteretic model is rate-independent. By using the proposed biaxial hysteretic model, one can derived the same simulated results while the model is subjected to the same loading paths with different loading rates. The tangent stiffness matrix of the proposed model is also constructed in this study. The proposed biaxial hysteretic model can be used to simulate structural not only global (such as story shear force versus story drift response of whole structure) but also local hysteretic behavior (such as moment versus curvature or plastic rotation response of structural element). The biaxial cyclic loading test data of six reinforced concrete columns, design with either flexural failure or shear failure, are used to verify the proposed biaxial hysteretic model.

Paper No. 381-5

The Influence of Vertical Earthquake Motion and Pre-Earthquake Stress State on the Seismic Response of Precast Segmental Bridge Superstructures
Mark Veletzos and José I. Restrepo, Department of Structural Engineering, University of California at San Diego

Precast segmental construction methods can ease bridge construction costs by reducing construction time while maintaining quality control. In addition, the absence of falsework can minimize traffic congestion and environmental impact. The research described here was motivated by the need for further research on the seismic response that would lead to reliability in its use. This research investigated the seismic response of precast segmental bridges with bonded tendons constructed with the balanced cantilever construction method, using detailed 2D non-linear time history analyses. A number of models were developed, including a validation model and two simulations of full scale balanced cantilever bridges with span lengths of 300 and 525 feet. These models utilized geometries and characteristics, similar to the Otay River Bridge and the San Francisco-Oakland Bay Bridge Skyway in California and were subjected to a suite of twenty near field earthquake records. This paper will show that the vertical component of ground motion significantly affects the segment joint response and the magnitude of the response can vary dramatically depending on the pre-earthquake stress-state (i.e., the effects of creep, shrinkage and temperature) in the superstructure.
Poster Abstracts

Moderator: Reginald DesRoches, Georgia Institute of Technology
Coordinator: Tina Hembree, South Carolina Department of Transportation

Poster No. P01
Nonlinear Analysis of Seismically Isolated Bridges with Inverted-T Cap Beams
Alp Caner, Middle East Technical University; Cenan Ozkaya, Yuksel Project International Co.

Seismically isolated bridges with inverted T-cap beams are not investigated in depth until now. Elastic response spectrum analysis is typically preferred in design of bridges. In this study, it has been demonstrated that elastic response spectrum analysis may not be the right analysis tool to design bridges with inverted T cap beams since pounding effects are ignored. Pier design forces determined from response spectra analysis may be significantly lower than the pier seismic forces determined from non-linear time history analysis performed with response spectrum compatible earthquake records. The purpose of this study is to suggest a nonlinear analysis guideline to check the design forces determined from response spectra analysis. Pounding may be mitigated by providing new design details.

Poster No. P02
2008 New York City DOT Seismic Design Guidelines for Bridges Considering Local Site Conditions
Ruben Gajer, Weidlinger Associates, Inc.; Ricardo Dobry, Consultant; Walter Silva, Pacific Engineering and Analysis; Thomas Thomann, URS Corp.; Kamal Kishore, Jay Patel, Abdur Razzaq and Sajjan Jain, New York City Department of Transportation

New Guidelines will soon replace the 1998 NYCDOT Seismic Design Guidelines for Bridges in the New York City region. A hazard study determined new region specific motions at very hard rock sites (Uniform Hazard Spectra (UHS), and associated acceleration time histories). A region–specific study of site effects for conditions representative of NYC followed in order to recommend generic rock and soil design spectra, and guidelines for site-specific studies. A fully probabilistic approach was used to develop horizontal and vertical UHS at soil sites. It accounted, in a rigorous probabilistic manner, for variations and uncertainties in soil stiffness, stress-strain nonlinearity (G/Gmax), material damping, depth of soil to rock, and rock stiffness under the soil. Current building and bridge codes specify spectra as a function of only the Soil Class. In the new Guidelines, the soil generic spectra are a function of three parameters: soil class, depth to rock, and rock class under the soil. Vertical design spectra and design V/H ratios needed to obtain site-specific vertical design motions, are also provided at soil sites as function of the same three parameters.

Poster No. P03
Seismic Performance of Reinforced Concrete Bridge Columns at Low Temperatures
Luis A. Montejo, Mervyn J. Kowalsky and Tasnim Hassan, Department of Civil Engineering, North Carolina State University

At sub-freezing temperatures, the properties of construction materials are expected to vary and consequently, the response of a structure to a seismic excitation is also expected to change. This paper presents the results obtained from eight large scale circular columns tested under increasing cyclic reversals and constant axial load while subjected to ambient and sub-freezing temperatures. All the units were designed for flexural failure; four of them were reinforced concrete filled steel tube columns. The remaining four test units were conventional reinforced concrete column members with different longitudinal steel ratio. It was found that columns tested at low temperatures exhibit an increase in the flexural strength accompanied by a reduction in the spread of plasticity and displacement capacity.
POSTER ABSTRACTS

Poster No. P05
Improving Tomorrow’s Infrastructure: Extending the Life of Concrete Structures with Solid Stainless Steel Reinforcing Bar
Raymond E. Schnell, Talley Metals Technology, Inc.; M. F. Bergmann, New York State Department of Transportation

Recent advances in concrete technology have provided structural designers with materials which can easily last more than 100 years, and the life of many concrete structures today is limited by the reinforcing bar. Improvements in the life of the reinforcing can translate directly into extended life of the structure. Current projections by several transportation agencies show that the use of solid stainless steel reinforcing bar in bridge decks will more than double the life of the bridge deck. While solid stainless steel reinforcing bar can increase the cost of the bridge deck by as much as 12% (compared to carbon steel reinforcing), the economic value of the longer life outweighs the initial higher cost. In most cases, the additional cost of solid stainless steel reinforcing bar represents less than 1% of the total cost of the structure. Where the reinforcing bar is completely resistant to corrosion, concrete cover can be reduced, saving costs of concrete and reducing the total weight of the structure. In some structures, design savings made possible by the use of solid stainless steel reinforcing bar will offset as much as 100% of the initial cost increase from using the stainless reinforcing.

Poster No. P06
Impacts of New Provisions on the Seismic Design of Tennessee’s Bridges
Timothy Huff, Tennessee Department of Transportation

AASHTO has plans to incorporate Interim seismic provisions to the 4th edition LRFD Bridge Design Specifications in 2008. The overall theme will remain a force-based approach to seismic design, but will require more attention to bridges located in some areas of Tennessee due to the increased ground motion return period. Also in 2008, AASHTO will introduce the new Guide Specification for LRFD Seismic Bridge Design, permitting the designer to approach the problem from a displacement-based theory. This paper presents some of the measures taken by TDOT to incorporate both sets of provisions into their bridge designs. More sophisticated analysis techniques than those commonly used in the past as well as details new to TDOT design are discussed.

