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Center for Infrastructure Engineering Studies

Fifth National Seismic Conference on Bridges & Highways

Innovations in Earthquake Engineering for Highway Structures

by

Genda Chen

A University Transportation Center Program
at Missouri University of Science & Technology

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16. Abstract

The 5th National Seismic Conference on Bridges and Conferences was held in San Francisco on September 18-20, 2006. The conference attracted over 300 engineers, academician, and students from around the world. More details are referred to http://mceer.buffalo.edu/meetings/5nsc.

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5NSC
San Francisco 2006

Fifth National Seismic Conference on Bridges & Highways

Innovations in Earthquake Engineering for Highway Structures

September 18-20, 2006 ▪ San Mateo Marriott Hotel ▪ San Mateo, California

Conference Program

U.S. Department of Transportation
Federal Highway Administration

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Welcome

W. Phillip Yen
Co-Chair,
Steering Committee

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 *Fifth National Seismic Conference on Bridges and Highways*. This conference was organized through the hard work and dedication of the Steering Committee, Technical Committee and the staff at MCEER. It was the Steering Committee's objective to focus on seismic events, lessons learned and design code developments that have taken place since 2002. Our theme is "Innovations in Earthquake Engineering for Highway Structures."

The Federal Highway Administration is proud to continue co-sponsoring this conference to provide a dedicated forum for seismic issues related to bridges and highways. The keynote speakers for plenary sessions each morning are nationally and internationally renowned experts in the bridge seismic arena. They will provide the most current technology and innovative techniques for earthquake engineering around the world. Fourteen sessions, including twelve different topic areas, will present the latest research and practical information on earthquake engineering for bridges and highways.

Each devastating earthquake has provided us with new lessons to learn, and frequently these lessons verified previous experimental studies. After the Loma Prieta earthquake in 1989 and the Northridge earthquake in 1994, NCHRP (co-sponsored by AASHTO and FHWA) completed a set of proposed new design specifications in 2002. These proposed design specifications were revised by the NCHRP Project 20-7 Task 193 last May. This revised proposal will be balloted by the AASHTO Bridge and Structure Subcommittee in 2007.

In the meantime, FHWA, in cooperation with MCEER, has been updating its "Seismic Retrofitting Manual for Highway Structures." The manual consists of two volumes: Part 1 – Bridges, and Part 2 - Retaining Structures, Slopes, Tunnels, Culverts and Roadways. Both are now in press. On Sunday (9/17), a one-day workshop was provided to acquaint participants with Part 1 of the manual.

Funded by the National Science Foundation (NSF), the newly established Network Earthquake Engineering Simulation (NEES) system has provided more opportunities and better facilities for advancing our seismic engineering technologies, and increasing seismic performance. Many of the technical papers presented at this conference have benefitted from NEES support. Japan recently completed the world's largest shake table and is working together with NSF and NEES to conduct cooperative research projects on bridges and building infrastructure.

You might have noticed that this national conference has attracted many international participants working in the bridge seismic arena. I am pleased to announce that FHWA is working together with other countries to establish an international bridge seismic engineering committee, and plans to continue to use this conference as a vehicle to exchange and disseminate up-to-date technology. The next conference will expand to include greater international involvement, and is planned for late 2008. The specific date and location will be announced soon.

Within the last twelve months, our bridge seismic community lost two tireless advocates, Mr. Jim Cooper, who retired from FHWA and Mr. Jim Roberts, of Caltrans. Their great contributions and leadership in the bridge engineering community will be deeply missed. During the opening ceremonies, I invite you to join me in a one-minute silent prayer to remember them.

On behalf of the organizers, I welcome the many the participants who have traveled from near and far to attend this conference. I hope you will all have an excellent time in the San Francisco area, while gaining valuable technical knowledge and lasting friendships through the activities of this conference.

W. Phillip Yen

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

Contents

Acknowledgements

Honorary Conference Chairmen

Myint Lwin, Director, Office of Bridge Technology, Federal Highway Administration

Richard Land, Chief Engineer, California Department of Transportation

Steering Committee

Phillip Yen, Federal Highway Administration (Co-Chair)

Kevin Thompson, California Department of Transportation (Co-Chair)

Jerome O'Connor, MCEER, University at Buffalo (Conference Coordinator)

Michel Bruneau, MCEER, University at Buffalo

Ian Buckle, University of Nevada, Reno

Amr Elnashai, Mid-America Earthquake Center

George Lee, MCEER, University at Buffalo

Stephen Maher, Transportation Research Board

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Rob Stott, California Department of Transportation

Ed Wasserman, Tennessee Department of Transportation

Technical Tour

Mike Keever, California Department of Transportation

Bob Tanaka, California Department of Transportation

Richard Heninger, California Department of Transportation

Steve Mitchell, California 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)

Technical Committee

Phillip Yen, Federal Highway Administration (Co-Chair)

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Dave Pierro, Graphics

Jane Stoyle, Proceedings & Program

Michelle Zuppa, Conference Website

General Information

Registration

San Mateo Marriott, Second Floor, just outside the Boardroom

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: First Floor, Lobby and Pool Courtyard
Casual dress

Poster Session / Reception

Monday 5:15 pm – 7:00 pm
Location: First Floor, Crystal Springs Room and Gazebo Courtyard
Business casual dress

Technical Exhibits

With the theme of the conference being *Innovations in Earthquake Engineering for Highway Structures*, we are fortunate to have over twenty companies available to explain the latest technology and services that they offer. Please stop by, visit, and leave your business card to receive additional information.

Location: San Mateo Marriott, Second Floor, Bay Bridge Room

Exhibit hours

Monday 7:30 am - 5:00 pm
Tuesday 7:30 am - 5:00 pm
Wednesday 7:30 am - noon

The Exhibit area will be closed during the Plenary Sessions from 8:00 - 9:50 am each day.

Climate and Clothing

The weather should be pleasant during the time of the conference. The average daytime temperature in San Mateo in September is 64 °F (18 °C). Business casual dress is acceptable for most of the technical sessions, daytime meetings and social functions. Business suit and cocktail attire is appropriate for the Tuesday evening banquet. Participants of the Technical Tour should take note of special instructions.

Hospitality Room

Spouses, guests of registrants, and others are invited to stop by the hospitality room for snacks and beverages. Directional signage will be placed near the conference registration table. The room will be open 8:00 am – 5:00 pm Monday and Tuesday and until Noon on Wednesday.

Meals

Complimentary **Continental Breakfast** will be served in the Bay Bridge Room 7:00 – 8:00 a.m. daily.

Complimentary morning and afternoon **COFFEE BREAKS** will be served in the Bay Bridge Room.

Lunch tickets are necessary for the buffet lunch which will be served Monday and Tuesday in the Crystal Springs Room. Tickets were included in each "full registration" packet. Additional lunch tickets may be purchased at the conference registration desk. Lunch is on your own on Wednesday. Participants of the boat tour will receive lunch as part of the tour.

Dinner on Monday evening is on your own. Downtown San Mateo is about a mile away. Please check with the hotel front desk for further information.

A special **Banquet** will be held on Tuesday in the Golden Gate Ballroom. Guest speaker Chuck Seim will reflect on the significant changes he has seen in the field of bridge engineering over the past 50 years. A cash bar will be available at 6:30 pm and the program begins at 7:00. Pre-registration is required for the banquet. Stop by the conference registration desk as early as possible if you did not pre-register but would like to attend the banquet. The cost is $60.

Spouse Tour

If sufficient interest exists, a shuttle bus will be arranged for transportation to Union Square, downtown San Francisco. It will depart the hotel Tuesday at 9:00 am and return around 3:00 pm. Please stop at the conference registration desk to sign up by Monday at 3:00 pm.

Technical Tour

Individuals who have pre-registered for the guided Boat Tour of San Francisco Bay Area bridges on Wednesday should be at the front door of the hotel at noon for a 12:15 pm bus departure. The ticket that was provided with your name badge holder at registration will give you admission to the bus, a buffet lunch at the beginning of the tour, and the boat. Since you will be on the water for approximately 5.5 hours, be sure to bring appropriate attire (e.g., warm clothing, rubber soled shoes) and sunscreen. It is estimated that buses will return to the hotel at approximately 7:30 p.m. The mobile phone number of Bob Tanaka, Boat Tour Coordinator, is (916) 606-6929.

Proceedings

Conference proceedings are included on a CD which is in the registration packet. The full technical paper associated with each oral presentation is included, as well as a synopsis paper of each poster presentation.

Agenda

Sunday, September 17, 2006

8:00 am – 5:00 pm	**Seismic Retrofitting Workshop** (Pre-Registration Required)	Bay Bridge Room
1:00 pm – 8:00 pm	**5NSC Conference Registration**	Boardroom
5:00 pm – 6:00 pm	**Pre-Conference Coordinators Meeting**	Boardroom
6:00 pm – 8:00 pm	**Ice Breaker Reception**	Hotel Lobby/Pool Area
7:00 pm – 10:00 pm	**Exhibitor Set-up**	Bay Bridge Room

Monday, September 18, 2006

8:00 am – 9:50 am	**Plenary Session I** Moderator: Jerome O'Connor, MCEER, University at Buffalo	Golden Gate Ballroom
8:00 am – 8:15 am	**Welcome** Phillip Yen, Federal Highway Administration	Golden Gate Ballroom
8:15 am – 8:40 am	**Innovations in Earthquake Engineering for Highway Structures** Myint Lwin, Federal Highway Administration	Golden Gate Ballroom
8:40 am – 9:05 am	**Seismic Safety – Challenges and Opportunities** Rick Land, California Department of Transportation	Golden Gate Ballroom
9:05 am – 9:50 am	**Enhancement of Seismic Performance of Bridges** K. Kawashima, Tokyo Institute of Technology	Golden Gate Ballroom
9:50 am – 10:15 am	**Break**	Bay Bridge Room
10:15 am – 12:00 pm	**Concurrent Technical Sessions: 1A1 and 1B1**	

Track A - Golden Gate A

Session 1A1: Design & Analysis of Major Bridges
Moderator: Kevin Thompson, California Department of Transportation

Seismic Characteristics of Bridge Steel Pedestals
Monique C. Hite, Reginald DesRoches, Roberto Leon, Paul Liles, Jr. and Y. Stanley Kim

Design and Analysis of Precast Concrete Bridges in Areas of High or Moderate Seismicity
Bijan Khaleghi

Retrofit of a Historic Three-Hinge Arch Bridge
Sherif S. Morcos

Seismic Retrofit of the Posey Tube: A Discussion of Soilcrete and the Construction of Large Diameter Triple Fluid Jet Grout Columns Over the Oakland Estuary in California
Marcia E. Kiesse and Thomas S. Lee

The Seismic Analysis and Design of a Steel Plate Girder Bridge with an Emphasis on Practical Considerations
Clint M. Krajnik

Track B - Golden Gate B

Session 1B1: Foundations & Geotechnical Considerations
Moderator: Michel Bruneau, MCEER, University at Buffalo

Effect of Backfill Soil Type on Stiffness and Ultimate Capacity of Bridge Abutments: Large-scale Tests
A. Bozorgzadeh, Scott A. Ashford and Jose I. Restrepo

Mechanical Axial Force Transfer within Cast-In-Steel-Shell Piles – Verification through Full-Scale Experimentation and Finite Element Analysis
Michael Gebman, Scott A. Ashford and José I. Restrepo

Field Testing and Analytical Modeling of a Reinforced Concrete Embedded Pile Under Lateral Loading
Eric Ahlberg, Changsoon Rha, Jonathan P. Stewart, Robert L. Nigbor, John W. Wallace and Ertugrul Taciroglu

Overcoming Hurdles that Limit the Application of Nonlinear Seismic Ground Response Analysis in Engineering Practice
Jonathan P. Stewart, On-Lei Annie Kwok, Youssef M.A. Hashash, Neven Matasovic, Robert Pyke, Zhiliang Wang and Zhaohui Yang

Global and Structural Stability Assessments of Fort Mason Tunnel for Seismic Rehabilitation
Zia Zafir, Stephen Klein and Matthew DeMarco

12:00 noon -1:00 pm	**Lunch**	Crystal Springs Room

(Continued)

Monday, September 18, 2006 (Continued)

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

Track A - Golden Gate A

1A2: Use of Innovative Technologies & Materials
Moderator: Ian Buckle, University of Nevada Reno

Multihazard-Resistant Highway Bridge Pier
Michel Bruneau, Shuichi Fujikura and Diego Lopez-Garcia

New Seismic Retrofit Technologies for a Historic Bridge in California
Paul Chung, Mohammad Ravanipour and Ray Wolfe

Seismic Design of Circular Bridge Columns with Unstressed Prestressing Strand for Transverse Reinforcement
Andrew Budek, Chin Ok Lee and M.J. Nigel Priestley

Rocking of Bridge Piers Subjected to Multi-Directional Earthquake Excitation
Andres Espinoza and Stephen Mahin

Retrofitting the Milford-Montague Truss: Challenges and Solutions
Thomas P. Murphy and Michael C. Irwin

Track B - Golden Gate B

1B2: Performance Criteria & Economic Considerations
Moderator: Elmer Marx, Alaska Department of Transportation

A Comparative Performance-Based Seismic Assessment of Traditional and Enhanced-Performance Bridge Pier Systems
Won K. Lee and Sarah L. Billington

A Rational Method for Calibrating Appropriate Response Modification Factors for Seismic Design of Bridge Columns
Abdallah Mechakhchekh and Michel Ghosn

Implementation of Displacement Based Design for Highway Bridges
Vinicio Suarez and Mervyn Kowalsky

Implications of Future Seismic Bridge Design Provisions for Illinois
Daniel H. Tobias, Ralph E. Anderson, Chad E. Hodel, William M. Kramer and Riyad M. Wahab

Seismic Hazard for California Bridges Using Deterministic and Probabilistic Methods
Fadel Alameddine and Mark Yashinsky

2:45 pm – 3:15 pm **Break** — Bay Bridge Room

3:15 pm - 4:15 pm **Concurrent Technical Sessions: 1A3 and 1B3**

Track A - Golden Gate A

1A3: Emerging Design & Retrofit Technologies
Moderator: Daniel Tobias, Illinois Department of Transportation

Seismic Design of Floating Bridges
Michael J. Abrahams

Seismic-Resistant Connections for Prefabricated Segmental Bridge Columns
Yu-Chen Ou, Ping-Hsiung Wang, Kuo-Chun Chang and George C. Lee

Proof-of-Concept Testing and Finite Element Modeling of Self-Stabilizing Hybrid Tubular Links for Eccentrically Braced Frames
Jeffrey W. Berman and Michel Bruneau

Track B - Golden Gate B

1B3: Effects of Near-Field Earthquakes on Bridges
Moderator: Hamid Ghasemi, Federal Highway Administration

An Overview of the Project of Next Generation of Ground Motion Attenuation Models for Shallow Crustal Earthquakes in Active Tectonic Regions
Brian Chiou, Maurice Power, Norman Abrahamson and Clifford Roblee

Effects of Near-Fault Vertical Ground Motions on Seismic Response of Highway Bridges
Emrah Erduran, Zeynep Yilmaz, Sashi Kunnath, Norman Abrahamson, Y. H. Chai, Mark Yashinsky and Li-Hong Sheng

Selection of Forward-Directivity Motions for Non-Linear Analyses of Bridges
Joanna L. Gillie, Adrian Rodriguez-Marek and Cole C. McDaniel

4:15 pm – 5:15 pm	**Open Discussion Panel on Multiple Hazard Design** Moderator: Frieder Seible, University of California San Diego	Golden Gate A
5:15 pm – 7:00 pm	**Poster Session/Reception** Moderator: Reginald DesRoches, Georgia Institute of Technology	Crystal Springs Room
7:15 pm – 10:00 pm	**Forum on Seismic Retrofitting (by Invitation)** Moderator: Glenn Smith, Federal Highway Administration	Lombard Room

AGENDA

TUESDAY, SEPTEMBER 19, 2006

8:00 am – 9:50 am	**Plenary Session II** Moderator: George C. Lee, MCEER, University at Buffalo	Golden Gate Ballroom
8:00 am – 8:35 am	**Life Cycle and Performance Based Seismic Design of Major Bridges** Lichu Fan, Tongji University	Golden Gate Ballroom
8:35 am – 9:10 am	**Seismic Design Issues for Long-Span Bridges** T.J. Zhu, Buckland and Taylor, Ltd.	Golden Gate Ballroom
9:10 am – 9:50 am	**Pushing the Span Limits for Long-Span Bridges – A State of the Art Review** Lars Hauge, COWI	Golden Gate Ballroom
9:50 am – 10:15 am	**Break**	Bay Bridge Room
10:15 am – 12:00 pm	**CONCURRENT TECHNICAL SESSIONS: 2A1 AND 2B1**	

Track A - Golden Gate A

2A1: DESIGN & ANALYSIS OF MAJOR BRIDGES
Moderator: Stephen Maher, Transportation Research Board

Geotechnical Earthquake Engineering Experience from Seismic Retrofit and New Design Projects of Major Toll Bridges in California
Hubert K. Law and Ignatius Po Lam

Analytical Assessment of a Major Bridge in the New Madrid Seismic Zone
Amr Elnashai, Aman Mwafy and Oh-Sung Kwon

Seismic Analysis and Design of a Multi-Span Bridge in a Region of High Seismicity using SCDOT Seismic Specifications
Amos Liu, William Stiller and Lucero Mesa

Collapse Simulation of RC Frame under Earthquakes. II: Verification Studies - Collapse of Cypress Viaduct
Yan Zhou, Leiming Zhang and Xila Liu

Seismic Response of Precast Segmental Bridge Superstructures with Bonded Tendons
Marc Veletzos and Jose Restrepo

Track B - Golden Gate B

2B1: SOIL-STRUCTURE INTERACTION & FOUNDATIONS
Moderator: Lucero Mesa, South Carolina Department of Transportation

Seismic Energy Dissipation by Foundation Rocking for Bridge SFS Systems
Bruce Kutter, Boris Jeremic, Jose Ugalde, Sivapalan Gajan and George Hu

Three-Dimensional Nonlinear Finite-Element Soil-Abutment Structure Interaction Model for Skewed Bridges
Anoosh Shamsabadi, Mike Kapuskar and Amir Zand

Comparison of Direct Method Versus Substructure Method for Seismic Analyses of a Skewed Bridge
Anoosh Shamsabadi, Hubert K. Law and Geoffrey R. Martin

Passive Force-Deflection Relationships from Full-Scale Tests
Kyle M. Rollins and R.T. Cole

Nonlinear Seismic Soil-Abutment-Structure Interaction Analysis of Skewed Bridges
Anoosh Shamsabadi, Mike Kapuskar and Geoffrey R. Martin

12:00 noon - 1:00 pm	**Lunch**	Crystal Springs Room
1:00 pm – 2:45 pm	**CONCURRENT TECHNICAL SESSIONS: 2A2 AND 2B2**	

Track A - Golden Gate A

2A2: INSTRUMENTATION & MONITORING SYSTEMS
Moderator: Robert Stott, California Department of Transportation

Real-time, State-of-the-Art Seismic Monitoring of the Integrated Cape Girardeau Bridge Array, Data and Analyses
Mehmet Çelebi

Lateral Deformation Capacity of Concrete Bridge Piers
Sungjin Bae and Oguzhan Bayrak

Caltrans / CGS Downhole Geotechnical Arrays
Pat Hipley, Anthony Shakal and Hamid Haddadi

Seismic Instrumentation at the I-40 Bridge in Memphis, Tennessee
Shahram Pezeshk and Mitch Withers

ShakeCast: Facilitating the Use of ShakeMap for Post-Earthquake Decision-Making and Response within Caltrans and other Critical Lifeline Communities
David J. Wald, Kuo-Wan Lin, Bruce Worden and Loren Turner

Track B - Golden Gate B

2B2: LIQUEFACTION & MITIGATION STRATEGIES
Moderator: E.V. Leyendecker, US Geological Survey

Lateral Response of Isolated Piles in Liquefied Soil with Lateral Soil Spreading
Mohamed Ashour, Gary Norris and JP Singh

Evaluation of Methods for Analyzing the Seismic Response of Piles Subjected to Liquefaction-Induced Loads
S.R. Rajaparthy and T.C. Hutchinson

Numerical Simulation of Soil-Foundation Interaction Subjected to Lateral Spreading
Yohsuke Kawamata, Scott A. Ashford and Teerawut Juirnarongrit

A Probabilistic Design Procedure that Incorporates the Pile-Pinning Effect in Bridge Foundations Undergoing Liquefaction-Induced Lateral Spreading
Christian Ledezma and Jonathan D. Bray

Liquefaction Mitigation using Stone Columns and Wick Drains for Utah Bridges
Kyle M. Rollins, Bradford E. Price, Emily Dibb and Jim B. Higbee

TUESDAY, SEPTEMBER 19, 2006 (Continued)

2:45 pm – 3:15 pm	**Break**	Bay Bridge Room
3:15 pm - 5:00 pm	**CONCURRENT TECHNICAL SESSIONS: 2A3 AND 2B3**	

Track A - Golden Gate A

2A3: LESSONS LEARNED FROM RECENT EARTHQUAKES

Moderator: Arun Shirole, Arora Associates

Seismic Response of the Hwy 46/Cholame Creek Bridge During the 2004 Parkfield Earthquake
Tom Boardman and Anthony V. Sanchez

Lessons Learned from the Seismic Retrofit of the Posey and Webster Street Tubes in Alameda County, California
Thomas S. Lee, Randy Anderson and Rod Murray

Post Seismic Inspection and Capacity Assessment of Reinforced Concrete Bridge Columns
Marc J. Veletzos, Marios Panagiogou, Jose I. Restrepo and Stephen Sahs

Study on the Seismic Settlement of the Alaskan Way Viaduct after the February 28, 2001 Nisqually Earthquake
Hongzhi Zhang

Track B - Golden Gate B

2B3: EMERGING DESIGN & RETROFIT TECHNOLOGIES

Moderator: Genda Chen, University of Missouri Rolla

Damping-Enhanced Seismic Strengthening of RC Columns for Multiple Performance Objectives
Genda Chen and Kazi R. Karim

