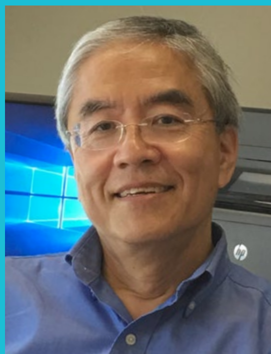
UC San Diego
Structural Engineering
JACOBS SCHOOL OF ENGINEERING

STRUCTURAL ENGINEERING
RESEARCH HIGHLIGHTS
2016–2017

WELCOME



It is my great pleasure to provide an update of the Structural Engineering Department and take this opportunity to brief you on our research activities. Being the only stand-alone Structural Engineering program in the country, we focus on civil as well as aerospace structures, and our research also encompasses biological, marine, and naval structures, with a common emphasis on engineering mechanics, materials engineering, analysis, and design. Our research covers a range of structural materials and structural types from nano-materials to large-scale structures, like aircraft bodies, ship hulls, geotechnical structures, buildings, and bridges.

Owing to the dedication of our faculty and staff to the academic training of our students, we were recently honored by the Graduate Student Association and the Graduate Division in the UC San Diego campus as the Best Department in Engineering based on the results of the 2014 Graduate and Professional Student Experience & Satisfaction survey. It is also my pleasure to mention that Elide Pantoli, our doctoral student, received one of the 2016 Gordon Graduate Engineering Leadership Awards of the Jacobs School of Engineering, for her leadership ability demonstrated in a large-scale experimental research project. Professor Michael Todd received the 2016 D.J. DeMichele Award from the Society of Experimental Mechanics for his exemplary service and support of promoting the science and education aspects of modal analysis technology. Professor Chia-Ming Uang received the prestigious 2015 T.R. Higgins Award from the American Institute of Steel Construction in recognition of the outstanding contribution of one of his published papers to advancing the design of steel structures. This year, our Department has added two outstanding faculty members, Professor H. Alicia Kim and Professor Kenneth Loh. Professor Kim's research is in multiscale and multiphysics optimization of structures and materials, with a special interest in aerospace structures, while Professor Loh's research interests are in structural health monitoring, multifunctional materials, and smart infrastructure materials.

In the coming academic year, a third new accomplished faculty member, Professor Veronica Eliasson, will join the department. Her expertise is in shock wave dynamics, shock-wave mitigation, and fluid-structure interaction.

The research of our faculty, researchers, and students has provided solutions to some of the most challenging problems in the structural engineering field. This includes the development of new design and assessment methods to improve the earthquake resilience of buildings and civil infrastructure systems; advanced engineering and safety inspection methods for aircraft structures made of advanced composites; new materials and intervention methods to protect structures and human bodies against extreme loading like explosions and impacts; advanced sensing and non-destructive evaluation techniques to detect structural defects and monitor structural health; advanced computational methods to study and improve the aerodynamics of wind-turbine blades for green energy production, and to predict the response of structures to extreme load events; advanced visualization methods for the preservation of heritage structures; and the modeling of biological structures to understand the nature and help develop new treatment methods for diseases.

The unique talents and the vast experimental facilities in the Department have been a major resource to private industries and governmental agencies. Our research has made direct impacts on structural engineering standards and practice. Some of our recent research activities are highlighted here. I hope you would enjoy reading them. Please do not hesitate to contact any of us or visit our website (structures.ucsd.edu) if you are interested in learning more about our Department.

Sincerely,
P. Benson Shing
Professor and Chair

DID YOU KNOW? The Department of Structural Engineering offers a unique program spanning across civil, aerospace, and mechanical engineering, and is ranked #16 among Civil Engineering Programs by *2017 US News & World Report*.

2016–2017 RESEARCH HIGHLIGHTS

Editor Jacqueline Vo
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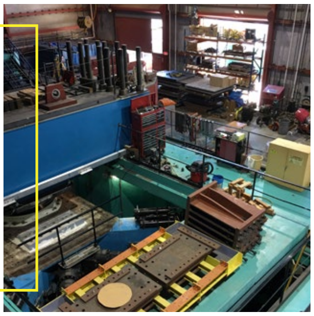
FACILITIES

STRUCTURAL AND MATERIAL ENGINEERING (SME) BUILDING Student enrollment at the Jacobs School of Engineering has increased to approximately 8,900 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 on 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, the former 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."

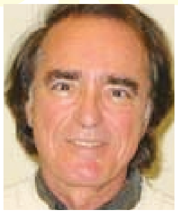
CHARLES LEE POWELL STRUCTURAL RESEARCH LABORATORIES The Charles Lee Powell Structural Research Laboratories are among the largest and most active full-scale structural testing facilities in the world. With its 50 ft. tall reaction wall and 120 ft. long strong floor, the Structural Systems Laboratory 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.

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 base-isolation bearings, 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 Testing Facility. The Blast Simulator, housed in the Center, is the world's first laboratory to simulate the effects of bombs without the use of explosive materials.

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

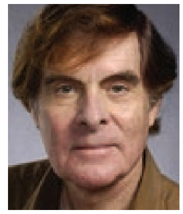
JIUN-SHYAN (JS) CHEN
Professor
Computational solid mechanics, multiscale materials modeling, modeling of extreme events.