Poster No. P07
Case Studies in High Channel Count Integrated Systems for Monitoring Bridge Structures
Kurt Veggeberg, National Instruments

Advances in PC based instrumentation along with flexible software tools have made it possible to design large channel count data acquisition systems capable of simultaneous measurements maintaining a tight phase relationship between a wide range of sensors such as accelerometers, cameras and strain gages over long distances or areas. These systems are very useful in the development of an integrated architecture for Structural Health Monitoring (SHM) for large-scale bridges that combine data acquisition, data transmission and data architecture. This is an outline of the Signal Based and Time Based architectures of the instrumentation systems that have been deployed for continuous monitoring of several bridges involving hundreds of mixed signals for improved decision making of their condition over long periods of time. These practical examples of SHM include the UCSD Powell Laboratory Smart Bridge Testbed, the Donghai Bridge near Shanghai, and the Shandong Binzhou Yellow River Highway Bridge. They illustrate advanced capabilities of detecting damage, stresses, fatigue, and structural condition for safer bridge operations.

Poster No. P08
Performance-Based Seismic Assessment of the Existing Grand Avenue Bridge in St. Louis Missouri versus Conventional Methods
Amir A. Arab and Kevin C. Kriete, HDR, Inc.; William Early, City of St. Louis – Design Division

This paper includes the findings and comparison of the performance-based seismic assessment of the existing Grand Avenue Viaduct in St. Louis Missouri versus the conventional methods currently practiced in the state of Missouri. The central portion of the existing bridge is comprised of seven (7) spans with a total length of 676’8”; consisting of a reinforced concrete deck slab on built-up steel girders supported by multi-column reinforced concrete bents founded on a combination of pile-foundations as well as spread footings. The existing structure reflects typical design techniques of 1950’s with the main focus on vertical load resistance. This study includes the seismic assessment of the existing bridge, evaluation of its performance as a critical structure prone to significant seismic risk due to close proximity to New Madrid and Wabash Valley seismic zones while serving a vital link between North and South Grand Boulevard, and final recommendations to the City of St. Louis for a comprehensive retrofit scheme. The findings presented in this paper also identify the advantages of a seismic analysis centered on performance based design criteria following South Carolina Seismic Design Specifications and proposed AASHTO Guide Specifications for LRFD Seismic Bridge Design versus the conventional AASHTO Div. I.A guidelines.

Poster No. P09
Seismic Evaluation and Retrofit of the Brooklyn Bridge
Serafim Arzoumanidis and Nicholas Edwards, Parsons Corporation; Jay Patel, Kamal Kishore, Hassan Ahmed, and Walter Kukczycki, New York City Department of Transportation

The Brooklyn Bridge, completed in 1883, is a National Historic and Civil Engineering Landmark, and a critical transportation link between Manhattan and Brooklyn. Its granite masonry towers with their gothic arches and graceful stay cables have a universal appeal. The main bridge is a combination of suspension and cable-stayed structure with several unique features. The bridge underwent in-depth seismic evaluation and is being retrofitted to enable it to sustain 2,500-year return period earthquakes with minimal or repairable damage. The evaluation was based on a comprehensive investigation of soils, testing of materials, field measurements of bridge vibrations and state-of-the-art analytical work. The paper describes the seismic evaluation of the main bridge and the masonry towers, which are supported on caissons with several layers of timber. Details of the work include aspects of the global non-linear analysis, the acceleration pushover analysis of the towers and the soil–caisson–tower interaction analysis. The superstructure and towers were found to respond in a satisfactory manner. Only certain unusual details of the superstructure require retrofitting.

Poster No. P10
Advances on On-Line Bridge Seismic and Structural Health Monitoring Using Fiber Optic Sensing Technology
Tom W. Graver, Steve Ferguson, Todd Haber, Andrei Csipkes, and Jeff Miller, Micron Optics, Inc.

Owners must manage and ensure the safety of their bridges even as their use might extend well beyond their original design lifetime. Traditionally, most structures rely on strict maintenance procedures, visual inspections, and very few sensors. However, maintenance operations are expensive; visual inspections can miss critical problems; and conventional sensors often fail in harsh environments. Can fiber-optic sensing (FOS) address these issues and provide a practical, effective and reliable sensing alternative? In this paper, we present a brief overview on the state-of-the-art of optical fiber sensors and instrumentation for bridge seismic and health monitoring applications. We will highlight several bridge projects where FOS were used, and describe the associated successes and challenges for each application. Many successes are coupled to improved FOS tools: better sensor packages, simpler and
less expensive instrumentation, improved installation techniques, and more efficient data analysis tools. Particular attention is given to the economics of instrumenting civil structures – when and how it pays.

**Poster No. P11**

**Development of ARS Curve for a Long Multi-Span Bridge at a Liquefiable (Type F) Site**
Endi Zhari and Houman Makanerchi, Kleinfelder, Inc.

This paper presents a practical approach to develop a site-specific design acceleration response spectral (ARS) curve for a soil profile Type F site due to liquefaction. A site-specific probabilistic seismic hazard analysis (PSHA) and a standard Caltrans deterministic analysis were performed to develop the target response spectrum at the soil model base. An equivalent-linear seismic response analysis using the computer program SHAKE91 was performed and compared with the nonlinear total-stress and effective-stress seismic response analyses using the computer code D-MOD2000. The ARS curve computed using the equivalent-linear approach significantly reduced the shorter period response, amplifying the longer period response. The equivalent-linear analysis cases used the pre-liquefaction and post-liquefaction soil properties. The surface ARS curves were further computed from the nonlinear analyses. Before the site-specific evaluation, a simplified ARS curve was recommended and used in the preliminary design. Differences and deficiencies of the surface ARS curves between using simplified method, the equivalent-linear and nonlinear effective-stress seismic response analyses are discussed and recommendations for bridge structures having different fundamental periods of vibration are provided.

**Poster No. P12**

**Web Buckling Prevention in Built-up Shear Links**
Marco Rossignoli, HNTB Corp.; Chiara Rossignoli

Passive steel links yielding in shear are being used as seismic energy dissipation systems for retrofit of existing bridges and the design of new long spans and cable-stayed bridges. Five built-up shear links with different web stiffening solutions were designed for bridge applications, and their 3D solid finite-element models were analyzed with ADINA. The dimensions of the links and the grades of steel were selected so as to permit a rapid use of the data gathered with this research in the design of twin-blade piers for long span bridges and towers of cable-stayed bridges in high seismicity regions. The objectives of the research were to investigate the plastic strain demands on built-up shear links, the buckling behavior, the degradation in the hysteretic loops generated by out-of-plane deformations in the web, and the improvements achievable with the use of horizontal web stiffeners in lieu of more conventional vertical stiffeners. A finite-element formulation reproducing the linear response of links to service loads and the inelastic shear-yielding response as resulting from load testing was also implemented for global analysis of long span bridges with SAP 2000.