Use of Partially Prestressed Reinforced Concrete Columns to Reduce Post-Earthquake Residual Displacements of Bridges
Stephen Mahin, Junichi Sakai and Hyungil Jeong

Seismic Performance and Design of Bridges with Curve and Skew
J. Jerry Shen and W. Phillip Yen

NCHRP 12-74 Development of Precast Bent Cap Systems for Seismic Regions – Background and Progress
Matthew J. Tobolski, Eric E. Matsumoto and José I. Restrepo

Improved Seismic Performance of Precast Segmental Bridges Using Jointed Column Connections and Unbonded Tendons
Marc J. Veletzos and Jose I. Restrepo

6:30 pm – 9:00 pm	**Banquet** Cash Bar Opens at 6:30 pm Master of Ceremonies: Phillip Yen, Federal Highway Administration Guest Speaker: Charles "Chuck" Seim, Consultant *Bridge Engineering – We've Come a Long Way*	Golden Gate Ballroom

Agenda

Wednesday, September 20, 2006

8:00 am – 9:50 am	**Plenary Session III** Moderator: Myint Lwin, Federal Highway Administration	Golden Gate Ballroom
8:00 am – 8:45 am	**Seismic Assessments of Bridges with Rubber Bearings during 1999 Taiwan Chi-Chi Earthquake** K.C. Chang, National Taiwan University	Golden Gate Ballroom
8:45 am – 9:25 am	**The Legacies of Jim Cooper & Jim Roberts** Roy Imbsen, Consultant	Golden Gate Ballroom
9:25 am – 9:35 am	**Presentation of Jim Cooper and Jim Roberts Best Paper Awards**	Golden Gate Ballroom
9:35 am – 9:50 am	**Remarks** Phillip Yen, Federal Highway Administration	Golden Gate Ballroom
9:50 am – 10:15 am	**Break**	Bay Bridge Room

10:15 am – 12:00 pm **Concurrent Technical Sessions: 3A1 and 3B1**

Track A - Golden Gate A	Track B - Golden Gate B
3A1: Seismic Risk Assessment of Highway Networks Moderator: Amr Elnashai, Mid America Earthquake Center	**3B1: International Technologies & Practices** Moderator: Roland Nimis, California Department of Transportation
Probabilistic Seismic Hazard Assessment for Spatially Distributed Systems Renee Lee and Anne S. Kiremidjian	**Seismic Design Practice of Steel Bridges in California** Lian Duan
Seismic Vulnerability of Typical Multiple-span California Highway Bridges Kevin Mackie and Bozidar Stojadinovic	**Seismic Design of Coronilla Viaduct** Joaquín Mejía Ramírez and Jose de Jesus Alvarez
Evaluation of Bridge Retrofit in Regions of Low-to-Moderate Seismicity Jamie Ellen Padgett and Reginald DesRoches	**China-U.S. Comparative Study on Seismic Design Philosophy and Practice for a Long Span Arch Bridge** Yan Xu, George C. Lee, Li-chu Fan and Shi-de Hu
Seismic Analysis of a Roadway System in the Los Angeles, California Area Stuart D. Werner, Sungbin Cho, Craig E. Taylor, Jean-Paul Lavoie and Charles K. Huyck	**New International Standard for Elastomeric Seismic-Protection Isolators** Nobuo Murota, James M. Kelly, Keith Fuller, Fu Lin Zhou, Toshio Nishi, Toshikazu Yoshizawa, Chiaki Sudou and Fumihiko Yazaki
Seismic Vulnerability Assessments of Bridges in Areas of Low to Moderate Seismic Activity Joseph B. Matarazzo, Artur Kasperski, José Santos, Gary Wang and Chris S.C. Yiu	**Inelastic Response of the San Antonio Viaduct Subjected to Synthetic Ground Acceleration Records** Héctor Sánchez Sánchez and Marcelino Cruz González

12:15 pm – 7:30 pm	**Optional Technical Tour: Bay Bridges by Boat** (Pre-registration Required) Tour Coordinators: Mike Keever, Bob Tanaka, Richard Heninger, Steve Mitchell	Meet at Hotel Front Door

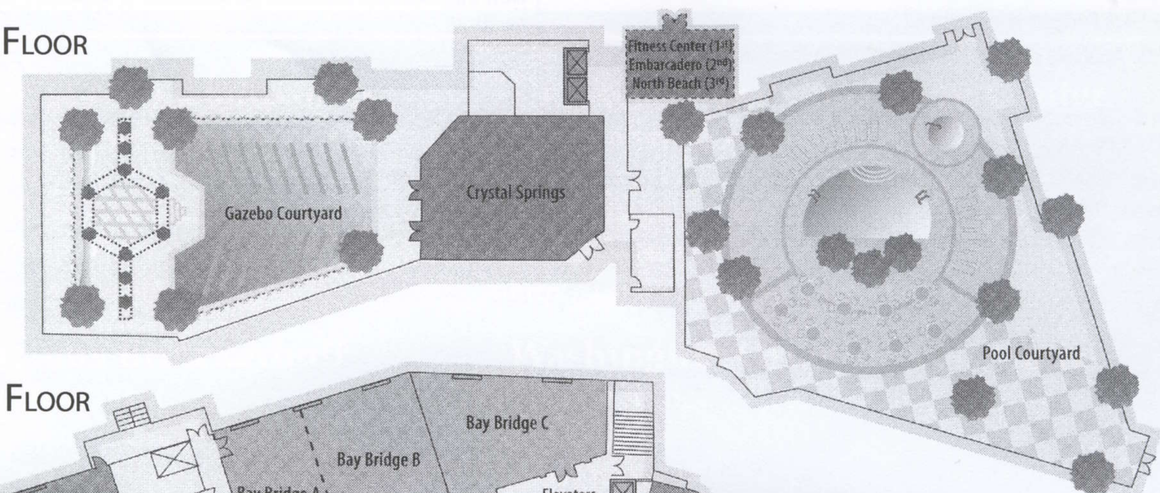
Agenda

Program at a Glance

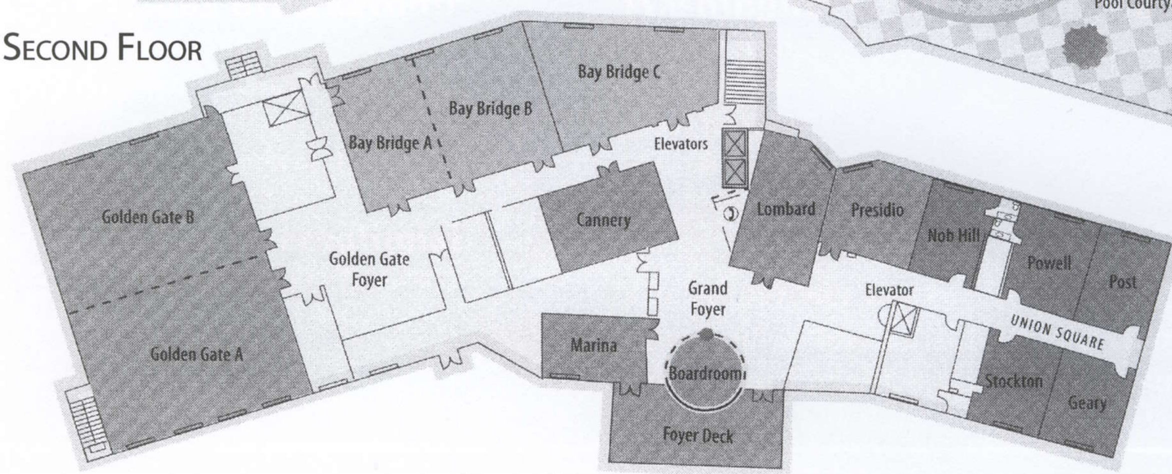
	Sunday 9/17/2006	Monday 9/18/2006	Tuesday 9/19/2006	Wednesday 9/20/2006
		The Technical Exhibition will be open daily from 7:30 am.		
8:00 am	Seismic Retrofitting Workshop (pre-registratoin required)	Plenary Session	Plenary Session	Plenary Session
		2 Concurrent Sessions	2 Concurrent Sessions	2 Concurrent Sessions
		Lunch Break Noon -1:00 pm		
		2 Concurrent Sessions	2 Concurrent Sessions	Boat Tour
		2 Concurrent Sessions	2 Concurrent Sessions	
5:00 pm		Multi-Hazard Discussion Panel (4:15 - 5:15 pm)		
	Ice Breaker Reception (6:00 - 8:00 pm)	Poster Session / Reception (5:15-7:00 pm)	Banquet (7:00 - 9:00 pm)	

Hotel Map

First Floor



Second Floor



Exhibitors

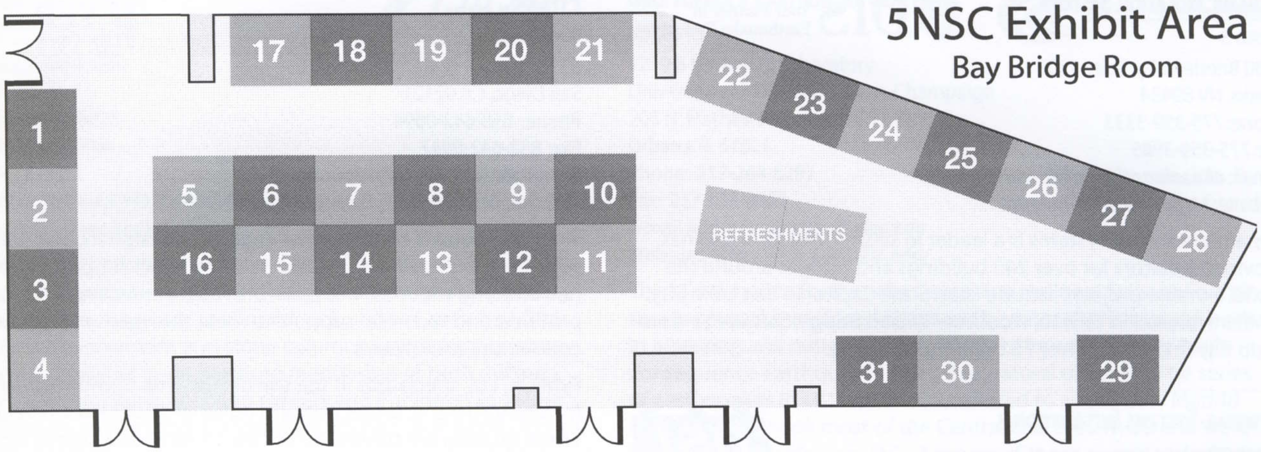


Exhibit Hours

Monday, September 18: 7:30 am -5:00 pm*

Tuesday, September 19: 7:30 am -5:00 pm*

Wednesday, September 20: 7:30 am -Noon

* The Exhibit area will be closed during the Plenary Sessions from 8:00-9:50 am each day.

California Strong Motion Instrumentation Program

Booth 26

801 K Street, MS 13-35
Sacramento, CA 95814
Phone: 916-322-3105
Fax: 916-323-7778
E-mail address: ***Shirley.Rowley@conservation.ca.gov***
Website: ***http://www.conservation.ca.gov/cgs/smip***

The California Strong Motion Instrumentation Program (CSMIP) was established in 1972 by California Legislation to obtain vital earthquake data for the engineering and scientific communities through a statewide network of strong motion instruments. When the planned network is completed, statewide coverage will ensure that strong ground motion for any moderate to larger size earthquake in the state will be recorded. CSMIP distributes strong-motion data and related information via the Engineering Data Center at ***www.quake.ca.gov/cisn-edc.***

Computers & Structures, Inc.

Booths 24 and 25

1995 University Avenue, Suite 540
Berkeley, CA 94704
Phone: 510-845-2177
Fax: 510-845-4096
E-mail address: ***info@csiberkeley.com***
Website: ***http://www.csiberkeley.com***

Computers & Structures, Inc. (CSI) is recognized worldwide as an innovative leader in the development of software tools for the analysis and design of civil structures. Our flagship program suite, SAP2000, can assist bridge designers with parametric bridge modeling. It has various bridge templates for generating bridge models as well as automated bridge live load analysis & design with influence lines and surfaces. Segmental bridge construction analysis (including creep and shrinkage), post tensioned concrete box girder design, cable supported/stayed bridge analysis, base isolation and pushover analysis features are also available. From its 3D object-based CAD-like graphical modeling environment to the wide variety of analysis & design options, SAP2000 has proven to be the most integrated, productive & practical bridge design program on the market today.

The D.S. Brown Company

Booth 10

300 East Cherry
North Baltimore, OH 45872
Phone: 419-257-3561
Fax: 419-257-2200
E-mail address: ***dsb@dsbrown.com***
Website: ***http://www.dsbrown.com***

The D.S. Brown Company is a manufacturer of expansion joints, bearing assemblies and specialty products. Their extensive bridge line includes Steelflex® Modular Expansion Joint Systems, Versiflex™ Bearing Assemblies, Cableguard™ Elastomeric Wrap, Exodermic® Bridge Deck, Fiberbond™ FRP (Fiber Reinforced Polymer) System and other specialty products.

D.S. Brown is fully integrated, performing and controlling all requirements of a project internally including: research and development; engineering design/CAD detailing; rubber compounding, mixing, extruding and molding; custom steel fabrication and machining; and load testing.

Exhibitors

Dynamic Isolation Systems

Booth 3

2080 Brierley Way, Suite #101
Sparks, NV 89434
Phone: 775-359-3333
Fax: 775-359-3985
E-mail: ***akasalanati@dis-inc.com***
Website: ***http://www.dis-inc.com***

Dynamic Isolation Systems is a leader in seismic isolation and has provided isolators for over 240 buildings and bridges around the world. Notable projects include Utah State Capitol in Salt Lake City, XindianHospital in Taiwan, Woodrow Wilson Bridge, San Diego-Coronado Bay Bridge and over 75 buildings in Japan.

Dywidag-Systems International

Booth 29

5220 Clark Avenue, Suite 220
Lakewood, CA 90712
Phone: 562-263-0256
Fax: 562-263-0285
E-mail address: ***ron.giesel@dsiamerican.com***
Website: ***http://www.dsiamerica.com***

DYWIDAG Post-Tensioning Systems are world renowned for reliability and performance, most suitable for all applications in post-tensioned construction. They embrace the entire spectrum from bridge construction and buildings, to civil applications, above and below ground. DYWIDAG-Systems International (DSI) offers a complete product line in strand and bar post-tensioning (bonded, unbonded and external) as well as stay-cables being able to fully serve the post-tensioning construction industry. For more information or to contact local representatives go to: ***www.dsiamerica.com***.

Earthquake Protection Systems, Inc.

Booth 30

451 Azuar Drive, Bldg. 759
Mare Island, CA 94592
Phone: 707-644-5993
Fax: 707-644-5995
E-mail address: ***eps@earthquakeprotection.com***
Website: ***http://www.earthquakeprotection.com/***

Earthquake Protection Systems is one of the world's leading manufacturers of seismic isolation bearings. Our Friction Pendulum™ bearings have been used in several of the world's largest and most critical seismic isolation projects. We offer complete seismic isolation services, including bearing design, structural design support, testing, and installation support. Our highly qualified and experienced engineers can provide bearings that have performance and economic benefits for your project.

Fyfe Co., LLC

Booth 21

6310 Nancy Ridge Drive, Suite 103
San Diego, CA 92121
Phone: 858-642-0694
Fax: 858-642-0947
E-mail address: ***info@fyfeco.com***
Website: ***http://www.fyfeco.com/***

The Fyfe Group is comprised of engineers, designers, material specialists, material manufacturers and project support personnel. Working together, this team provides innovative construction products and technical support to meet the needs of engineers, contractors and owners.

Fyfe Co., LLC specializes in the use of Fibrwrap Composite systems for strengthening, protection and repair of structural elements. These systems are comprised of carbon, glass and aramid fiber reinforced polymer materials. We also offer other innovative construction products and structural systems. Among these are disc bearings, expansion joints, concrete repair products, blast mitigation and ballistic products.

Kinemetrics, Inc.

Booth 11

222 Vista Avenue
Pasadena, CA 91107
Phone: 626-795-2220
Fax: 626-795-0868
E-mail address: ***mcr@kmi.com***
Website: ***http://www.kinemetrics.com/***

Kinemetrics Inc. is the world leader in the design, manufacture, and supply of earthquake and structural monitoring solutions and instrumentation through state-of-the-art technology. As an ISO 9001:2000 Quality System certified company, Kinemetrics has provided the structural monitoring and earthquake observation communities with the highest-quality products for their monitoring challenges since 1969. Visit our booth to see our latest solutions.

LARSA, Inc.

Booth 2

105 Maxess Road, Suite 115N
Melville, NY 11747
Phone: 212-736-4326
Fax: 631-249-3089
E-mail address: ***info@LarsaUSA.com***
Website: ***http://www.larsa4d.com/***

LARSA's flagship product LARSA 4D brings two decades of experience in the structural analysis of bridges and structures to the new millennium. Based on a rock-solid nonlinear analysis engine, LARSA 4D pioneered staged construction analysis with time-dependent materials and tendons and also features progressive collapse, dynamic analyses for earthquake analysis, influence line and surface live load analysis, and a modern user interface with a lean learning curve. LARSA is located in New York and is partnered with Bentley Systems to provide unbeatable support services world-wide.

Exhibitors

Layne GeoConstruction

Booth 31

Layne GeoConstruction
6 Barcroft Road
French Town, NJ 08825
Phone: 908-996-2716
Fax: 908-996-3851
E-mail address: ***tllewis@laynechristensen.com***
Website: ***http://www.laynegeo.com***

Layne GeoConstruction, a division of Layne Christensen Co., is one of the premier contractors in jet grouting, limited mobility grouting, high mobility grouting, post tensioned rock and soil anchors, vibratory ground improvement and stone columns. Layne GeoConstruction has the capability to do real time monitoring of both drilling and grouting operations, enabling owners and engineers to assess the work as it is progressing. We invite you to visit us at booth #31 to discuss your projects.

LUSAS

Booth 8

230 Park Avenue, Suite 864
New York, NY 10169
Phone: 800-97-LUSAS; 212-295-2197
Fax: 212-295-2121
E-mail address: ***info@lusas.com***
Website: ***http://www.lusas.com***

LUSAS develops, markets and supports LUSAS Bridge – finite element software for the analysis, design and assessment of all types of bridge structures. Used on major structures worldwide, LUSAS Bridge solves all types of linear and nonlinear stress, seismic, composite, fatigue, buckling, thermal, or soil structure interaction analysis problem.

MCEER

Booth 4

University at Buffalo, State University of New York
Red Jacket Quadrangle
Buffalo, NY 14261
Phone: 716-645-3391
Fax: 716-645-3399
E-mail address: ***mceer@buffalo.edu***
Website: ***http://mceer.buffalo.edu***

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 event 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, and funded primarily by the National Science Foundation, Federal Highway Administration, New York State and other sources, the Center comprises a consortium of researchers from numerous disciplines and institutions throughout the United States.

Mid-America Earthquake Center

Booth 15

1239 B Newmark Laboratory
University of Illinois at Urbana-Champaign
205 N. Mathews Avenue
Urbana, IL 61801
Phone: 217-244-8297
Fax: 217-333-3821
E-mail address: ***smenke@uiuc.edu***
Website: ***http://mae.cee.uiuc.edu/***

The Mid-America Earthquake Center is a National Science Foundation earthquake engineering research center that is a world leader in assessing and mitigating the effects of low-probability/high-consequence earthquakes and other natural disasters. The series of earthquakes in 1811 and 1812, referred to as the New Madrid earthquakes, shook most of the Central and Eastern US and were felt as far as Washington, D.C. A repeat of those events today would cause significant losses and have enormous impacts throughout the US and even the global economy. Through the Center's highly interdisciplinary Consequences-Based Risk Management framework, risk is being assessed in the Central and Eastern US as well as in seismic regions around the world, and suitable plans and prioritization of mitigation and response actions are being developed to protect communities vulnerable to natural disasters.

Olson Engineering, Inc./Olson Instruments, Inc.

Booth 12

12401 West 49th Avenue
Wheat Ridge, CO 80033
Phone: 415-978-5326
Fax: 303-423-6071
E-mail address: ***mclark@olsonengineering.com***
Website: ***http://www.olsoninstruments.com***

Headquartered in Wheat Ridge, Colo., Olson Engineering is an industry leader in nondestructive evaluation and internal condition assessment of civil structures and infrastructure worldwide. Founded by Larry Olson, Olson Engineering is a pioneer in research and development of NDE software and hardware for condition evaluation. The staff includes civil, mechanical, electrical, structural and geophysical engineering professionals. For more details about Olson Engineering, visit ***www.olsonengineering.com*** and for more information about Olson Instruments, visit ***www.olsoninstruments.com***, or contact Cathy Szilagyi at 303- 423-1212 or ***cathys@olsonengineering.com***.

PCB Piezotronics, Inc.

Booth 1

3425 Walden Avenue
Depew, NY 14043
Phone: 716-684-0001
Fax: 716-684-0987
E-mail address: ***info@pcb.com***
Website: ***http://www.pcb.com/***

PCB Piezotronics, Inc. is a leading manufacturer and worldwide supplier of laboratory and industrial grade sensors servicing a wide variety of applications and markets. We carry a full line of low frequency piezoelectric seismic accelerometers as well as high output capacitive and piezoresistive accelerometer that respond down to DC. PCB also supplies sensors for the measurement of force, load, torque, pressure, shock, vibration, acoustics, and dynamic strain.

EXHIBITORS

PEER

Booth 16

325 Davis Hall, MC 1792
University of California at Berkeley
Berkeley, CA 94720
Phone: 510-642-3437
Fax: 510-642-1655
E-mail address: ***djacob@berkeley.edu***
Website: ***http://peer.berkeley.edu/***

PEER is a national earthquake engineering research center, with headquarters at the University of California, Berkeley. PEER is supported by the National Science Foundation, State of California, and private funding. PEER's overall mission is to develop and disseminate performance-based methodology, tools and data for seismic design of facilities in order to meet the diverse needs of owners and society. To accomplish this mission, PEER has organized a program built around research, education and technology transfer. The primary emphases of the research program are on seismic performance of buildings, bridges and transportation systems, and electric power transmission systems and networks.

