University of Michigan - EERI Student Chapter

2010-2011 Annual Report

I. General Chapter Information

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2. Xiaohu Fan
3. Matthew Fadden
4. Remy Lequesne
5. Clinton Carlson
6. Adam Lobbestael
7. Qi Wu

II. Summary of the 2010-2011 EERI Seminar Series

Seminar 1

Date: April 29, 2010
Speaker: Lawrence C. Novak
Speaker's affiliation: Portland Cement Association
Title of the seminar: Design Philosophy for the Burj Khalifa Tower, Dubai, The World's Tallest Structure
Seminar abstract:

The recently opened Burj Khalifa Tower, formally known as the Burj Dubai, is the world's tallest manmade structure. The multi-use skyscraper soars to over a half mile high (828 meters, 2717 feet). The 280,000 m2 (3 million square feet) reinforced concrete multi-use Tower is utilized for Retail, a Giorgio Armani Hotel, Residential and Office. The goal of the Burj Khalifa Tower is not simply to be the world's highest building; it is to embody the world's highest aspirations.

The Tower, located in Dubai, UAE, an equivalent UBC 97 seismic zone 2A, is schedule to be completed in 2010. Designers purposely shaped the structural concrete Burj Dubai – "Y" shape in plan – to reduce the wind forces on the tower, as well as to keep the structure simple and foster constructability. The structural system can be described a "buttressed" core. Each wing, with its own high performance concrete core and perimeter columns, buttresses the others via a six-sided central core, or hexagonal hub. The result is a tower that is extremely stiff laterally and torsionally. Skidmore, Owings & Merrill (SOM), the architects and engineers for the project, applied a rigorous geometry to the tower that aligned all the common central core and column elements. Each tier of the building steps back in a spiral stepping pattern up the building. The setbacks are organized with the Tower's grid, such that the building stepping is accomplished by aligning columns above with walls below to provide a smooth load path. This allows the construction to proceed without the normal difficulties associated with column transfers. The Tower's width changes at each setback. The advantage of the stepping and shaping is to "confuse the wind". The wind vortices never get organized because at each new tier the wind encounters a different building shape. This enhanced wind behavior coupled with the mass and damping provided by the high performance concrete, work together to minimize the forces and motions of the structure. High performance concrete is becoming the material of choice for the next generation ultra-tall high-rise buildings.

The presentation will discuss the philosophy behind the structural design and sustainable design of the world's tallest structure.

Seminar 2 EERI Distinguished Lecture

Date: September 24, 2010
Speaker: Professor Sharon L. Wood
Speaker's affiliation: University of Texas at Austin
Title of the seminar: The Potential of Ubiquitous Sensing
Seminar abstract:

During the past decade, our expectations regarding mobile computing and connectivity have increased exponentially. With smart phones, we can remain in constant contact with the internet, receive immediate notification of each email message, and know our exact location at any time. If the bandwidth issues could be resolved, one could easily envision post-earthquake rescue service similar to those currently used to deploy emergency responders after automobile crashes, as most current hardware already includes GPS chips and MEMS accelerometers. Similarly, structural engineers could define thresholds of response before an earthquake and sensor systems deployed within buildings and bridges could automatically trigger yellow or red flags based on the measured response.

Smart meters for electric power consumption, and the associated software, provide a model for how we can improve our existing infrastructure. The Google website includes testimonials from beta testers who have dramatically reduced their power bills by understanding how each of their electrical appliances contributes to the total consumption. Their byline "You can measure it… You can improve it…" also applies to structural performance. Ignoring for the moment that damaging earthquakes are rare events, side-by-side comparisons of various schemes for rehabilitation and strengthening of existing structures could lead to the development of field-tested recommendations for individual structural systems of specific ages.