**Poster No. P13**

**Effects of CFRP Wraps on Strength and Ductility of Slender Concrete Columns**
Pedram Sadeghian, Amir H. Shekari and Farid Mousavi, Islamic Azad University of Qazvin

In recent years, retrofitting of concrete structures is the major problem of existing civil structures. Concrete columns are essential structural components in concrete structures such as bridges and buildings. Most researches have mainly concentrated on the stress-strain model, the compressive strength, and the shape of cross section of short columns. The fact is commonly accepted that FRP composites are most effective in increasing the strength and ductility of slender columns. The fact is commonly accepted that FRP composites increase the strength and ductility of short columns. But, with increasing slenderness, slenderness effects can prohibit the column from attaining its maximum performance and the column may become susceptible to instability. Because the FRP composites have a higher strength and lower stiffness than steel, the FRP wrapped columns tend to be more susceptible to slenderness effects. This paper presents the results of experimental studies about axial stress-strain behavior of retrofitted slender concrete columns with CFRP composites. In this study, 30 un-reinforced concrete cylinders 100 mm diameter with variable height of 200, 400, 600, 800, and 1000 mm were prepared and retrofitted. In each group, a plain specimen (unwrapped) and five wrapped specimens with different fiber orientations (0, 0/0, 90/0, 45, and 45/0) were tested under compressive axial force up to failure. The results have shown that the CFRP composites are most effective in increasing the strength and ductility of slender columns.

**Poster No. P14**

**Effect of Abutment Modelling on the Seismic Response of Bridge Structures**
Ady Aviram and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley; Kevin Mackie, Department of Civil and Environmental Engineering, University of Central Florida

Abutment behavior significantly influences the seismic response of a bridge structure. Specifically in the case of short bridges with relatively stiff superstructures typical of highway overpasses, embankment mobilization and inelastic behavior of the soil material under high shear deformation levels dominate the response of the bridge and its column bents. This paper investigates the sensitivity of bridge seismic response with respect to three different abutment modeling approaches. Modal, pushover and nonlinear dynamic time history analyses are conducted for the six bridges using three abutment models for each bridge. Comparisons of the analysis results show major differences in mode shapes and periods, ultimate base shear strength, as well as peak displacements of the column top obtained due to dynamic excitation. The adequacy of the three abutment models used in the study to realistically represent all major resistance mechanisms and components of the abutments, including an accurate estimation of their mass, stiffness, and nonlinear hysteretic behavior, is evaluated. Recommendations for abutment modeling are made.

**Poster No. P15**

**Post-Earthquake Bridge Repair Cost Evaluation Methodology**
Kevin Mackie, Department of Civil and Environmental Engineering, University of Central Florida; John-Michael Wong and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California, Berkeley

Post-earthquake repair costs are important for evaluating the performance of new bridge design options and different existing bridge configurations in the next major earthquake. Hazard and structural demand models provide information on the probabilistic structural response during earthquakes. Damage and decision models are needed to link the structural response to decisions on bridge repair actions and repair costs. A new step-by-step probabilistic repair cost methodology is proposed in this paper to evaluate the costs of repairs for different bridge components and the bridge as a system corresponding to varying degrees of damage. Repair actions, quantities, and costs are input into spreadsheet templates and a numerical tool evaluates expected repair costs and repair cost variance for a range of earthquake intensities. Central to the proposed methodology is the concept of performance groups—groups defined to account for bridge components that are repaired together. Six spreadsheets are used to track all of the necessary data: bridge information, structural response, component damage states, repair methods and repair quantities, and unit costs or production rates. Data can be customized for repair methods and bridge types particular to different state departments of transportation. The methodology is illustrated using repair cost fragilities for a typical multi-span reinforced concrete highway overpass bridge in California.

**Poster No. P16**

**Use of Steel Jackets to Retrofit Reinforced Concrete Columns in Tidal Water/Wetland**
Hongzhi Zhang, Bridge and Structures Office, Washington State Department of Transportation

A new construction method has been developed by WSDOT/Bridge and Structures Office to save construction cost and to reduce the environmental impact of installing steel jackets. The method uses a
specially designed rubber ring at the bottom of the steel jacket as the seal material. The jacket can be installed from the bridge deck, welded, and then lowered down to the top of the footing. The water is then pumped out and grout is filled to the full height of the jacket. Timber floating docks are used to carry small equipment and to store materials resulting in reducing the duration of traffic controls. Using this method, two column retrofit projects in tidal water or wetland have been completed in 2006 and millions of dollars in construction cost was saved. The same method has been used to repair deteriorated R.C. columns in tidal water/wetland.

Poster No. P17
Low-Cycle Fatigue Behavior of Stainless Steel Reinforcing Bars
Yihui Zhou, Yu-Chen Ou and George C. Lee, Department of Civil Structural and Environmental Engineering, University at Buffalo; Jerome S. O’Connor, MCEER, University at Buffalo

The use of stainless steel reinforcing bars in reinforced concrete structures is one of the promising solutions to corrosion issues. For stainless steel reinforcing bars to be used in seismic applications, several mechanical properties need to be investigated such as specified and actual yield strengths, tensile strengths, elongations and low cycle fatigue behavior. A research task was initiated at MCEER to experimentally investigate the above-mentioned mechanical properties of various types of stainless steel reinforcing bars that are currently available in the market, including the 316LN, and Enduramet 32 bars. For comparison, A706 G60 carbon steel reinforcing bars, which are typical for seismic applications, were also examined. Low-cycle fatigue tests of the bars were conducted under strain control with constant amplitude to obtain the strain life models of the bars. In the future test plan, the bars will be subjected to random amplitude strain inputs, which simulated conditions under earthquakes, to validate the applicability of various existing damage accumulation models.