PORTLAND CEMENT ASSOCIATION

Booth 22

5420 Old Orchard Road
Skokie, Illinois 60077
Phone: 847-972-9100
Fax: 847-972-9101
E-mail address: ***info@cement.org***
Website: ***http://www.portcement.org/*** or ***http://www.cement.org/***

Portland Cement Association (PCA) is the nucleus of the North American cement industry's work in research, market development, educational, and government affairs. PCA provides a full range of products and services to its members, cement companies in the United States and Canada. PCA programs seek to improve concrete and concrete construction and to ensure concrete's use in an ever-growing range of applications.

In Canada, the Cement Association of Canada conducts programs. PCA's Washington, D.C. office represents the U.S. cement industry in government affairs. A separate, for-profit subsidiary of PCA, CTL-Group, offers engineering, testing, and consulting services.

In partnership with PCA, the American Concrete Pavement Association represents cement and concrete interests in highways, streets and local roads, and airport paving.

REINFORCED EARTH COMPANY

Booth 20

8614 Westwood Center Drive, Suite 1100
Vienna, VA 22182-2233
Phone: 800-446-5700
Fax: 703-821-1815
E-mail address: ***aolson@reinforcedearth.co***
Website: ***http://www.reinforcedearth.com/***

The Reinforced Earth Company is a world leader in the design and supply of proprietary retaining wall systems and earth-related technologies. Recognized as the supplier to some of our nation's largest highway construction projects, working as a subcontractor/material supplier on Department of Transportation and privately owned projects, we perform all duties associated with our jobs from sales, marketing, engineering, design, supply and construction assistance.

SYNCHROPILE

Booth 19

5123 Blanco Road
San Antonio, TX 78216
Phone: 210-380-0449
E-mail address: ***americo.fernandez@synchropile.com***
Website: ***http://www.synchropile.com/***

Synchropile, Deep Foundation consultants are specialized in enhancing the performance of foundation systems for a broad range of applications including bridges and highly loaded structures. We are constantly examining particular methods or techniques customized for specific applications, that often allow us to provide innovative solutions that go beyond the bounds of conventional methods. This extra effort frequently produces improved time and cost savings as well as enhancement of the final product quality.

TALLEY METALS TECHNOLOGY, INC.

Booth 14

P.O. Box 2494
Hartsville, SC 29550
Phone: 800-334-8324 x2121; Outside U.S.: 843-332-5849 x2121
Fax: 843-335-5160
E-mail address: ***Rschnell@cartech.com***
Website: ***http://www.talley-metals.com***

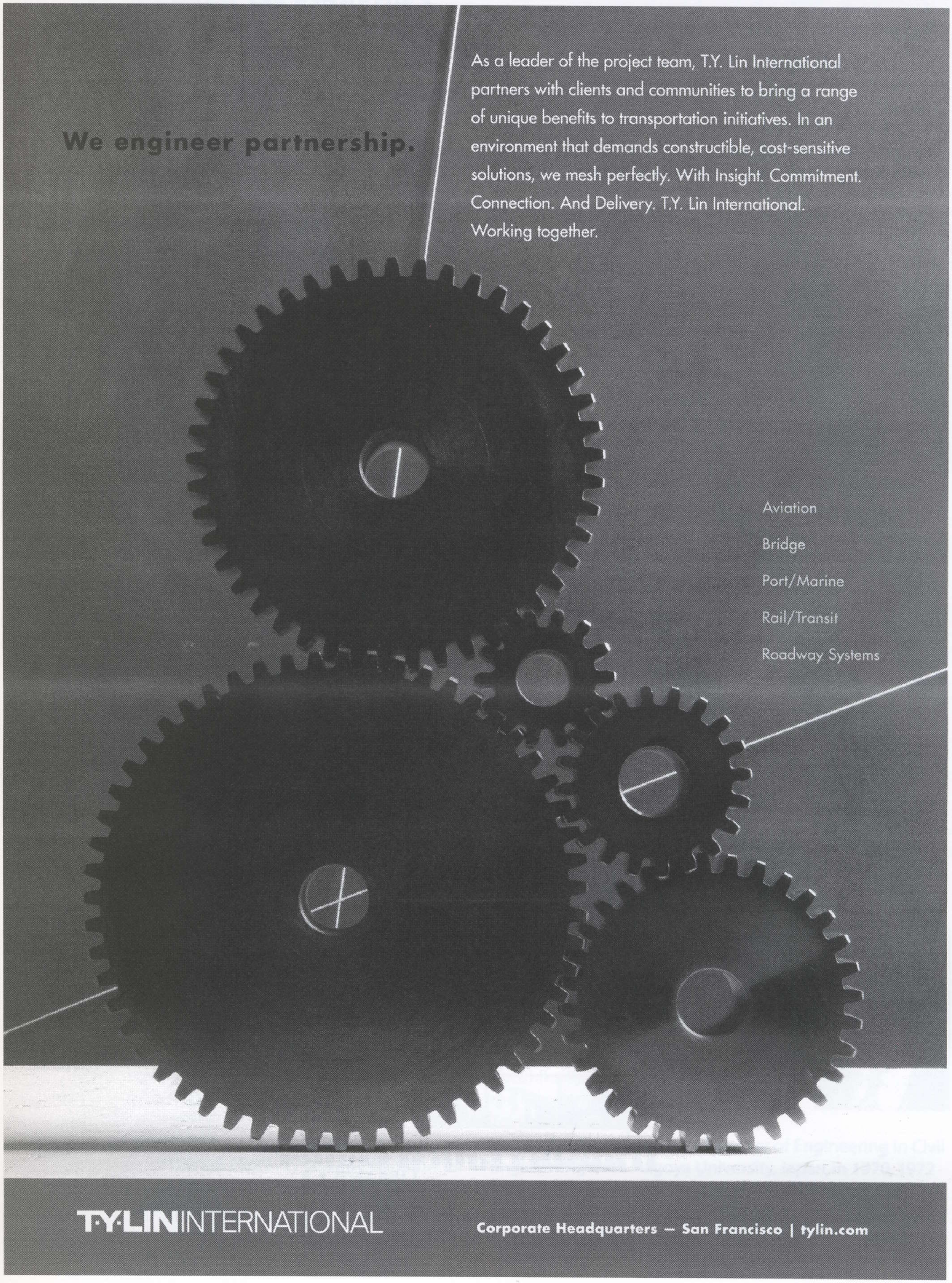
Talley Metals Technology, Inc., a subsidiary of Carpenter Technology Corporation, produces high-strength, EnduraMet™ grades of solid stainless steel rebar, dowel bars and stainless welded wire mesh, in addition to other stainless steel bar products. Talley products have been used for concrete reinforcement in a wide range of construction projects requiring long-term resistance from seismic areas, road salt, harsh marine environments, and the concrete itself. Solid stainless steel rebar is superior in corrosion resistance and strength to epoxy coated, SS clad, HDG, 8% C_r alloy steel, and carbon steel rebar.

TRC IMBSEN

Booth 23

9912 Business Park Dr. Suite 130
Sacramento, CA 95827
Phone: 916-366-0632
Fax: 916-366-1501
E-mail address: ***info@imbsen.com*** or ***tmaechler@trcsolutions.com***
Website: ***http://www.imbsen.com***

TRC Imbsen has provided a full range of consulting engineering services in support of the transportation industry since 1986. We offer in-house capabilities in structural, civil, and transportation engineering; construction administration; and much more. TRC Imbsen 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 design and analysis of highway structures. TRC Imbsen also markets and supports its own line of engineering design software.


We engineer partnership.
As a leader of the project team, T.Y. Lin International partners with clients and communities to bring a range of unique benefits to transportation initiatives. In an environment that demands constructible, cost-sensitive solutions, we mesh perfectly. With Insight. Commitment. Connection. And Delivery. T.Y. Lin International. Working together.
Aviation
Bridge
Port/Marine
Rail/Transit
Roadway Systems
T·Y·LIN INTERNATIONAL
Corporate Headquarters – San Francisco | tylin.com

Plenary Session I

Monday, September 18, 2006, 8:00 - 9:50 am

PHILLIP YEN, FEDERAL HIGHWAY ADMINISTRATION

8:00 am

Welcome

Phillip Yen is the Program Manager of the Seismic Hazard Mitigation Program, Office of Infrastructure R&D, Federal Highway Administration. He has the technical responsibility to conduct earthquake engineering research in highway construction. Dr. Yen has published many technical papers in the area of modal identification of bridges structures, non-destructive evaluation and testing, seismic design, shake table testing of bridge columns and bridge vibration tests, and cable stress assessment of cable-stayed bridges. Dr. Yen is FHWA's representative to the National Earthquake Loss Reduction Program, and is a steering committee member and the chair of the technical committee of the 4th & 5th National Seismic Conference on Highway and Bridges. He is the chair of FHWA's National Seismic Engineering Team. He serves as the US side chair of the US-Japan Bridge Engineering Annual Workshop. He is a registered Professional Engineer in the state of Virginia. Dr. Yen was named "The Engineer of the Year 2000" for the FHWA and has received many outstanding awards from the agency including an Engineering Excellence Award in 1999.

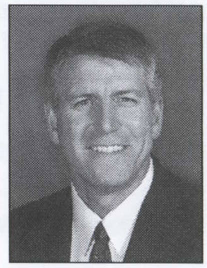
MYINT LWIN, FEDERAL HIGHWAY ADMINISTRATION

8:15 am

Innovations in Earthquake Engineering for Highway Structures

Myint Lwin was educated at the University of Rangoon, Burma and obtained his Master's degree from the University of Washington in Seattle.
He was previously State Bridge Engineer, Washington State Department of Transportation and Structural Design Engineer, FHWA Western Resource Center, San Francisco, California. He is currently Director of the Office of Bridge Technology for the Federal Highway Administration in Washington DC, with responsibility for policy and program direction, bridge technology research, development, and implementation of SAFETEA-LU funded programs, and successful delivery of the U.S. Highway Bridge Program. Mr. Lwin is a registered Professional Engineer in Civil and Structural Engineering, a member of the American Concrete Institute, a Life Member of ASCE, and a member of Transportation Research Board Committees on Steel Bridges, Construction, and Basic Research. He has authored numerous papers and books, e.g. "Seismic Design and Retrofit of Highway Bridges in Washington State," "Use of High Performance Concrete in Highway Bridges in Washington State," "Chapter 22 Floating Bridges, Bridge Engineering Handbook," "High Performance Steel Designers' Guide" and "Self-Compacting Concrete in Japan, Europe and the U.S."

RICHARD D. LAND, CALIFORNIA DEPARTMENT OF TRANSPORTATION



8:40 am

Seismic Safety - Challenges and Opportunities

Richard D. (Rick) Land is currently the California Department of Transportation's Chief Engineer and Deputy Director for Project Delivery. He has been with Caltrans for over 27 years. For the three years prior to his current assignment, Mr. Land was Chief of the Caltrans' Structure Design operations and Caltrans State Bridge Engineer. After graduating from California State University, Sacramento with a Bachelor's degree in Civil Engineering, Mr. Land went to work for Caltrans in the Marysville Area (District 3) as an entry level civil engineer. In 1980, he transferred to what was then the Division of Structures and was promoted through the levels to senior management after working at various positions in Structure Design, Structure Construction and Structure Specifications. Mr. Land's management career began in 1993, when he became the Chief of the Structures Special Projects Office. In 1995, he became one of the two Office Chiefs in Structure Design before finally taking over as the Division's Deputy of Structure Design. The majority of Mr. Land's career with the Department has been focused on the delivery of transportation improvement projects, from inception to completion of construction.

KAZUHIKO KAWASHIMA, TOKYO INSTITUTE OF TECHNOLOGY

9:05 am

Enhancement of Seismic Performance of Bridges

Kazuhiko Kawashima is a Professor in the Department of Civil Engineering, Tokyo Institute of Technology, Japan.
He received his B.E., M.E. and Doctor of Engineering in Civil Engineering from Nagoya University, Japan, in 1970, 1972 and 1980, respectively. He joined the Public Works Research Institute of the Japanese Ministry of Construction in 1972 and was involved in developing seismic design codes for highway facilities. He chaired the Seismic Design

Subcommittee of the Japan Road Association in the revision of the 1990 and 1996 versions of "Seismic Design Specifications of Highway Bridges." He joined the Tokyo Institute of Technology in 1995. He is interested in the ductility evaluation of structural components, structural response, seismic retrofit and seismic isolation of bridges. He authored and co-authored over 250 technical papers on ground motions, structural response with pounding effect, residual displacement, ductility evaluation of reinforced concrete columns, and seismic isolation and variable control of bridges.

Plenary Session II

Tuesday, September 19, 2006, 8:00 - 9:50 am

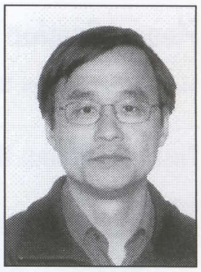
LICHU FAN, TONGJI UNIVERSITY

8:00 am

Life Cycle and Performance Based Seismic Design of Major Bridges

Lichu Fan is the deputy director of the academic committee of the State Key Laboratory for Disaster Reduction in Civil Engineering (SLDRCE) at Tongji University, Shanghai, China. He is also the president of the China Civil Engineering Society, and the alternate committee member of the Standing Committee of the International Association of Bridge Engineering Society. Dr. Fan has devoted himself to the seismic analysis and design of bridges for more than 40 years. He developed a 3-D nonlinear seismic analysis method and computer program for long span bridges, and guided most of the seismic design of long span bridges in China. He invented two new types of seismic rubber bearings and one new type of seismic buffer retaining block, and developed some new seismic retrofitting techniques for RC bridge piers. In 1999, Dr. Fan was awarded the Mao-Yisheng Prize (Individual Achievement Award) owing to his outstanding contributions in China, and was awarded "National Excellent Teacher" from the China Ministry of Education for his prominent contribution to undergraduate teaching at Tongji University in 2004. Dr. Fan is currently working on the first Specifications of "Seismic Design for Urban Bridges" initiated by the Ministry of Construction of PRC, and also promoting US-China international cooperative research and practices in bridge engineering.

T.J. ZHU, BUCKLAND & TAYLOR, LTD.



8:35 am

Seismic Design Issues for Long-Span Bridges

T.J. Zhu is a senior bridge engineer and seismic specialist with Buckland & Taylor Ltd. in North Vancouver, British Columbia, Canada. He obtained his Ph.D. degree in structural and earthquake engineering from McMaster University in Ontario, Canada in 1990. After receiving his Ph.D. degree, he continued research in earthquake engineering at McMaster University. Dr. Zhu joined Buckland & Taylor Ltd. in 1991 and has worked on most of the Company's major seismic projects since, including both design of new bridges and retrofit of existing bridges. His bridge project experience includes the Messina Strait Crossing in Italy, the Chacao Channel Bridge in Chile, the Rion Antirion Bridge in Greece, the Cooper River Bridge in the US, and seismic retrofit design of the Golden Gate Bridge in the US. He serves on the seismic subcommittee of the Canadian Highway Bridge Design Code and has co-authored several papers on seismic analysis and design of bridge structures.

LARS HAUGE, COWI

9:10 am

Pushing the Span Limits for Long-Span Bridges - A State of the Art Review

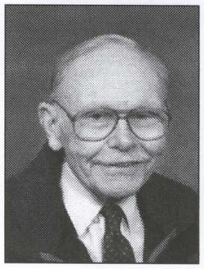
Lars Hauge is the Director for International Bridge Projects at COWI in Copenhagen, Denmark. He graduated from the Technical University of Denmark in 1986 and has been employed by COWI since 1990. Mr. Hauge has considerable experience in design and construction of cable supported bridges - gained through involvement in the design of some of world's largest bridges including the Normandy Bridge in France, the Great Belt Suspension Bridge and the Øresund Link in Denmark, the Stonecutters Bridge and the Sutong Bridge in China and the Busan-Geoje Fixed Link in Korea. He was stationed in Asia from 2001 to 2005 and since his return, he has been involved in the design of Chacao Bridge in Chile and the Messina Bridge in Italy.

Invited Speaker Biographies

Conference Banquet

Tuesday, September 19, 2006, 7:00-9:00 pm

Charles Seim, Consultant



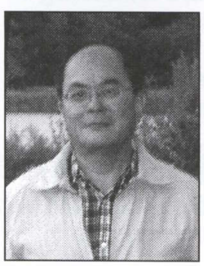
Bridge Engineering - We've Come a Long Way

Charles "Chuck" Seim began his professional career in 1954 with the State of California, Division of Bay Toll Crossings (which later became part of Caltrans), as an engineer for the construction of the Richmond-San Rafael Bridge. He was later the design engineer for the San Diego-Coronado Bay Bridge and the Dumbarton Bridge over San Francisco Bay. He left Caltrans in 1980 as the Maintenance Engineer for all nine California State-owned toll bridges and joined T. Y. Lin International as a Vice President and Senior Bridge Engineer. He retired from T. Y. Lin International in June 2004 and established his own office as a consulting bridge engineer. He is a registered Professional Engineer in California, Arizona, Oregon, Idaho, Colorado, and Louisiana. Mr. Seim is an ASCE Fellow, a past member of the Long Span Bridge Committee, and is currently an Associate Editor of the Journal of Bridge Engineering. He is a past member of the Transportation Research Board Committee on Steel Bridges. He is also a member of the International Association of Bridge and Structural Engineers, American Concrete Institute and the Structural Engineers Association of Northern California. In 2006, Mr. Seim received the John A. Roebling Medal, a lifetime achievement honor.

Plenary Session III

Wednesday, September 20, 2006, 8:00 - 9:50 am

K.C. Chang, National Taiwan University

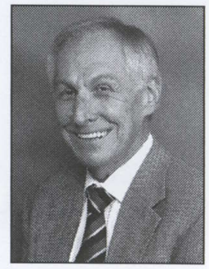


8:00am

Seismic Assessments of Bridges with Rubber Bearings during 1999 Taiwan Chi-Chi Earthquake

Kuo-Chun Chang is Professor and Chairman at the Department of Civil Engineering, National Taiwan University. He is also in charge of bridge research at the National Center for Research on Earthquake Engineering (NCREE), Taiwan. He received a B.S. degree from National Taiwan University, and M.S. and Ph.D. degrees from the University of Buffalo. His research experiences related to earthquake engineering for bridges include seismic behavior and retrofit with fiber reinforced polymers of conventional reinforced concrete bridge columns, development of bridge seismic bearing systems and health monitoring systems with optical fibers, and seismic behavior of precast segmental concrete bridge columns. In addition, he has been involved in the development of design codes and guidelines related to the seismic design of bridges and highways in Taiwan. His current research interests include structural control, innovative bridge bearing systems, structural and geotechnical health monitoring systems with advanced sensor technologies and the seismic behavior of precast bridge columns.

Roy A. Imbsen, Consultant



8:45 am

The Legacies of Jim Cooper & Jim Roberts

Roy Imbsen has 45 years of experience as a practicing bridge engineer. His experience includes design, analysis, research and construction of transportation facilities. As President of Imbsen & Associates, Inc., now TRC Imbsen, he led a team of bridge and highway engineers for 20 years. Dr. Imbsen's experience covers a broad range of projects within the US and several other countries. He is a registered Professional Engineer in 18 states and is the Engineer of Record on several major transportation facilities. Additionally, Dr. Imbsen has been Principal Investigator on many bridge related research projects (sponsored by NSF, FHWA, AASHTO, NHI, SCDOT and Caltrans) covering bridge rating, wheel load distribution, thermal effects in concrete, computer program development for analysis and design and writing new design specifications. Dr. Imbsen has been a pioneer in developing, implementing, teaching and applying seismic design principles to bridges since the San Fernando earthquake in 1971. He was a co-recipient of the AASHTO Dr. L.I. Hewes Award for the development of the first comprehensive seismic design specifications, which remained in effect for fifteen years. Additionally, Dr. Imbsen participated in the development of the current AASHTO Division IA and is currently completing the LRFD Guideline Specifications for the Seismic Design of Bridges.

9:25 am

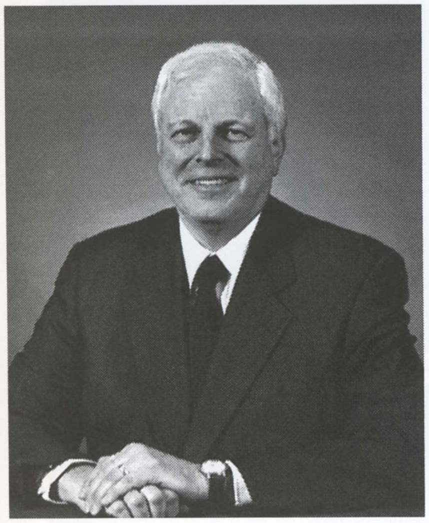
Presentation of Jim Cooper and Jim Roberts Best Paper Awards

Photo courtesy of Tom Saunders VDOT/Public Affairs

Best Paper Awards

James Cooper Best Paper Award

The Jim Cooper Best Paper Award will be awarded to the paper with the greatest potential impact, contribution to society and best overall quality.



James D. Cooper, 63, an internationally recognized structural engineer and leader in the field of bridge engineering, with a specialty in earthquake engineering, died on November 23, 2005.

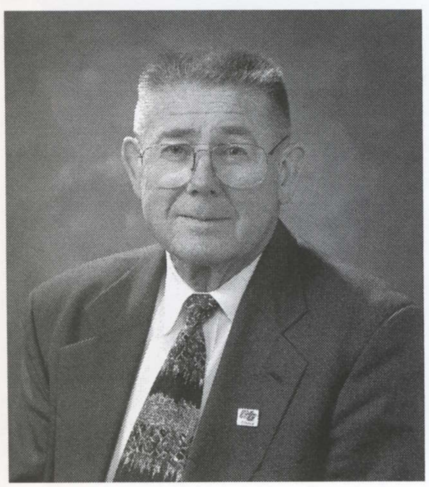
Mr. Cooper, who retired from the Federal Highway Administration in 2003 as Director of the Office of Bridge Technology, served as a bridge engineer for over three decades. As Director, he provided national leadership in the development of policies, standards, and criteria for the location, design, construction, 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.

