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SUBMISSION PREVIEW

Submission ID: 499638

Earthquake and Windstorm Research in the Natural Hazards Engineering Research Infrastructure

Submission Type: Full Session with Abstracts

Submission Status: Active

Presenter(s)

Abdollah Shafieezadeh, Ph.D.

Assistant professor

The Ohio State University

Role: Presenter

Background
Professor Shafieezadeh interests are: (i) Numerical modeling and fragility assessment of complex systems, such as seaports, bridges, and physical assets of power grids with consideration of soil-foundation-structure interactions and liquefaction effects
(ii) Probabilistic modeling of deterioration processes of reinforced and prestressed concrete structures coupled with FE simulations
(iii) Optimal maintenance policies for large aging infrastructure assets using stochastic methods
(iv) Advanced protection of critical geo-structural systems against extreme hazards such as earthquakes and strong winds using passive, active, and semi-active control strategies based on stochastic methods
(v) Reliability and resilience assessment of geo-structural systems and critical infrastructures against natural and manmade hazards

Catherine Gorle

Assistant professor

Stanford University

Role: Presenter

Background
Gorlé received her BSc (2002) and MSc (2005) degrees in Aerospace Engineering from the Delft University of Technology, and her PhD (2010) from the von Karman Institute for Fluid Dynamics in cooperation with the University of Antwerp. Afterwards she was a Postdoctoral Fellow at the Center for Turbulence Research at Stanford University and a Research Professor at the von Karman Institute funded by a Pegasus Marie Curie fellowship. Before joining the Civil & Environmental Engineering Department at Stanford she was an Assistant Professor in the Department of Civil Engineering & Engineering Mechanics at Columbia University.

Gorle's research focuses on the development of predictive flow simulations to support the design of sustainable buildings and cities. Specific topics of interest are the coupling of large- and small-scale models and experiments to quantify uncertainties related to the variability of boundary conditions, the development of uncertainty quantification methods for low-fidelity models using high-fidelity data, and the use of field measurements to validate and improve computational predictions.

Arindam Chowdhury, Ph.D., Iowa State University

Professor

Department of Civil and Environmental Engineering, Florida International University

Role: Presenter

Background
Professor Chowdhury worked as an engineer in industry before joining Florida International University. In addition to his teaching duties, he serves as Director, NHERI Wall of Wind Experimental Facility, and Co-Director, Laboratory of Wind Engineering Research, Extreme Events Institute (an FIU preeminent program).

Julio Ramirez

Professor and NHERI-NCO Director

Purdue University

Role: Moderator

Background
Dr. Julio A. Ramirez is a Professor of structural engineering in the Lyles School of Civil Engineering of Purdue University. He is the Principal Investigator and Center Director of the Network Coordination Office (NCO) of the NSF funded Natural Hazards Engineering Research Infrastructure (NHERI). Dr. Ramirez is a voting member of the technical Joint Committee ACI-ASCE 445, Shear and Torsion; and ACI-ASCE Committee 408, Bond and Development of Reinforcement. He served as the chief officer for the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) during the period of October 2009 to September 2015. He has served as an Associate Editor for the Committee on Concrete and Masonry Structures

(CCMS) Division of the American Society of Civil Engineers (ASCE) Structural Journal and has been a member of several National Cooperative Highway Research Program (NCHRP) research panels. Prof. Ramirez has served in NSF proposal review panels for several directorates. Dr. Ramirez is a Fellow of the American Concrete Institute and the recipient of the 2000 Delmar Bloem Award and the 2006 Joe W. Kelly Award of the American Concrete Institute.

For the past 30 years Prof. Ramirez has been teaching and conducting research in structural engineering. His areas of expertise cover design, evaluation of performance and code development of reinforced and prestressed concrete bridges and buildings. Since 1994, Prof. Ramirez has been involved in eight-reconnaissance missions following the earthquakes of Northridge CA, Manzanillo Mexico, Kobe Japan, Duzce-Bolu Turkey, Puebla Mexico, Armenia Colombia, and Bingol Turkey. The goal of these missions was to gather perishable data on the performance of reinforced and prestressed concrete bridges and buildings immediately following major earthquakes in what constitutes a major real life and very costly test of the built environment in order to synthesize lessons that could help mitigate the impact of earthquakes on society. He was also engaged as project Co-PI in the recently completed NSF funded study “Mitigation of Collapse Risk in Vulnerable Concrete Buildings” aimed at identifying collapse triggers in non-ductile reinforced concrete buildings subjected to seismic actions. Dr. Ramirez has also led the training of personnel for the post-earthquake safety evaluation of bridges for the Indiana Department of Transportation, and the identification of emergency routes for the state. He has collaborated with the Indiana State Management Agency (SEMA) in efforts to establish of a volunteer coalition to assist the Indiana Department of Homeland Security in the condition assessment of buildings after a natural or man-made disaster. His research work in the area of bond of mild reinforcement and prestressing strand in high-strength concrete has been widely referenced and serves as the basis for the extension of the AASHTO LRFD Specifications on development of mild reinforcement and prestressing strand to higher strength concretes.