JOEL CONTE
Professor
Structural Analysis and Dynamics, Structural Reliability and Risk Analysis, Earthquake Engineering.

AHMED-WAEIL ELGAMAL
Professor and Associate Dean
Information Technology, Earthquake Engineering, Computational Geomechanics.

VERONICA ELIASSON
Associate Professor
Experimental mechanics within areas of shock wave focusing, shock wave dynamics, shock wave mitigation, high strain rate impact, fluid-structure interaction.

CHARLES FARRAR
Adjunct Professor
Analytical and experimental solid mechanics problems with emphasis on structural dynamics.



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.

ALICIA KIM
Associate Professor
Structural and topology optimization, multiscale and multiphysics optimization of structures and materials, optimization for composite materials, aerospace structures.

HYONNY KIM
Professor
Impact effects on composite materials and structures with aerospace and other applications, multifunctional 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
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.

KENNETH LOH
Associate Professor
Damage detection and localization, multifunctional materials, nanocomposites, scalable nano-manufacturing, smart infrastructure materials, structural health monitoring, thin films and coatings, tomographic methods, wearable technology.

ENRIQUE LUCO
Distinguished Professor
Earthquake engineering, strong motion seismology, soil structure interaction.

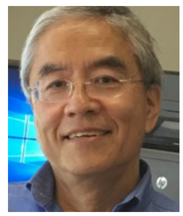
JOHN MCCARTNEY
Associate Professor
Geotechnical and geoenvironmental engineering, thermo-hydro-mechanical behavior of soils, design and analysis of thermally active geotechnical systems.

GILBERTO MOSQUEDA
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, pseudynamic and fast hybrid test techniques.

MICHAEL TODD
Professor
Structural health monitoring (SHM) strategies for civil/mechanical/aerospace systems, fiber optic and ultrasonic sensor solutions for SHM, nonlinear dynamics and mechanics, uncertainty and probabilistic modeling for SHM.

CHIA-MING UANG
Professor
Earthquake engineering, seismic design of steel buildings and bridges.

LELLI VAN DEN EINDE
Lecturer (LPSOE)

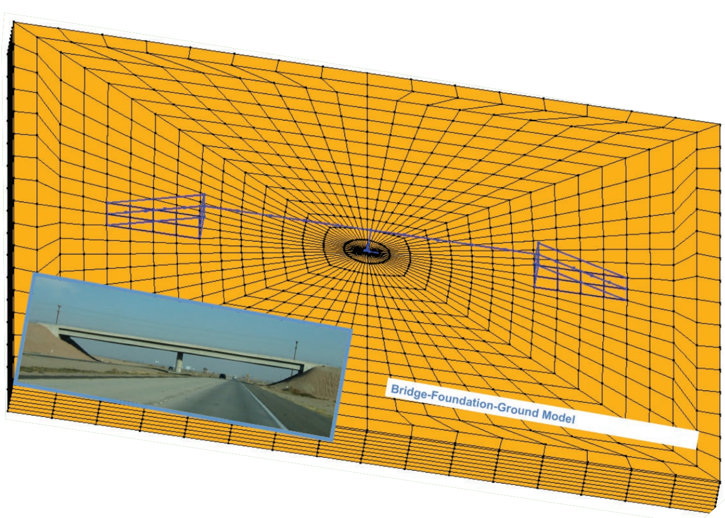
QIANG ZHU
Associate Professor
Ocean engineering, biomechanics.

RESEARCH

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.

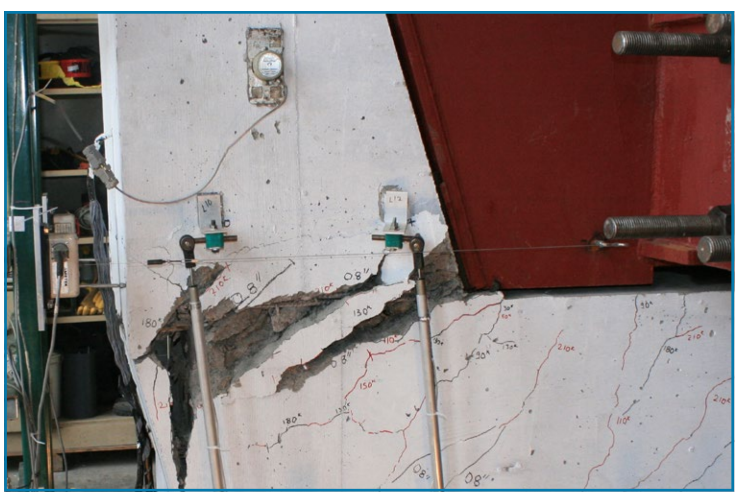


For more info, visit http://www.soilquake.net/openseespl and http://peer.berkeley.edu/bridgepbee