James Roberts Best Paper Award

The James Roberts Best Paper Award will be given to a Caltrans employee whose paper discusses a deployable research innovation that is expected to have a significant impact on the practice of the bridge engineering profession.



James E. "Jim" Roberts, 75, who capped his half-century career with Caltrans as the state's top bridge engineer, died on July 6, 2006.

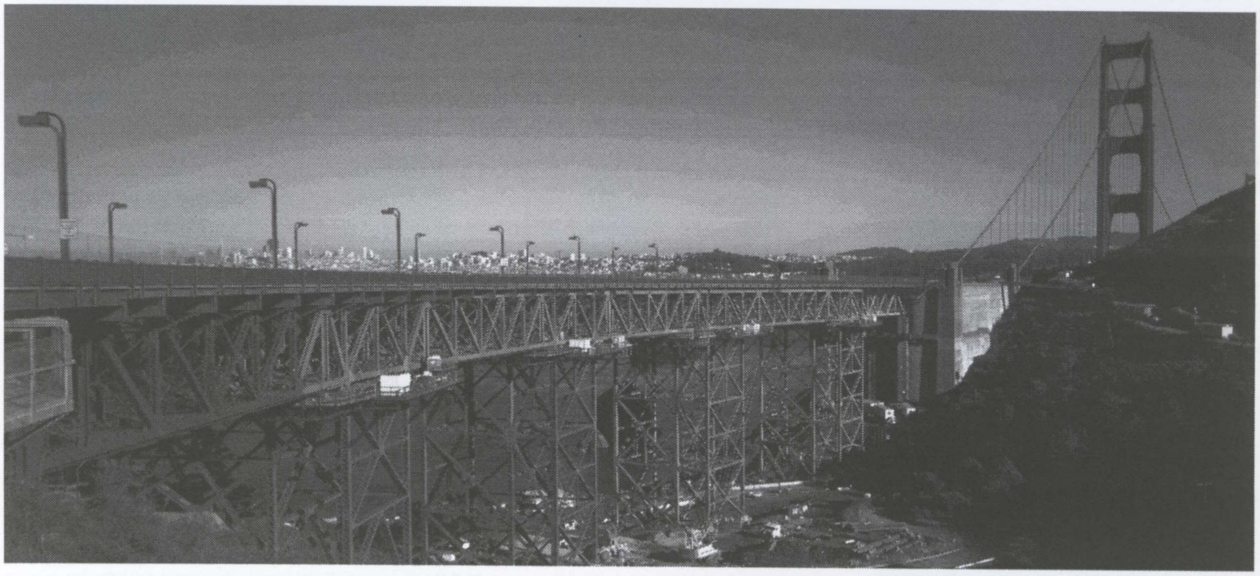
Mr. Roberts, who retired in 2001 as the Department's Chief Deputy Director, served as a structural engineer at Caltrans for more than half a century, including 15 years as California's State Bridge Engineer. He spearheaded the Department's $4.5 billion seismic retrofit program and oversaw nearly $50 million in seismic research projects. He was also named to the National Academy of Engineering in 1996, the only state-employed engineer to be so honored.

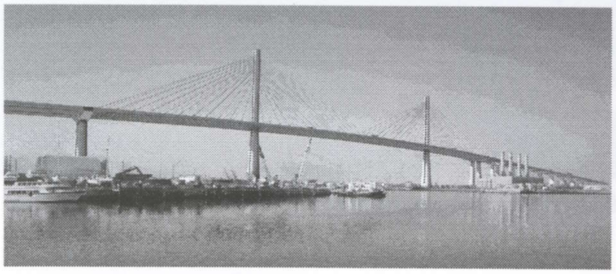
During his half-century of service, Mr. Roberts compiled a comprehensive background in planning; budgeting; design; construction; administration; equipment acquisition, maintenance and management; and major project management.

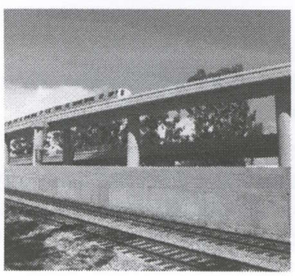
From 1995 to 1999 he was Director of the Engineering Service Center where he managed a staff of more than 1,700 professional engineers, architects and support staff, as well as 600 consultants, who designed and delivered an annual structures construction program exceeding $650 million.

He was an acknowledged expert in bridge technology, and he wrote and published dozens of technical papers on bridge design and maintenance.

Mr. Roberts received a Bachelor of Science degree in Civil Engineering from the University of California, Berkeley, in 1953 and a Master of Science degree in Structural Engineering from the University of Southern California in 1966. After completing college, he spent two years of active duty in Korea with the U.S. Corps of Engineers. He completed 33 years as a reserve officer, and retired as a colonel.







Paper Abstracts

(Arranged by Technical Session)

1A1: Design & Analysis of Major Bridges

Moderated by Kevin Thompson, California Department of Transportation

Paper A01

Seismic Characteristics of Bridge Steel Pedestals

Monique C. Hite, Reginald DesRoches, Roberto Leon, School of Civil and Environmental Engineering, Georgia Institute of Technology; Paul Liles, Jr. and Y. Stanley Kim, Georgia Department of Transportation

Some bridges in Georgia have been rehabilitated using steel pedestals as a unique and cost-effective means for elevating bridges to increase the clearance height. Steel pedestals are W-shape members ranging in height from 19" to 33½", that act like stub columns connected between the bridge girders and bent caps. Steel pedestals perform a similar function as steel bearings, where loads are transferred from the bridge deck to the substructure. Previous studies have shown that typical steel bearings have been vulnerable components in past earthquakes due to their potential instability and lack of deformation capacity. To evaluate the behavior of steel pedestals under lateral loads expected from low-to-moderate earthquake loads, a detailed experimental investigation is conducted. The experimental test setup consists of a 40' span bridge system with steel pedestals subjected to cyclic quasi-static loads. Short (19") pedestals are tested along their strong and weak axes. The results from experimental tests are used to characterize the behavior of the short (19") steel pedestals. In particular, moment-rotation curves are presented and will be used to define the connection behavior of the steel pedestals in a bridge model. The bridge model will evaluate the seismic performance based on a suite of ground motions representative of the seismic hazard in Georgia. Recommendations are made on the connection details for ensuring adequate seismic behavior. The results of the study are useful for other states in low-to-moderate seismic zones considering the use of steel pedestals to increase the clearance of bridges.

Paper A02

Design and Analysis of Precast Concrete Bridges in Areas of High or Moderate Seismicity

Bijan Khaleghi, Washington State Department of Transportation

The seismic design and detailing of bridges made of precast prefabricated members has always been a challenge among bridge engineers and bridge builders. In recent years, there has been an increasing public demand for accelerated bridge construction using precast members or other innovative techniques. 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 and other design specifications in areas of high or moderate seismicity. It discusses the different seismic design methodologies and their application to precast bridges.

Paper A03

Retrofit of a Historic Three-Hinge Arch Bridge

Sherif S. Morcos, HDR Engineering, Inc.

North Main Street Bridge over the Los Angeles River located within the City of Los Angeles, California, was built in 1910 and was identified as the first three-hinge concrete arch rib bridge constructed in the southwestern United States. The bridge is located within 4 kilometers from the Elysian Park Blind/Thrust fault with an estimated Maximum Credible Earthquake (MCE) magnitude of 7.0 and peak bedrock acceleration of 0.55g. Multi-modal seismic analysis was performed. The analysis results indicated that the bridge is unstable under seismic loads and the arch ribs and spandrel columns do not have adequate capacities to carry the seismic force demands induced by the MCE event. A retrofit strategy which prevents the bridge from collapsing under the MCE event was developed. The retrofit strategy has minimum adverse effects on the historic character defining features of the bridge.

Paper A04

Seismic Retrofit of the Posey Tube: A Discussion of Soilcrete and the Construction of Large Diameter Triple Fluid Jet Grout Columns Over the Oakland Estuary in California

Marcia E. Kiesse, California Department of Transportation; and Thomas S. Lee, Parsons Brinckerhoff, Quade & Douglas, Inc.

Oakland and the island city of Alameda are linked by two historically-significant traffic corridors that traverse beneath the Oakland Estuary: the Posey and the Webster Street Tubes. Completed in 1928, the 3,200 foot long Posey Tube was the first precast concrete underwater tube structure of its kind. The tube consists of twelve 200-foot-long precast concrete tube segments and an 800 foot long cast-in-place concrete tube section. Following the Loma Prieta earthquake, Caltrans issued a construction contract for an innovative seismic retrofit design by Parsons, Brinckerhoff, Quade & Douglas, Inc. in San Francisco. The design included jet grout columns along each side of Posey Tube that serve as a pair of cut-off walls to confine the liquefiable loose sand bedding below the tube, thereby mitigating the uplift potential during a major earthquake. This paper describes construction of the overlapping six-foot-diameter soilcrete columns using a triple fluid jet grout system and the unique challenges that were encountered, especially when working over water. In addition, results of strength tests performed on laboratory-mixed soilcrete are also presented, which are followed by suggestions for quality control programs for similar triple fluid jet grouting operations, based on the experience gained from this unique seismic retrofit project.

Paper A05

The Seismic Analysis and Design of a Steel Plate Girder Bridge with an Emphasis on Practical Considerations

Clint M. Krajnik, Federal Lands Highway Bridge Office, Federal Highway Administration

The Steven Memorial Bridge is a 364-ft long and 31-ft wide straight structure consisting of three spans (92-ft, 180-ft, 92-ft). The superstructure is composed of four continuous, composite, constant depth steel plate I-girders. Semi-integral abutments and single round column hammerhead piers (40-ft & 46-ft tall) provide support for the girders. The bridge is in seismic Zone 4 and the design complies to the AASHTO LRFD Specification 3rd Edition w/2005 interims. Several issues concerning the analysis and design are unique to steel plate girder bridges. Analysis results were found sensitive to the assumptions made for the composite superstructure transverse stiffness (moment of inertia about the vertical axis). Steel bridge components such as cross-frames (diaphragms), bearings, and anchor rods have special seismic considerations. Semi-integral abutments consist of concrete girder endwalls and wingwalls integrally connected to the superstructure. The endwalls and wingwalls resist seismic forces from the bridge by engaging passive soil pressure longitudinally and transversely. There are seismic advantages and design considerations associated with this configuration. The pier columns rest on mono-shaft foundations using shallow socket penetrations into strong rock. Foundation considerations include using cracked (effective) column stiffness, accounting for column slenderness with P-Δ analysis, rock socket design criteria, and inelastic hinging.

Paper Abstracts

1B1: Foundations & Geotechnical Considerations

Moderated by Michel Bruneau, MCEER

Paper B01

Effect of Backfill Soil Type on Stiffness and Ultimate Capacity of Bridge Abutments: Large-scale Tests

A. Bozorgzadeh, Scott A. Ashford, and Jose I. Restrepo , Department of Structural Engineering, University of California-San Diego

Bridge abutments play an important role in the magnitude of earthquake-induced forces transmitted into the bridge structure. Many factors such as nonlinear soil behavior, soil properties, and abutment dimensions must be considered for realistic characterization of abutment-backfill interaction. However, for simplicity, in many existing models for abutment capacity and stiffness, the effects of soil properties are not considered. The main goals of this research program are to determine the abutment capacity and stiffness from field tests, using different soil types and to develop a simplified soil dependent model to predict abutment behavior. In the first phase of the experiment, an abutment wall (without a foundation) was built at 50% scale of a prototype abutment, to study the longitudinal stiffness and strength of a backwall. Two different soil types were used to characterize the range of soil properties to be expected behind bridge abutments. A proposed second phase of this research program will investigate the system effect on the stiffness and strength of an abutment and evaluate the accuracy of a proposed model of the soil springs.

Paper B02

Mechanical Axial Force Transfer within Cast-In-Steel-Shell Piles – Verification through Full-Scale Experimentation and Finite Element Analysis

Michael Gebman, Scott A. Ashford and José I. Restrepo, Department of Structural Engineering, University of California-San Diego

In this study, the axial force transfer within Cast-In-Steel-Shell (CISS) Piles through mechanical axial force transfer mechanisms fixed to the steel shell interior surface, and through surface bond was investigated through a full-scale experiment and finite element analysis. The experimental program consisted of twenty-one full-scale CISS pile test units, with typical diameters of 24 in. (610 mm), and steel shell diameter to thickness ratios (D/t) ranging from 24 to 128. Test units were subjected to a quasi-static reversed cyclic axial loading. The shear ring mechanism was found to be the most effective of the designs tested. This mechanism was studied further experimentally by examining the effect of shear ring spacing, and the effect of D/t ratio on the shear ring force transfer. This mechanism was also studied analytically through finite element modeling using ABAQUS/EXPLICIT. Three dimensional solid element models were developed to study the axial force through the shear ring mechanism, and surface bond. The models were computationally intense and were run on at the San Diego Supercomputer Center at UCSD. The nonlinear models involved a complex contact analysis, concrete crushing, core deformation, and circumferential yielding of the steel shell and the shear ring. Results for two of the models, at a high D/t ratio, and at a low D/t ratio will be presented in this paper and compared to experimental results.

Paper B03

Field Testing and Analytical Modeling of a Reinforced Concrete Embedded Pile Under Lateral Loading

Eric Ahlberg, Changsoon Rha, Jonathan P. Stewart, Robert L. Nigbor, John W. Wallace, and Ertugrul Taciroglu, Department of Civil and Environmental Engineering, University of California, Los Angeles

We report the results of the two tests in a series of five that subject cast in drilled hole (CIDH) foundation systems with variable head and geometric conditions to lateral loading. Both test specimens are two two-feet diameter reinforced concrete drilled shafts that extend 24ft below ground line, with one in a flagpole configuration extending 13.3ft above ground line and the other capped at the surface in a fixed-head configuration. The test site consists primarily of low plasticity alluvial clay that is expected to exhibit an undrained response to the cyclic lateral loading. Quasi static loading was applied with a hydraulic control system in displacement-control mode. The test data have been reduced to provide cyclic load-deflection backbone curves, curvature profiles at pre-yield deflection levels, and hysteresis curves. Pre-test response predictions were obtained via (1) a three dimensional finite element model, (2) a macro-element model, and (3) the strain wedge model developed at University of Nevada-Reno. All of the three numerical approaches yielded reasonably accurate predictions of these small diameter shafts.

Paper B04

Overcoming Hurdles that Limit the Application of Nonlinear Seismic Ground Response Analysis in Engineering Practice

Jonathan P. Stewart and On-Lei Annie Kwok, Dept. of Civil and Environmental Engineering, University of California, Los Angeles; Youssef M.A. Hashash, Dept. of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign; Neven Matasovic, GeoSyntec Consultants; Robert Pyke, Consulting Engineer; Zhiliang Wang, Geomatrix Consultants, Inc. and Zhaohui Yang, URS Corporation

One-dimensional seismic ground response analyses are often performed using equivalent-linear procedures, which require few, generally well-known parameters (shear wave velocity, modulus reduction and damping versus shear strain, and soil density). Nonlinear analyses provide a more robust characterization of the true nonlinear soil behavior, but their implementation in practice has been limited, which is principally a result of poorly documented and unclear parameter selection and code usage protocols. Moreover, the benefits and potentials of nonlinear analysis relative to equivalent linear are not well defined. In this paper, we present preliminary results of a "benchmarking study" of nonlinear ground response analysis procedures. Key issues that are discussed include: (1) the use of a simple curve-fitting parameter to describe the shape of the backbone curve, avoiding the need to determine dynamic shear strength (which is often unavailable); (2) strategies for managing excessive large-strain material damping that occurs when Masing's rule is applied to the backbone curve to evaluate hysteretic damping; (3) specification of input motion as "outcropping" (i.e., equivalent free-surface motions) versus "within" (i.e., motion recorded at depth in a vertical array); and (4) specification of viscous damping, specifically the target value of the viscous damping ratio and the frequencies for which the viscous damping produced by the model matches the target.

Paper B05

Global and Structural Stability Assessments of Fort Mason Tunnel for Seismic Rehabilitation

Zia Zafir, Kleinfelder, Inc.; Stephen Klein, Jacobs Associates; and Matthew DeMarco, Federal Highway Administration

The Fort Mason tunnel runs east-west beneath historic Fort Mason, which is located on the bay just west of Fisherman's Wharf in San Francisco, CA. Spanning the Fort Mason grounds, the tunnel is approximately 1500 ft long. The tunnel, built in 1914, runs less than 60 ft beneath a number of buildings within the Fort Mason complex, several of which are historic structures. The project included assessment of the entire tunnel structure, both portals and portal approaches. Primary concerns for the tunnel are potential of liquefaction and/or lateral spreading during a major seismic event, significant crack in the crown within the cut and cover section, and water inflow. Our research showed that during the 1989 Loma Prieta earthquake, no liquefaction damage was observed at Ft. Mason while significant liquefaction damage occurred in the Marina District, immediately west of Ft. Mason. The results of our investigation and analyses show that liquefaction and lateral spreading is not a concern for this tunnel but settlement of uncompacted fills below and around the tunnel can have impact on the tunnel stability. The structural analyses indicate that portal retaining walls are adequate for static loading but FOS for overturning under seismic loading is less than 1. Tension in existing tunnel lining due to static compression and bending exceeds the allowable stress levels. This paper will present an assessment of the existing tunnel conditions, the results of our investigation and analyses, and our recommendations.

PAPER ABSTRACTS

1A2: USE OF INNOVATIVE TECHNOLOGIES & MATERIALS

MODERATED BY IAN BUCKLE, UNIVERSITY OF NEVADA RENO

Paper A06

Multihazard-Resistant Highway Bridge Pier

Michel Bruneau and Shuichi Fujikura, MCEER and Department of Civil, Structural and Environmental Engineering, University at Buffalo, The State University of New York; and Diego Lopez-Garcia, Departamento de Ingenieria Estructuraly Geotecnica, Pontificia Universidad Catolica de Chile

There are some similarities between seismic and blast effects on bridge structures: both major earthquakes and terrorist attacks/accidental explosions are rare events that can induce large inelastic deformations in the key structural components of bridges. Since many bridges are (or will be) located in areas of moderate or high seismic activity, and because many bridges are potential terrorist targets, there is a need to develop structural systems capable of performing equally well under both events. This paper presents the findings of research to establish a multi-hazard bridge pier concept capable of providing an adequate level of protection against collapse under both seismic and blast loading, and whose members' dimensions are not very different from those currently found in typical highway bridges. A series of experiments on 1/4 scale multi-hazard bridge piers was performed. Piers were concrete-filled steel tube columns (CFST columns) with different diameters (D = 4", 5" and 6"), connected to a steel beam embedded in the cap-beam and a foundation beam. Fiber reinforced concrete was used for the cap-beam and the foundation beam to control cracking, which was deemed desirable against spalling of the concrete. The CFST column exhibited a ductile behavior under blast load, and no significant damage was suffered by the fiber reinforced concrete cap-beam as a result of the blast pressures.

Paper A07

New Seismic Retrofit Technologies for a Historic Bridge in California

Paul Chung, Mohammad Ravanipour and Ray Wolfe, California Department of Transportation

The California Department of Transportation has nearly concluded a landmark effort to retrofit all bridges in its inventory determined seismically deficient. Several historic bridges were among the structures identified at risk. Historic structures are defined as those included on the "National Register of Historic Places". Identification as such imparts a higher standard with respect to the visual impacts of modifications, including a review by the Advisory Council on Historic Preservation and/or the State Historic Preservation Office, of any proposed work. The Laurel Street Bridge, spanning State Route 163 just North of downtown San Diego, is one of these historic structures targeted for seismic retrofitting. In addition to the identified seismic deficiencies, the structure suffers from substantial concrete deterioration and reinforcing steel corrosion. This paper outlines the current retrofit strategies contemplated during the project planning phase, noting some of the requisite challenges still under investigation.

Paper A08

Seismic Design of Circular Bridge Columns with Unstressed Prestressing Strand for Transverse Reinforcement

Andrew Budek, Department of Civil Engineering, Texas Tech University; Chin Ok Lee, Department of Civil Engineering, Chungnam University, and M.J. Nigel Priestley, Department of Structural Engineering, University of California at San Diego

Following ATC-32 provisions for shear-critical bridge columns using Gr.60 transverse reinforcement to limit shear-crack width can result in structures that suffer from shear congestion to the point of being unbuildable. To investigate the possibility of using high-strength reinforcement at lower volumetric ratios, five reinforced concrete columns were tested using unstressed Gr. 250 prestressing strand as transverse reinforcement. Aspect ratio of the test columns was 2, and the columns were tested in double bending. Axial load was varied, and both single-wire and seven wire prestressing strand were used. Both quasi-static and dynamic testing was performed. In three columns designed for competent shear performance, with a limiting design strain in the transverse reinforcement of 0.005 at maximum shear, excellent results were obtained through the use of volumetric reinforcement ratios that were considerably below that specified by ATC-32. Even though strain in the reinforcement was 250% higher than the currently codified limiting yield strain, the commensurately wider shear cracks did not degrade performance, and the columns failed in flexure at high drift and ductility levels. Seven-wire strand had slightly better performance than single-wire. Two columns were underdesigned for shear, to examine the impact of dynamic loading. Dynamic effects were found to have no effect on ultimate shear strength. Test results are compared to columns of similar configuration in the PEER database and other published sources to place them in context with current research and practice.

Paper A09

Rocking of Bridge Piers Subjected to Multi-Directional Earthquake Excitation

Andres Espinoza and Stephen Mahin, Department of Civil 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 larger, Caltrans-funded investigation to develop guidelines for the design of bridges supported on piers that rock on their foundations, a series of preliminary shaking table tests of a simple inverted pendulum reinforced concrete bridge column was conducted. These tests are among the first to consider the effects of three components of excitation. For the shaking table tests, the underlying soil is modeled by a neoprene pad, upon which the pier is allowed to rock. Preliminary results from these tests comprise the focal point of this paper. These shaking table experiments provide data to validate analytical models that are in turn used to assess and improved design guidelines related to rocking foundations.

Paper A10

Retrofitting the Milford-Montague Truss: Challenges and Solutions

Thomas P. Murphy and Michael C. Irwin, Modjeski and Masters, Inc.