Nenad Gucunski, Dr.

Professor and Chairman, Civil and Environmental Engineering

Rutgers University

Role: Presenter

Background
Nenad Gucunski is professor and chair of the Department of Civil and Environmental Engineering at Rutgers. Gucunski is an internationally recognized expert in nondestructive evaluation (NDE/NDT) technologies and an elected member of NDT Academia International. In addition to his extensive work in various seismic, ultrasonic, and electromagnetic NDE techniques, he has conducted research in the areas of geotechnical earthquake engineering and dynamic soil-structure interaction.

Jeffrey Berman, Ph.D.

Thomas & Marilyn Nielsen Associate Professor

University of Washington

Role: Presenter

Background
Prof. Berman joined the University of Washington Civil and Environmental Engineering department in 2006 after completing his Ph.D. and a short Post-Doctoral period at the State University of New York at Buffalo. He has worked on numerous large-scale destructive experimental investigations involving steel and heavy timber structures and sub assemblages. His research strives to blend experimental and analytical investigations to help develop the tools and understanding necessary for practicing engineers to design structures to resist the forces of earthquakes, blasts, and other hazards.

Joseph Wartman

H. R. Berg Professor

University of Washington

Role: Presenter

Background
H. R. Berg Professor of Civil and Environmental Engineering. The author of over 60 professional articles, Wartman edits the Journal of Geotechnical and Geoenvironmental Engineering and chairs the Geo-Institute (GI) Committee on Embankments, Dams, and Slopes. He is the recipient of several awards and honors including the U.S. National Science Foundation Faculty Early Career Development Award, the John J. Gallen Memorial Award for Technical Advancements from Villanova University, and the Geotechnical Engineer of the Year award from the Philadelphia section of ASCE. Prior to his arrival at the University of Washington in 2010, Wartman spent nearly 10 years at Drexel University, where he was a founding Co-Director of the Drexel Engineering Cites Initiative. In 2008, he was a Visiting Scholar at the Universitat Politècnica de Catalunya (UPC) in Barcelona, Spain. Before his career in academia, Wartman was a professional practitioner in California and Pennsylvania for 5 years. He received his B.C.E. from Villanova University, and his MS, MEng, and PhD degrees from the UC Berkeley. Wartman is a Registered Professional Engineer in Pennsylvania and California.

Topic

Natural Disasters

- Earthquake
- Hurricane
- Storm surge
- Tornado
- Tsunami

Session Proposal

This session requested for the 2018 Structures Congress (SEI) aims to describe the impact on the resilience of civil infrastructure against earthquakes and windstorms of the ongoing research conducted by the users of the National Science Foundation (NSF) funded Natural Hazards Research Infrastructure (NHERI). Sessions describing the capabilities of NHERI facilities as a multi-user, distributed, national platform that provides state-of-the-art research infrastructure to explore and test ground-breaking concepts to protect homes, businesses and infrastructure lifelines from earthquakes and windstorms, including tsunamis and storm surges, have been presented at the 2016 and 2017 Structures Congress. This 2018 session will consist of five presentations of the work of researchers using the NHERI facilities and the impact of that research on practice aimed at reducing the vulnerabilities of civil infrastructure against natural hazards. The benefits of a multi-hazard research to improve the resilience against single and multi-hazard threats will also be illustrated.

Abstracts Connected to Session

Experimental and Computational Investigations of Overhead Power Transmission Systems under Hurricane Wind Loads

Abdollah Shafieezadeh, Ph.D.