Poster No. P18
Cyclic Behavior of RC Bridge Columns under Combined Loadings including Torsion
Suriya Prakash Shanmugam and Abdeljellil Belarbi, Missouri University of Science and Technology; Ashraf Ayoub, University of Houston

Reinforced concrete (RC) bridge columns can be subjected to torsional moments in addition to flexure, axial, and shear forces during earthquake excitations. The addition of torsion is more likely in skewed and horizontally curved bridges, bridges with unequal spans or column heights, and bridges with outrigger bents. This combination of loadings can result in complex flexural and shear failure of these bridge columns. An experimental study is being conducted to understand the behavior of RC circular columns under combined loadings. The results of the five columns tested under cyclic pure bending, cyclic pure torsion, and various levels of combined cyclic bending and torsion respectively are presented in this paper. The effects of combined loading on the hysteretic load-deformation response, spiral and longitudinal reinforcement strain variations, and plastic hinge characteristics are discussed. Normalized interaction diagrams for bending and torsion based on the test results are presented and discussed. The significance of proper detailing of transverse reinforcement and its effect on the torsional resistance under combined loadings is also highlighted. Based on the test results, it is concluded that the flexural as well as torsional capacity is decreased due to the effect of combined loading and there is also a change in the failure mode and deformation characteristics.

Poster No. P19
Effect of Coupled Shear-Bending Deformations on the Behavior of RC Highway Structures Subjected to Extreme Seismic Loading
T. Ravi S. Mullapudi and Ashraf Ayoub, University of Houston; Abdeljellil Belarbi, Missouri University of Science and Technology

Reinforced concrete highway structures are prone to experience shear failure if subjected to extreme seismic loading. The paper investigates the effect of coupled shear-bending deformations on the behavior of RC bridge piers subjected to severe seismic excitations. In order to accomplish this task, a new inelastic nonlinear beam element with axial, bending, and shear force interaction was developed. The concrete model uses an orthotropic constitutive relation in which the directions of orthotropy are the principal directions of total strain. These directions will change during the loading history, in accordance with the well-known rotating crack model. The concrete model accounts for the axial state of stress and the directions of orthotropy, in addition to degradation under reversed cyclic loading. The shear mechanism is modeled by assuming the strain field of the section as given by the superposition of the classical plane section hypothesis. Transverse strains are internal variables determined by imposing equilibrium between concrete and vertical steel stirrups. Element forces are obtained by performing equilibrium based numerical integration on section axial, flexural, and shear behavior along the length of the element. The validity of the model is established by correlation of analytical results with experimental tests of shear-sensitive RC specimens.

Poster No. P20
Seismic Performance Goals and Probabilistic Assessment of Expansion Joints for Highway Bridges
Jamie E. Padgett, Rice University; Regional DesRoches, Georgia Institute of Technology; Paul Bradford, Watson Bowman Company

Seismic specifications acknowledge the need for post-event functionality for essential and critical bridges, either explicitly or implicitly, in terms of structural seismic performance. A move towards performance based design and assessment of bridges and their components necessitates the ability to evaluate the likelihood of achieving a given set of performance goals within a level of confidence. However, these strategic performance goals for seismic expansion joints in bridges have yet to be adequately defined and little research has considered the influence and performance of seismic expansion joints on the post-event functionality of bridge systems. Uncertainties in the ground shaking, seismic demand, and capacity must be characterized in order to assess the potential for damage to the joints themselves and their effect on the failure potential for the overall bridge system. Additionally, the states of damage evaluated should have links to anticipated functionality of the bridge in order to investigate how joint selection ultimately affects bridge functionality. This paper proposes a framework for reliability assessment of seismic expansion joints through the development of seismic fragility curves. Damage due to pounding in non-seismic joints and engineered seismic expansion joints are compared probabilistically. The curves can be used to evaluate the reliability of different expansion joints, as well as the influence of the joints on the bridge performance as a whole including anticipated allowable traffic carrying capacity.

Poster No. P21
A Simple Procedure for Evaluating Seismic Isolation in Bridges
Mary Jacak, Seismic Energy Products

This paper presents a simple method for evaluating the performance of seismic isolation for most bridge structures. Through application of the basic theory of seismic isolation and the graphic representation of the modified acceleration and displacement spectra of the AASHTO Guide Specification for Seismic Isolation Design (1999), the user can determine with reasonable accuracy the force and displacement levels achievable with any isolation system. The method employed can be used to independently verify the force and displacement levels reported by isolation bearing suppliers. Detailed analyses will generally result in overall performance similar to that obtained using the method presented here. The method presented is not intended as a replacement for detailed analysis, and the analysis requirements of the AASHTO Guide Specifications for Seismic Isolation Design (1999 and 2000) must be satisfied. This paper does not describe methods for configuring isolation bearing units. This task should only be done in close consultation with the design engineer. Such an approach will better ensure that the isolation system performance and bearing geometry shown on the plans can be achieved. In addition, the isolation bearing suppliers will insure that the most current and economical bearing designs are used.
Poster No. P22
Seismic Analysis of Frame Bridges in Distrito Federal, Mexico
Hugo Hernández-Barrios, José Manuel Jara-Guerrero and Manuel Jara-Díaz, Universidad Michoacana de San Nicolás de Hidalgo

There is a lack of explicit regulations for the seismic design of integral bridges in Mexico. However, many bridges built in the urban environment are located in high seismicity areas. In Mexico City, two span reinforced concrete frame bridges are very common. Many of them are over 40 years old and some of them are tilted because of the flexible soil conditions. This study aimed at determining the seismic behavior of frame bridges located in Mexico City. In order to assess the time domain response of the bridges, numerical models were subjected to typical ground motion records of the September 19, 1985, Mexico earthquake. The bridge responses are evaluated by the analysis of shear forces and overturning moment demands.

Poster No. P23
Liquefaction Evaluation of the CREC Geotechnical Experimentation Site near Charleston, South Carolina Based on Cone Tests
Ronald Boller and William Camp, S&ME, Inc.; Ronald Andrus and Hossein Hayat, Department of Civil Engineering, Clemson University; Sarah Gassman, Department of Civil and Environmental Engineering, and Pradeep Tallaw, Department of Geological Sciences, University of South Carolina

A geotechnical experimentation site is being developed at the Clemson University Coastal Research and Education Center (CREC) near Charleston, South Carolina. The development of the CREC geotechnical site is part of a three-year research project sponsored by the National Science Foundation on characterization of the liquefaction resistance of aged soils. The site is located on a beach deposit of the 100,000-year-old Wando Formation. Investigations conducted at the site include 3 seismic and 3 non-seismic cone tests with pore pressure measurements. The beach sand is 10 to 13 ft (3 to 4 m) thick. The groundwater table is located at a depth of about 3 ft (0.9 m). Field evidence indicates that this beach sand did not liquefy during the 1886 Charleston earthquake. To correctly predict low liquefaction potential at the site based on the cone penetration test data, an age (or deposit resistance) correction is needed. This finding agrees with a recent liquefaction potential mapping study of Charleston peninsula. Because aged soils are common in South Carolina and throughout the world, these findings may have a significant economic impact on the seismic design of bridges and highways.