However, in order to achieve the vision of 2056 developed for the 2010 EERI Annual Meeting, the structural engineering community must learn more about the actual performance of complete systems, including the performance of nonstructural elements. This can only be achieved by developing comprehensive models and conducting verification studies of the few buildings with sensor networks. The information available from the Center for Engineering Strong Motion Data website (http://www.strongmotioncenter.org/) is an invaluable tool for testing and improving our models and understanding system response. Our challenge is to use these data sets to the maximum extent possible to improve the infrastructure and reduce the vulnerability to earthquake damage.

Seminar 3

Date: October 1, 2010
Speaker: Professor Jamie E. Padgett
Speaker's affiliation: Rice University
Title of the seminar: Seismic Vulnerability and Loss Estimation for Aging Bridge Infrastructure
Seminar abstract:

Our nation's bridge infrastructure is exposed to a host of threats, ranging from increased demands, to aging and deterioration, to natural hazard loading. The coupling of these threats, although seldom considered, such as the joint exposure to deterioration and seismic hazards, poses significant risks of structural damage and subsequent economic consequences. This presentation provides an overview of ongoing research to probabilistically assess the performance of aging bridges under seismic loads, and presents a new model proposed to evaluate the seismic losses or seismic life-cycle costs for aging bridge infrastructure. The formulation of a time-dependent seismic fragility format for bridges is developed and illustrated with case study bridges. The results offer new insights into the potential effects of aging and deterioration on seismic vulnerability traditionally neglected in fragility modeling, including joint impacts of multiple component deterioration not investigated to date. These time dependent fragility curves are integrated into a new model for loss assessment to help support decision making on needed upgrade or risk mitigation actions. This seismic loss model of aging bridges is derived based on a non-homogeneous Poisson process, allowing the statistical moments of seismic losses to be efficiently estimated. The approach is unique in its account for time varying seismic vulnerability, uncertainty in component repair, and the contribution of multiple correlated aging components. Ongoing and future work is highlighted, such as the method's

application to regional bridge infrastructure in the Charleston, SC region and opportunities to update the vulnerability models with field condition data.

Seminar 4

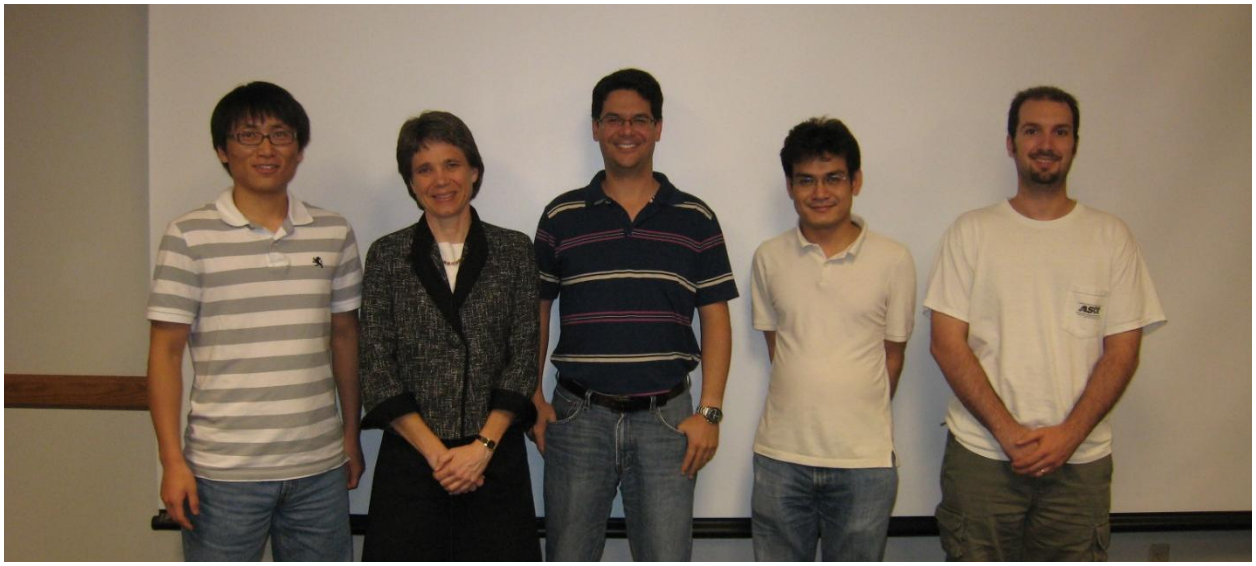
Date: October 8, 2010
Speaker: Prof. Abolhassan Astaneh-Asl
Speaker's affiliation: University of California Berkeley
Title of the seminar: Blast Protection of Steel and Composite Buildings and Bridges
Seminar abstract:

The first part of this seminar focuses on blast resistance of steel and composite *building* structures. After discussing how buildings designed according to the current codes and practice, will respond to various sizes of blasts, the design concepts and technologies developed to mitigate such vulnerabilities will be presented. The second part of the seminar focuses on long span cable stayed and suspension *bridges and elevated freeways.* The response of orthotropic desk as well as the steel girder/concrete deck in these bridges subjected to various sizes of explosives will be presented showing the consequence of such failure. Then, design concepts and technologies that can mitigate deck vulnerabilities will be discussed. The blast response of the steel towers of long span bridges as well as the steel piers in elevated freeways were also studies in this program and information on this part of research will also be presented.

Seminar 5

Date: October 29, 2010
Speaker: Professor Hitoshi Shiohara
Speaker's affiliation: The University of Tokyo, Japan
Title of the seminar: Comprehensive Series of Tests on Seismic Performance of Reinforced Concrete Interior Beam-Column Joints
Seminar abstract:

Results of seismic test on one third scale, reinforced concrete interior and exterior beam-column joint subassemblages are introduced. The effects of the combination of design parameters of joints on lateral capacity and post yielding behavior are investigated. Three major parameters selected in the test are (1) amount of longitudinal reinforcement, (2) ratio of the flexural strength of the beams to the flexural strength of the columns framing into a joint, and (3) ratio of the depth of the beam to the depth of the column. Maximum story shear of some specimens fell 5% to 30% short of the story shear calculated by the flexural strength of the beam or the column, although the joints have enough margin of the nominal joint shear strength by 0% to 50% compared to the calculated value by a current seismic provision. The extent of insufficiency in the story shear is larger if the flexural strength of the column is equal or nearer to the flexural strength of the beam, and if the depth of the column is larger than that of the beam. This kind of combination of design parameters is not a rare feature but is rather seen frequently in existing reinforced concrete buildings. This means that current seismic provisions for RC beam-column joints are deficient and cannot secure the lateral strength of moment resisting frames predicted by the flexural theory of RC sections. Hence, a large number of existing moment resisting frame reinforced concrete structures may be more vulnerable than we expect. Immediate actions by engineers, researchers and code writers are necessary.



Prof. Wood Lecture (From left to right: Xiaohu Fan, Sharon Wood, Gustavo Parra-Montesinos, Monthian Setkit, and Alexander DaCosta)

III. Community Outreach

EERI members actively participated in outreach programs at local elementary schools. EERI members gave several tours of the laboratories to young students, encouraging careers in the civil and earthquake engineering fields. Students from 5 years old through high school age visited the Structural Engineering Laboratory, as well as the Geotechnical Engineering Laboratory. These students enjoyed learning about earthquakes and watching live concrete compression tests.

IV. Civil and Environmental Engineering Graduate Research Symposium

In addition to seminars, three years ago our chapter initiated a department wide student-led effort to organize and host the annual Civil and Environmental Engineering Graduate Research Symposium. The concept was born from the perceived need for improved cross-disciplinary communication within our department. To address this, the symposium provides a venue for graduate and undergraduate students to present their research to their peers and faculty. It is hoped that by making students more aware of other research being done within the department, channels of communication will be opened that may help students develop more diverse perspectives on their own research work. This year the symposium was held on March 18, 2011 and built on the previous success of the previous years. Below is a table with a list of the topics presented.

