

# RESEARCH HIGHLIGHTS



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# WELCOME



## to the Department of Structural Engineering at UC San Diego.

We appreciate your interest in our program. The Department website at <http://structures.ucsd.edu> presents a detailed view of the graduate and undergraduate programs that the Department offers, together with an overview of current research areas; descriptions of our computational and experimental facilities; and profiles of our faculty and researchers. Following are some highlights of the unique characteristics of the Department:

In most Schools of Engineering, Structural Engineering is offered as a discipline within a Department of Civil and Environmental Engineering. Typically, additional courses and research opportunities on aerospace structures are offered through Departments of Mechanical Engineering and/or Aerospace Engineering. At UCSD, for the last 30 years, all of the teaching and research on civil and aerospace structures have been centralized in one group, which in 1998 became the current Department of Structural Engineering. This unique organization, which takes advantage of the many commonalities among sub-disciplines of Structural Engineering, provides focused and yet rich educational and research experiences built on theoretical, computational and experimental efforts, and gives graduates of the program a unique perspective as well as more flexible employment opportunities. Over the years, the focus on Structural Engineering has been expanded beyond civil and aerospace structures to include biological and marine structures.

Aligned with the unique vision just described, the Department has assembled an outstanding group of faculty and researchers with a wide range of backgrounds in civil structures, geotechnical engineering, aerospace engineering, mechanical engineering, computational mechanics, and computer and materials science. The faculty delivers graduate and undergraduate curricula of significant depth and unprecedented scope. The range of research conducted in the Department is simply astonishing. Some current or recent research projects illustrating this range include: Full- or large-scale experimental studies of the seismic response of wind turbines, reinforced concrete bridge columns, a 3-story precast parking structure and industrial steel structures; experimental evaluation of landing gear for a major new aircraft; structural modeling of blood cells; blast mitigation in civil and marine structures; computational model of the skull and brain of a whale and its response to sound waves in water; computational model of the aerodynamic response of wind turbines, evaluation of effects of soil-structure interaction on the response of nuclear power plant structures; non-destructive evaluations of rails, wind turbine blades and components of unmanned aerial vehicles and composite materials ships; experimental study on the NEES/UCSD shake table of the seismic response of the non-structural content of a 5-story reinforced concrete building including a hospital Intensive Care Unit and Operating Room; and research on heritage structures.

The Structural Engineering Department is also home of the world-class Powell Laboratories both on campus and at the UCSD Englekirk Structural Engineering Center. These laboratories focus on the full- or large-scale testing of all types of structures. The campus facilities include the High-Bay Structural Systems Laboratory, the Structural Components Laboratory, and the 6-DOF shake table at the Caltrans Structural Response Modification Devices (SRMD) Laboratory. The facilities at the Englekirk Center include the NEES/UCSD Large High-Performance Outdoor Shake Table, the Blast Simulation Facility, the Rail Defect Testing Facility, the Caltrans Soil-Structure Interaction Testing Facility, and the Large Soil Box and two smaller laminar soil shear boxes to be used in conjunction with the NEES/UCSD Shake Table. In 2012, the Department moved to the new 183,000 sq-ft Structural and Materials Engineering (SME) Building, which offers excellent teaching laboratories and workshops, and additional research laboratories for Non-destructive Evaluation, Aviation Safety, and Computer Visualization.

The reputation of the Department continues to grow as measured by different rankings, by the growing number of undergraduate and graduate admissions applications, and by the quality of the faculty. In 2012, the Department was ranked 6th in the US and 20th in the world by the QS World ranking of Civil Engineering Departments. In Fall 2012, the undergraduate enrollment reached an unprecedented number of 642 SE majors. The graduate enrollment reached 155 students, 86 MS and 69 PhD. Also, in 2012, two outstanding new faculty members joined the Department bringing the total faculty to 23. The additions are Prof. Gilberto Mosqueda with expertise in the area of civil structures and Prof. Chiara Bisagni with world expertise in aviation safety. The Department has one faculty position open for 2013 in the area of Blast Mitigation.

I encourage you to explore our website and, perhaps, visit in person, and to offer any thoughts or comments.

With warm regards,

**J. E. Luco**

Professor and Chair  
UCSD Department of Structural Engineering

**DID YOU KNOW?** The Department of Structural Engineering is the 6th Best Civil Engineering Program in the U.S. and 20th Best Civil Engineering Program in the World  
*World University Rankings*

## 2015 Research Highlights

**Editor** Jacqueline Vo  
**Design & Layout** A.S. Graphic Studio  
**SME Photography** Nic Lehoux

**STRUCTURAL ENGINEERING DEPARTMENT**  
9500 Gilman Drive 0085, La Jolla, CA 92093-0085  
[structures.ucsd.edu](http://structures.ucsd.edu)



## STRUCTURAL AND MATERIAL ENGINEERING (SME) BUILDING

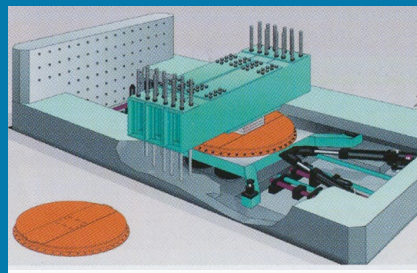
In recent years, student enrollment at the Jacobs School of Engineering has increased to approximately 6,800 undergraduate and graduate students. To accommodate the critical need for space, UC San Diego built the Structural and Materials Engineering Building. Campus officials dedicated the building Sept. 14, 2012 during a standing-room only ceremony. The event brought together the engineers, medical device researchers and visual artists who will work in the new facility, as well as top campus administrators, supporters and industry representatives.

The 183,000-square-foot building houses the structural engineering department, nano-engineering, a medical devices group and parts of the visual arts department. The building includes 62 research and instructional laboratories, 160 faculty, graduate student and staff offices, 12 Visual Arts studios distributed across all four building's floors, art exhibition and performance space, and Cymer Conference Center. Frieder Seible, Dean of the Jacobs School of Engineering, remarked, "The hope and aspiration for this building is that it is not a physical location for four seemingly disparate academic units, but that it will be transformational for our campus and how we collaborate in our research and education mission."