SEISMIC PERFORMANCE OF ABUTMENT SHEAR KEYS IN BRIDGE STRUCTURES

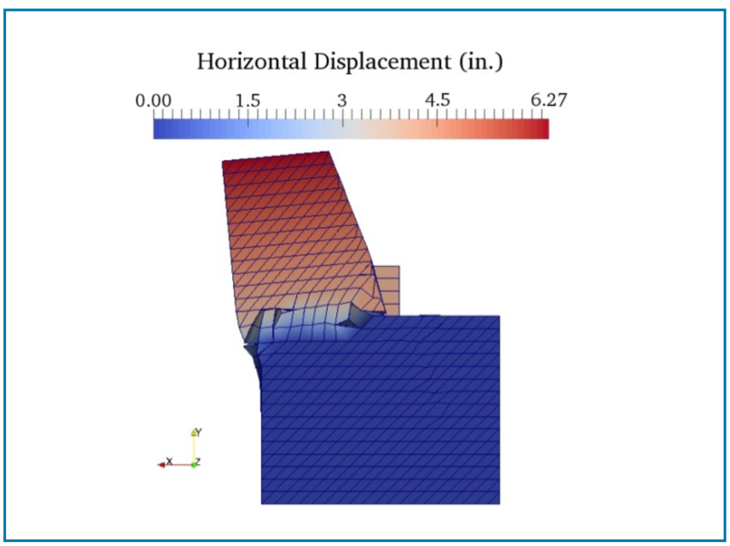
Shear keys are used in bridge abutments to provide lateral restraints to bridge superstructures under normal service loads and moderate earthquake forces. In the event of a severe earthquake, shear keys should function as structural fuses to prevent the transmission of large seismic forces to the abutment piles. A comprehensive study was carried out in a project supported by Caltrans to acquire a good understanding of the behavior and lateral load resisting mechanisms of external shear keys in bridge abutments. Six 40%-scale shear key-stem wall specimens were tested. One specimen had two shear keys isolated from the stem wall with a construction joint, and four had shear keys monolithic with the stem wall. One had post-tensioned shear keys, designed with an innovative concept to allow rocking. The tests have shown that post-tensioned shear keys can develop very high ductility through rocking.

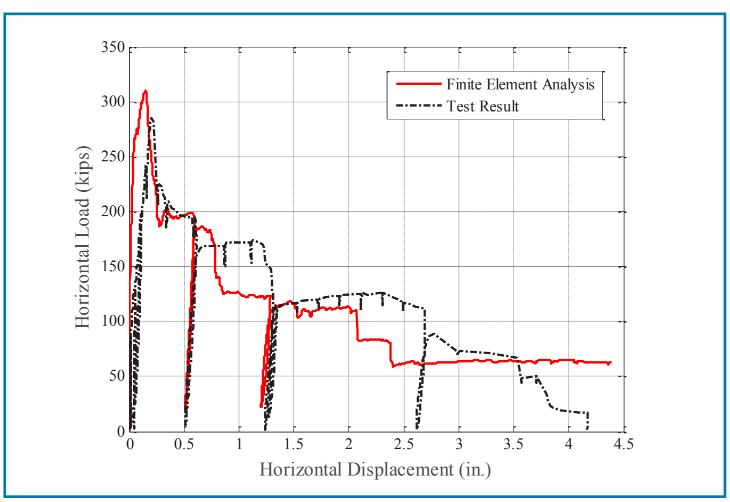
To complement the experimental study and acquire a better understanding of the loading resisting mechanism



Professor P. Benson Shing and Professor Jose Restrepo

of shear keys, nonlinear finite element models have been developed. The models account for the cohesive force and shear-friction resistance in concrete as well as the dowel action of reinforcing bars crossing cracks and construction joints including geometric nonlinearity. A parametric study has been performed with nonlinear finite element models to investigate the influence of the angle of skew on the lateral resistance of the shear key. Results of the experimental and numerical studies have been used to develop reliable simplified analytical methods for calculating the lateral resistance of shear keys considering the shear key geometry, the concrete strength, the amount of the vertical dowel reinforcement connecting the shear key to the stem wall, the surface condition of the construction joint if any, and the angle of skew of the abutment. These methods can be used for the design of shear keys and stem walls to achieve desired performance, and are being considered by Caltrans for possible adoption into the Caltrans Design Criteria.