Poster No. P24
Reinforced Concrete Bridge Seismic Damage and Loss Scenarios
John-Michael Wong and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California, Berkeley; Kevin Mackle, Department of Civil and Environmental Engineering, University of Central Florida; Richard Porter, California Department of Transportation

Post-earthquake performance of bridges is better defined in terms of consequences and the economic costs associated with these consequences, such as repair costs, repair time, and down time. The probabilistic loss estimation methodology proposed by the authors is extended in this paper to include repair time as well as repair costs. Use of the methodology for post-earthquake loss estimation is demonstrated for two damage scenarios on a typical reinforced concrete bridge in California. The damage scenarios are based on Caltrans specifications and case histories, and illustrate repair methods, unit costs, and repair times. The scenarios do not correspond to a particular earthquake but were designed to illustrate the range of damage states and repair methods that can be expressed within the repair cost methodology for the example bridge. A major damage scenario contains low-level damage consisting of column retrofits and minor structure and approach repairs. A major damage scenario involves column replacement and significant foundation and abutment repairs. Drawings are provided to illustrate the extent of repairs on the example bridge. Representative quantities, costs, and schedules were obtained with collaboration between Caltrans and UC Berkeley. The example can be modified and customized for different bridge types, configurations, and state department of transportation practices.

Poster No. P25
Seismic Vulnerability Study of the Auburn-Foresthill Bridge
Wei Li and Hassan Sederat, SC Solutions, Inc.; John Quincy and Mark Reno, Quincy Engineering Inc.

The Auburn-Foresthill Bridge is a 2,428 ft steel suspension bridge that links the towns of Auburn and Foresthill, California and was built in 1973. While it is ranked 3rd in the U.S., it is the tallest bridge in California. The bridge is located in the seismically active Foothills fault zone and is supported by two 403 ft tall unconfined concrete piers. The seismic vulnerability of the bridge is critical in developing a retrofit strategy. This paper discusses the development of a 3D non-linear finite element model of bridge, the non-linear time history analysis, and the seismic performance of key bridge components. A detailed three-dimensional model of the bridge was constructed using the general purpose finite element program ADINA. The FE model includes nonlinearities in the material and geometry. Non-linear plastic beam elements are used to simulate the behavior of the perforated and non-perforated elements in the superstructure and the piers. The non-linear plastic beam properties are obtained using SC Solutions’ section analysis program SPEMC. These superstructure non-linear plastic elements are able to capture global buckling of superstructure elements. The buckling behavior of these members was validated using detailed shell FE models for both perforated and non-perforated sections. The pier non-linear plastic beam elements are able to capture concrete and steel reinforcement strains.
SIXTH NATIONAL SEISMIC CONFERENCE ON BRIDGES & HIGHWAYS

A sandblow from a paleo-earthquake has recently been identified at University; William Camp, S&ME, Inc. of South Carolina; Ronald Andrus, Department of Civil Engineering, Clemson University; and Pradeep Talwani, Department of Geological Sciences, University of South Carolina. The site is being studied as part of a three-year National Science Foundation research project on characterizing the liquefaction resistance of aged soils. Field investigations conducted at the site to date include seven cone penetrometer test soundings with pore pressure measurements (six with seismic), three vibrocoring, two dilatometer test soundings, and a shallow test pit. These investigations indicate the depth and thickness of the source sand layer varies over the site and is found within about 15 ft (4.6 m) of the ground surface. The water table is at a depth of approximately 17 ft (5.2 m). The 1886 Charleston earthquake caused significant structural damage to the walls of Fort Dorchester, however field evidence indicates that liquefaction did not occur during the 1886 earthquake, but liquefaction did occur during an earlier prehistoric earthquake, which produced the recently discovered sandblow. The in situ geotechnical data are being used with paleo-liquefaction evaluation methods that account for soil age to estimate the magnitude and acceleration of the prehistoric earthquake. The findings from this study may have a significant impact on the seismic design of regional bridges because soils of varying ages occur in the South Carolina Coastal Plain.

Seismic Pushover Analysis – Results Presentation
Douglas Sarkkinen and Greg Dreeszen, Kramer Gehlen & Assoc., Inc.

Seismic evaluations of two existing bridge structures were performed utilizing pushover techniques. A unique method of results presentation was done that allowed not only easy of understanding by the bridge owners but also allowed retrofit strategies to be developed; this gave the ability to maximize the cost-benefit return for seismic mitigation. The pushover analysis was performed in each direction for each structure, based on a determined force-displacement relationship for each one of the components in the seismic resisting system. The components included anchorages, bearings, end walls, girders stops, piers, end stops and earth pressure against the abutments. The results were tabulated on an overall force–displacement curve and compared with the mapped seismic demand. Because of the stiffness of the structure type, softening of the lateral resistance and subsequent period lengthening were not considered. The seismic demand was based on a linear relationship using the demand for 0.2 sec period. The combination of orthogonal demands of 100% and 30% were not shown in the charts but can be combined when ascertaining individual components for potential upgrades.

Seismic Vulnerability Assessment of Highway Bridges Considering Ground Motion Directionality
Swagata Banerjee and Masanobu Shinozuka, Department of Civil and Environmental Engineering, University of California, Irvine

As highway transportation network systems are highly vulnerable to severe earthquakes, it is desirable to consider directionality effect of earthquake ground motion in assessing the seismic damageability of highway bridge structures. However, it is very difficult to rigorously incorporate the multi-dimensional effect of ground motions in the design and response analysis of bridges. The current paper presents a procedure in which bridges can be designed to ensure safety under single or a pair of independent orthogonal ground motions traveling horizontally with an arbitrary direction to bridge axis. This procedure uses nonlinear time history analysis and expresses the prediction of bridge seismic damageability in the form of fragility curves. Fragility curves are gaining practical recognition through, for example, their use in HAZUS for seismic risk assessment. Change in fragility characteristics of bridges for different direction of ground motion propagation directly indicates the effect of directionality on bridge seismic response. Result showed that ground motion directionality can alter bridge seismic damageability substantially and hence, plays an important role in the estimation of maximum seismic demand. In this context, the result here may add directionality as another factor to be considered in HAZUS to adjust fragility curves for standard bridges. The word directionality used here is different from “directivity” used in seismology to mean a specific characteristic of seismic fault movement.

Geotechnical Characterization of the Fort Dorchester Site in South Carolina for Paleoliquefaction Evaluation
Michael Hasek and Sarah Gassman, Department of Civil and Environmental Engineering, and Pradeep Talwani, Department of Geology and Geological Sciences, University of South Carolina; Ronald Andrus, Department of Civil Engineering, Clemson University; William Camp, S&ME, Inc.