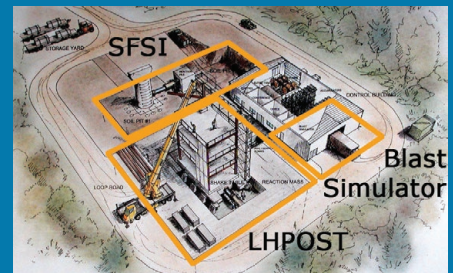
### Charles Lee Powell Structural Research Laboratories

The Charles Lee Powell Structural Research Laboratories are the largest and most active full-scale structural testing facilities in the world. With its 50 ft. tall reaction wall and 120 ft. long strong floor, the Structural Systems Laboratory is equipped for full-scale testing of bridges, buildings and aircraft. The Structural Components Laboratory includes a 10 x 16 ft. shake table for realistic earthquake simulations. The main testing facility was dedicated in 1986. Throughout the years, additional facilities have been added as the scope and nature of Powell Labs research has expanded.



### Caltrans Seismic Response Modification Device (SRMD) Testing Laboratory

One of the world's largest shake tables, the six-degree-of-freedom shake table is used for the dynamic testing of full-scale bearings, isolators, and dampers. Computer-controlled hydraulic actuators that can apply up to 12 million pounds of force during earthquake simulations power SRMD.



### The Englekirk Center

In 2005, the Englekirk Structural Engineering Center opened as an expansion of Powell Labs, equipped with the world's first outdoor shake table. It is adjacent to the country's largest Soil Foundation-structure Interaction Facility. UCSD Blast Simulator is the world's first laboratory to simulate the effects of bombs without the use of explosive materials.

# FACILITIES

# WORLD-CLASS FACULTY



**Robert Asaro**

**Professor**

Composite design and manufacturing technologies for large scale structures and marine applications as well as the deformation, fracture and fatigue of high temperature intermetallics.



**Yuri Bazilevs**

**Professor**

Design of robust and efficient computational methods for large scale, high performance computing.



**David Benson**

**Professor**

Computational mechanics and computer methods for solving problems in mechanical engineering.



**Jiun-Shyan (JS) Chen**

**Professor**

Computational solid mechanics, multiscale materials modeling, damage prediction of extreme events.



**Joel Conte**

**Professor**

Structural Analysis and Dynamics, Structural Reliability and Risk Analysis, Earthquake Engineering.



**Ahmed Elgamal**

**Professor**

Information Technology, Earthquake Engineering, Computational Geomechanics.



**Charles Farrar**

**Adjunct Professor**

Analytical and experimental solid mechanics problems with emphasis on structural dynamics.



**Patrick Fox**

**Professor**

Geotechnical and geoenvironmental engineering.



**Gilbert Hegemier**

**Distinguished Professor Emeritus**

Earthquake engineering to retrofit bridges, roadways and buildings for improved public safety and structural performance.



**Tara Hutchinson**

**Professor**

Earthquake and geotechnical engineering, performance assessment of structural/nonstructural components, and machine learning and computer vision methods for damage estimation.



**Hyonny Kim**

**Professor**

Impact effects on composite materials and structures with aerospace and other applications, multi-functional materials, nano-materials, and adhesive bonding.



**John Kosmatka**

**Professor**

Design, analysis, and experimental testing of light-weight advanced composite structures.



**Petr Krysl**

**Professor**

Finite element computational modeling techniques for solids and structures, model order reduction in nonlinear mechanics, and computer and engineering simulations in multiphysics problems.



**Falko Kuester**

**Associate Professor**

Scientific visualization and virtual reality, with emphasis on collaborative workspaces, multi-modal interfaces, and distributed and remote visualization of large data sets.



**Francesco Lanza Di Scalea**

**Professor**

Health Monitoring, Non-destructive Evaluation and Experimental Mechanics of Structural Components using novel sensing technology.



**Enrique Luco**

**Professor**

Earthquake engineering, strong motion seismology, soil structure interaction.



**Gilberto Mosqueda**

**Associate Professor**

Earthquake engineering, structural dynamics, seismic isolation and energy dissipation systems, seismic response of structural and nonstructural building systems, experimental methods including hybrid simulation.



**Yu Qiao**

**Professor**

High-performance infrastructure materials, smart materials and structures, energy-related materials, failure analysis for engineering materials and structures.



**Jose Restrepo**

**Professor**

Seismic design of buildings for improved response during earthquakes.



**Frieder Seible**

**Distinguished Professor Emeritus**

Design and retrofit of buildings and bridges for earthquake safety, new technologies to renew the nation's aging infrastructure, and bomb blast-resistant design of critical infrastructure.



**Benson Shing**

**Professor**

Earthquake engineering, structural dynamics, inelastic behavior of concrete and masonry structures, bridge structures, finite element modeling of concrete and masonry structures, structural testing, structural control, pseudodynamic and fast hybrid test techniques.



**Michael Todd**

**Professor**

Structural dynamics, nonlinear vibrations, time series modeling, structural health monitoring strategies for civil, mechanical, and aerospace systems, fiber optic sensor system design and noise propagation modeling.



**Chia-Ming Uang**

**Professor**

Steel design of structures for optimal performance during earthquakes and vibrations.



**Lelli Van Den Einde**

**Lecturer (LPSOE)**



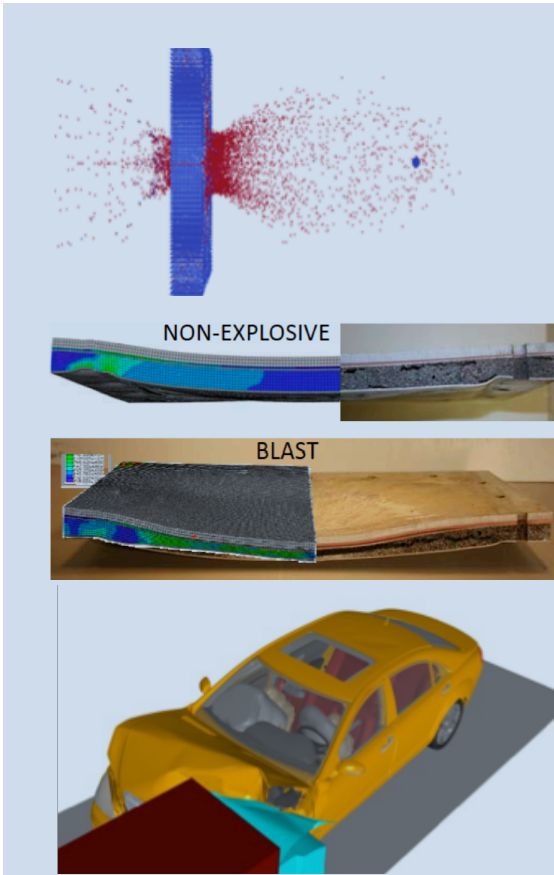
**Qiang Zhu**

**Associate Professor**

Ocean engineering, biomechanics.