This paper presents the challenges and solution for the seismic evaluation and retrofit of the Milford-Montague truss bridge crossing the Delaware River between Pennsylvania and New Jersey. The seismic vulnerabilities are presented, along with the retrofit strategies considered including base isolation and added damping systems. Special emphasis is placed on the difficulties presented by the stone-faced lightly reinforced piers common in many older truss bridges. The state-of-the-practice in retrofitting these piers is explored. Unique aspects of the bridge behavior and their impacts on the final retrofit strategy chosen are highlighted.

1B2: PERFORMANCE CRITERIA & ECONOMIC CONSIDERATIONS

MODERATED BY ELMER MARX, ALASKA DEPARTMENT OF TRANSPORTATION

Paper B06

A Comparative Performance-Based Seismic Assessment of Traditional and Enhanced-Performance Bridge Pier Systems

Won K. Lee and Sarah L. Billington, Department of Civil and Environmental Engineering, Stanford University

To minimize residual displacements and improve post-earthquake functionality of a bridge, a system is proposed and evaluated in which vertical, unbonded post-tensioning (UBPT) is used to facilitate self-centering of the piers. In addition, a high performance fiber-reinforced cement composite (HPFRCC) material replaces concrete in the hinging regions of the piers. The HPFRCC provides improved damage-tolerance to the

system by reducing large cracks and preventing spalling, which in turn prevents longitudinal bar buckling. This study evaluates the dynamic behavior of self-centering bridge piers with and without the use of HPFRCC and assesses quantitatively several benefits of using enhanced-performance systems in seismic regions by comparing them to a bridge with conventional reinforced concrete piers. A formalized performance-based earthquake engineering assessment methodology developed by the Pacific Earthquake Engineering Research (PEER) Center is used to carry out the comparison.

Paper B07

A Rational Method for Calibrating Appropriate Response Modification Factors for Seismic Design of Bridge Columns

Abdallah Mechakhchekh and Michel Ghosn, Department of Civil Engineering, The City College of New York & The Graduate Center of CUNY

The seismic safety of bridges designed using the force-based method is related to the values of the response modification factors R_{μ} applied for proportioning bridge members. Recent investigations showed that the safety of R-C bridge columns designed using mean values of R_{μ} may be severely compromised due to the large scatter in the actual response modification factors as compared to the mean values. Based on these observations, this paper proposes a method to calibrate nominal values for R_{μ} based on a nonlinear dynamic reliability analysis. This approach would be consistent with the LRFD philosophy for modern structural design codes. The proposed reliability approach incorporates, in addition to the uncertainties in the seismic input, the variability in R-C column material properties and modeling uncertainties. This approach is based on a comprehensive evaluation of the reliability of the seismic design process including the expected return period and the specified design spectrum. The proposed procedure is demonstrated through its application to seismic data for a site located in San Francisco. The results show that the R_{μ} values recommended in the current AASHTO standard design code provide adequate safety margins and reliability levels when used in conjunction with the NEHRP seismic design spectrum.

Paper B08

Implementation of Displacement Based Design for Highway Bridges

Vinicio Suarez and Mervyn Kowalsky, North Carolina State University

Six bridges classified as ordinary bridges in the Seismic Design Criteria (SDC) by Caltrans are designed according to that criteria and are also designed using the Direct Displacement Based Design (DDBD) method. The bridges include two types of substructures, symmetric and asymmetric configurations and plan curvature. The performance of each of the resulting structures is evaluated by performing nonlinear time history analysis. This work aims to (1) compare the effectiveness of DDBD and SDC in the design of a sample of six ordinary bridges and (2) investigate the items needed for improvement of current DBD practice emphasizing in the determination of displacement demand, displacement capacity and soil-structure interaction effects. Special attention is put on the determination of the displacement demand and an alternative procedure is proposed based on the Substitute Structure Method (SSM). Also, the existing target ductility limits are reviewed considering P-Delta effects for column bents on rigid foundations and drilled shafts bents.

Paper B09

Implications of Future Seismic Bridge Design Provisions for Illinois

Daniel H. Tobias, Ralph E. Anderson, Chad E. Hodel, William M. Kramer and Riyad M. Wahab, Bureau of Bridges and Structures, Illinois Department of Transportation

AASHTO and the NCHRP are currently formulating new provisions for the seismic design of highway bridges. As a member of the AASHTO Seismic Design Sub-Committee (T-3), Illinois is playing an advisory role in the process. A vote by AASHTO members on adoption of these provisions into the *LRFD Bridge Design Specifications* or as guide specifications, in part or in full, could come in the late spring of 2007 with initial publication as early as 2008. The proposed formulation of the new provisions is quite different than those in the current *AASHTO LRFD Bridge Design Specifications* as well as the *Standard Specifications for Highway Bridges*. There are two key aspects of differentiation between the current codified provisions and the proposed which Illinois is focusing on for implementation. The design earthquake return period is increasing from 500 to 1000 years and the newly formulated method for seismic analysis and design is primarily "displacement based" as opposed to the current "force based" or "R-factor" approach. Illinois has already begun to lay the foundation for implementation of these expected provisions. The paper presents an overview of these efforts.

Paper B10

Seismic Hazard for California Bridges Using Deterministic and Probabilistic Methods

Fadel Alameddine and Mark Yashinsky, Office of Earthquake Engineering, California Department of Transportation

The California Department of Transportation uses a Deterministic Seismic Hazard Analysis (DSHA) for the design of Ordinary bridges. All bridges are considered Ordinary unless classified as Important bridges. A Probabilistic Seismic Hazard Analysis (PSHA) is used for the seismic design of Important bridges, the seismic design of temporary bridges or of bridge shoring, and to make economic decisions about retrofitting and replacing older structures. Because of the inherent differences between the two methods, seismic hazard demand used for the design of a particular bridge at a given location can vary depending on the method used and the proximity to earthquake faults. This variation is further complicated by the fact that California has regions of extremely high and relatively low seismicity in addition to areas that are characterized as seismically highly active, moderately active or inactive. Using PSHA or DSHA for the design of a bridge may lead to different levels of safety against collapse. This paper compares the DSHA One-Second Spectral Acceleration based on the Maximum Credible Earthquake (MCE) with the PSHA One-Second Spectral Acceleration for bridge sites grouped in different regions of California. Cost curves developed by OPAC Consulting under a contract from PEER (Ketchum, 2003) and with Caltrans support and monitoring were used to integrate a cost comparison between DSHA and PSHA spectral acceleration values for different regions of California as well as statewide.

Paper Abstracts

1A3: Emerging Design & Retrofit Technologies

Moderated by Daniel Tobias, Illinois Department of Transportation

Paper A11

Seismic Design of Floating Bridges

Michael J. Abrahams, Parsons Brinckerhoff Quade & Douglas, Inc.

This paper will discuss the seismic design of two floating bridges. The Hood Canal Bridge is a 1.5-mile long concrete floating bridge. The bridge includes a 600-foot-long draw span to allow passage of vessels through a navigation channel to Bangor Naval Base. Currently, the East Half is being replaced, based on plans that were prepared at the same time as those for the West Half replacement and then recently updated. The approximately 1-mile-long Ford Island (Admiral Clarey) Bridge, is comprised of a 3,638-foot-long pile-supported fixed bridge element and a 1,035-foot-long movable element, and provides two 12-foot-wide traffic lanes, two 8-foot-wide shoulders/bikeways, and a 4-foot-wide sidewalk. A 930-foot-long retractable floating draw span provides a 650-foot-wide navigational channel for large ships. A 100-foot-wide small boat channel with a 30-foot vertical clearance is located east of the draw span. Both bridges were designed for seismic events.

Paper A12

Seismic-Resistant Connections for Prefabricated Segmental Bridge Columns

Yu-Chen Ou, Department of Civil, Structural and Environmental Engineering, University at Buffalo, State University of New York; Ping-Hsiung Wang, National Center for Research on Earthquake Engineering, Kuo-Chun Chang, National Taiwan University, and George C. Lee, Department of Civil, Structural and Environmental Engineering, University at Buffalo, State University of New York

Prefabricated bridge construction has recently gained increased attention in the United States. The advantages of using prefabricated bridge construction include accelerating bridge construction, minimizing traffic disruption, lessening the environmental impact, improving safety in work zones and decreasing the life-cycle cost of bridges. However, the use of segmental bridge columns is very limited in regions of high-seismicity such as the state of California. One of the main reasons is the lack of design information to ensure the seismic resistance of connections between two precast units. This paper describes a joint project between the Multidisciplinary Center for Earthquake Engineering Research (MCEER), University at Buffalo, and the National Center for Research on Earthquake Engineering (NCREE), National Taiwan University, on the development of seismic-resistant connections in precast segmental bridge columns. The analytical study carried out at MCEER, funded by FHWA, identified several critical parameters. These parameters were used as the basis for the design of a series of connection tests conducted at NCREE.

Paper A13

Proof-of-Concept Testing and Finite Element Modeling of Self-Stabilizing Hybrid Tubular Links for Eccentrically Braced Frames

Jeffrey W. Berman and Michel Bruneau, Department of Civil, Structural and Environmental Engineering, University at Buffalo, State University of New York

This paper describes the design, testing, and finite element modeling, of a proof-of-concept eccentrically braced frame specimen utilizing a hybrid rectangular shear link. The link is self-stabilizing and does not require lateral bracing, making it suitable for use in steel bridge piers where lateral bracing can be difficult to provide (building applications are possible as well). Equations used for design are given and references for their derivations are provided. The quasi-static cyclic testing is described, and results are reported and compared with a finite element model to be used as the basis for a future parametric study. Stable and full hysteretic loops were obtained and no signs of flange, web, or lateral torsional buckling were observed. The link was subjected to 0.15 radians of rotation in the final cycle, which is almost twice the maximum rotation allowed in building codes for links with I-shaped cross-sections. Although the final failure mode was fracture of the bottom link flange, the large rotations achieved were well above what would be required in a seismic event, indicating that hybrid rectangular links without lateral bracing of the link can indeed be a viable alternative for applications in steel bridge piers in seismic regions.

1B3: Effects of Near-Field Earthquake on Bridges

Moderated by Hamid Ghasemi, Federal Highway Administration

Paper B11

An Overview of the Project of Next Generation of Ground Motion Attenuation Models for Shallow Crustal Earthquakes in Active Tectonic Regions

Brian Chiou, Division of Research and Innovation, California Department of Transportation; Maurice Power, Geomatrix Consultants; Norman Abrahamson, Pacific Gas and Electric Company; and Clifford Roblee, NEES Consortium Inc.

The "Next Generation of Ground Motion Attenuation Models" (NGA) project is a partnered research program conducted by Pacific Earthquake Engineering Research Center-Lifelines Program (PEER-LL), U.S. Geological Survey (USGS), and Southern California Earthquake Center (SCEC). The project has the objective of developing updated ground motion attenuation relationships through a comprehensive and highly interactive research program. Five sets of updated attenuation relationships are developed by teams working independently but interacting throughout the development process. The main technical issues being addressed by the NGA teams include magnitude scaling at close-in distances, directivity effects, polarization of near-field motion (fault-strike-normal component vs. fault-strike-parallel component), nonlinear amplification by shallow soil, and sedimentary basin amplification. The attenuation relationships development is also facilitated by the development of an updated and expanded database of recorded ground motions; conduct of supporting research projects to provide constraints on the selected functional forms of the attenuation relationships; and a program of interactions throughout the development process to provide input and reviews from both the scientific research community and the engineering user community. An overview of the NGA project components, process, and products developed by the project is presented in this paper.

Paper B12

Effects of Near-Fault Vertical Ground Motions on Seismic Response of Highway Bridges

Emrah Erduran, Zeynep Yilmaz, Sashi Kunnath, Norm Abrahamson and Y. H. Chai, University of California, Davis; and Mark Yashinsky and Li-Hong Sheng, California Department of Transportation

Preliminary findings from an ongoing research study that systematically characterizes ground motion parameters and investigates the effects of near-fault vertical accelerations on the overall response of typical highway bridges will be presented. Nonlinear simulation models with varying configurations of an existing bridge in California are considered in the analytical study. A comprehensive set of ground motions with horizontal PGA in excess of 0.5g and recorded within 15 km from the nearest fault were selected from the PEER NGA (Next Generation Attenuation) project. The selected ground motions are classified by source mechanism, fault distance, vertical to horizontal acceleration ratios, and other relevant ground motion measures. The simulation models were subjected to the selected ground motion set in two stages: at first, only horizontal components of the motion were applied; while in the second stage the structures were subjected to both horizontal and vertical components applied simultaneously. Important response measures were monitored to gain an insight into the effects of vertical acceleration on the inelastic response of typical ordinary standard bridges. The analytical simulations will provide a basis for investigating features of the ground motion that most significantly contribute to adverse effects from vertical accelerations. Findings from the study will contribute to the development of revised guidelines to address vertical ground motion effects, particularly in the near fault regions, in the seismic design of highway bridges.

Paper Abstracts

Paper B13

Selection of Forward-Directivity Motions for Non-Linear Analyses of Bridges

Joanna L. Gillie, HWA GeoSciences Inc.; Adrian Rodriguez-Marek, Department of Civil and Environmental Engineering, Washington State University; and Cole C. McDaniel Architectural Engineering Department, California Polytechnic State University

Seismic design of structures located close to the causative fault of earthquakes must account for special characteristics of ground motions in the near-fault region, including forward-directivity (FD) effects. Most of the energy in FD motions is concentrated in a narrow frequency band and is expressed as one or more high intensity velocity pulses. Seismic design of bridges generally includes nonlinear time-history analyses, requiring selection of a suite of input time histories. Given that FD motions have special characteristics, it is recommended that the suite of motions include FD motions. Design time histories are generally obtained by modifying recorded time histories through spectral matching to fit the equal hazard spectra (EHS), which is controlled by both near-fault earthquakes and far-field earthquakes for a bridge close to a fault. However, spectral matching on FD motions could lead to the generation of unrealistic time histories. This work presents an alternative method for selecting time histories for design at sites where hazard is controlled by near-fault and far-field earthquakes. The process involves a probabilistic approach for far-field motions, and a deterministic approach for selecting appropriate FD motions. The process is illustrated through the selection of design ground motions for a bridge close to the Seattle fault in Washington State.

Paper Abstracts

2A1: Design & Analysis of Major Bridges

Moderated by Stephen Maher, Transportation Research Board

Paper A14

Geotechnical Earthquake Engineering Experience from Seismic Retrofit and New Design Projects of Major Toll Bridges in California

Hubert K. Law and Ignatius Po Lam, Earth Mechanics, Inc.

This paper discusses the writers' experience on geotechnical earthquake engineering issues from the seismic retrofits of existing toll bridges and the designs of new long span bridges in California. The discussion includes some of the pitfalls observed during the early stage of vulnerability assessment and the eventual improvements made during the final PS&E stage. The subjects consist of seismic ground motion development, site response analysis, and foundation modeling techniques utilizing soil-structure interaction. The lessons learned from the earlier seismic retrofit program paved the way for the designs of new major bridges, including the East Span San Francisco – Oakland Bay Bridge, the New Carquinez Bridge, the New Benicia – Martinez Bridge, and the New Gerald Desmond Bridge.

Paper A15

Analytical Assessment of a Major Bridge in the New Madrid Seismic Zone

Amr Elnashai, Aman Mwafy and Oh-Sung Kwon, Mid-America Earthquake Center, University of Illinois at Urbana-Champaign

A comprehensive study is underway at the Mid-America Earthquake (MAE) Center to assess the seismic response of an existing major bridge, considering soil-structure interaction. The Caruthersville Bridge on the I-155 has 59 span of total length 7100 feet and was built in the early seventies across the Mississippi River between Missouri and Tennessee. The site is in the vicinity of the New Madrid central fault, at a distance of about 5 km from a presumed major fault. Detailed three-dimensional dynamic response simulations of the entire bridge including Soil-Structure Interaction (SSI) effects are undertaken using several analytical platforms. The finite element analysis programs SAP2000 and ZEUS-NL (the Mid-America Earthquake Center analysis platform) are employed for elastic and inelastic analysis of the structure, respectively. The Pacific Earthquake Engineering Research (PEER) Center analysis platform OpenSees is used for an inelastic simulation of the foundation and the underlying sub-strata. The SSI analysis is a key element in the current study due to the length of the bridge, the massive and stiff foundation and the relatively soft deep soil underlying the site. The comprehensive hazard study, the realistic modeling approach and the advanced analytical tools employed in the assessment enable the identification of areas of vulnerability in the bridge and assessment of its response with a number of retrofitting schemes. The state-of-the-art simulation methodologies described in the paper help in bringing the most recent research outcomes to support practice and to improve public safety.

Paper A16

Seismic Analysis and Design of a Multi-Span Bridge in a Region of High Seismicity using SCDOT Seismic Specifications

Amos Liu and William Stiller, Ralph Whitehead Associates; and Lucero Mesa, South Carolina Department of Transportation

The Fantasy Harbour Bridge located in Myrtle Beach SC, incorporated several details to create a structure highly resistant to seismic damage. The structure location is near Charleston SC, the most seismically active region on the east coast. The bridge consists of 12 spans with a total bridge length of 1800'. It is a high-level bridge with an 870', 3-span haunched steel girder span over the Intracoastal Waterway. The remainder of the spans feature 72" prestressed concrete girders. The substructure consists of pile footings for all of the bents of the approach regions. A combined drilled shaft footing is used for the main channel unit. The bridge is designed using *2001 SCDOT Seismic Design Specifications of Highway Bridges*. The bridge is classified as critical bridge and assigned seismic performance category D. Features incorporated to ensure high seismic performance include: shear keys, seismic restrainers, joint shear reinforcement, butt-welded hoops, ultimate mechanical couplers, and combined drilled shaft footings. Structural steel shear keys were detailed for the haunched plate girder spans to prevent unseating in the transverse direction. Four, 40'-0" long seismic restrainers, each with 4 – ¾" diameter cables were used at the expansion bents to minimize out of phase movement in the longitudinal direction. Additional joint reinforcing was required around the column to cap connection to fully develop the plastic hinge moment. Ultimate mechanical couplers and butt welded hoop reinforcement is required by the SCDOT to ensure high plastic rotation capacity in the plastic hinge regions of the columns.

Paper A17

Collapse Simulation of RC Frame under Earthquakes. II: Verification Studies - Collapse of Cypress Viaduct

Yan Zhou, Leiming Zhang and Xila Liu, Shanghai Jiao Tong University

A new modeling scheme for collapse analysis of RC Frames is outlined in Part I. In this part, the results from collapse analysis of the Cypress Viaduct under the Loma Prieta Earthquake are summarized to establish the validity of the new modeling scheme. Considering general similarities in soil conditions and proximity, the ground motion records obtained at Emeryville are chosen. Real material parameters are also collected as the input. The simulated collapse process showed that during ground movement, it was the failure of the pedestals that triggered the collapse of the viaduct, which is consistent with damage observation and speculation from the EERC, UC Berkeley.

2B1: Soil-Structure Interaction & Foundations

Moderated by Lucero Mesa, South Carolina Department of Transportation

Paper B14

Seismic Energy Dissipation by Foundation Rocking for Bridge SFS Systems

Bruce Kutter, Boris Jeremic, Jose Ugalde, Sivapalan Gajan and George Hu, Department of Civil and Environmental Engineering, University of California Davis

Bridge structures residing on competent soil are typically designed with rectangular spread footings that are sufficiently proportioned to allow for a fixed base response. This generally leads to inelastic behavior in the column during moderate to large earthquakes. This mode of behavior dissipates input energy, but results in damage to the column. Consideration of rocking or uplift of the bridge pier foundation on the supporting soil introduces other modes of nonlinearity and energy dissipation. Soil inelasticity combined with uplift can reduce demands on the bridge structure, effectively acting as an isolation mechanism. We present a collaborative effort involving numerical and physical modeling and simulations of foundation rocking for bridge structures. In particular, a number of numerical models as well as scaled model tests on a geotechnical centrifuge at UC Davis are used to gain better understanding of the problem of rocking. This paper focuses on the results of the numerical and physical modeling and simulations involving the footing and soil beneath.

Paper B15

Three-Dimensional Nonlinear Finite-Element Soil-Abutment Structure Interaction Model for Skewed Bridges

Anoosh Shamsabadi, Office of Earthquake Engineering, California Department of Transportation; Mike Kapuskar, Earth Mechanics, Inc.; and Amir Zand, Department of Civil Engineering, University of Southern California, Los Angeles

The nonlinear backfill response of wide highway bridge abutments is commonly analyzed as a two-dimensional plane-strain lateral earth pressure problem. In common abutment design practice, the abutment load-deformation relationship due to passive resistance is based on load test data or presumptive values for a wall pushed normal to the soil. However, the lateral force-displacement capacity behind a skewed wall is a three-dimensional problem involving deck rotation during dynamic loading. The soil resistance and stiffness for the skewed wall is expected to be smaller than for the non-skewed wall due to deck rotation. The mobilized passive resistance depends on wall displacement, bridge geometry (skew angle, deck width and height), soil stress-strain properties, and ground motion characteristics. A three-dimensional model is required to capture the geometry and capacity of the full soil wedge behind the skewed wall. This paper presents 2D and 3D models of a normal and skewed bridge abutment incorporating the nonlinear soil-displacement capacity of the passive wedge which is compared with results from a field wall load test in typical structure backfill. The force-displacement relationship can be used to evaluate the seismic performance of skewed bridges. A global 3D model of a skewed bridge is presented to demonstrate the interaction between deck, abutment and soil.

Paper B16

Comparison of Direct Method Versus Substructure Method for Seismic Analyses of a Skewed Bridge

Anoosh Shamsabadi, Office of Earthquake Engineering, California Department of Transportation; Hubert Law, Earth Mechanics, Inc.; and Geoffrey R. Martin, Department of Civil Engineering, University of Southern California

Numerical methods used for seismic Soil-Foundation-Structure Interaction of highway bridge structures can be classified into direct approach and substructure approach. In the direct approach, nonlinear soil and foundation behaviors are explicitly included in the global model to account for geotechnical and structural behavior of the pile foundation. The computational effort required for the direct analysis is very high and not economical in some cases. The substructural approach divides the system into two subsystems, a superstructure which includes the bridge columns, bridge deck and bridge abutments and a substructure which includes the pile foundation and the surrounding soil media. The substructure approach is more efficient. The objective of this paper is to compare the result of the direct approach vs. substructure approach. A three dimensional fully coupled superstructure-pile foundation nonlinear finite element model is developed to evaluate seismic response of a two-span skew bridge for the direct model. Shell elements are used to represent bridge deck and beam elements are used to represent the bridge columns and pile foundation with the crack section properties. To simulate earthquake excitations, real earthquake acceleration records are used as input ground motion acceleration time histories. Static condensation is used to develop foundation stiffness matrix and kinematic motion for the substructure approach.