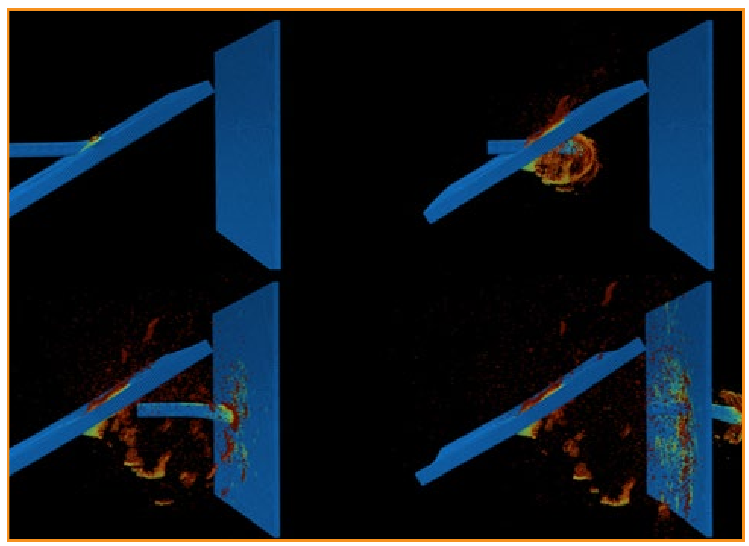


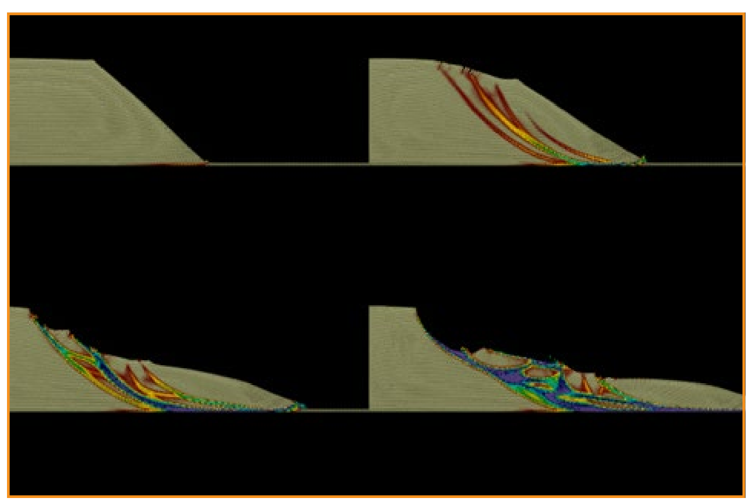


MESHFREE METHOD FOR EXTREME EVENTS MODELING

Professor J. S. Chen

The complex multi-scale failure modes, damage evolution, and fragmentation resulting from high velocity contact-impact processes in solids and structures pose considerable difficulties in simulations using finite element methods. J. S. Chen is one of the original developers of meshfree methods for modeling material damage in fragment-impact processes. The in-house Nonlinear Meshfree Analysis Program (NMAP) developed by Chen's group has been successfully applied to the modeling of Behind Armor Debris as shown in the figure below, simulated using the newly developed stabilized nodal integration and natural kernel contact algorithm. The simulation results have been validated by the Army Engineer Research & Development Center (ERDC). NMAP has also been applied to landslide modeling as shown in the left bottom figure where the shearband localization and damage processes were properly captured by the proposed micro-crack informed damage model and implicit gradient regularization method.



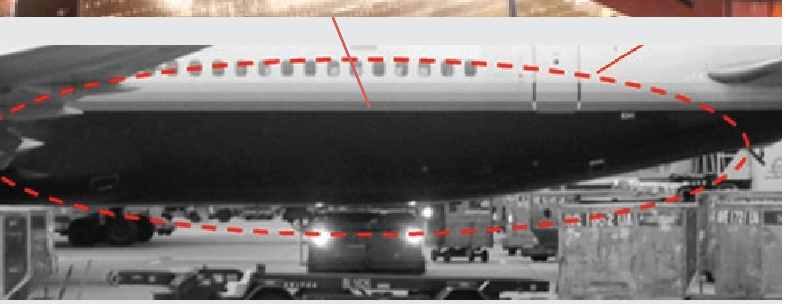


RESEARCH

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.



HYDRAULIC/HIGH PRESSURE NITROGEN BASED BLAST SIMULATOR

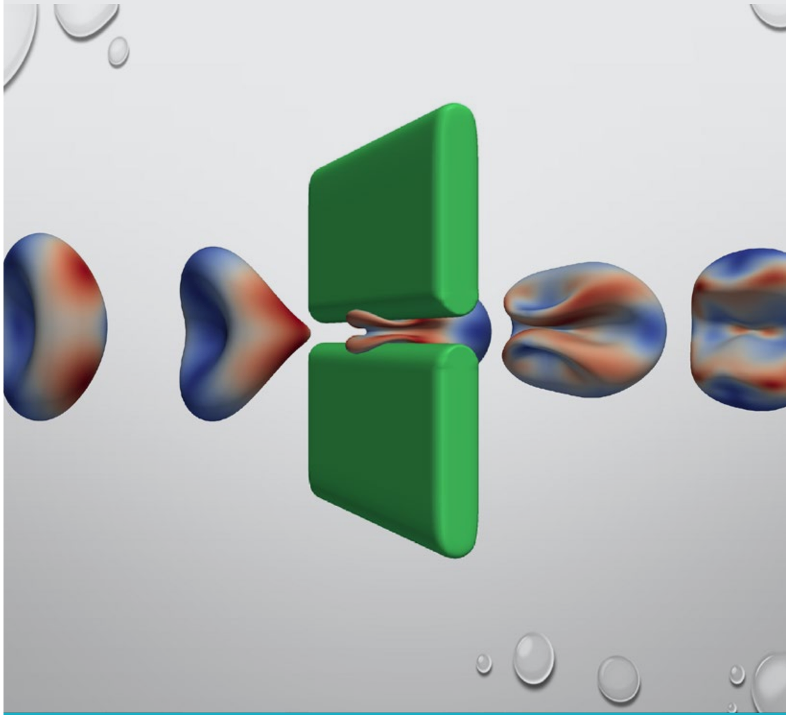
Professor Gilbert A. Hegemier

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.