# INNOVATIVE RESEARCH

# RESEARCH



## CENTER FOR EXTREME EVENTS RESEARCH

### STRUCTURAL ENGINEERING

R. Asaro, Y. Bazilevs (Associate Director),  
D. Benson, J. S. Chen (Director), P. Fox,

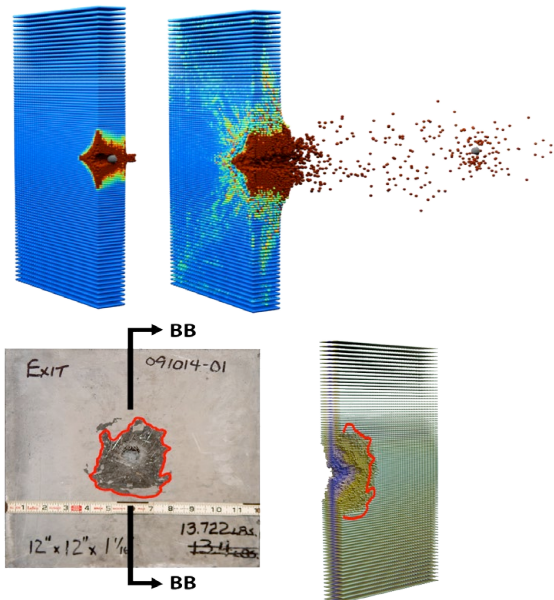
G. Hegemier (Associate Director), H. Kim,  
**MECHANICAL AND AEROSPACE ENGINEERING**

A. Marsden, V. Nesterenko, A. P. Pisano,  
S. Sarkar, **MATHEMATICS**, R. Bank, L. T. Cheng,

M. Holst, **RADIOLOGY**, S. Sinha, **SAN DIEGO  
SUPERCOMPUTER CENTER**,

A. Majumdar, M. Tatineni

Center researchers are world-renowned experts in experimental and computational methods for extreme events research. We leverage this expertise to develop better ways to protect entire built infrastructures, as well as bio-systems, from extreme events such as blasts from terrorist attacks and mining explosions, car crashes, sports collisions, and natural disaster such as landslides. Challenges we address are: protect the nation's built infrastructure, perform extreme event mitigation and recovery, and protect bio-systems injury from extreme loading.



## Meshfree Method for Impact and Penetration Modeling

**Professor J. S. Chen**

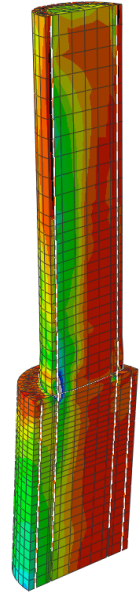
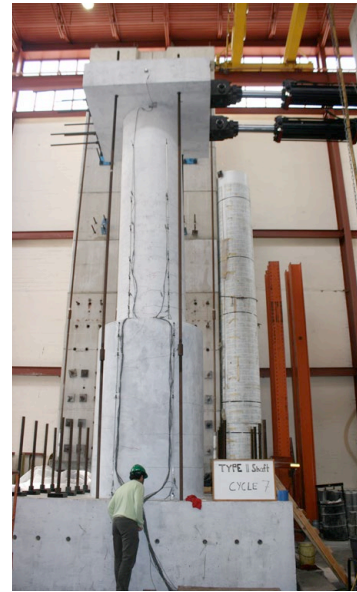
Professor J. S. Chen and his students are working with the U.S. Army Engineer Research and Development Center to develop a micro-crack informed damage model and multiscale reproducing kernel particle method (RKPM) formulation to model impact and penetration into brittle materials. By developing a semi-Lagrangian stabilized nodal integration formulation, key phenomena such as multi-body contact, material fragmentation, and large material flow are accurately modeled. The multiscale formulation provides a critical link between microstructure failure and macroscale damage, leading to improved modeling of material softening and failure, which is crucial in penetration events. These computational techniques have been extended to the assessment of structural damages due to extreme events such as blasts and shocks under Center for Extreme Events Research.

## Column Reinforcement Extended Into Enlarged (Type II) Shafts

### Professor P. Benson Shing

In spite of recent changes, the seismic design specifications of the California Department of Transportation (Caltrans) on the development of longitudinal column reinforcement in enlarged (Type II) CIDH shafts are still very conservative. For large-diameter bridge columns, #14 and 18 bars are common. With the older specifications that were recently replaced, these large-diameter bars would call for very long development lengths, which could significantly drive up the construction costs. Little research data are available on the cyclic bond-slip behavior of large-diameter bars to assess the development and splice length requirements in current design codes.

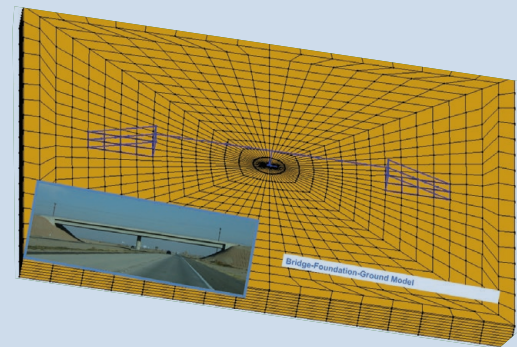
In a project sponsored by Caltrans, Professor Shing is leading an experimental and analytical study to characterize the bond-slip behavior of large-diameter bars, assess the level of conservatism in current Caltrans specifications, and develop new design recommendations that can further minimize the required development length and improve the performance of these shafts under extreme seismic load conditions. The study includes basic bond-slip experiments and bar pullout experiments as well as detailed nonlinear finite element modeling of the bond-slip behavior in column-shaft assemblies. Finally, four large-scale column-shaft assemblies are being tested in the Charles Lee Powell Structural System Laboratory at UC San Diego to validate the design recommendations and finite element models developed in this study. This research can lead to a significant reduction of the depth of the column rebar cage and construction joint in a shaft, which will result in significant cost savings in construction and safer work conditions.