A sandblow from a paleo-earthquake has recently been identified at Fort Dorchester, South Carolina. The site is being studied as part of a three-year National Science Foundation research project on characterizing the liquefaction resistance of aged soils. Field investigations conducted at the site to date include seven cone penetrometer test soundings with pore pressure measurements (six with seismic), three vibrocores, two dilatometer test soundings, and a shallow test pit. These investigations indicate the depth and thickness of the source sand layer varies over the site and is found within about 15 ft (4.6 m) of the ground surface. The water table is at a depth of approximately 17 ft (5.2 m). The 1886 Charleston earthquake caused significant structural damage to the walls of Fort Dorchester, however field evidence indicates that liquefaction did not occur during the 1886 earthquake, but liquefaction did occur during an earlier prehistoric earthquake, which produced the recently discovered sandblow. The in situ geotechnical data are being used with paleo-liquefaction evaluation methods that account for soil age to estimate the magnitude and acceleration of the prehistoric earthquake. The findings from this study may have a significant impact on the seismic design of regional bridges because soils of varying ages occur in the South Carolina Coastal Plain.

Seismic Response Simulations of Bridges Considering Shear-Flexural Interaction of Columns
Jian Zhang and Shi-Yu Xu, Department of Civil and Environmental Engineering, University of California, Los Angeles

This paper evaluates the seismic response of three prototype reinforced concrete bridges under earthquake shakings using comprehensive numerical models that are capable of simulating the complex soil-structural interaction effects and nonlinear behavior of columns. A hysteretic model that can describe shear-flexural interacting behavior of columns is implemented as user element in software ABAQUS to model the realistic nonlinear behavior due to combined actions of shear force, axial force and bending moment. The hysteretic model is capable of capturing the pinching behavior of RC columns due to the opening and closing of propagating cracks, and the strength deterioration and stiffness softening due to low cycle fatigue. The hysteretic model was validated against cyclic loading tests as well as dynamic shake table test of bridge columns. Seismic response analyses were conducted on the prototype bridges under suites of ground motions that correspond to different hazard levels at a specific site in Southern California. The response quantities including relative displacement, acceleration, section force and section moment etc. were derived and compared among three prototype bridges to gain insight on seismic responses of concrete bridges. The numerical simulations systematically evaluate the effects of vertical motion and the significance of axial-shear-flexural interaction on seismic demand of bridges.

The Use of Paleoliquefaction Features in Seismic Hazard Assessment – the Charleston Experience
Pradeep Talwani, Department of Geological Sciences and Sarah L. Gassman, Department of Civil and Environmental Engineering, University of South Carolina

The 1886 Charleston earthquake caused widespread liquefaction, with observed cases of sand blows and lateral spread features up to 200 km away. In the past two decades more than 100 such features associated with prehistoric earthquakes (occurring up to 6,000 ago) have been found and dated to develop a chronology and recurrence times of liquefaction inducing earthquakes. CPT, SPT and shear wave velocity measurements at locations of these paleoliquefaction features were used to estimate the ground accelerations associated with these prehistoric earthquakes, and therefrom, their magnitudes. After correcting for the age of the soils, the results indicate a recurrence rate of ~500 years for liquefaction inducing earthquakes, with magnitudes of 6.7 to 7 in the Charleston region. These results are now being used in the seismic hazard assessment in the region.
specific ground motions for both short period Ss and long period S1 acceleration coefficients. Differences in response spectrum values for different periods analyzed and the resulting effects are discussed. Finally, recommendations are to be made to answer the following question: How deep of a borehole do we need to drill to have a good representation of soil information for accurate site response analysis.

Poster No. P32
Life-Cycle Cost Evaluation of Neutralized Reinforced Concrete Bridges Subjected to Earthquake
Y.C. Sung, C.K. Su, C.C. Hsu and M.C. Lai, Department of Civil Engineering, National Taiwan University; M. Pillay, South African National Roads Agency

For the reinforced concrete (RC) bridges, the deterioration of surface concrete caused by neutralization often leads to corrosion of the steel reinforcement. As neutralization progresses, the corrosion could become serious enough to endanger the structural performance of the bridge. Our previous study has established some essential mathematical expressions and important parameters to predict the neutralization effect of existing RC bridges in Taiwan, such as the diffusive coefficients of neutralized concrete, the corrosive speed and corroded depth of the reinforcements, time for initial corrosion of the reinforcements, and time for cracking of cover concrete were be able to be evaluated. As a consequence, the performance degradation of the structure can be determined quantitatively. This paper will further make the study on the life cycle cost evaluation of the neutralized bridges subjected to earthquake. The results obtained will benefit the proposing of an optimum maintenance plan for the bridges.

Poster No. P33
Vulnerability Assessment of an Existing Highway Bridge by Pushover and 3-D Nonlinear Time History Analyses for its Seismic Retrofit
Mahmood Hosseini, Structural Research Center, International Institute of Earthquake Engineering and Seismology; Yashar Banaeizadeh, Civil Engineering Department, South Tehran Branch of the Islamic Azad University; Seyyed Reza Khavari, Earthquake Engineering Department, Science and Research Branch of the Islamic Azad University

The seismic vulnerability of an existing two span reinforced concrete slab bridge with round columns as piers was studied for its retrofit design. First, the bridge design was checked by AASHTO seismic provisions, showing that the bridge is seismically weak in bending resistance and particularly shear resistance of its piers columns. Next, a push over analysis (POA) was performed, for which the target displacement was calculated by shear-displacement relationship for the center of gravity of the bridge deck. The rotations of plastic hinges in columns, obtained by POA were compared with the FEMA 356 acceptance levels, which confirmed the high vulnerability of the bridge. Finally, three various retrofit designs, including: 1) adding the strength and stiffness of pier columns by R/C jackets, 2) adding some steel diagonal elements in both lateral and longitudinal directions, and 3) fixing the deck to abutments connections in lateral direction to make it possible to use the abutment walls as shear walls, were considered and checked by both POA and Nonlinear Time History Analyses (NLTHA). The bridge specifications for NLTHA were defined based on FEMA 356 regulations by using the AASHTO design spectra. Several accelerograms, with the PGAs compatible with the level of seismic hazard in the site and the frequency contents compatible with the condition of the bridge site soil, were used for NLTHA. The analyses results show that all three proposed retrofit designs are acceptable, however, the third method seems to be practically and economically more feasible.