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.

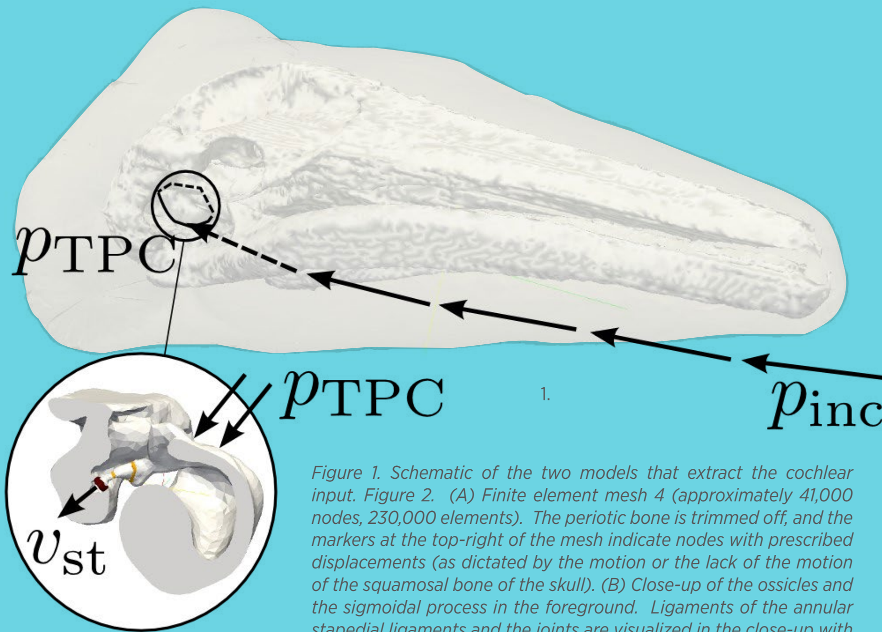


RESEARCH

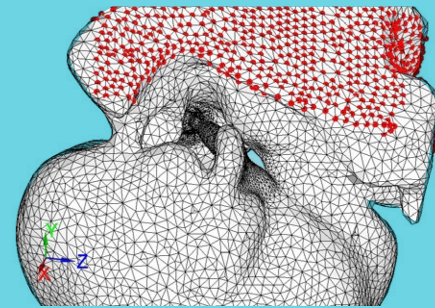
MULTISCALE SIMULATION OF RED BLOOD CELLS IN CIRCULATION

Professor Qiang Zhu

Since the size of red blood cells is comparable to those of micro-vessels and capillaries, in microcirculation blood cannot be treated as continuum fluid. In physiological conditions, red blood cells undergo tremendous deformation due to the combined effect of fluid forcing and constraints from various boundaries. We have conducted a multi-disciplinary study and created a high-fidelity multiscale model to relate cell deformations to the internal stress distribution inside the cell down to the molecular level. This model can be used to predict the structural stability and structural damage which leads to pathological conditions. Of particular interest is the in vivo mechanical performance of cells with mutations, diseases (e.g. malaria), or after storage (as happens in blood transfusion).

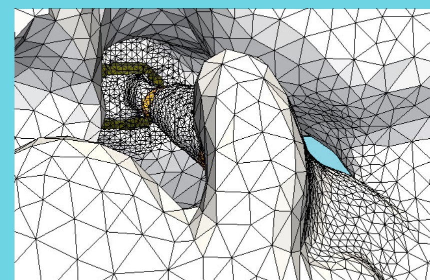


1.



2. (A.)

Figure 1. Schematic of the two models that extract the cochlear input. Figure 2. (A) Finite element mesh 4 (approximately 41,000 nodes, 230,000 elements). The periotic bone is trimmed off, and the markers at the top-right of the mesh indicate nodes with prescribed displacements (as dictated by the motion or the lack of the motion of the squamosal bone of the skull). (B) Close-up of the ossicles and the sigmoidal process in the foreground. Ligaments of the annular stapedial ligaments and the joints are visualized in the close-up with yellow color.



2. (B.)

FIN WHALE SOUND RECEPTION MECHANISMS: SKULL VIBRATION ENABLES LOW-FREQUENCY HEARING

Professor Petr Krysl

Hearing mechanisms in baleen whales (Mysticeti) are essentially unknown but their vocalizations overlap with anthropogenic sound sources. Synthetic audiograms were generated for a fin whale by applying finite element modeling tools to X-ray computed tomography (CT) scans. We CT scanned the head of a small fin whale (Balaenoptera physalus) in a scanner designed for solid-fuel rocket motors. Our computer (finite element) modeling toolkit allowed us to visualize what occurs when sounds interact with the anatomic geometry of the whale's head.