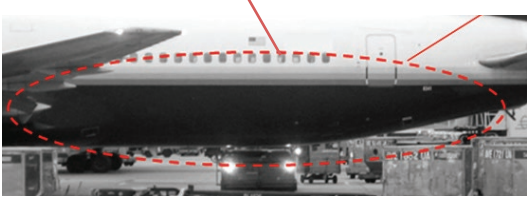
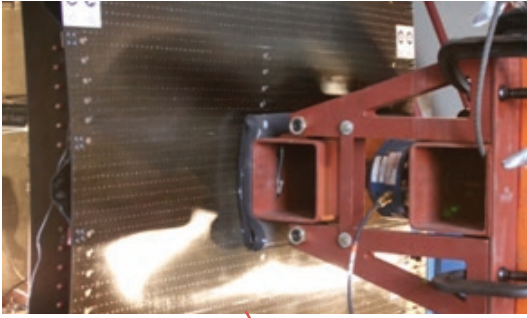
## SOIL-STRUCTURE INTERACTION AND PERFORMANCE-BASED EARTHQUAKE ENGINEERING

### Professor Ahmed Elgamal

Three-dimensional (3D) nonlinear finite element simulations are becoming increasingly feasible for geotechnical applications. OpenSeesPL, created by J. Lu, A. Elgamal, and Z. Yang, is a versatile framework that uses a Windows-based graphical-user-interface (GUI) developed for 3D footing/pile-ground interaction analyses. Various ground modification scenarios may be addressed utilizing the 3D tool. Building on OpenSeesPL, a new GUI has been developed to combine nonlinear dynamic time history analysis of coupled soil-structure systems with an implementation of performance-based earthquake engineering (PBEE) for a single-column 2-span bridge configuration (research with Prof. K. Mackie, UCF). In this new interface, functionality is extended for analysis of multiple suites of ground motions and combination of results probabilistically using the Pacific Earthquake Engineering Research Center (PEER) PBEE framework. Definition of the bridge, the underlying ground strata, and the material properties are greatly facilitated via this integrated analysis and visualization platform.



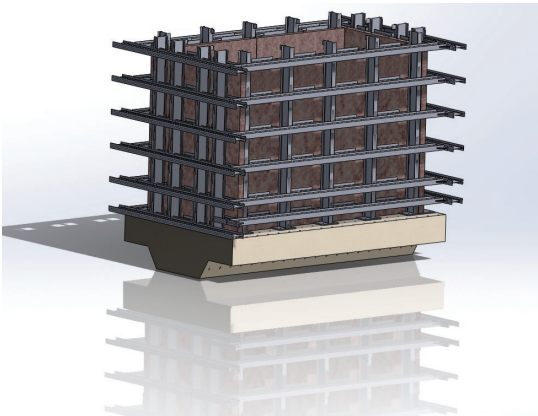
For more info, visit <http://www.soilquake.net/openseespl> and <http://peer.berkeley.edu/bridgepbee>



## Wide Area Blunt Impact on Composite Aircraft Structures

**Professor Hyonny Kim**

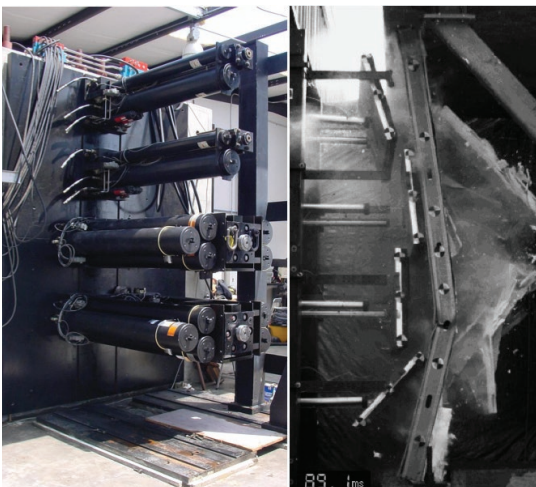
The largest source of damage to a commercial aircraft is caused by accidental contact with ground service equipment (GSE). The cylindrical bumper typically found on GSE distributes the impact load over a large contact area, possibly spanning multiple internal structural elements, which can lead to widespread damage that is difficult to visually detect, particularly for resilient composite fuselage skin. To better understand internal damage formation versus visual detectability, stiffened composite panels of various size and complexity have been tested at UCSD's Powell Labs. The experimental observations have established that visual detectability is dependent on the impact location and immediately-adjacent internal structure of the panel, as well as the impactor geometry and total deformation of the panel. In parallel to the experiments, modeling capability to predict blunt impact damage is being established. This research is funded by the Federal Aviation Administration.



## SEISMIC TESTING OF FULL-SCALE MSE RETAINING WALLS

**Professors Patrick Fox and Ahmed Elgamal**

Retaining wall systems constitute an integral and ever-growing component of our nation's infrastructure, much of which is vulnerable to strong seismic activity. Mechanically Stabilized Earth (MSE) walls are earth retaining structures composed of facing elements, tensile reinforcement, and backfill. Prof. Patrick Fox and co-PI Prof. Ahmed Elgamal will conduct landmark seismic tests of MSE walls on a scale never before achieved. The tests will be conducted through the use of the Large High Performance Outdoor Shake Table at the UCSD site of the George E. Brown, Jr. Network for Earthquake Engineering Simulation program. These full-scale walls (7 m in height) will provide high quality data on overall seismic response, which can be used to enhance design guidelines for MSE walls in seismic regions and help validate previous research and numerical models.



## Hydraulic/High Pressure Nitrogen Based Blast Simulator

**Professor Gilbert A. Hegemier**

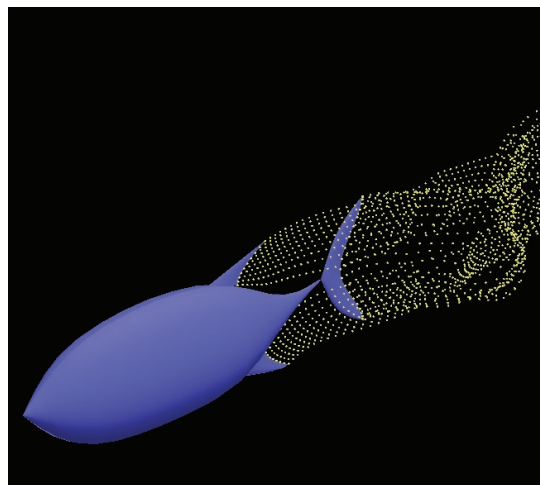
The UC San Diego blast simulator characterizes the response of civilian and military components and systems to terrorist explosive attack and high impact scenarios. It identifies threat mitigation and hardening optimization strategies using both retrofit and new construction methods and materials. The hydraulic/high pressure nitrogen based blast simulator simulates full-scale explosive loads up to 12,000 psi-msec without live explosives and without a fireball permitting structural responses to be seen as they occur. Energy deposition takes place in time intervals of 2 to 4 ms, the same as in a live explosive event. Impact scenarios with longer durations are also simulated. High-speed cameras with tracking software, and strain gages and accelerometers collect test data.



