

# 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

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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

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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 Transportation'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.

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Poster P07

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

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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

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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 Stefcsek 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 from 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.

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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 Hibley, 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 Hibley, 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 Hibley 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

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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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