Poster No. P34
Expansion Dams/Deck Joint Systems - Closed Cell Foam Technology for Armorless Joints
Doug Zuberer, Chase Construction Products

Bridge and bridge approach joints offers the most challenging conditions for designers. These joints must be designed with long term serviceability in mind with little to no maintenance. These joints are designed taking into account expansion and contraction movements resulting from thermal, rotational and other external forces. Water on these joints creates problems as well as certain chemicals and ultra violent generation. The combination of these factors can contribute to often times increased deterioration in the steel or concrete joints, concrete or asphaltic pavements. Many other factors in the design of the bridge/approach must be considered such as drainage, parapet barriers and location. This paper reviews some alternatives for bridge joints.

Poster No. P35
Long Term Protection for Concrete Bridges
Doug Zuberer, Chase Construction Products

Rutting and shoving are two of most significant problems with Hot Mix Asphalt pavement designs, albeit today many of these are being replaced with Polymer Modified Asphalt to increase the resistance to these problems, but none can also address the concerns of also providing a waterproofing system. Rosphalt 50 is a “Dry Mix” polymer additive introduced directly to the heated aggregates that coats these aggregates prior to the blending of the asphalt content. This material will then enhance the standard HMA design significantly providing increased tensile, elongation, and hence resilience characteristics decreasing the potential of permanent deformation or rutting. The coating process provides a superior material that can be used in designs as a one-step solution in paving operations providing waterproofing and wearing course that ultimately saves more than fifty percent (50%) in traffic control concerns of today’s construction business.

Poster No. P36
Contribution of Rail Stiffness to the Design and Retrofit of Simply Supported Multi-Span Bridges
Muhammad Sarwar, URS Washington Division

A major concern in the design and retrofit of simply supported multi-span railway bridges is to meet ductility and seat width demands in high seismic areas. Simply supported girders are subject to unseating and out of phase movements. Utilizing the longitudinal stiffness of the rails, the likelihood of unseating can be reduced. The rail establishes a link among the neighboring spans as an elastic element and restrains the girders longitudinal movement, and hence, the potential unseating. The stiffness of the rail system, when introduced into a finite element model, minimizes the displacement demands on girders, columns and footings. Multi-span bridges, when connected with directly fixed tracks, do not behave purely as simply supported spans; rather, they behave as an integral frame until the rails have failed or slippage of the rail connectors occur. This exercise of modeling a fixed rail system was performed on aerial structures for the San Francisco Bay Area Rapid Transit (BART). There exists the potential for significant savings by including the effects of the rails, avoiding the potential for unseating. One bridge study will be presented to compare the effects of rail stiffness contribution and how this will reduce the overall retrofit scheme of the structure.

Poster No. P37
Passive Control System of a Cable-stayed Bridge
Kehai Wang and Qian Li, Research Institute of Communications, The Ministry of P.R. China; W. Phillip Yen, Federal Highway Administration

The Guozigou Bridge is located in Xinxian Autonomous Region of China. This bridge is a three-span continuous steel truss girder cable-stayed bridge which has a main span length of 360 m and a reinforced concrete tower 215.5m in height. At the initial design stage, the response of floating system was analyzed, but relative longitudinal displacements were so large that deformation ability of the bearings
at the side piers can’t meet the demand of the earthquake excitation force. In order to reduce the longitudinal displacement, a semi-floating system was developed, but the results weren’t perfect still, so viscous dampers were added at the side piers and two towers. In this paper, the study of damping coefficient and exponent of the viscous damper, and its reasonable position will be presented. According to the site conditions, the effects of the dynamic pile-soil-structure interaction were considered. Through nonlinear time history analysis, the results indicated that the relative displacement of key positions and the forces of the bridge were reduced obviously by setting the dampers in longitudinal direction of the bridge.

Poster No. P38
Innovative Designs for Rapid Construction of Military Bridge Systems Using Vanadium Containing High Strength Low Alloy (HSLA-V) Steel
D.C. Rizos, Department of Civil and Environmental Engineering, University of South Carolina; T. Stanton, US Army Engineering Research & Development Center; A. Ferro, Intelligent Engineering; J. Mulliken, The LPA Group, Inc.; G. Bovard, Augusta Iron and Steel Works, Inc.
A research study that was recently completed at the University of South Carolina in collaboration with the Engineer Research and Development Center (ERDC) of the U.S. Army Corps of Engineers and sponsored by the Army Research Laboratory has identified the need of the U.S. Army for bridges which can span long gaps and are readily deployable, as well as the leveraging benefits of using Vanadium containing High Strength Low Alloy (HSLA-V) steel in bridge applications. The primary motivation for developing HSLA steels was the need for a high strength-to-weight ratio material that is easier to weld, exhibits a higher toughness, and is more resistant to the effects of corrosion than previous high strength steels. In recent years, these high performance steels have become an economical alternative for the design and fabrication of steel girders for civilian applications. The proposed design is modular and suitable for single spans of overall length between 40 and 200 feet accommodating all current military design vehicles, including extreme military vehicle loads, in one or two traffic lane configurations. The proposed bridge adopts the "bridge in a box" concept and is suitable for rapid construction.

Poster No. P39
Dynamic Traveller Response Modelling for Seismic Risk Analysis of Transportation Systems
Hyun Chan Kim, Xuesong Zhou and Steven F. Bartlett, Department of Civil and Environmental Engineering, University of Utah
Earthquakes could significantly impact road network capacity and further change spatial and temporal traffic demand patterns. Based on a case study in the Salt Lake City metropolitan area, we first present a day-to-day demand adjustment model to capture the traveler behavior in a damaged transportation network, and then discuss how to use a robust network design tool to enforce existing infrastructure systems so as to minimize expected structural risk and post-event traffic delays.

Charleston Trivia

1670 Charles Town, the capital city of Carolina, is founded. The city was located across the Ashley River from its present location.

1700 The city of Charles Town has grown into a major trading center. Plantations begin to appear along the rivers.

1718 The pirate Blackbeard arrives in Charles Town harbor with four ships. He proceeds to take hostages for ransom.

1721 South Carolina becomes a royal colony.

1861 Confederate troops fire on Fort Sumter, sounding the first shots of the Civil War.

1886 An earthquake estimated to be a 7.5 on the Richter scale strikes Charleston, resulting in 83 deaths and $6 million in damages.

1925 A new dance begins in Charleston’s pubs and dance halls and is soon named “The Charleston.”

1989 Hurricane Hugo hits Charleston. Seventy-five percent of the homes in Charleston’s historic district are damaged and 80 percent of the homes on Sullivan’s Island and Folly Beach are damaged or destroyed. The total price tag for the disaster reaches $2.8 billion. Hugo prompted a huge resurgence of restoration and rebuilding.