## Biomimetic Investigation Of Fish-Like Propulsion

**Professor Qiang Zhu**

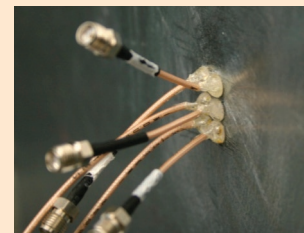
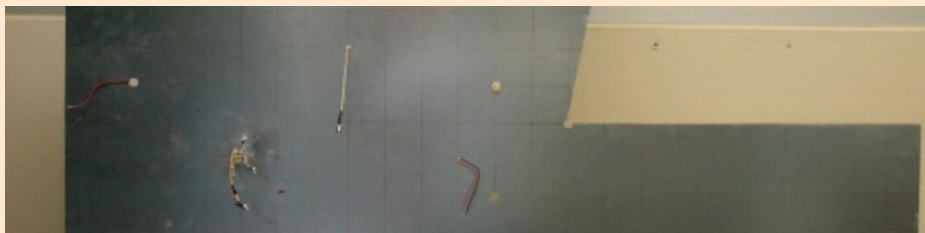
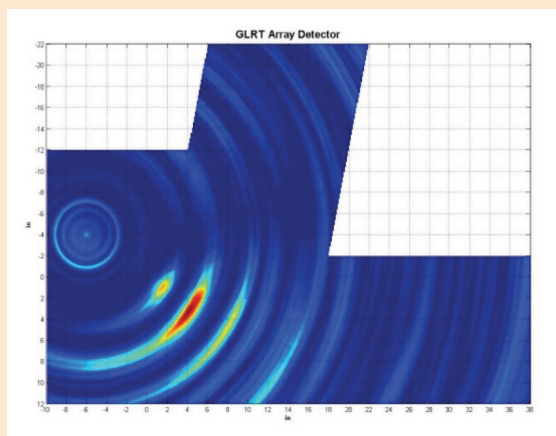
Inspired by the efficient locomotion of fish, insects, and other creatures, innovative ocean vehicles that imitate animal propulsion and maneuvering are now being developed. This requires a multi-disciplinary effort involving unsteady fluid dynamics, structural mechanics, autonomous sensing and control, shipbuilding technology, as well as advanced materials. UC San Diego researchers are developing state-of-the-art computer models to help us understand the underlying fluid-structure interactions in the locomotion of aquatic animals. They are also creating numerical tools for the design and operation of biomimetic flapping-foil actuators, which will be implemented on autonomous underwater vehicles, high-performance surface vehicles, and ocean energy harvesting devices.

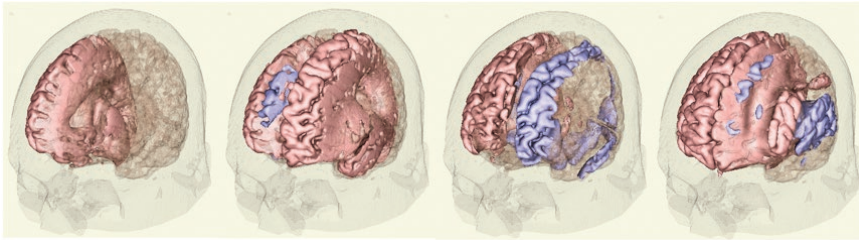


## OPTIMAL DAMAGE DETECTION AND PROGNOSIS VIA ELASTIC STRESS WAVE SCATTERING

**Professor Michael Todd**

Ultrasonic guided wave interrogation using both coherent-phase arrays and sparse arrays (sparsity defined as arrays whose average sensor-to-sensor distance is significantly longer than the interrogating wavelengths) has evolved into a very active research area. This research focuses on the detection, classification, and prognosis of damage using elastic waves as the interrogation mechanism. The novel approach in this work is the embedding of stochastic models to account for uncertainty of model/physical parameters, in order to derive an optimal detection process that supports predictive modeling with quantified uncertainty. Research is focusing on maximum likelihood estimates for detecting and localizing small scatterers (holes, asymmetric cracks) in metallic plate-like structures. Detection is accomplished using generalized likelihood ratio test (GLRT) and Bayesian detectors in conjunction with a broadband beamformer to estimate the arrival angle of scattered waveforms.





## Sources of Error in Finite Element Simulations of Effects of Blasts on the Human Brain

**Professor Petr Krysl**

Recent military conflicts have resulted in an increase in the number of blast related traumatic brain injuries. The present project examines the mechanical effects in a brain impinged upon by a blast wave as simulated by a finite element coupled fluid-solid framework. Various sources of errors were assessed and conclusions are (a) the least important source of error was the assumption of linear kinematics and linear constitutive equation; (b) the discretization error was significant, and controlling it will remain a challenge; and (c) the most significant source of error was found to be the uncertainty of the input parameters (experimental variability) and the lack of knowledge of the detailed micro-mechanics of deformation of the brain tissues under conditions of blast loading.

*In collaboration with Mark W. Bondi, Samuel R. Ward, and Lawrence R. Frank, UCSD/VA San Diego Healthcare System. Project was supported by Dr. Frank Stone and Dr. Ernie Young at the Chief of Naval Operations, Environmental Readiness Division Photo: Acoustic pressure (red positive, blue negative) in the cortex. (Snapshots spaced -0.035 ms).*



## Battle of Anghiari Project: The Search for Leonardo da Vinci's Lost Masterpiece

**Professors Falko Kuester and Maurizio Seracini**

Leonardo da Vinci's mural, The Battle of Anghiari, has not been seen in nearly 500 years. It was painted in the Palazzo Vecchio's Hall of the 500, and disappeared when the hall was remodeled by Giorgio Vasari starting in 1563. Was Anghiari destroyed? Or did Vasari build a brick wall in front of Leonardo's work before painting his own fresco over it? IGERT-TEECH PI Falko Kuester and co-PI Seracini undertook detailed LIDAR and multispectral scans of the Hall of the 500 to produce a detailed, 3D computer model to aid in the search-and-discovery effort, and graduate students affiliated with the Center of Interdisciplinary Science for Art, Architecture and Archaeology (CISA3) spent extended periods of time in Florence. In 2011-12 Seracini resumed the search leading up to the use of a new type of imaging that has not been used in connection with cultural heritage until now. The nuclear technology - neutron activation analysis - has the potential to see inside the wall, and to determine at the atomic level whether the mural still exists, and if so, to determine what may be left of da Vinci's work.