Our publication in PLOS One of 2015 was the first account of the computational construction of an audiogram of an experimentally unapproachable marine mammal. Simulations reveal two mechanisms that excite each bony ear complex, (1) the skull-vibration enabled bone conduction mechanism and (2) a pressure mechanism transmitted through soft tissues. Bone conduction is the predominant mechanism. The mass density of the both bony ear complexes and their rigid attachments to the skull are universal across the Mysticeti, suggesting that sound reception mechanisms are similar in all baleen whales. Interactions between incident sound waves and the skull cause deformations that induce motion in each bony ear complex, resulting in best hearing sensitivity for low-frequency sounds. This predominant low-frequency sensitivity has significant implications for assessing mysticete exposure levels to anthropogenic sounds. The din of man-made ocean noise has risen steadily over the last half century. Our results provide valuable data for U.S. regulatory agencies and concerned large-scale industrial users of the ocean environment. This study transforms our understanding of baleen whale hearing and provides a means to predict auditory sensitivity across a broad spectrum of sound frequencies.

The publication was in the first year since its appearance viewed 6 ½ thousand times and downloaded almost 900 times. This is a good indication of the timeliness and relevance of the investigation.

In collaboration with Ted W. Cranford, San Diego State University, Department of Biology, and Quantitative Morphology Consulting, Inc., 2674 Russmar Dr., San Diego, CA 92123-3422. We thank the following people for their support on various aspects of this project. Michael Wiese, James Eckman, and Dana Belden at the Office of Naval Research (N00014-12-1-0516); Frank Stone, Ernie Young, and Robert Gisiner at the Chief of Naval Operations (CNO45) along with Curtis Collins and John Joseph at the Naval Postgraduate School (N00244-08-1-0025).

RESEARCH

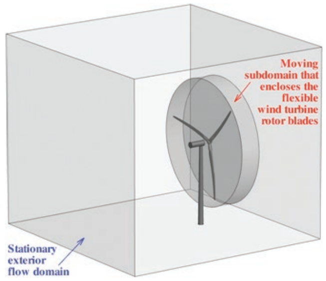
SEISMIC DESIGN AND MODELING OF "DEEP" STEEL COLUMNS

Professor Chia-Ming Uang

Steel special moment frame is widely used for multistory building construction in high seismic regions due to its excellent ductility capacity and architectural versatility. To control lateral deflection, design engineers also prefer to use "deep" columns to gain higher flexural stiffness. While a significant amount of research has been conducted on the cyclic performance of beams and beam-to-column connections, research on columns, especially deep columns, is very limited. This study showed that deep, slender columns were prone to local buckling and significant axial shortening, a phenomenon typically not captured in nonlinear finite element simulation. Column global buckling would occur when not only the member slenderness ratio was high but also more compact sections was used that caused significant strain hardening. Based on the test results, criteria that would limit the amount of local buckling to ensure sufficient column rotation capacities are in development. The implication of column shortening on the collapse vulnerability of multistory steel moment frame buildings is also been evaluated.

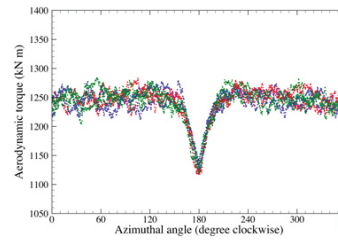
FLUID—STRUCTURE INTERACTION MODELING OF WIND TURBINES AT FULL SCALE

Professor Yuri Bazilevs



(a) Methodology

(b) FSI Simulation

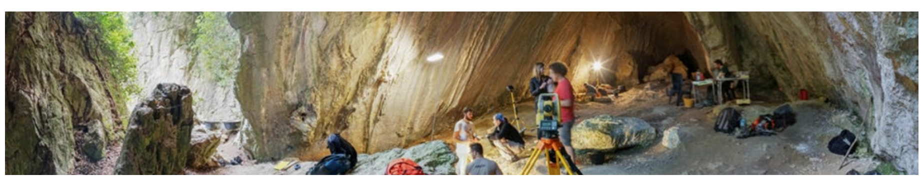


(c) Rotor-tower interaction

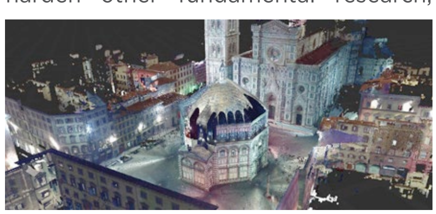
A fully coupled fluid–structure interaction (FSI) simulation methodology for wind turbines was developed in order to address a variety of engineering questions related to their aerodynamic and structural performance. Our FSI modeling takes place in 3D and at full scale, using novel finite-element-based 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 above.

CHEI INTERNATIONAL PROJECTS AND THE EXCAVATION OF THE ARMA VEIRANA CAVE IN ZUCCARELLO, ITALY

Professor Falko Kuester



Over the past two years, CHEI has worked in Mexico, Chile, El Salvado, Guatemala, Switzerland, Italy, Spain, Greece, Cyprus, Egypt, Jordan, Israel, Saudi Arabia, Mongolia, India, Japan and the United States of America studying monuments, structures, sculptures, paintings, archaeological sites, natural environments and habitats, to name a few, and inform, validate, and field-harden other fundamental research, create experience-based learning environments and opportunities for international collaboration.



In the summer of 2015, CHEI collaborated with researchers from the University of Colorado-Denver and the University of Tubingen to excavate and document a Paleolithic Cave in Liguria, Italy. Located close to the medieval town of Zuccarello, the cave is hidden inside a tall cliff in one of the valleys extending towards the Piedmont. Featuring fascinating geology, the cave has Paleolithic Artifacts from two different time periods. CHEI assisted in the digital 3D documentation of the site and its excavation.