Presenter	Topic	Title
Manu Akula	Construction	Context-Aware Computing for Improved Bridge Inspections
Yao Zhang	Geotechnical	Frost heave in soils around a culvert
Lauren Strahs	Environmental	Analysis of Bacteria and Chemical Compounds in Drinking Water
Matt Fadden	Structures	Cyclic testing of hollow structural section members for seismic applications
Yuqiang Bi	Environmental	Oxidative dissolution of uraninite by dissolved oxygen under simulated groundwater conditions in the presence of mackinawite (FeS)
Yoichi Shiga	Environmental	Designing a North American In-Situ CO2 Monitoring Network to Improve Atmospheric Inverse Studies
Suyang Dong	Construction	Collaborative visualization of simulated processes using tabletop fiducial augmented reality
Derya Ayral	Environmental	Impact of chlorinated waste solvent-clay interaction on transport and storage of chlorinated solvents in low permeability zones
Jeff Bergman	Structures	Monitoring Tension in an Inclined Cable using Ambient Vibrations
Jenahvive Morgan	Environmental	Flow characterization in vegetated marsh environments
Xunchang Fei	Geotechnical	Bioreactor Landfill: state of the art technology and future
Sanat Talmaki	Construction	VirtualWorld - Using Virtual Reality to assist Excavators in Pipeline Collisions
Qianru Guo	Structures	Stochastic Methods for Structural Safety Evaluation in Fire
Clinton Carlson	Geotechnical	Ground motion modification techniques and their impact on ground motion characteristics and seismic analyses

Students at the Civil and Environmental Engineering Graduate Research Symposium

V. EERI Annual Meeting

The 63rd annual meeting was held in San Diego, CA in February 2011. Monthian Setkit, President of the chapter during the 2010-2011 academic year, represented the University of Michigan Student Chapter. He presented a poster on the chapter activities and his own research.

VI. Ongoing Earthquake-Related Research Projects at the University of Michigan

NEESR-CR: Assessment of Punching Shear Vulnerability of Slab-Column Connections with Shear Stud Reinforcement

Flat plates or flat slabs are commonly used in reinforced concrete framed construction due to their architectural appeal and low cost. In regions of high seismicity, these systems are often used in combination with laterally stiffer and stronger systems, such as structural walls and special moment resisting frames. Although generally not intended to resist earthquake-induced forces, slab-column frames must be capable of maintaining their gravity load capacity while undergoing lateral displacements during earthquakes.

The behavior of slab-column connections with various arrangements of shear stud reinforcement is investigated through large-scale subassembly tests subjected to combined gravity load and bi-axial lateral displacements at the NEES-MAST Laboratory. When used in slab-column connections subjected to combined gravity load (gravity shear ratio of 50%) and bi-axial lateral displacements, a maximum drift capacity of approximately 1.8% for each perpendicular loading direction was obtained when orthogonally placed shear studs were provided such as to resist the entire expected shear demand. When only the minimum amount of shear studs required by Chapter 21 of the ACI Code was provided, a punching failure occurred during the cycle to 1.15% in each direction. Steep diagonal cracks were observed at failure, indicating that the maximum shear stud spacing of 0.75 times the slab effective depth may not be effective in ensuring the critical crack is crossed by shear reinforcement. Further, the use of an orthogonal layout of shear studs was found to leave substantial slab areas unreinforced, which allowed extensive damage to develop in the slab areas adjacent to the column corners. Results from these tests therefore indicate that the use of a cruciform shear stud layout, regardless of the amount of shear studs provided, does not ensure adequate drift capacity in slab-column connections subjected to combined gravity load and inelastic displacement reversals. The use of a more uniform spacing of shear stud reinforcement around the column, on the other hand, is believed to be a better alternative to ensure adequate seismic behavior.