## VIBRATION SUPPRESSION AND DAMAGE DETECTION IN WIND TURBINE BLADES

**Professor Francesco Lanza di Scalea**

The performance of a wind turbine is driven, among other factors, by structural fatigue experienced due to wind-induced vibrations. Under National Science Foundation funding, UCSD is studying a system for mitigating the blade vibrations by using a network of piezo-composite transducers with both active (feedback) and passive (shunt) controls. This system has the potential to increase the fatigue life of the wind turbine system by reducing the vibrations during operation. In addition, UCSD is developing a statistical-based Infrared Thermographic method for imaging structural defects in the blades. These techniques are being tested on a unique test turbine blade at the Powell Laboratories that was designed in collaboration with the world renowned Wing Energy Group of the Sandia National Laboratory.

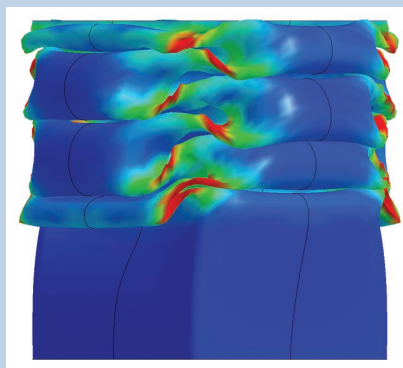


# LARGE DEFORMATION ISOGEOMETRIC STRUCTURAL ANALYSIS

## Professor David Benson

Traditional finite element methods use low degree, piecewise continuous polynomials to model the geometry of a structure. Modern computer aided design uses non-uniform rational B-splines (NURBS) to represent the geometry of a structure exactly. Isogeometric analysis is an extension of the finite element method that also uses NURBS and related functions. Among the advantages are few equations to solve than traditional finite element methods combined with better accuracy. The figure shows the final state of an initially square tube that has been crushed in an accordion mode, a type of collapse engineered into modern cars to absorb energy to protect its occupants. It was performed using isogeometric elements with less than half the unknowns of typical conventional analyses and is faster than the standard elements in most commercial finite element codes.

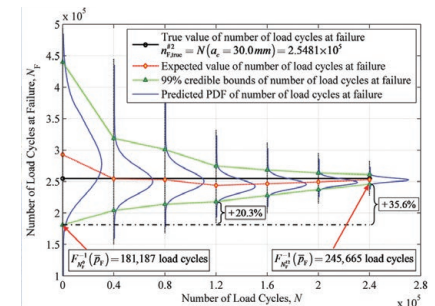
*This work is a collaborative effort with Professor Yuri Bazilevs (UC San Diego) and Professor T. J. R. Hughes (U Texas, Austin).*



# Seismic Performance and Design of Metal Building Moment Frames

## Professor Chia-Ming Uang

Metal Building Systems, which represent a large portion of low-rise construction in the United States, are typically composed of steel moment frames and slender tapered beam sections. To answer questions concerning frame behavior in large seismic events, three full-scale frames were tested on the UCSD/NEES Large High Performance Outdoor Shake Table. Based on their observed behavior, two new seismic force resisting systems are in development. To assess the collapse reliability of the new systems, large parametric studies are being conducted. Ten beam-column assemblies were cyclically tested in the UCSD Powell Labs to provide data for the strength and cyclic performance of lateral buckling of tapered I-beams. Test data will be used to validate inelastic finite elements used to model the cyclic behavior of the metal building frames.



# Remaining Fatigue Life Predictions of Monitored Structural Systems

## Professors Joel. P Conte and John B. Kosmatka

UC San Diego has developed a methodology for predicting and updating the Remaining Fatigue Life (RFL) of monitored aerospace structures and/or structural sub-components. According to this framework, NDE inspection results and Bayesian inference are used to (a) assess the current state of damage of the system and (b) update the probability distribution functions of the damage extents and damage evolution model parameters. Probabilistic models for future operational loads and calibrated mechanics-based damage evolution models are then used as essential predictive tools to propagate stochastically the identified damage mechanisms throughout the pre-identified damageable sub-components. Combined local and global failure criteria are used to estimate the time-varying probability of failure and the RFL of the entire structural system. The proposed methodology can lead to either an extent of the RFL - with consequent economical benefits - or an increase of safety by detecting a fault earlier than anticipated.

## BUILDING SYSTEM PERFORMANCE DURING EARTHQUAKES & POST-EARTHQUAKE FIRE

**Professors Tara Hutchinson, Joel Conte, and Jose Restrepo**  
**Doctoral students Rodrigo Astroza, Michelle Chen,**  
**Hamed Ebrahimian, Steve Mintz, Elide Pantoli, and Xiang Wang**

*A collaboration between four Universities, the National Science Foundation, the California Seismic Safety Commission, the Englekirk Advisory Board, the Charles Pankow Foundation, and over 45 industry partners.*

This landmark project centers upon the earthquake and post-earthquake fire testing of a five-story building built at full-scale. The building is completely furnished with nonstructural components and systems (NCSs), including a functioning passenger elevator, stairs, partition walls, cladding and balloon framing systems, piping, HVAC, ceiling, sprinklers, building contents, as well as passive and active fire systems. Using the NEES@UCSD large high performance shake table, and equipped with over 500 channels of sensors and over 80 cameras, test data generated from this project will help advance our understanding of the full-scale dynamic response and kinematic interaction of complex structural and nonstructural components and systems. In addition, this project is investigating the potential for protecting critical NCS systems using base isolation and post-earthquake fire and life safety performance of both the structure and its NCSs has been evaluated by conducting non-thermal and live fire testing. Data from this unique experiment will be used to compare with earthquake performance predictions using available commercial and research computational modeling platforms. Findings from these efforts will be immediately translated to practice. Additional information on this project may be found at: [bncs.ucsd.edu](http://bncs.ucsd.edu).