Abstract

The power grid, as the most critical infrastructure in the nation, is key to the economic growth, national security, and public health and safety. However as highlighted during past hurricane events, the overhead transmission and distribution infrastructure of the grid are vulnerable to weather related hazards. In order to provide for the ability to reliably characterize this vulnerability, a series of numerical and experimental investigations for the wind responses of transmission tower-line systems are conducted. The experiments on multiple spans of scaled transmission tower-line systems are performed at NSF NHERI Wall of Wind Experimental Facility at Florida International University. The numerical studies are conducted in OpenSees finite element platform. An ensemble of stochastic wind pressure field histories are generated based on stochastic properties of recorded wind pressures at a finite number of points during wind tunnel experiments. Applying the produced pressure histories to the finite element model of the tower spine and cables, time history responses of the system at key points are determined using geometrically nonlinear dynamic analysis. Aerodynamic and aeroelastic characteristics of the structures from the experiments and finite element model are subsequently analyzed. The study also carries out a comparison of the base forces and moments measured using multi-axes load cells at the base of the tower spine during wind tunnel experiments and those determined from time-history analyses. The presented experimental and computational procedures for wind analyses of transmission tower-line systems offer new insights about their complex nonlinear dynamic behaviors. The findings can lead to improved analysis and design procedures for overhead transmission structures.

Quantifying uncertainty in RANS predictions for wind pressure coefficients on buildings.

Catherine Gorle

Abstract

Computational fluid dynamics can be used to quantify pressure loads on buildings, but simulations of atmospheric boundary layer (ABL) flows can be affected by uncertainty in the inflow boundary conditions and the turbulence model. We will present a framework to quantify the resulting uncertainty in the predicted pressure coefficients, focusing primarily on Reynolds-averaged Navier-Stokes (RANS) simulations. We model a high-rise building at a 1:50 scale, considering an open terrain exposure and two different wind directions. The results are compared to wind tunnel measurements obtained in two different facilities for validation. The uncertainty in the inflow boundary condition is characterized using 3 uncertain input parameters: the reference velocity, the ABL roughness length, and the model orientation. These uncertainties are propagated to the quantities of interest using a polynomial chaos expansion approach. Results for the time-averaged pressure coefficients are presented in terms of the expectation and 95% confidence intervals at 450 pressure taps, considering 2 different wind directions. Comparison to the experiments shows that the uncertainty in the inflow conditions is non-negligible, but insufficient to explain the discrepancy with the experimental data. The turbulence model form uncertainty is quantified by introducing perturbations in the Reynolds stress tensor, making the turbulence more one-, two-, or three-component. The results show that introducing perturbations towards the one- and three-component limiting states produce an upper and lower bound for the baseline turbulence model prediction in most locations on the building façade; these bounds are largest in the upstream region where flow separation occurs. Finally, the two methods are integrated in a mixed aleatory-epistemic uncertainty quantification (UQ) framework, where perturbed simulations are performed for each of the inflow UQ simulations. Ongoing work focuses on calculating root mean square and peak pressure distributions from the RANS averaged flow field, and applying the UQ framework to these new quantities of interest.

Predicting realistic responses of light-frame low-rise buildings under wind loads

Arindam Chowdhury, Ph.D., Iowa State University

Abstract

Low-rise wood frame buildings are one of the most vulnerable structures that are often damaged in windstorms. Numerically modeling the structural behavior of wood frame buildings poses significant challenges. This presentation focuses on a computational modeling methodology that can help determine the realistic behavior of light-frame low-rise buildings under wind loadings throughout the linear to the nonlinear range. A three-dimensional finite-element (FE) model was developed to capture the behavior of a building under wind loading. Large-scale model of the building was tested at the NHERI Wall of Wind (WOW) Experimental Facility (EF) at Florida International University to provide data for the validation of the FE modeling. This comprehensive numerical model can accommodate various materials and structural connections (e.g., sheathing nails and framing-to-framing connections) that are the most vulnerable parts of a low-rise structure as witnessed during past hurricanes. The modeling methodology applied is capable of simulating the nonlinear behavior of connections as well as the entire structure and has advantages of more accurate performance predictions over linear behavior based counterparts. The predicted structural responses of the computational framework showed reasonable agreement when compared to the experimental measurements in terms of the deflection at roof sheathings and roof-to-wall connections (RTWCs). This validated numerical framework can be used to analyze different modeling effects. The new knowledge will help in reducing the vulnerabilities of wood frame buildings against wind hazards. This accomplishment supports the NHERI's vision to build the basic science knowledge and computational modeling and simulation capabilities to evaluate hazard resilient and sustainable civil infrastructure and communities.