-Source: Charleston Area Convention & Visitor Bureau
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The role of the South Carolina Department of Transportation (SCDOT) is to provide the infrastructure for economic growth in our state by planning, designing, building and maintaining the state’s highway system, and coordinating mass transit systems all around the state. The goal is to provide the means in which people, goods, and services can efficiently and safely travel so as to enhance the overall quality of life in South Carolina. Significant points in this goal include good stewardship of the taxpayers' money and maintaining and preserving the state's resources and environment.

SCDOT is responsible for operating and maintaining 41,500 miles of roads and bridges, which ranks as the fourth largest state-owned highway system in the nation according to the Federal Highway Administration. The Palmetto state is home for five interstate highways: I-95, I-85, I-20, I-26 and I-77, all of which account for over 800 miles of the state highway system.

SCDOT is one of the largest state agencies in South Carolina and has a staff of approximately 5,000 men and women who work in all of the state's 46 counties and the central headquarters located in Columbia. The Governor appoints the Secretary of Transportation who serves as the Chief Administrative Officer. A seven member Commission sets policy for the Department.

SCDOT has been on the cutting edge of innovative financing for highway needs. The key to the success in funding highway projects can be summed up in one word, “partnerships.” The recent increase in the number of local sales taxes for transportation, the creation of the South Carolina Transportation Infrastructure Bank, and the expansion of regional and metropolitan planning organizations, the importance of partnering has grown. SCDOT has committed itself to making partnerships work to benefit the people of South Carolina.

SCDOT has been recognized for efficiency, innovative financing and for the quality of our highway facilities. The Arthur Ravenel Jr. Bridge that crosses the Cooper River and Town Creek to connect the city of Charleston and the town of Mount Pleasant is the longest cable-stay bridge in North America. The 5635 million bridge opened in the summer of 2005 on budget, and one year ahead of schedule. This structure features the signature diamond towers that are visible all around the Charleston area. The bridge has won numerous international and national awards for its design which includes architecture, lighting, bicycle & pedestrian facilities and seismic protection.

SCDOT has been fortunate to have received honors in the areas of work zone safety, quality management in construction and maintenance, ecosystem preservation, innovations in outdoor advertising, highway beautification, recycling of highway materials and excellence in financial reporting among other awards.

FHWA is charged with the broad responsibility of ensuring that the nation's roads and highways continue to be the safest and most technologically up-to-date. Although state, local, and tribal governments own most of the Nation's highways, FHWA provides financial and technical support to them for constructing, improving, and preserving the highway system. Technical support is provided through the Turner-Fairbank Highway Research Center (TFHRC), a federally owned and operated research facility in McLean, Virginia. TFHRC is the home of FHWA's Office of Research, Development, and Technology. Their Vital Few priorities are focus areas that show the biggest performance gaps in the transportation system and present opportunities for FHWA to make the greatest difference. These focus areas include safety; congestion mitigation; and environmental stewardship and streamlining.

Safety on highways is FHWA's top priority. FHWA has been studying new opportunities and developing new technologies for saving lives. FHWA is aggressively advancing the activities and projects already known to prevent crashes and reduce fatalities and serious injuries when crashes happen. In addition, FHWA conducts safety research, technology, and outreach projects that contribute to multiple objectives. These include speed management to encourage wider adoption of safe travel speeds appropriate for road and travel conditions; safety management to ensure that resources are allocated to achieve the maximum returns in reducing the severity and frequency of crashes; human-centered systems to incorporate human factors into all aspects of highway design; work zone safety improvements; and a variety of safety outreach efforts.

Congestion mitigation is among their top priorities. Demand for highway travel continues to grow as population increases. FHWA is working with regional partners to address all aspects of congestion, including two of the most prevalent causes of traffic congestion; work zones and traffic incidents. FHWA is providing substantial assistance to State and local transportation agencies as they develop projects to increase capacity and remove bottlenecks.

FHWA is committed to protecting and preserving the environment through stewardship and timely reviews. In recent years, FHWA and their partners have made substantial contributions to the environment and to communities; through planning and programs that support wetland banking, habitat restoration, historic preservation, air quality improvements, bicycle and pedestrian facilities, context-sensitive solutions, wildlife crossings, public and tribal government involvement, among many more.
ABOUT THE ORGANIZERS

MCEER

MCEER is a national center of excellence dedicated to the discovery and development of new knowledge, tools and technologies that equip communities to become more disaster resilient in the face of earthquakes and other extreme events. MCEER accomplishes this through a system of multidisciplinary, multi-hazard research, education and outreach initiatives.

Headquartered at the University at Buffalo, The State University of New York, MCEER was originally established by the National Science Foundation (NSF) in 1986, as the first National Center for Earthquake Engineering Research (NCEER). In 1998, it became known as the Multidisciplinary Center for Earthquake Engineering Research (MCEER), from which the current name, MCEER, evolved.

Comprising a consortium of researchers and industry partners from numerous disciplines and institutions throughout the United States, MCEER’s mission has expanded from its original focus on earthquake engineering to one which addresses the technical and socio-economic impacts of a variety of hazards, both natural and man-made, on critical infrastructure, facilities, and society.

Funded principally by NSF, the Research Foundation of the State of New York, and the Federal Highway Administration, the Center derives additional support from the Department of Homeland Security/Federal Emergency Management Agency, other state governments, academic institutions, foreign governments and private industry.

TRANSPORTATION RESEARCH BOARD (TRB)

The Transportation Research Board (TRB) is a division of the National Research Council, which serves as an independent advisor to the federal government and others on scientific and technical questions of national importance. The National Research Council is jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The mission of the Transportation Research Board—one of six major divisions of the National Research Council—is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation.

TRB fulfills this mission through the work of its standing committees and task forces addressing all modes and aspects of transportation; publication and dissemination of reports and peer-reviewed technical papers on research findings; management of cooperative research and other research programs; conduct of special studies on transportation policy issues at the request of the U.S. Congress and government agencies; operation of an on-line computerized file of transportation research information; and the hosting of an annual meeting that typically attracts 9,000 transportation professionals from throughout the United States and abroad.

TRB’s varied activities annually draw on more than 10,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest by participating on TRB committees, panels, and task forces. The program is supported by state transportation departments, the various administrations of the U.S. Department of Transportation and other federal agencies, industry associations, and other organizations and individuals interested in the development of transportation.
The conference organizers thank the following professional organizations and industry associations who have provided valuable assistance by promoting the conference to their memberships. While these organizations did not provide direct financial contributions, their efforts in making announcements, spreading information and supporting the goals of the conference organizers have helped make the conference a success.