## EARTHQUAKES

### LARGE-SCALE VALIDATION OF SEISMIC PERFORMANCE OF BRIDGE COLUMNS

**Professor José I. Restrepo, UCSD; Professor Stephen Mahin, UCB; Professor Ian Buckle, Univ. of Nevada, Reno**



A full-scale, circular reinforced concrete bridge pier designed in accordance to Caltrans' Seismic Design Criteria and Bridge Design Specifications guidelines has been tested under seismic excitation on the NEES-UCSD Large High Performance Outdoor Shake Table. The 4-ft (1.2-m) diameter cantilever pier spanned 24 ft (7.2-m) above the footing. A massive 261-ton (2,322-kN) reinforced concrete block supported by the pier generated gravity and lateral inertial forces.

The specimen was tested under historical ground motions,

starting with low-intensity shaking and bringing the column progressively near collapse. Under the design earthquake the pier underwent a displacement ductility of 4.3, with only superficial concrete spalling and minor signs of incipient longitudinal bar buckling in the plastic-hinge region at the base. Under higher-intensity ground motions the system reached a displacement ductility of 7.6, preserving its vertical and shear force bearing capacity. Failure involved buckling and subsequent fracture of longitudinal bars, after yielding of the hoops; the concrete core suffered only superficial crushing in proximity of the buckled and fractured bars.

This test has proved that current design practices provide a safe and resilient structure: not only the system performed as desired under the design earthquake, but it was able to sustain a much larger displacement demand before reaching collapse.

# STRESS WAVE MITIGATION IN POROUS MATERIALS

**Professor Yu Qiao**

Stress wave mitigation in porous materials, such as silica monoliths and PTFE foams, are investigated. As shown in Figure 1, a hat-shaped setup on the SHPB testing system is used to induce force on the porous silica monoliths with different average pore sizes, from a few nanometers to a few hundreds of microns. Under the same shear rate and the same shear displacement, if the pore size is as large as 100 microns, the local softening caused by cell collapse will promote the formation of shear banding along the direction of shear force, and the influence area encircled by orange line will be localized. Whereas if the pore size is small enough like tens of nanometers, local hardening ahead of the shear banding will happen, leading a large influence area and thus more energy will be absorbed by the porous materials.

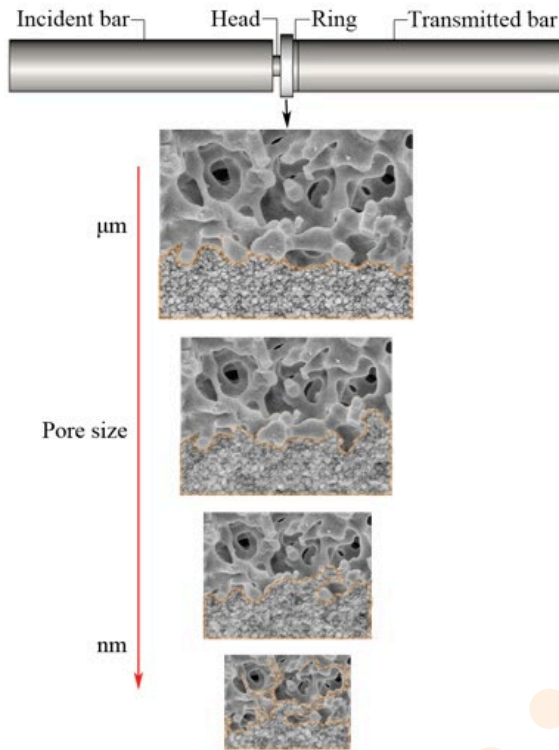
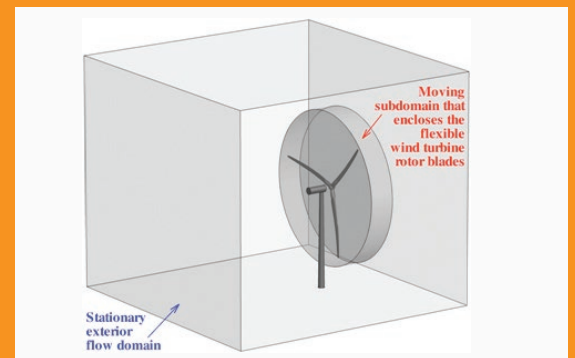


Fig.1. Influence area for porous silica monoliths with different average pore sizes under the forced shear stress.

# FLUID—STRUCTURE INTERACTION MODELING OF WIND TURBINES AT FULL SCALE

**Professor Yuri Bazilevs**

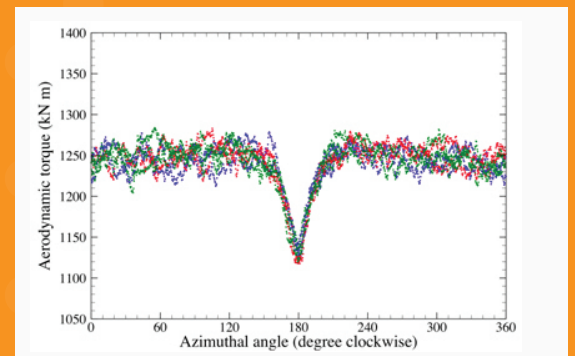
A fully coupled fluid-structure interaction (FSI) simulation methodology for wind turbines was developed in order to address a variety of engineering questions related to their aerodynamic and structural performance. Our FSI modeling takes place in 3D and at full scale, using novel finite-element-based methods for aerodynamics, and state-of-the-art isogeometric methods for blade structures. This one-of-a-kind FSI modeling methodology for wind turbines was extensively validated against experiments. The modeling ideas and simulation results are illustrated in the figures below.