Paper B17

Passive Force-Deflection Relationships from Full-Scale Tests

Kyle M. Rollins, Civil Engineering Department, Brigham Young University; and R.T. Cole, IGES, Inc.

Cyclic passive force-deflection relationships were measured in a series of tests on a full-scale pile cap and compared with existing theories. The pile cap was 3.67 ft high, 17 ft wide and 10 ft deep and was supported by 12 concrete-filled driven steel pipe piles with a 12.75 inch outside diameter. Four different soils (sand, silty sand, fine gravel and coarse gravel) were selected as backfill in front of the pile cap. The backfills were compacted to between 92 and 95% of the modified Procter maximum density. Tests were conducted with and without backfill to isolate the contribution from passive resistance. Load was applied incrementally and fifteen cycles of loading were applied at each deflection increment. The log spiral theory provided the best agreement with the measured passive resistance. The Rankine theory significantly underestimated the resistance while the Coulomb theory generally overestimated the resistance. The displacement necessary to mobilize the maximum passive force ranged from 3.0 to 5.2% of the cap height. A hyperbolic model provided the best agreement with the measured monotonic passive force-deflection curves and was superior to procedure recommendations by Caltrans and the U.S. Navy. However, this model overestimated the passive resistance for cyclic loading conditions due to backfill stiffness degradation and the formation of a gap between the pile cap and backfill. Based on the test results, a cyclic hyperbolic model was developed to define load-deflection relationships for both virgin and cyclic loading conditions with the presence of a gap.

Paper B18

Nonlinear Seismic Soil-Abutment-Structure Interaction Analysis of Skewed Bridges

Anoosh Shamsabadi, Office of Earthquake Engineering, California Department of Transportation; Mike Kapuskar, Earth Mechanics, Inc.; and Geoffrey R. Martin, Department of Civil Engineering, University of Southern California

This paper investigates the impact of the bridge skew angle on the force-deformation characteristics of abutments and seismic bridge response. Three-dimensional models of a two-span box girder bridge were developed with 0, 25, 45 and 60-degree skew. Abutment-soil interaction was modeled by normal springs skewed to the principal bridge axis and a hyperbolic force-displacement (HFD) relationship. Nonlinear time-history analyses were performed using nine ground motions with two lateral components incorporating near-fault effects. The analyses show that the abutment-soil interaction causes seismic bridge behavior to become more complex with increasing skew. The superstructure undergoes significant rotations about the vertical axis that result in permanent lateral deck offset at the abutments. Deck rotation is due to asymmetric passive soil reactions between the acute and obtuse corners of the abutment wall. Seismic bridge behavior is strongly influenced by ground motion characteristics. The magnitude of permanent rotation and lateral offset varied among all motions with no discernable trend in regards to skew angle. This strongly suggests that bridges with significant skew should be analyzed using motions with both horizontal components and several earthquake records should be considered to capture the behavior of structure details such as pads and shear keys that affect overall bridge response.

Paper Abstracts

2A2: Instrumentation & Monitoring Systems

Moderated by Robert Stott, California Department of Transportation

Paper A18

Real-time, State-of-the-Art Seismic Monitoring of the Integrated Cape Girardeau Bridge Array, Data and Analyses

Mehmet Çelebi, Earthquake Hazards Team, U.S. Geological Survey

The cable-stayed New Cape Girardeau (MO) Bridge is approximately 80 km from the epicentral region of the 1811–1812 New Madrid earthquakes and is designed for the possibility of a strong earthquake (magnitude 7.5 or greater). The seismic instrumentation system, implemented in cooperation with Federal Highway Administration (FHWA), Multidisciplinary Center for Earthquake Engineering Research (MCEER) and Missouri Department of Transportation (MoDAT), integrates subarrays on the superstructure, pier foundations and the free-field (both surface and downhole) of the 1206 m (3956 ft) span of bridge. The 84-channel system records, streams, transmits and broadcasts synchronized real-time data via the internet, the signals from combinations of uniaxial and tri-axial accelerometers. Data recorded at the bridge during an earthquake (Mw=4.1) that occurred in Manila, Arkansas at an epicentral distance of 175 km, analyzed to identify unique dynamic characteristics that also dispalys the traveling of the seismic waves from downhole through the foundations to the superstructure. The interaction of the cables in defining the response of the deck and towers are clearly evident The response data obtained from the bridge during earthquakes is aimed to better design future similar bridges, and identify possibilities for health monitoring of the bridge.

Paper A19

Lateral Deformation Capacity of Concrete Bridge Piers

Sungjin Bae and Oguzhan Bayrak, Department of Civil, Architectural and Environmental Engineering, University of Texas at Austin

In this paper, the derivation of a simple closed-form equation based on the lateral load response of reinforced concrete columns due to the P-effect is presented. To investigate the validity of this simple expression in predicting the lateral drift capacity of concrete bridge piers, results from a large number of concrete column tests are collected from the UW/PEER column database for rectangular and circular column sections. The predicted drift capacities of the concrete columns tested by various researchers are compared with the experimentally-obtained drift capacities. This comparison shows that the use of a simple expression developed in this research provides conservative estimates for the lateral deformation capacity of reinforced concrete columns. As such, this expression is recommended for use in seismic design of reinforced concrete bridge piers.

Paper A20

Caltrans / CGS Downhole Geotechnical Arrays

Pat Hipley, California Department of Transportation; and Anthony Shakal and Hamid Haddadi, CSMIP, California Geological Survey

Structural engineers rely on the knowledge gained by the geotechnical earthquake engineering and the seismological communities to predict how the base of a structure and its associated pile foundation will react to large seismic events. Recording subsurface movement, which is currently sparse, is invaluable to seismologists and earthquake engineers in determining soil dynamic properties and to accurately predict ground motions. For the last twelve years, Caltrans has been working with the California Geological Survey (CGS) to install downhole accelerometers at various depths to record subsurface soil and rock motions caused by earthquakes. There are currently 16 sites up and running and many more planned for the near future. These sites are spread throughout the state and range from soft soil sites to weathered rock sites. The data will be used to verify and calibrate geotechnical analytical modeling techniques. Most of the sites have the deepest sensors at a few hundred feet down but some locations have sensors as deep as 800 feet. With more sites coming on line, the likelihood of having a downhole array near an earthquakes epicenter is better realized.

Paper A21

Seismic Instrumentation at the I-40 Bridge in Memphis, Tennessee

Shahram Pezeshk, Department of Civil Engineering, University of Memphis; and Mitch Withers, Center for Earthquake Research and Information, University of Memphis

The purpose of this paper is to describe the development and installation of a seismic instrumentation system that has been proposed to be deployed on and in the vicinity of the I-40 Hernando DeSoto Mississippi River Bridge in Memphis, Tennessee. This bridge has been retrofitted to withstand a magnitude (m_b) 7 event at 65 km distance from the site with a depth of 20 km. The goal of the retrofit is to have this bridge fully operational following the maximum probable earthquake (2500 year return period). As part of the I-40 bridge retrofit, Friction Pendulum™ Isolation Bearings will be used to insure the integrity of the main spans of the bridge. Currently, in the United States and elsewhere in the world, there is very little data available on the response of long-span bridges during seismic events. Since such data are scarce, our ability to understand the behavior of such structures and to verify dynamic analyses performed on such structures during design/analyses/retrofit phases is limited. Data collected from instrumentation of the I-40 Bridge in Memphis will be an invaluable asset in evaluating the structure. The data will be used to assess the performance of the bridge following the retrofit and in particular for the assessment of the performance of the base-isolation system that will be used in the retrofit project.

Paper A22

ShakeCast: Facilitating the Use of ShakeMap for Post-Earthquake Decision-Making and Response within Caltrans and other Critical Lifeline Communities

David J. Wald and Kuo-Wan Lin, National Earthquake Information Center, U.S. Geological Survey; Bruce Worden, U.S. Geological Survey; and Loren Turner, Division of Research & Innovation, GeoResearch Group, California Department of Transportation

ShakeMap is a tool used to portray the extent of potentially damaging shaking following an earthquake. ShakeCast, short for ShakeMap Broadcast, is a fully automated system for delivering specific ShakeMap products to critical users, generating maps, and triggering established post-earthquake response protocols. ShakeCast allows utilities, transportation agencies, and other large organizations to automatically determine the shaking value at their facilities, set thresholds for notification of damage states (typically: damage unlikely, possible, or likely) for each facility, and then automatically notify (via pager, cell phone, or email) specified operators, inspectors, etc., within their organizations who are responsible for those particular facilities so they can prioritize response. For example, Caltrans uses ShakeCast to provide an instantaneous snapshot of the likelihood of damage to each bridge and overpass, allowing them to prioritize inspections following a damaging event. Caltrans evaluates potential impact using ShakeMap's 1- and 3- Hz response spectral acceleration values, in conjunction with well-established vulnerability functions based on National Bridge Inventory (NBI) structural characteristics. Highway and bridge transportation engineers can best take advantage of the ShakeCast system since they are concerned about numerous facilities and typically have knowledge of the seismic vulnerability of their structures. ShakeCast will provide visualization tools showing both the distribution and likely damage states of the users structures, allowing rapid mapping, analyses, and reconnaissance and response planning.

PAPER ABSTRACTS

2B2: LIQUEFACTION & MITIGATION STRATEGIES

MODERATED BY E.V. LEYENDECKER, US GEOLOGICAL SURVEY

Paper B19

Lateral Response of Isolated Piles in Liquefied Soil with Lateral Soil Spreading

Mohamed Ashour, Department of Civil Engineering, West Virginia University Institute of Technology; Gary Norris, Department of Civil Engineering, University of Nevada Reno; and JP Singh, JP Singh and Associates

This paper provides a new analysis procedure for assessing the lateral response of an isolated pile in saturated sands as liquefaction and lateral soil spread develop in response to dynamic loading such as that generated during earthquake shaking. The phenomenon of lateral soil spread and its impact on deep foundations is still under investigation via lab and field testing. The analysis of piles in liquefied soils with lateral soil spread carries a number of challenging issues such as the evaluation of the driving force exerted by crust layer(s), the mobilized strength of the liquefied soil, and the amount of lateral soil displacement developed during the phase of lateral spread. The analytical and empirical concepts employed in the Strain Wedge model technique allow the extension of this technique to handle the sophisticated phenomenon of the lateral soil spreading that could accompany or follow the occurrence of seismic events. As a result, the p-y curve of liquefied soil with lateral spreading can be assessed based on soil and pile properties and the characteristics of the seismic event. The amount of soil lateral spreading can also be calculated to provide a representative p-y curve without using modifying parameters or shape corrections.

Paper B20

Evaluation of Methods for Analyzing the Seismic Response of Piles Subjected to Liquefaction-Induced Loads

S.R. Rajaparthy and T.C. Hutchinson, Department of Civil and Environmental Engineering, University of California Irvine

Observations from past earthquakes have shown that lateral spreading or liquefactdion induced ground movement results in undesirable excessive movements and potential failure of the below ground portion of a pile foundation. This study reviews current design methods and mechanisms involved in the response of pile foundations when subjected to liquefaction-induced loads and displacements. A case study pile foundation is evaluated for its response to inertial and kinematic loading, considering different soil conditions: homogenous sand, homogeneous liquefiable sand, layered liquefiable sand, and a stiff crust overlying liquefiable layers. Soil-pile performance is evaluated using LPILE, considering nonlinear pile behavior. Liquefaction behavior is modeled using different simplified design methods: p-y reduction factors, liquefaction induced ground displacements, and lateral earth pressures from the liquefied layers (JRA guidelines). Results are evaluated in terms of nondimensional plastic hinge length and nondimensional depth of maximum moment. Comparison of these methods sheds light on the variability of local response and the need for validation against test data, where the nonlinearity of the pile and soil are considered under earthquake-induced liquefaction demands.

Paper B21

Numerical Simulation of Soil-Foundation Interaction Subjected to Lateral Spreading

Yohsuke Kawamata, Scott A. Ashford, and Teerawut Juirnarongrit, Department of Structural Engineering, University of California San Diego

Two full-scale tests using controlled blasting were performed at the Port of Tokachi on Hokkaido Island, Japan to estimate the behavior of single pile, 4-pile group, and 9-pile group subjected to lateral spreading during liquefaction. From these experiments, the moment profiles along the piles, free field ground displacements, pile cap rotations and relevant information are available. In these tests, the pile behavior subjected to lateral spreading was obviously dependent on the permanent ground deformation. Previous research by the authors showed that pushover analyses using an equivalent single pile model could provide reasonable results for the overall behavior of pile group. However, due to the limitation of the 1-D model, it could not be used to explain the behavior of individual piles in the group and how they interact. Therefore, analyses using a 2-D pile group model were conduced to gain a better understanding of the behavior of individual piles in the group. OpenSees, developed by UC Berkeley, was used in this study. This paper presents the results of the numerical study of 2-D model using OpenSees, and compares experimental and numerical results of an equivalent single pile model.

Paper B22

A Probabilistic Design Procedure that Incorporates the Pile-Pinning Effect in Bridge Foundations Undergoing Liquefaction-Induced Lateral Spreading

Christian Ledezma and Jonathan D. Bray, Department of Civil and Environmental Engineering, University of California, Berkeley

Liquefaction-induced lateral spreading has caused significant damage to a number of bridge structures during past earthquakes. Ground displacements due to lateral spreading can impose large forces on the bridge superstructure and large bending moments in the laterally displaced piles, which may lead to severe damage or collapse of the bridge structure. Ground improvement is a viable strategy to reduce liquefaction hazard, however it may be difficult and costly at some sites, and it may not be necessary if the piles can be designed to withstand the displacement and forces induced by the lateral spreading. Piles may actually "pin" the upper layer of soil that would normally spread atop the liquefied layer below it into the stronger soils below the liquefiable soil layer, which is known as the "pile-pinning" effect. Piles have been designed as "pins" across liquefiable layers in a number of projects, and this design methodology was standardized in the MCEER/ATC-49-1 document. A number of simplifying assumptions were made in developing this practical design procedure, and several of these assumptions warrant re-evaluation. In this paper, some of the key assumptions adopted in MCEER/ATC-49-1 are critiqued, and a simplified probabilistic design framework is proposed for the evaluation of the effects of liquefaction-induced lateral spreading on bridges. Primary sources of uncertainty are incorporated in this framework with the intention of developing a procedure that is compatible with the Performance-Based Earthquake Engineering framework.

Paper B23

Liquefaction Mitigation using Stone Columns and Wick Drains for Utah Bridges

Kyle M. Rollins, Dept. of Civil & Environmental Engineering, Brigham Young University; Bradford Price, RBG Engineering; Emily Dibb, Dept. of Civil & Environmental Engineering, Brigham Young University; and Jim B. Higbee, Utah Dept. of Transportation

Stone column treatment is very common for mitigating liquefaction hazard. Although this approach is effective for clean sands, experience suggests that little improvement will be achieved when the fines content exceeds 20%. However, this paper presents two cases where sands having high fines contents were successfully compacted using stone columns. One case, with an average fines content of about 50%, required the use of pre-fabricated vertical wick drains, while a site with about 30% fines did not. In both cases, the soils were either non-plastic or had very low plasticity and clay content (<5%). Liquefaction analyses established the penetration resistance criteria as a minimum $(N_1)_{60\text{-}cs}$ of 25 with an average $(N_1)_{60\text{-}cs}$ of 30. Treatment without drains was generally effective but required secondary columns in some cases which increased the cost. At the site with 50% fines, wick drains were installed at a spacing of 2 m on centers prior to installation of stone columns. During installation, water exiting the wick drains up to 6 m away from the installation point. Pre- and post-mitigation borings were used to directly evaluate improvement and fines content. In all but two cases, the measured penetration resistance exceeded required minimums and the average $(N_1)_{60\text{-}cs}$ increased from 17 to 33, an increase of 94%. Improvement compared well with USBR experience at Salmon Lake Dam where wick drains were used with stone columns in sands with high fines content. However, the improvement was still about half of that obtained in clean sands without drains.

Paper Abstracts

2A3: Lessons Learned from Recent Earthquakes

Moderated by Arun Shirole, Arora Associates

Paper A23

Seismic Response of the Hwy 46/Cholame Creek Bridge During the 2004 Parkfield Earthquake

Tom Boardman, Kleinfelder, Inc.; and Anthony V. Sanchez, T.Y. Lin International

On September 28, 2004 a magnitude 6.0 earthquake occurred along the San Andreas Fault near Parkfield, California. Peak horizontal accelerations of 1.0g and absolute displacements of 4 inches were measured on a reinforced concrete slab bridge located 4 miles from the rupture zone. The California Geologic Survey (CGS) had installed six strong motion accelerometers on the bridge, and one free-field accelerometer east of the bridge, prior to the earthquake. Ground motions resulted in longitudinal soil displacements in front of the abutments and around the bent piles due to the structure swaying back and forth. Structural damage consisted of diagonal cracking of the northern wing wall, cracking around the bent piles at the bridge deck connection, and transverse cracking through the asphalt concrete at each bridge approach. Caltrans inspected the bridge after the earthquake and concluded that the damage was not serious and repairs were not necessary. The seismic response of the bridge was studied under a grant from the CGS, Strong Motion Instrumentation Program (CSMIP). Based on our displacement analyses, we found that using the current Caltrans seismic design approach resulted in a close match with the measured bridge displacements during the 2004 seismic event.

Paper A24

Lessons Learned from the Seismic Retrofit of the Posey and Webster Street Tubes in Alameda County, California

Thomas S. Lee, Parsons Brinckerhoff Quade & Douglas, Inc.; and Randy Anderson, and Rod Murray, California Department of Transportation

The Posey Tube and the Webster Street Tube link the cities of Oakland and Alameda via the Oakland Estuary. Both tubes are located in a seismically active area between the Hayward Fault and the San Andreas Fault. Although the Tubes sustained only minor damage during the Loma Prieta Earthquake in 1989, the California Department of Transportation (Caltrans) included these vital transportation facilities in its seismic retrofit program. In 1995, Parsons Brinckerhoff Quade & Douglas (PBQD) was retained by Caltrans to prepare and develop a seismic retrofit Plan/Specification/Estimate (PS&E) package for the Tubes. The primary seismic retrofit consisted of jet grout columns and pipe pile stone columns respectively at both sides of the Posey and Webster Street Tubes. These ground improvement methods are the first of their kind ever applied to any immersed tubes of such length. This paper will discuss the seismic retrofit employed, the lessons learned during construction of the jet grout columns, installation of the pipe pile stone columns, and the lessons learned from this entire project.

Paper A25

Post Seismic Inspection and Capacity Assessment of Reinforced Concrete Bridge Columns

Marc J. Veletzos, Marios Panagiogou and Jose I. Restrepo, Department of Structural Engineering, University of California, San Diego; and Stephen Sahs, Office of Structure Maintenance and Investigation, California Department of Transportation

California has experienced several moderate size earthquakes in the last 30 years, yet the Office of Structures Maintenance and Investigation at Caltrans does not have a standard procedure or a training program for the assessment of damage and the determination of the remaining load capacity of earthquake damage reinforced concrete (RC) bridge elements. In order to develop a standard procedure and training program, a Visual Bridge Catalog has been developed that documents damage from laboratory experiments and from historic earthquakes and classifies the performance of an array of bridge components, sub-assemblages, and systems in a consistent format. Results from the evaluation of numerous case studies using this damage/performance approach has lead to the formulation of Training and Inspection Manuals to aid in post-earthquake visual inspection of reinforced concrete bridges. In addition to these manuals and the visual catalog, an online computer based training class has been developed to easily communicate this information to Caltrans Maintenance and Inspection Engineers. This paper presents excerpts of the Visual Catalog, summarizes the Training and Inspection Manuals, and outlines the damage assessment and load capacity determination procedures for earthquake induced damage to reinforced concrete bridge columns.

Paper A26

Study on the Seismic Settlement of the Alaskan Way Viaduct after the February 28, 2001 Nisqually Earthquake

Hongzhi Zhang, Bridge and Structures Office, Washington State Department of Transportation

The Alaskan Way Viaduct is a two and a half mile long structure along Elliott Bay in the busy Seattle downtown area. The daily traffic on the viaduct is approximately 100,000 vehicles. The viaduct is a complex structure with 183 bents. The northern third of the viaduct (Bents 1-53) consists of two, single-deck structures that were designed in 1950. The viaduct then transitions to a double-deck configuration (Bents 53-121) also designed in 1950. The double-deck southern third of the viaduct (Bents 121-183) was designed in 1956. Immediately after the Nisqually earthquake (M=6.8, February 28, 2001), five to six inches of seismic settlement was reported at Piers 98 and 99. However no visible cracks or damage on the longitudinal edge girders were observed. A Finite Element study suggested a possible construction error in the 1950's as opposed to a seismic settlement. One year after the earthquake, the pile foundations of Piers 93 and 94 suddenly started settling and the settlement was recorded by the monitoring system of the Alaskan Way Viaduct. After ten months, the progressive settlement stabilized. The total settlement was four inches. Progressive cracks on the edge girders in the adjacent area were also observed during the ten months of settlement. In order to determine what triggered the settlements, a PUSHOVER analysis (in vertical direction) was performed. The study concluded that the four inch settlement was the result of the approximate 30% bearing capacity losses of the pile foundations at Piers 93 and 94 during the earthquake. The study predicted at what settlement level the edge girders would collapse if the settlement continued. The study also explained why the settlement started one year after the earthquake but stabilized within ten months.