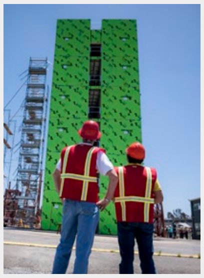
EARTHQUAKE SHAKE TABLE WINS $5.2M GRANT

A full-scale six-story steel-frame building; a low-damage column for bridges; and innovative designs to isolate buildings from earthquake forces. These are some of the projects that structural engineers at the Jacobs School and beyond will have the opportunity to test on an exceptional scale thanks to a $5.2 million grant from the National Science Foundation.

In the past 11 years, research at UC San Diego's shake table, the largest outdoor shake table in the world, has led to important changes in design codes for commercial and residential structures and new insights into the seismic performance of geotechnical systems, such as foundations, tunnels and retaining walls. It also has helped validate the use of new technologies to make buildings more likely to withstand earthquakes.

The five-year grant, awarded after a highly competitive process by NSF's Natural Hazards Engineering Research Infrastructure (NHERI) Program, will provide funding for the facility's operation and maintenance. "The data and fundamental knowledge provided by the landmark tests performed at this facility support the development, calibration and validation of the next generation of computer simulation models for civil infrastructure systems. They also allow us to continually improve design methodologies," said Joel Conte, the grant's principal investigator and a professor of structural engineering at the Jacobs School. "We are helping engineers come up with new concepts, new technologies and new seismic safety systems."

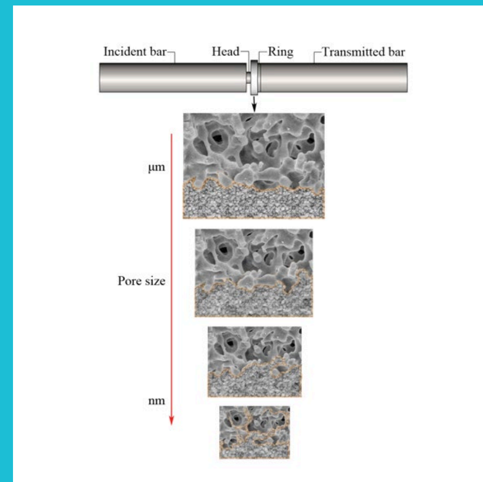
For example, the six-story building will be the first of its kind to be tested for seismic loading and post-earthquake fire. Its frame will be made of cold-formed steel (CFS), a light-weight material made from recycled steel that is easy to manufacture, durable and non-combustible.



STRESS WAVE MITIGATION IN POROUS MATERIALS

Professor Yu Qiao

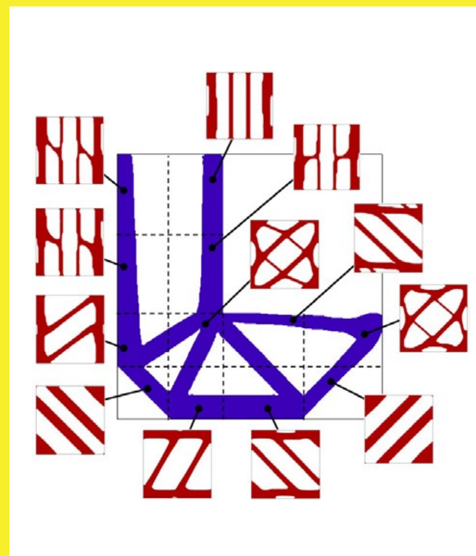
Stress wave mitigation in porous materials, such as silica monoliths and PTFE foams, are investigated. As shown in Figure 1, a hat-shaped setup on the SHPB testing system is used to induce force on the porous silica monoliths with different average pore sizes, from a few nanometers to a few hundreds 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.



M2DO: MULTISCALE MULTIPHYSICS DESIGN OPTIMIZATION

Assoc. Professor Alicia Kim

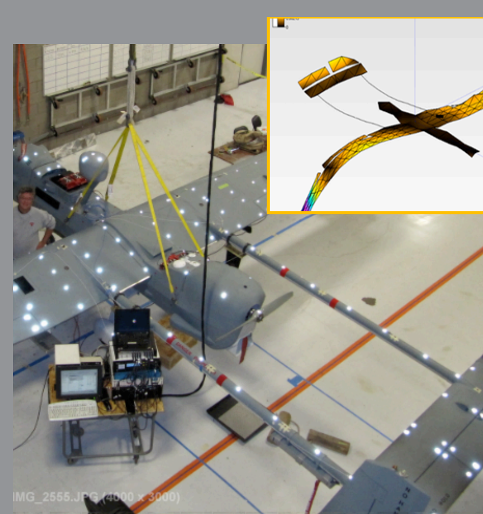
With the rise of advanced additive manufacturing, it has become possible to make engineering components with an unprecedented level of complexity across the range of length scales that have not been possible before. This means it has now become possible to tailor material properties and optimize across multiple scales. Professor H Alicia Kim and her researchers are developing a design optimization method that accounts for complex relationship between the microstructures of structured materials and the macroscopic structural topology. The fundamental basis of the method is topology optimization which has demonstrated at single scale its capability to produce revolutionary designs. The multiscale topology optimization method provides the optimum solutions both at materials and structural scales simultaneously. Design of such complex material systems would be considered beyond the capability of the standard design methods. The use of the level set method during optimization enables the direct integration of design and manufacture without the need for further post processing. The full potential of exploiting the materials-structural systems are investigated for a variety of design problems