(a) Methodology



(b) FSI Simulation



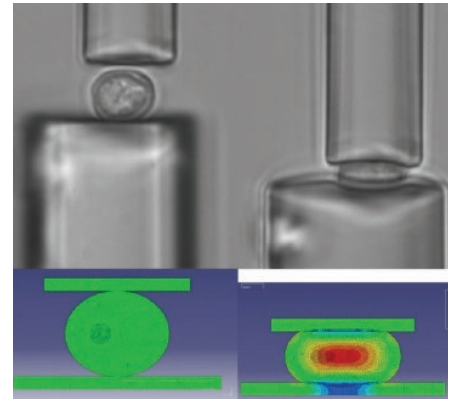
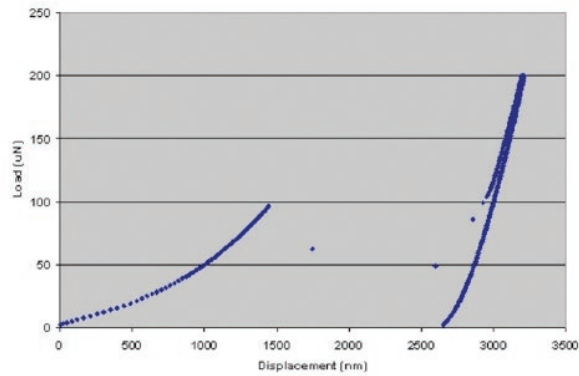
(c) Rotor-tower interaction

# RESEARCH

## MODELING THE NANO-MECHANICS OF SINGLE-CELL STRUCTURES

**Professor Robert J. Asaro**

The cell wall of *S. cerevisiae* serves to protect the cell from thermal, oxidative and mechanical stresses and it is the target for anti-fungal drugs in pathogenic strains. It also serves as a model for cell wall formation in higher eukaryotes. Little is known about its mechanical properties due to the complex nature of its protein and polysaccharide components, and their interconnections. A multi-scale model describing



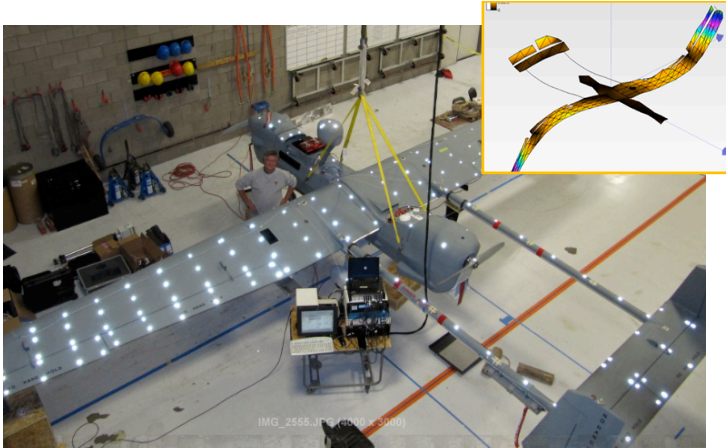
the cell walls nano-mechanical response to AFM tip indentation and the whole cell's response to high hydrostatic pressure, nano-indentation and micro-manipulation compression experiments is under development.



## COSMOS: EARTHQUAKES IN ACTION

**Professor Lelli Van Den Einde**

The California State Summer School for Mathematics and Science (COSMOS) is a four-week, educational summer program for gifted and talented high school students. Science and engineering topics are presented via a variety of “clusters” located at four of the University of California campuses. The “Earthquakes in Action” cluster at UCSD presents basic concepts in geophysics of earthquakes and structural design of building components and systems. It employs hands-on and interactive activities, experimental investigations, relevant site visits, and research-based group projects, all of which are integrated with lectures. Often the laboratory or hands-on exercises involve the introduction to and use of computer programs such as Microsoft Excel for data analysis, Google SketchUp for structural modeling, and Google Earth for geophysics activities. The goals of the cluster are to present these topics at a high level, meet national math and science program standards for high school students, and to encourage the students to pursue math- and science-based majors at public, in-state universities. Students visit the numerous large-scale structural research facilities on the UCSD campus, and the large, high-performance outdoor shake table at the Englekirk Center, to see first-hand the significance of testing structural systems and components for seismic design. During the four-week program students conduct small research projects that involve background literature searches to learn about science and engineering concepts. In teams of three or four, students design and construct small-scale models and test them on a shake table, develop predictions of structural response, and compare expected structural behavior with measured response observed through the experiments.



## IMPROVED GROUND VIBRATION TESTING METHODS FOR FLIGHT STRUCTURES

**Professor John B. Kosmatka**

**T**ypical Ground Vibration Tests of flight vehicles are performed by attaching a moderate number (10 to 100) of discrete accelerometers to a free-free flight vehicle where the excitation is provided using one or more electro-mechanical shakers. A new approach involves using a noncontacting scanning laser vibrometer on the free-free flight vehicle. The SLV has the advantage over discrete accelerometers in that

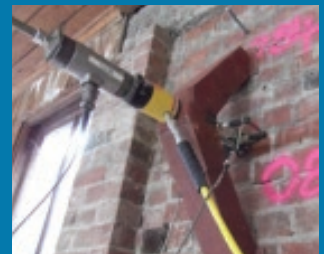
a near infinite number of data points can be measured without altering the mass configuration of the flight vehicle. This large number of data points makes it easy to: (a) correlate the experimental data with analytical (finite element) results, (b) investigate local modes, and (c) investigate the affects of subtle vehicle configuration changes on the modal properties. Dr Kosmatka is working with Northrop-Grumman to develop and use this new approach to evaluate their Hunter MQ-5B Unmanned Air Vehicle.



## INTERNATIONAL UNDERGRADUATE RESEARCH EXPERIENCE FOR STRUCTURAL ENGINEERING STUDENTS

**Professor Lelli Van Den Einde**

**F**or the past 8 years, students from the Department of Structural Engineering have participated in a 10-week summer research internship in earthquake engineering as part of the Pacific Rim undergraduate experience program (PRIME) at UCSD (<http://prime.ucsd.edu/>). The highly successful PRIME program provides undergraduates with hands-on research experiences in internationally collaborative settings to prepare students for participating in the global workplace of the 21st Century. UCSD SE students have been integrated into research teams at two pacific rim laboratories: the National Centre for Research in Earthquake Engineering (NCREE) in Taiwan, and the University of Auckland Centre for Earthquake Engineering Research (UACEER) in New Zealand. Students are prepared for their research by Dr. Van Den Einde prior to their program, and are supervised by host mentors while abroad. Students participate in multi-disciplinary projects that involve large-scale testing, field reconnaissance, and computer modeling. Projects over the years included testing and analyzing nonstructural components such as computer racks and hospital sprinkler systems for earthquake resistance, performing static pushover analyses on school structures, and investigating the seismic response of bridges such as the effects of lateral spreading following the Christchurch, New Zealand 2010 and 2011 earthquakes.



# ENGINEERS IN TRAINING



Department of Structural Engineering  
Irwin & Joan Jacobs School of Engineering

University of California, San Diego  
9500 Gilman Drive, Mail Code 0085  
La Jolla, CA 92093-0085  
[structures.ucsd.edu](http://structures.ucsd.edu)