2B3: Emerging Design & Retrofit Technologies

Moderated by Genda Chen, University of Missouri Rolla

Paper B24

Damping-Enhanced Seismic Strengthening of RC Columns for Multiple Performance Objectives

Genda Chen and Kazi R. Karim, Department of Civil Engineering, University of Missouri Rolla

Constrained viscoelastic (VE) layers with their constraining layer anchored into the footing of a column or a bent cap was recently proposed by the authors. This paper is focused on the analytical derivation of VE layer effects on circular column responses and modeling of the VE layers with discrete springs in the finite element model of a highway bridge. The effect of single versus double curvatures on the damping effect was investigated in detail using the out-of-plane and in-plane motions of a three-column bent that represents a three-span regular highway bridge in the New Madrid Seismic Zone. The numerical solutions from the proposed finite element model are in excellent agreement with the analytical results. Based on the numerical studies on full-scale columns, a VE layer covering the lower 40% of three columns of the bent can reduce the out-of-plane acceleration and displacement of the column by 44% and the in-plane responses by approximately 40%. In comparison with the retrofit scheme at both ends of the columns, retrofitting one end of the columns with the same 40% VE coverage can further reduce the elastic response from 25% to 40%.

Paper Abstracts

Paper B25

Use of Partially Prestressed Reinforced Concrete Columns to Reduce Post-Earthquake Residual Displacements of Bridges

Stephen Mahin, University of California, Berkeley; Junichi Sakai, Public Works Research Institute; and Hyungil Jeong, University of California, Berkeley

To minimize residual displacements in reinforced concrete columns, a design is proposed whereby a longitudinal post-tensioning tendon replaces some of the usual longitudinal mild reinforcing bars. The seismic performance of such partially prestressed, reinforced concrete columns is investigated through a series of earthquake simulator tests. The effects of unbonding of longitudinal mild reinforcement and providing a steel jacket are also investigated. The partially prestressed, reinforced concrete columns studied perform remarkably well under strong ground excitations. Very small permanent deformations are observed after the tests, especially when the longitudinal mild reinforcement is unbonded and a steel jacket is provided.

Paper B26

Seismic Performance and Design of Bridges with Curve and Skew

J. Jerry Shen, LENDIS/Federal Highway Administration; and W. Phillip Yen, Office of Infrastructure R&D, Federal Highway Administration

Horizontal curve and skew generally are not preferred features in seismic design of bridges. The eccentricity and other irregularities associated with curve and skew introduce complex force effects during earthquakes. Special design considerations for structural elements, joints, and bearings are needed to accommodate such force effect and to prevent undesirable failure mechanisms. Existing seismic provisions for bridges provide very limited help for curved or skewed bridges. As structural systems and materials become more efficient and site restraint more stringent, the demand for construction of bridges with various degrees of curve and skew, as well as reliable seismic design for such bridges increase rapidly. This paper presents the progress and available results of a FHWA study on the seismic performance and design procedures of curved and skewed bridges. Potential deficiencies, and consequences thereof, in current practice are studied. Numerical models are established based on the calibrated superstructural models available from previous FHWA studies on curved girder steel bridges. The effects of curve and skew are studied by varying selected structural parameters. Possible failure scenarios are examined to identify the critical design parameters. Effects of structural detailing to failure mechanisms are manifested and necessary further studies proposed.

Paper B27

NCHRP 12-74 Development of Precast Bent Cap Systems for Seismic Regions – Background and Progress

Matthew J. Tobolski, Department of Structural Engineering, University of California San Diego; Eric E. Matsumoto, Department of Civil Engineering, California State University, Sacramento; José I. Restrepo, Department of Structural Engineering, University of California San Diego

In increasingly congested urban areas around the country, thousands of bridges are in need of replacement or rehabilitation. One strategic means to accelerate construction is the use of precast bent caps. NCHRP recently funded Project 12-74 to develop design methodologies, connection details, and design and construction specifications for precast bent caps in seismic regions. This paper summarizes progress on the first five research tasks, including a literature review, industry survey, and development of candidate details. In addition, an overview of relevant seismic design concepts related to this research is presented. Through a comprehensive survey of the bridge community, information regarding prior uses of precast bent cap systems has been obtained. This information was used in the development of new connection details to be validated through experimental testing. Candidate integral and non-integral systems that have been developed are expected to provide the necessary seismic performance in a constructible, cost-effective manner. In addition, initial stages of the analytical and experimental work are currently underway. This effort will include: component bent cap-to-column connection tests; a large-scale, system test of an integral system; strut-and-tie and finite element modeling; and non-linear time history analyses.

Paper B28

Improved Seismic Performance of Precast Segmental Bridges Using Jointed Column Connections and Unbonded Tendons

Marc J. Veletzos and Jose I. Restrepo, Department of Structural Engineering, University of California San Diego

Precast segmental construction of bridges can significantly reduce construction time and minimize construction cost of bridges in highly congested urban environments and environmentally sensitive regions. Recent research has shown that the seismic performance of precast segmental bridges can be similar to that of cast-in-place construction if designed and detailed properly. If designed to current seismic standards, full plastic hinges will develop in the columns during a Maximum Credible Earthquake and the structure will not collapse. The structure may, however, need extensive repairs or, as a worst case, may need to be demolished due to excessive residual displacements and damage. By allowing damage, the current design philosophy permits undue financial losses, as well as unnecessary traffic congestion. Using the Otay River Bridge as a case study, this paper will investigate the influence of the type of non-linear response on the overall bridge behavior and will show that if the top and bottom column segment joints are allowed to open during a seismic event, the displacement capacity of the structure may increase, while simultaneously reducing the level of damage. The mechanism for this improved behavior is unbonded post-tensioning tendons that allow for large non-linear elastic column deformations and will pull the structure back into its original geometry and virtually eliminate residual deflections.

Paper Abstracts

3A1: Seismic Risk Assessment of Highway Networks

Moderated by Amr Elnashai, Mid America Earthquake Center

Paper A27

Probabilistic Seismic Hazard Assessment for Spatially Distributed Systems

Renee Lee and Anne S. Kiremidjian, Department of Civil and Environmental Engineering, Stanford University

An earthquake scenario is described by a deterministic magnitude and location of rupture in space and in time and can be used to assess bounds on system performance. Casting the system problem into a probabilistic seismic hazard framework has posed challenging computational issues. A spatially distributed system composed of interconnected roadways, bridges, and tunnels, will be affected by the same earthquake. Thus, a site specific probabilistic hazard analysis does not adequately capture the spatially varying ground motion system wide. This study focuses on assessing the seismic risk faced by a spatially distributed transportation system. In particular, ground motion and damage correlation effects in the aggregate loss and in the system reliability are addressed. The sensitivity of these correlation effects to the two decision variables, loss and reliability, is quantified, and a retrofit prioritization approach based on the importance of individual components to overall system reliability is considered. Results indicate that correlation in ground motion and in damage will affect the system risk curve in a significant way. The loss is investigated via Monte Carlo simulation and the appropriate algorithm for introducing correlation in the case of simulating jointly discrete damage states is discussed. Moreover, the importance of incorporating correlation effects is emphasized by observed changes to system reliability. System failure for a sample network is estimated through first order reliability method.

Paper A28

Seismic Vulnerability of Typical Multiple-Span California Highway Bridges

Kevin Mackie and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley

Most bridges in California are multiple-span reinforced concrete highway overpass bridges, particularly those of new design. Therefore, performance of these bridges is integral to evaluating transportation network post-earthquake performance. Additionally, probabilistic quantification of bridge response and vulnerability will provide insight for evaluating current designs at different levels of seismic hazard. Performance of bridges at the demand, damage, and loss levels is evaluated using PEER's performance-based earthquake engineering framework. This paper illustrates seismic bridge vulnerability for two typical single column-per-bent, five-span, reinforced concrete highway bridge types. The first bridge type has 22-foot columns of equal height above grade and the second bridge type has 50-foot high columns. A complex model for four structural configurations is created in OpenSees using a modular approach that accounts for nonlinear behavior of the columns, deck, abutments, and expansion joints at the abutments. Seismic demand models are developed using nonlinear time history analysis; damage in the columns is determined from a database of experimental tests; and approximate repair cost ratios are estimated from the discrete damage states. Vulnerabilities of the base bridge types presented in this paper provide a benchmark for later comparisons of performance-enhanced elements and liquefaction and lateral spreading demands in a bridge-soil system.

Paper A29

Evaluation of Bridge Retrofit in Regions of Low-to-Moderate Seismicity

Jamie Ellen Padgett and Reginald DesRoches, School of Civil and Environmental Engineering, Georgia Institute of Technology

Many states in the low-to-moderate seismic regions of the Central and Southeastern United States are beginning to develop programs aimed at retrofitting bridges that may be vulnerable during earthquakes. The types of bridges and the nature of the hazard in the Central and Southeastern US requires a different approach from that which is used in regions of high seismicity, such as the West Coast. This paper outlines a methodology for bridge retrofit evaluation, based on the use of bridge fragility curves. Retrofitted bridge fragility curves offer the probability of reaching various levels of bridge damage with different retrofit measures, given a specific hazard level. The fragility curves facilitate assessment of the impact of retrofit on the bridge performance and reduction of vulnerability. In regions of low-to-moderate seismicity, funds for seismic upgrade and retrofit of bridges are limited. Therefore, the relative benefit and cost-effectiveness of different strategies are important in the overall assessment and decision-making for bridge retrofit. This study illustrates the use of fragility curves for identifying viable retrofit measures for common classes of bridges, and selection of the most effective retrofit measure for a given bridge type and performance objective. The retrofitted bridge fragility curves are then applied in a probabilistic cost-benefit analysis of bridge retrofit. This approach targets maximizing the impact of investing limited funds for improving the seismic performance of bridges in low-to-moderate seismic zones.

Paper A30

Seismic Analysis of a Roadway System in the Los Angeles, California Area

Stuart D. Werner, Seismic Systems & Engineering Consultants; Sungbin Cho, ImageCat, Inc.; Craig E. Taylor, Natural Hazards Management Inc., Jean-Paul Lavoie, Geodesy; and Charles K. Huyck, ImageCat, Inc.

A new methodology for deterministic or probabilistic seismic risk analysis (SRA) of roadway systems has been programmed into a public-domain software package named REDARS™ 2. This paper describes this methodology, along with results from its application to a roadway system in the Los Angeles area. This application shows how SRA results can support performance-based engineering as well as seismic-risk reduction decision making.

Paper A31

Seismic Vulnerability Assessments of Bridges in Areas of Low to Moderate Seismic Activity

Joseph B. Matarazzo and Artur Kasperski, Earth Tech; José Santos, New York State Department of Transportation; and Gary Wang and Chris S.C. Yiu, Imbsen Consulting Engineers, PC

In the northeast United States, there has been an increased interest in seismic design over the past 15 to 20 years. Although this part of the country is mostly of a low to moderate seismic activity, a Magnitude 5 event could have severe consequences. In October 1985, a Magnitude 4 event occurred approximately 25 miles north of midtown Manhattan. This created much concern among government officials. In March 1990, the New York State Department of Transportation (NYSDOT) issued its first seismic policy, which primarily involved adopting the 1983 *AASHTO Guide Specifications for Seismic Design of Highway Bridges*. In October 1995, the Department issued their first *Seismic Vulnerability Assessment Manual* (NYSDOT, 2004), which was based in part on FHWA's *Seismic Retrofitting Manual for Highway Bridges* (May 1995). The assessment procedure used by NYSDOT is both empirical and qualitative. This method of assessment is useful for evaluating existing structures in areas of low to moderate seismic activity. It allows for a quick and reliable identification of vulnerable structures and their conditions. It allows a bridge owner to prioritize structures that need to be retrofit, rehabilitated, or replaced; and it identifies areas where further study is needed. In 2003, NYSDOT began a pilot program to assess 450 bridges in New York City. These bridges are on and over designated emergency routes. The results of the study indicate that 50% of the assessed bridges require some form of remedial work.

PAPER ABSTRACTS

INTERNATIONAL TECHNOLOGIES & PRACTICES SESSION 3B1, 10:15 AM – 12:00 NOON

MODERATED BY ROLAND NIMIS, CALIFORNIA DEPARTMENT OF TRANSPORTATION

Paper B29

Seismic Design Practice of Steel Bridges in California

Lian Duan, California Department of Transportation

This paper presents an overview of the newly developed Caltrans *Guide Specifications for Seismic Design of Steel Bridges*. The new Guide Specifications are based on required seismic performance criteria, displacement-based approach and capacity design concept. All bridges shall be designed to withstand deformations imposed by the design seismic event. Structural components are classified as *Ductile and Capacity-protected* and shall be designed to provide sufficient strength and/or ductility to ensure collapse will not occur during a Maximum Credible Event. Inelastic deformations are generally expected in substructure components which shall be identified and detailed for ductile response. Inelastic behavior in the form of controlled flexural damage may be permitted in some of the superstructure components such as end cross frames, shear keys and bearings to prevent damage in other parts of structures. Capacity-protected components shall be designed to resist the force demands determined from the overstrength capacity of ductile components connected. Details such as seat width, bearing assemblies, end cross frames, splice and connections, welds, limiting slenderness ratios, concrete end diaphragms, and integral connections between concrete bent cap and steel girders shall be properly designed to ensure continuity of load path during earthquake and to ensure the design objectives are achieved.

Paper B30

Seismic Design of Coronilla Viaduct

Joaquín Mejía Ramírez, Manuel González Ureña and Jose de Jesus Alvarez, Universidad Michoacana de San Nicolas de Hidalgo

This paper deals with the seismic design of Coronilla Viaduct, which promises to be, at the end of 2007, the longest arch span in México. The bridge is an upper-deck arch bridge mainly composed of reinforced concrete slabs, steel girders and columns, and single span steel arch ribs. The total length of the bridge is 896 ft, and two end-fixed steel arch has a 656 ft span with a rise at the crown of 111.5 ft. The arch consists of three box section ribs. The bridge will be constructed in Morelia, Michoacán, over a deep ravine (305 ft), in a high seismic risk area. The structure was analysed and designed in compliance with Mexican practice. Seismic assessment of forces and deformation demands was performed by means of modal elastic dynamic análisis, using the response spectrum proposed by the Mexican Code, modified to take into account a 2% critical damping.

Paper B31

China-U.S. Comparative Study on Seismic Design Philosophy and Practice for a Long Span Arch Bridge

Yan Xu, Department of Bridge Engineering, Tongji University; George C Lee, Department of Civil, Structural & Environment Engineering, University at Buffalo, State University of New York; Li-chu Fan and Shi-de Hu, Department of Bridge Engineering, Tongji University

This paper presents the first of a series of case studies on the seismic design of long span bridges (cable-stayed bridges, suspension bridges and arch bridges) under a cooperative research project on seismic behavior and design of highway bridges between the State Key Laboratory for Disaster Reduction in Civil Engineering, Tongji University and the Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo. The objective of this series of case studies is to examine the differences and similarities on the seismic design practice of long span bridges in China and the U.S., to identify research needs and to develop design guidelines beneficial to bridge engineers in both countries. Unlike short to medium span bridges, long span bridges are not included in most seismic design specifications, mainly because they are location dependent and structurally unique. In this paper, an available model of a steel tied half through arch bridge with a main span of 550m in China is discussed. Analysis is focused on comparisons of the seismic responses due to different ground motions. Seismic design criteria and seismic performance requirements for long span bridges in both countries were first introduced and compared, and then three near field earthquake records with large vertical components were selected as the excitations to examine the seismic behavior and seismic vulnerability of the bridge. The study provides some comparative results of the bridge seismic response relative to those resulted from site specific ground motions.

Paper B32

New International Standard for Elastomeric Seismic-Protection Isolators

Nobuo Murota, Bridgestone Corporation; James M. Kelly, Department of Civil and Environmental Engineering, University of California, Berkeley; Keith Fuller, Tun Abdul Razak Research Centre; Fu Lin Zhou, Earthquake Engineering Research Test Center, Guangzhou University; Toshio Nishi, Department of Organic and Polymeric Materials, Tokyo Institute of Technology; Toshikazu Yoshizawa and Chiaki Sudou, Bridgestone Corporation; and Fumihiko Yazaki, Yokohama Rubber Company

Since the year 2000, the ISO standard for elastomeric isolators for buildings and bridges has been under development by the technical-committee 45/sub-committee 4/working-group 9, of International Organization for Standardization (ISO/TC45/SC4/WG9). Through five international meetings in Malaysia (2000), India (2001), Japan (2002), Great Britain (2003), and Germany (2004), the ISO standard for elastomeric isolators has been completed and was published on 2005 July as ISO 22762. The standard consists of three parts: *Part-1- Test Methods, Part-2- Application for Bridges-Specifications*, and *Part-3- Application for Buildings-Specifications*. Part-2 and Part-3 are the product specifications. Among many items in the product specifications, "Requirements" is considered as one of the most important and influential. These consist of performance requirements for the isolators and material requirements for the rubber. The performance requirements, and corresponding tolerances, specified for isolators include compression, compression-shear, and ultimate property characteristics. In this paper, an overview of the developed ISO standard is presented focusing on the isolator requirements.

Paper B33

Inelastic Response of the San Antonio Viaduct Subjected to Synthetic Ground Acceleration Records

Héctor Sánchez Sánchez and Marcelino Cruz González, SEPI, ESIA, IPN

In 1989, during the Loma Prieta earthquake, some bridges were damaged in California. The Cypress Street Viaduct was a two-level elevated freeway structure, and it collapsed catastrophically. At present, two-level elevated viaducts have been built in Mexico City. San Antonio Viaduct is part of the transport system. Seismic areas affect the performance of these structures, therefore they could be vulnerable to damage in future earthquakes, which provides an opportunity to evaluate their seismic response and prevent collapse. This research is focused on studying the behavior and structural response of the viaducts type frame of concrete placed in soft soil of the Mexico Valley. The structures were modeled as an assemblage of small members where they modify their geometrical and mechanical properties. The columns were modeled as constant section members with rigid zones in joint regions, and the post-tensioned box-girders were modeled as tapered members with rigid zones in joint regions. The model was analyzed using synthetic ground acceleration records to obtain time-histories. The numerical results obtained in this research indicate that procedures implemented in the regulations or codes to estimate the total inelastic deformations do not take into account a nonlinear behavior, therefore it provides minor lateral deformations (drifts) than those allowed by RCDF 2004 (Mexican code).

Poster Abstracts

Coordinator: Reginald DesRoches, Georgia Institute of Technology

Poster P01

Collapse Simulation of RC Frames under Earthquakes. I: Theoretical Modeling

Leiming Zhang, Yan Zhou and Xila Liu, Shanghai Jiao Tong University

Most of the current researches so called collapse simulations are actually limited to the analysis of structural elastic-plastic response. The major difficulties of collapse analysis lie in the description of displacement discontinuity and the analysis of collisions. Conventional member models, such as the plastic hinge model, are no more appropriate. In this paper, a new modeling scheme is developed. At first, the concept of mixed hinge is introduced to depict displacement discontinuity. Based on singularity functions that possess great advantages in describing sharp changes, a mixed hinge model of beam-column member is brought forward, which can be used consistently with classic structural analysis procedures. Furthermore, an effective solution method for studying collisions is developed. By introducing a Lagrange multiplier, the velocity constraint condition imposed by collisions is incorporated into the equations of motion, which will lead to the equilibrium equation in impulse after integration in time domain. And thus the dynamic effects of collision can be fully considered.

Poster P02

Refined Seismic Design of a Bridge Structure on Soft Soils

Paul Chung, California Department of Transportation

This paper describes the seismic analysis and design of a bridge founded on soft soils and complex site and geotechnical conditions. The bridge is located in the San Francisco Bay Area and identified as an "Important" lifeline structure. The site introduced a high seismicity and the lifeline designation imposed special seismic performance criteria on the design. The bridge is located amid an array of roadways, utilities, and railroad lines that results in variable skew bents and sits in a "bathtub" of soft mud. The assembly of irregular geometry, "bathtub" conditions, and the lifeline seismic criteria presented engineering challenges to design. As a solution, nonlinear structural models were used including soil-structure interactions and refined dynamic analyses were conducted. Innovative design measures were developed meet the seismic safety and serviceability criteria.

Poster P03

Seismic Behavior of the Pinzandaran Bridge

H. Hernández-Barrios, J. Álvarez-Sereno and M. Jara-Díaz, Universidad Michoacana de San Nicolas de Hidalgo, Ciudad Universitaria

Recently, XXI Century highway was built, one of the most important in the Mexican highway system. Pinzandaran Bridge is located in XXI Century highway at 137 km from Lazaro Cardenas shore in Michoacan, in a potentially seismic zone. In this work is analyzed the possibility of collocate base isolators, of multi-rotational, to improve its dynamic behaviour. There is evidence of the use of this kind on insulators in the Infiernillo II Bridge, located approximately at 4 km from the studied bridges. AASTHO specifications are used to define equivalent parameters for linear and nonlinear analysis. Effectiveness of these devices is evaluated in terms of reduction of seismic forces produced during nonlinear dynamics analysis and the verification of the bridge pier displacements. Simulated time histories and seismic records were used in the analysis.

Poster P04

Seismic Performance of Alaska Bridges by Denali 2002 Earthquakes

J. Leroy Hulsey, University of Alaska Fairbanks; Dileep Cherlopalle, The Weintraub Organization Ltd; and Z. John Ma, University of Tennessee Knoxville

A 7.9 magnitude earthquake was triggered by the Denali Fault in interior Alaska on November 3, 2002. As part of an NSF project, the authors conducted a field survey of affected areas and investigated the response of two structures near the November excitation. One was a building and the other was a 1944 highway bridge. This paper will focus on the bridge. A 946-ft 2-lane 3 span truss highway bridge near Tok, Alaska spans the Tanana River. There is a 430-ft main span and two 258-ft shorter spans. The bridge was designed for moveable bearings at the abutments and fixed at the piers. The structure is 149 miles from the epicenter with an orientation nearly parallel to the Denali Fault. The November 2002 earthquake caused the superstructure to move transversely 4.8 inches. This paper presents findings from field investigations and shows results from an earthquake analysis of the bridge. Maximums for displacements, member forces and member stresses were studied. Results show that only minimal structural damage should have occurred for the bridge. Findings compare favorably with field inspection results reported by others.