Large-Scale Testing of Hollow Structural Sections for Seismic Applications

HSS are currently used in a number of building applications such as columns, bracing members in braced frame systems, axial members in truss systems, and supports for exterior cladding Benefits for considering further use of HSS members in structural applications include favorable properties such as compression, bending, torsion, and high strength-to-weight ratio. For moment frame systems, current seismic design standards require the majority of the inelastic behavior to occur in the beam member to provide for a strong column-weak beam design. Previous studies have focused on the behavior HSS in bending under monotonic loading up to failure but few studies have considered the hysteretic behavior. This research aims at evaluating the plastic hinge behavior of HSS members under large bending cycles. This will be carried out by investigating the effect of parameters such as width-to-thickness ratio (*b/t*) and depth-to-thickness ratio (*h/t*). These parameters will help determine the limiting values needed to achieve stable plastic hinge formation. This testing will also provide preliminary data for the use of HSS beams and the development of HSS-to-HSS moment connections.

Seismic Behavior of Slender HPFRCC Coupling Beams

Coupled structural walls are efficient lateral load resisting systems for medium- and high-rise structures in zones of moderate to high seismicity. During a large earthquake, it is anticipated that the coupling beams will undergo significant inelastic deformations and thus, it is important for these coupling beams to be strong and stiff, behave in a ductile manner, and possess significant energy dissipation capacity. In order to ensure adequate behavior under earthquake-induced deformations and stresses, intricate reinforcement detailing is required for reinforced concrete coupling beams, typically in the form of diagonal bars and extensive confinement reinforcement. Such reinforcement detailing, however, creates major construction difficulties. Furthermore, in slender coupling beams where beam span-to-depth ratios are on the order of 3, the effectiveness of diagonal reinforcement is questionable because of its shallow angle (less than 20 degrees) with respect to the beam longitudinal axis. In this study, a design alternative for the slender coupling beams that put less reliance on diagonal reinforcement was experimentally investigated through the use of high-performance fiber reinforced concrete (HPFRC). HPFRC materials exhibit a tensile strain-hardening response after first cracking and a compression behavior resembling that of well-confined concrete. To validate this design alternative, six precast slender coupling beams were tested. The use of HPFRC as a means to relax or totally eliminate diagonal bars and substantially reduce confinement reinforcement was evaluated. Results from large-scale tests indicated excellent damage tolerance, and drift and stiffness retention capacity for slender HPFRC coupling beams. Moreover, diagonal reinforcement can be completely eliminated without a detrimental effect on seismic behavior.

NEESR-Time-Dependent Strength Gain in Recently Liquefied Granular Materials

Time-dependent strength gain in recently liquefied granular materials is commonly called sand aging. It refers to the phenomenon of a disturbed or liquefied sand deposit gaining strength with time after settlement and dissipation of excess pore pressure is complete. The purpose of the project is to gain a better understanding of sand aging through three highly instrumented field tests. A loose, saturated sand deposit will be liquefied through explosive compaction, vibro-compaction, and the NEES vibro-seis. By comparing the energy input from these three different methods to the magnitude of the aging after liquefaction, the investigators hope to develop a metric for aging based on energy input.

NEESR SG-Damage Detection and Health Monitoring of Buried Pipelines after Earthquake Induced Ground Motions

Clean water is essential to emergency response, making assessment of water delivery systems crucial to recovery from earthquakes, tsunamis, hurricanes, or other disasters. Because pipelines are buried and often very congested in urban areas, rapid post-disaster assessment and response is very difficult. Currently, inspection techniques require interpretation of results and are labor intensive. Most sensor-based inspection methods are prohibitively expensive. This project will use wireless sensing technologies to develop a self-sufficient health monitoring system for buried pipelines using electrical probes with electrical impedance spectroscopy (EIS) data and acoustic emission.