Inferring Dynamic Characteristics of a Bridge and Significance of Dynamic Soil-Structure Interaction on Its Response Using Large Mobile NHERI Shakers

Nenad Gucunski, Dr.

Abstract

Boundary conditions of a structure affect its response to dynamic excitations. Most commonly, an underlying assumption in the highway bridge analysis and design is that bridge piers and abutments have fixed-ends. The dynamic soil-structure interaction and its effects are not considered. One the other hand, foundation flexibility and soil dynamic stiffness (impedance), whether it is a shallow or deep foundation, can significantly influence the response of substructure/superstructure system. This may lead to deviations of the actual response compared to the design assumptions, depending on soil properties and geometrical and structural characteristics of the bridge. Bridge shaking using large NHERI mobile shakers can be used as the means of evaluation of actual dynamic characteristics of a bridge and the significance of dynamic soil-structure interaction (DSSI) on its overall response. Moreover, numerical simulations of the same bridge with the same low-magnitude shaking load on the bridge can be used to model the dynamic response of the bridge, with the consideration of the dynamic soils structure interaction. In this paper, a comparison between the actual response of a bridge in Hamilton Township, New Jersey, and results from numerical simulations is presented. The shaking of the bridge was done using T-Rex, a large mobile shaker from NHERI Experimental Facility at University of Texas at Austin. The test setup and results from both numerical simulations and field-testing, including the conclusions about the significance of DSSI, are presented and discussed.

Analysis and Modeling of Seismic Resistant Cross Laminated Timber Post-Tensioned Rocking Walls

Jeffrey Berman, Ph.D.

Abstract

Using cross laminated timber (CLT) panels in a post-tensioned rocking wall system shows great potential for creating reliable, cost-effective, and rapidly constructible ductile seismic load resisting systems. The NHERI TallWood Project includes research on the behavior of rocking CLT wall systems in tall timber buildings, including the development of performance-based and resilience-based seismic design procedures. The project involves testing and modeling tasks, including the recent completion of a full-scale two-story shake table test, utilizing the rocking CLT Walls. This two-story building was tested on the world's largest outdoor shake table in San Diego, California at the NHERI@UCSD facility. The lateral system consisted of two post-tensioned CLT rocking walls which each had two CLT panels, coupled together with U-shaped flexural plate (UFP) energy dissipaters. Numerical modelling of the post-tensioned CLT rocking walls was performed using OpenSees and calibrated to the test results. Elastic Timoshenko beam column elements were used for the CLT walls and spring elements for the post-tensioning bars. The rocking motion and the CLT deformation at the wall base were simulated with a distributed spring model. The results of the modeling are extended to a parametric study that is used to verify the system's performance prior to designing a full-scale ten-story structure and returning to the NHERI@UCSD facility in 2020 for resting. Here, the modeling and analysis of the two story test and how the results will be extended to the ten-story test will be discussed in detail.

Application of the NHERI RAPID Facility's Equipment for Assessing Building Damage

Joseph Wartman

Abstract

The NHERI RAPID Facility hosts a unique equipment portfolio for natural hazards reconnaissance including lidar scanners, image collection equipment, surveying equipment, unmanned aerial vehicles (UAVs), thermal imaging cameras, and other tools. In recent reconnaissance missions, this state-of-the-art equipment has been used to collect perishable data on the performance of buildings during natural hazards. This presentation will highlight a sampling of recent applications of field instrumentation similar to those in the RAPID's portfolio to inspire potential facility users to advance the building damage data collection and interpretation methods in the future through systematic processes available with these technologies. Recent applications that will be highlighted include (i) characterizing damage to houses in Christchurch, New Zealand that were impacted by seismically-induced rockfalls, (ii) quantifying of building deformations from ground shaking and bridge deformation from lateral spreading following the Maule Chile earthquake, (iii) capturing tsunami impacts on a variety of structures in Japan, (iv) characterizing external damage to Florida housing from Hurricanes Matthew and Irma, and (v) applications in laboratory settings such as documenting instrumentation and damage to a large-scale test of a timber building on the NHERI@UCSD shake table and documenting wind and rain induced damage during a demonstration test at the NHERI Wall of Wind Facility. Finally, research challenges and needs in processing and interpreting collected data will also be highlighted.