Poster P05

Seismic Retrofit Needs of the Historic McCullough Bridge - One of Oregon's Longest Bridges

Ling Shang, Bob Grubbs and James Burford, Oregon Department of Transportation

The McCullough Bridge is one of the longest historical and landmark bridges in Oregon. It carries the Oregon Coast Highway (US 101) across Coos Bay, along the Oregon Pacific coast line. The 5305 foot long, 23 span bridge was built in 1936. Originally named The Coos Bay Bridge, it was designed by the famous Oregon bridge engineer Conde B. McCullough. The bridge was later renamed to the "McCullough Bridge" in recognition of the engineers contribution to bridge design in Oregon and the United States. With years of corrosion from coastal salt spray, increased traffic volume, and heavier truck loads on the bridge, the bridge has seen deterioration. ODOT has and will continue to maintain the bridge to minimize this deterioration and reverse these effects. Another danger to the bridge is the possible seismic effects. The bridge is located in Cascadia Subduction seismic zone. There are also a number of local crustal faults. To help prevent the bridge from sustaining damage from seismic activity, ODOT would enact several possible seismic retrofit measures. These measures include, but are not limited to: bridge bearing replacement, beam seat lengthening, analysis and strengthening of columns, and liquefaction hazard investigation and possible mitigation.

Poster P06

Validation of Finite Element Model Ability to Evaluate Residual Live Load Capacity of Bridge Columns

Vesna Terzic, Kevin Mackie and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley

Modern highway bridges in California designed according to the California Department of Transpotation's Seismic Design Criteria are expected to perform adequately during both frequent and extreme seismic events. Adequate performance implies ductile system and component response, limited and repairable damage, and the ability to maintain at some gravity and live load load-carrying capacity such that regular bridge traffic capacity could be restored within a reasonable amount of time. The analytical models in widespread use today are calibrated to reproduce the behavior of bridge columns during a major earthquake event. However, they are not calibrated to model the strength and deformation of the same bridge after some damage, moderate or severe, has occurred. Estimates of the residual axial load-carrying capacity of an array of typical Caltrans bridge columns subjected to progressively increasing levels of lateral displacement ductility are presented in this paper. The analytical models of the bridge and the columns are developed in OpenSees using force-formulated, fiber cross-section beam-column elements. The initial results show that the remaining axial load-carrying capacity of columns, subjected to lateral displacement ductility demands consistent with regions of high and moderate seismicity, is satisfactory.

Poster Abstracts

Poster P07

Site Identification for Port Access Bridge in Anchorage by Extended Kalman Filter with the Recorded Seismic Data

He Liu, Mansheng Wang and Feifei Bai, School of Engineering, University of Alaska Anchorage; Yibin Zheng, Department of Electrical and Computer Engineering, University of Virginia Charlottesville; and Xiyuan Zhou, College of Architecture and Civil Engineering, Beijing University of Technology

The Port Access Bridge which connects the Port of Anchorage with the remainder of Alaska's transportation system is located in the Ship Creek valley where the soil site is class E according to NEHRP site class definitions. Therefore, the soil-structural-interaction is a critical issue for the bridge safety assessment. In order provide a reasonable basis for the nonlinear dynamic analysis of soil-structure interaction (SSI), a new site identification approach is applied to the site of Port Access Bridge in this paper. In contrast to the conventional soil models with single spring and damping components, a two-degree-of-freedom mechanical model (2DOF) with eight integrated constant parameters was used here as the foundation soil model. In order to determine the values of the integrated parameters in the 2DOF model, a system identification technique using the extended Kalman filter (EKF) was developed. To improve the computational accuracy and simplicity, the first order polynomial approximation is applied in the EKF procedure. This new identification method was applied to the site of the Port Access Bridge to approximate the dynamic properties of foundation soils and the recorded seismic data were used. Results demonstrate the feasibility and practicality of the proposed identification technique. Based on the identified integrated parameters, the impedance functions were estimated.

Poster P08

The Effect of Nonlinear Soil Behavior on the Seismic Response of RC Pile-Columns

Andrew Budek, Department of Civil Engineering, Texas Tech University; and Gianmario Benzoni, Department of Structural Engineering, University of California San Diego

A nonlinear inelastic finite element analysis was performed on a representative reinforced concrete pile using three soil models, one of which was linear, and two nonlinear. The nonlinear soil models were a bilinear response model in which the soil stiffness was reduced to 25% of its original value after a lateral deflection of 25.4 mm, and a model based on p-y curves. The parameters varied were initial soil stiffness and abovegrade height of the superstructure supported by the pile-column. The effects of using nonlinear soil models were most significant for low values of soil stiffness, and low superstructures, because these cases mandated greater soil participation to develop the full flexural capacity of the pile section. The results suggest that higher levels of displacement ductility will arise from nonlinear soil response.

Poster P09

Seismic Response of Bridge Approach Fill Sites Improved by Deep Mixing

Raj V. Siddharthan, Department of Civil Engineering, University of Nevada Reno; Ali Porbaha, Department of Civil Engineering, California State University Sacramento; and Aravinthan Thurairajah, Department of Civil Engineering, University of Nevada Reno

The objective of this study is to present two applications of a recently developed simplified design procedure to study the effectiveness of liquefaction remediation relative to deep mixing (DM) treatment. The seismic response characteristics of the DM sites have been assessed based on the residual porewater pressure response (or liquefaction) since this is a widely-used engineering design parameter. The two applications reported are: Oriental Hotel in Japan in Kobe Earthquake of 1995 and the case of a bridge approach fill. The proposed simplified approach showed clearly the effectiveness of the treated columns in reducing the porewater pressure response at locations closer to DM treated zone.

Poster P10

Equivalent Linear Stiffnesses of Piles and Pile Foundations

Jin-xing Zha, Division of Geotechnical Design and Services, California Department of Transportation

This paper reviews definitions of impedance functions for single piles and pile foundations for seismic analysis of bridges. For a non-linear pile-soil system, the equivalent-linear stiffness is calculated so that the linear response using secant stiffness closely approximates the true nonlinear system response. Commonly used methods utilizing the principle of superposition generate an unsymmetrical stiffness matrix and can cause considerable inaccuracy when used for calculating the force vector from the displacement vector. To eliminate this inaccuracy, a rigorous method is proposed for constructing the equivalent stiffness matrix that not only is symmetric but also exactly correlates the displacement/rotation vector with the corresponding force/moment vector for the non-linear pile-soil system. The proposed method is both simple and accurate. A numerical example is presented to illustrate the proposed method and to show significant inaccuracy resulting from the use of superposition.

Poster P11

Seismic Risk Assessment of Steel Highway Bridges

Ying Pan, Gilsanz Murray Steficek LLP; and Anil Kumar Agrawal and Michel Ghosn, Department of Civil Engineering, The City College of the City University of New York

This paper presents an improved approach for the seismic fragility analysis of typical steel highway bridges. Uncertainties associated with the estimation of material strength, bridge mass, friction coefficient of expansion bearings and expansion-joint gap size are considered. To account for the uncertainties related to the bridge structural properties and earthquake characteristics, statistical bridge samples are established, and earthquake ground motions are simulated numerically. The uncertainties in estimating structural capacity and demand are calculated for different limit states to construct seismic fragility curves as a function of PGA and fragility surfaces as a function of moment magnitude and epicentral distance. Fragility curves and surfaces are thus established for individual components and the complete bridge system. To account for seismic-risk from multiple failure modes, a second-order reliability method is used to provide narrow bounds on the probability of failure. Fragility curves and surfaces obtained with the proposed method are applied for seismic risk assessment of highway bridges in Northeastern United States.

Poster P12

The Effect of Bridge and Highway System Improvements on the Network's Accessibility Reliability after a Major Earthquake

Afshin Shariat Mohymani, Navid Kalantari and Poria Mohammadian, Iran University of Science and Technology

Major earthquakes have different effects on the transportation system; they can increase the network's demand and decrease its capacity in a probabilistic manner. We will analysis the effects of network improvements on its accessibility reliability accounting the effects of mitigating disconnection and detour in the network, and the existence of alternative routes for emergency response and their capacity with respect to the location of different areas on the earthquake hazard map and their probable damage state. Based on our experiences form some recent earthquakes such as Bam(2004) and Gilan(1990) in Iran, accessibility is one of the most important measures in emergency response, therefore we will use an accessibility measure to analyze the accessibility reliability of the network then, to investigate the effect of the network improvements on the accessibility reliability of the network. Finally, the accessibility reliability of an example network will be calculated to demonstrate the method and the way to account for network improvements.

Poster Abstracts

Poster P13

Probabilistic Seismic Loss Analysis for Bridges in the Central United States

Erdem Karaca and Nicolas Luco, U.S. Geological Survey

Transportation systems are spatially distributed systems within which different components can be exposed to different ground motions (GMs) from the same seismic event. Spatial correlation of GMs and damage are important in the risk analysis of such distributed and linked systems. Although most of the emphasis in risk analysis of highway systems is given to post-earthquake functionality of the highway links and the resulting increases in travel times and associated losses, the repair/restoration costs of the bridges are also of interest to many state and federal officials. We calculate losses to bridges in the Central United States, specifically those around Memphis, TN, and compute the loss exceedance probability curves using a methodology that takes into account the correlation in GM across sites that are affected by common seismic events. Furthermore, we quantify the epistemic uncertainty in the loss curves that is induced by differences in available GM attenuation relations. Finally, we provide deaggregation of loss curves at different return periods to assist in the understanding of the relative contributions from different earthquake sources, which can be of interest to researchers and agencies involved in pre-earthquake planning and post-earthquake recovery studies.

Poster P14

Bayesian Updating of Bridge Fragility Curves using Sensor Data

John-Michael Wong, Kevin Mackie and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley

A method is presented for combining measured performance data from sensors with response estimates from analytical models to obtain improved estimates of bridge seismic performance. Low- and high-intensity sensor data are used to revise bridge fragility curves using Bayesian updating. Such improved estimates can be used, for example, to re-prioritize seismic upgrade work and increase the safety and reliability of a regional transportation system. This method is particularly constructive when generic fragility curves are used for classes of similar bridges, as is commonly done when it is infeasible to develop bridge-specific fragility curves for large regions. The proposed method is demonstrated using numerical simulations of a typical five-span reinforced concrete highway overpass bridge in California. Seismic performance assessment is conducted using the Pacific Earthquake Engineering Research center's performance-based evaluation framework. Prior distributions of bridge seismic demands are obtained using nonlinear time history analysis. Measured data obtained using simulated sensors on a bridge model are processed to produce likelihood functions for parameters representing the observed structural demands. Bayesian updating combines the prior distribution and likelihood function to produce a posterior distribution encapsulating the knowledge gained from the sensors. Different scenarios of the effect of low- and high-intensity sensor data points on the posterior distributions of demand, damage, and decision variables are illustrated.

Poster P15

Method for Post-Earthquake Highway Bridge Repair Cost Estimation

Kevin Mackie, John-Michael Wong and Bozidar Stojadinovic, Department of Civil and Environmental Engineering, University of California Berkeley

Repair costs are useful not only to transportation managers for inventory assessment and decision making, but also in a performance-based design setting for evaluating different design choices. Derivation of post-earthquake repair costs is a complex problem entailing the expected site seismicity, bridge configuration and geometry, seismic response of the structure, failure modes, and possible repair methods/costs. A probabilistic highway bridge repair cost method, based on the Pacific Earthquake Engineering Research Center's performance-based framework, is illustrated in this paper. Repair cost probability first and second moments are derived using a simple graphical tool called Fourway. Three constituent models are necessary for utilization of Fourway: a probabilistic seismic demand model relating earthquake intensities to bridge response parameters, a probabilistic damage model relating levels of demand to discrete damage states of key bridge components, and a cost model relating the damage states to estimated monetary or material quantities required for repair. The graphical process is repeated for each bridge component considered and the results are combined into a total cost by taking into account correlation between components. The method is demonstrated using an in-depth analysis of a reinforced concrete highway overpass bridge in California with four single-column bents. The demand, damage, and cost models are developed individually for each of the abutments, columns, deck segments, and expansion joints.

Poster P16

The Hayward Fault Network and Bay Area Bridges

Douglas Dreger, Robert Nadeau, Robert Uhrhammer and Richard Clymer, Berkeley Seismological Laboratory, University of California; and Pat Hipley, Office of Earthquake Engineering, California Department of Transportation

The Hayward Fault Network is comprised of borehole stations at the region's major bridges operated by Caltrans and at other locations. These stations provide essential coverage of the active Hayward fault, and ongoing analyses of recorded microearthquake and non-volcanic tremor waveform data is beginning to illuminate this fault's behavior. The sites that are situated along the major bridges have been providing waveforms that may be used to investigate velocity structure in general and path and site effects specific to the instrumented bridges. Caltrans provides funding and performs the drilling operations for many of these borehole sites. Our two newest sites are located at the Napa River Bridge and the Petaluma River Bridge on Highway 37. These two new sites will provide unprecedented high-resolution coverage of the region between the northern Hayward and Rodgers Creek faults, and lead to improved understanding of faulting mechanics, the seismic response of the San Pablo Bay sedimentary basin and regional seismic hazard.

Poster P17

Analysis of Some Strong Motion Records of CSMIP/Caltrans Downhole Arrays

Hamid Haddadi and Anthony Shakal, California Geological Survey; and Pat Hipley, Office of Earthquake Engineering, California Department of Transportation

The California Strong Motion Instrumentation Program (CSMIP) started operating downhole arrays in 1987 to provide critical data for studying the effects of local soil conditions. As of June 2006, 22 downhole arrays are being operated by CSMIP, 17 of these in cooperation with the California Department of Transportation (Caltrans). More arrays are underway to be installed. Most of the ground motions recorded so far at the CSMIP downhole arrays are low amplitude. However, the records are used to study the linear characteristics and wave propagation in soil layers. Also, the P- and S- wave velocities obtained from in-situ measurements at the sites are compared to the velocities obtained from acceleration ground motions at the downhole arrays. The records of 3 downhole arrays are discussed in this paper. Each array has triaxial sensors located at the ground surface and at depths. The depths at which accelerometers are located depend on the local geology and soil layers.

Poster P18

Bay Area Toll Bridge Strong Motion Instrumentation

Pat Hipley and Li-Hong Sheng, Office of Earthquake Engineering, California Department of Transportation; and Moh Huang and Anthony Shakal, California Strong Motion Instrumentation Program, California Geological Survey

Caltrans has nine large bridges that span the San Francisco and San Pablo bays. All of these are toll bridges. At any time, hundreds of people could be crossing any one of these massive structures. Each one of these bridges is an important link for the State's transportation system and represents a huge investment to the people of California. Since these structures are so vital to the public and the State's economy, Caltrans has worked with the California Geological Survey to undertake a program that monitors these structures for movement in

Poster Abstracts

the event of an earthquake. This recorded data will be used to gain an understanding of how these structures respond to earthquakes and may be utilized for damage assessment after major events. Many interesting and unique aspects of the instrumentation were undertaken, such as placing sensors in new piles. Many piers are instrumented full height, from the bottom of the piles, at water level, at road level and up to the top of the towers. A sufficient amount of sensors are placed so important modes of vibration of the structure are recorded.

Poster P19

Shanghai Maglev Guideway Seismic Design

David N. Bilow, Portland Cement Association; and Jingyu Huang, Maglev Transportation Development Co., Ltd.

Fast, safe, and efficient Maglev trains are being considered for passenger transport by Los Angeles, Las Vegas, Pittsburgh, Baltimore, and Atlanta. Because of Maglev's top speeds of 250 to 310 mph, most of the systems will include elevated guideways. The first large capacity Maglev system in the world is the 19 mile elevated double track Shanghai Maglev which went into service in early 2003. The foundation soils along the Maglev route are alluvial deposits of weak saturated clay, and loose sands and silts which are subject to liquefaction during seismic events. The frequent movements of tectonic plates created large seismic fault zones with a history of violent earthquakes in China. Nearly 600 earthquakes over magnitude 6 have occurred in the last 100 years. The frequency, magnitude, and shallow focal depth of these earthquakes create a serious threat to China's infrastructure. Engineers designed the guideway to withstand seismic forces from 7.5 Richter Scale earthquakes. The guideway girders are each supported on reinforced concrete piers, six feet by six feet in plan and typically 26 feet high. Each pier rests on a 6.5 feet thick pile cap. The pile caps in turn are supported on up to 24 piles each about two feet in diameter. The piles bear on a sandy clay stratum 100 feet to almost 200 feet below natural grade and a portion of the piles are battered to increase resistance to horizontal loads. The earthquake environment, methods used to design the guideway structures, and the guideway features developed to resist the seismic forces are described in the paper.

Poster P20

Seismic Design of the Temporary Bypass Structure for the New East Span of the San Francisco-Oakland Bay Bridge

Roy A. Imbsen, Consulting Engineer

The construction of the East Span of the San Francisco-Oakland Bay Bridge to increase the seismic resistance of this crossing is currently underway. A portion of this project includes the construction of the South-South Detour known as the Temporary Bypass Structure (TBS), which will facilitate construction of the self-anchored suspension bridge. The TBS, a Caltrans Design/Build contract which is currently underway, was awarded to the C.C. Myers/Imbsen & Associates, Inc. Team on March 11, 2004. The TBS alignment is on the south side of the existing alignment and extends 1773 feet from the west end of the detour to the east end of the detour. The detour (i.e., TBS) is composed of three parts: 1) West Tie-In (375 feet), 2) Viaduct (1066 feet), and 3) East Tie-In (332 feet). Each of these three double level structures are being designed to carry five lanes of westbound traffic (upper level) and five lanes of east bound traffic (lower level). All three structures must meet unique alignment and site conditions with no disruption in the movement of traffic throughout the construction staging. The seismic design hazard for these temporary structures and the seismic design strategy tailored to interface with the existing bridge will be presented in this paper.

Poster P21

Seismic Simulation of Reinforced Concrete Bridge Columns

Y.L. Mo, Department of Civil and Environmental Engineering, University of Houston; Jianxia Zhong, SMM Consultants; and Thomas T.C. Hsu, Department of Civil and Environmental Engineering, University of Houston

Reinforced concrete (RC) bridge columns are crucial to the safety and serviceability of bridges subjected to earthquake. The shear strengths of elements in bridge column walls depend strongly on the softening of concrete struts in the principal compression direction due to the principal tension in the perpendicular direction. This softening phenomenon, which has been clarified for monotonic loading during the past three decades, has now been extended to cyclic loading, resulting in the Cyclic Softened Membrane Model (CSMM). In this paper, a material stiffness matrix relating the state of stresses and strains for a plane stress element is formulated. The CSMM is implemented in a finite element program based on the framework of OpenSees to predict the seismic behavior of wall-type bridge columns. For the implementation procedure, a tangent material stiffness matrix is derived. The accuracy of the modeling technique is confirmed by comparing the simulated responses with five series of tests on hollow bridge columns and framed shear walls under reversed cyclic loading or shake table excitation. This new modeling technique greatly improves the simulation capability available to bridge engineers.

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About the Organizers

Federal Highway Administration (FHWA)

FHWA is charged with the broad responsibility of ensuring that the nations 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.

Caltrans

Caltrans manages more than 45,000 miles of California's highway and freeway lanes with more than 12,000 bridges, provides inter-city rail services, permits more than 400 public-use airports and special-use hospital heliports, and works with local agencies. The department has been active in moving the people and commerce of California for more than 100 years from a loosely connected web of footpaths and rutted wagon routes to the sophisticated system that today serves the transportation needs of well over 30 million residents.

From the beginning, commissioners from what was then the Bureau of Highways, worked from a simple philosophy: "The state highways should be the great arteries of a road system from which should branch out the minor highways serving counties and districts." It should link "the great belts of timber, fruit, agricultural and mineral wealth" to the state's population centers and county seats. During the 1920s the Yolo Causeway and Carquinez Straits Bridge opened a direct route from the San Francisco Bay Area to Sacramento. The seeds of the farm-to-market road system were planted in the early 1930s when the U.S. Bureau of Public Roads called on America to "get the farmer out of the mud," a slogan that led an expanded system of paved rural roads. The era also saw the completion of the Pacific Coast Highway. The 1940s saw the birth of the "freeway era" with the Arroyo Seco Freeway, among the first in the nation. The 1950s and 1960s were a time of technological innovation when interstate freeways were cut through areas that once were believed to be virtually impassable. The 1960 Winter Olympics in Squaw Valley added impetus to building Interstate 80, the first all-weather, trans-Sierra Nevada highway.

In the wake of the frenetic 1960s, the 1970s were a time of austerity. The then-current political philosophy urged alternatives to highway building, a trend that would continue into the 1980s. Such thinking led to a new name for the department, Caltrans, short for the California Department of Transportation. The 1990s saw recognition that California could not merely build its way out of traffic congestion and air pollution. Caltrans began to emphasize the more-efficient use of highways and their integration with other "modes" of transportation.

Since 1971 Sylmar earthquake struck the Los Angeles area, Caltrans has been engaged in an ongoing seismic retrofit program. In 1989 and 1994, the Loma Prieta and Northridge earthquakes focused attention on the need to strengthen state highway bridges against the immense power of seismic forces. More than 2000 bridges on the state highway system, including seven major toll bridges, have been strengthened or replaced as a part of the retrofit effort.

About the Organizers

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

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.

5NSC Program at a Glance

	Sunday 9/17/2006	Monday 9/18/2006	Tuesday 9/19/2006	Wednesday 9/20/2006
		The Technical Exhibition will be open daily from 7:30 am.		
8:00	Seismic Retrofitting Workshop (Pre-registration required)	Plenary Session	Plenary Session	Plenary Session
		2 Concurrent Sessions	2 Concurrent Sessions	2 Concurrent Sessions
		Lunch Break Noon - 1:00 pm		
		2 Concurrent Sessions	2 Concurrent Sessions	Boat Tour
		2 Concurrent Sessions	2 Concurrent Sessions	
5:00		MH Discussion Panel (4:15 - 5:15)		
	Ice Breaker Reception (6:00 - 8:00)	Poster Session / Reception (5:15 - 7:00)	Banquet (7:00 - 9:00)	

Technical Exhibition will be open daily: Mon. 7:30 am - 5:00 pm
Tues. 7:30 am - 5:00 pm
Wed. 7:30 am - Noon

Hotel Map

First Floor