Electrical Impedance Tomography for Damage Detection of Cementitious Structures

Cementitious materials such as concrete are identified as semi-conductive mediums that electric currents are carried through the ions existing within the pore solutions. This semi-conductive nature enables the damage detection to be conducted electrically, which is more economic and comprehensive. Electrical impedance tomography (EIT) is an electrical mapping technique that reconstructs the electrical resistivity or conductivity maps of the investigated object. Since damages of cementitious materials could significantly change their electrical properties (current paths are blocked), these electrical inhomogeneities can then be captured via the reconstructed electrical maps. EIT is performed by deploying numbers of discrete electrodes along an object's boundaries. Certain pairs of electrodes serve for current drain and sink and rest of the electrodes serve for electrical potential measurements. The current-voltage relationships of a conductive mediums is governed by the well know Poisson's equation. Since analytical solution of Poisson's equation holds only for very few cases, this equation is then implemented into a numerical model such as finite element method via computer programming. Through iterations of forward simulation and inverse optimization, the finite element model is updated so as to fit the actually electrical responses acquired from the boundary electrode pairs. Once the electrical responses are well simulated by the FEM model, the resistivity/conductivity maps are then assembled and illustrated by the meshed conductive elements. Resolution of the EIT maps to identified different degrees of damages are controlled by the number of electrodes installed along objects' boundaries.

Structural Controls: Market-Based Algorithm

In seismic regions, some buildings are equipped with mechanical systems to help control their behavior when an earthquake strikes. Restricting the deflection of the structure reduces damage and leads to safer, more durable buildings. One type of structural control system uses magnetorheological (MR) dampers that absorb energy to limit the amount of drift that each story undergoes. The dampers' stiffness can be altered using electric current regulated by a computer. Associate Professor Jerry Lynch led a collaborative effort to improve these systems. They implemented a wireless sensor network to control the dampers, and embedded a market-based algorithm that seeks to reduce the amount of power used by the dampers. The group recently tested this setup at the National Center for Research on Earthquake Engineering (NCREE) in

Taipei, Taiwan. The team included current CEE Ph.D. student Michael Kane, Professor C.H. Loh from National Taiwan University, Professor Kincho Law from Stanford University, and Professor Andrew Swartz from Michigan Technological University. Professor Swartz is also an alumnus of the University of Michigan CEE Ph.D. program.

THE IMPACT OF GROUND MOTION MODIFICATION ON SEISMIC ANALYSES

Ground motion modification is a necessary yet misunderstood process in the field of earthquake engineering. The need for input ground motions in dynamic analyses of critical structures, such as dams, nuclear facilities and highways, commonly results in ground motion modification to match a target spectrum. Yet, the effects that different ground motion modification techniques have on the ground motion characteristics, site response analyses and structural responses are not well understood. Modifying a certain ground motion in the time domain may greatly decrease the Arias Intensity, but only slightly decrease the max shear stress in the soil profile, whereas modifying the same ground motion in the frequency domain may have the opposite effect. Therefore, a research investigation is being conducted at the University of Michigan to fundamentally understand the strengths and limitations of the ground motion modification process. The objective of this research is to provide guidance on recommended procedures/approaches to use for modification for the given design conditions.

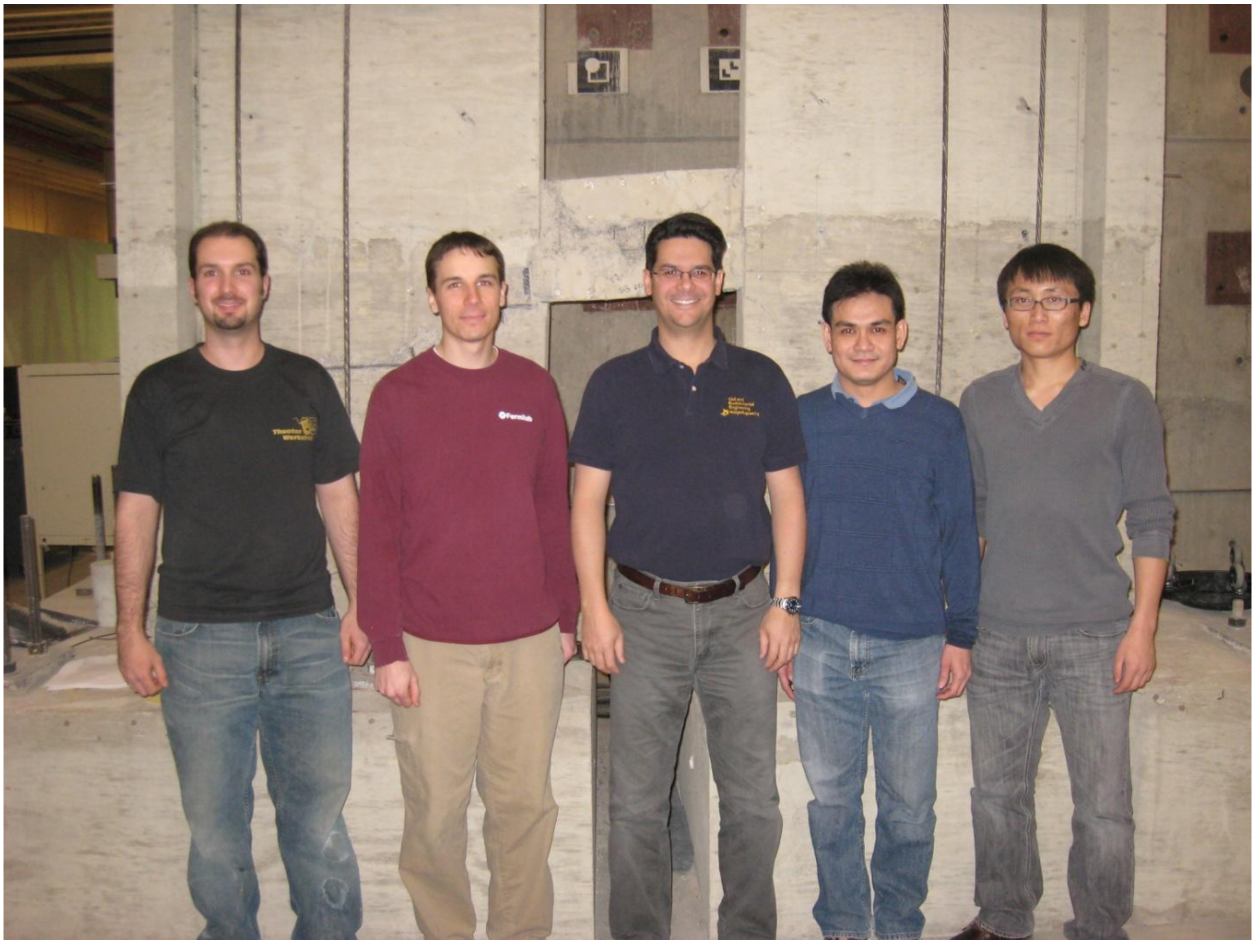
VII. New Officers of the Student Chapter

The new officers selected for the 2011-2012 academic year are:

President:	Xiaohu Fan
Vice-President:	Clinton Carlson
Treasurer:	Julie Fogarty
Secretary:	Alexander DaCosta
Faculty Advisor:	Gustavo J. Parra-Montesinos

VIII. Acknowledgements

I would like to thank our faculty advisor Gustavo J. Parra-Montesinos and the other current officers for aiding in the preparation of this report.



EERI Officers (From left to right: Alexander DaCosta, Michael Kane, Gustavo Parra-Montesinos, Monthian Setkit, Xiaohu Fan)

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