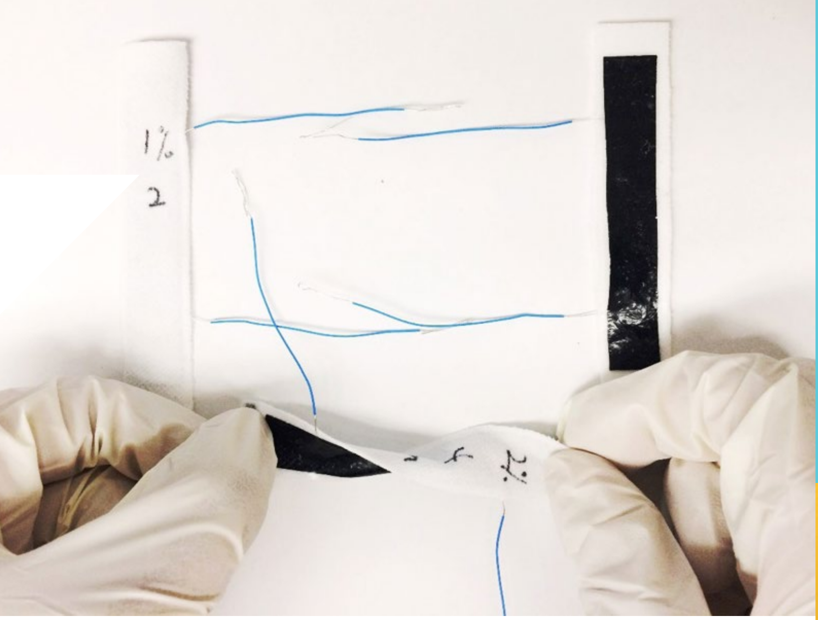
IMPROVED GROUND VIBRATION TESTING METHODS FOR FLIGHT STRUCTURES

Professor John B. Kosmatka

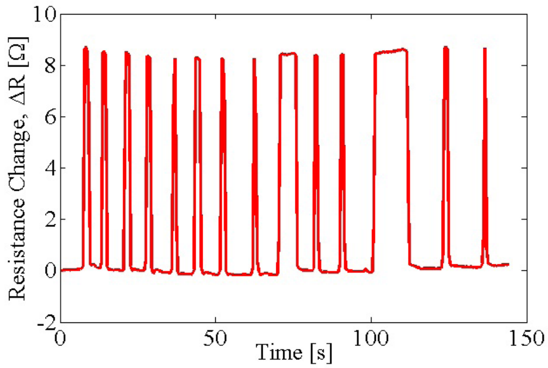
Typical Ground Vibration Tests of flight vehicles are performed by attaching a moderate number (10 to 100) of discrete accelerometers to a free-free flight vehicle where the excitation is provided using one or more electro-mechanical shakers. A new approach involves using a noncontacting scanning laser 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.



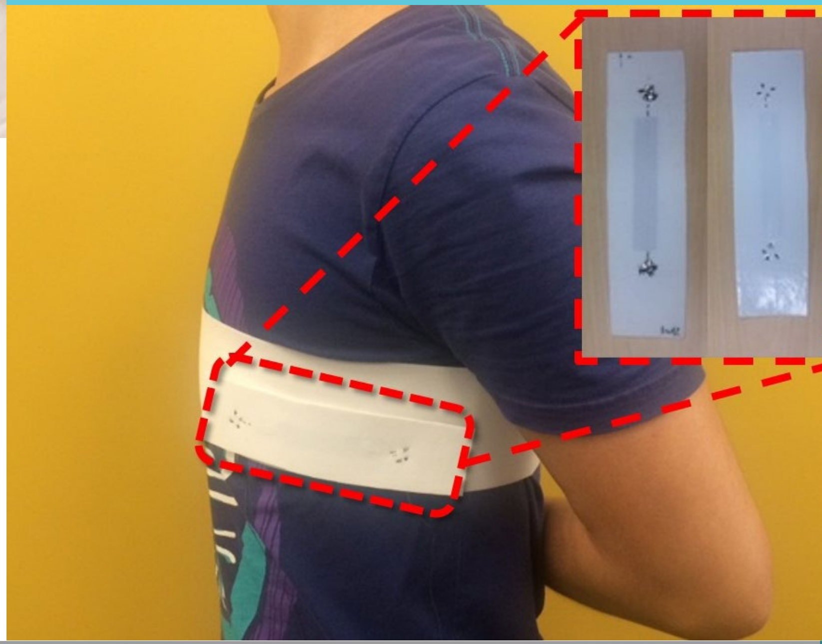
RESEARCH



Insert Fig 1 (Fabric Sensor)



Insert Fig 2 (Respiration Monitoring)



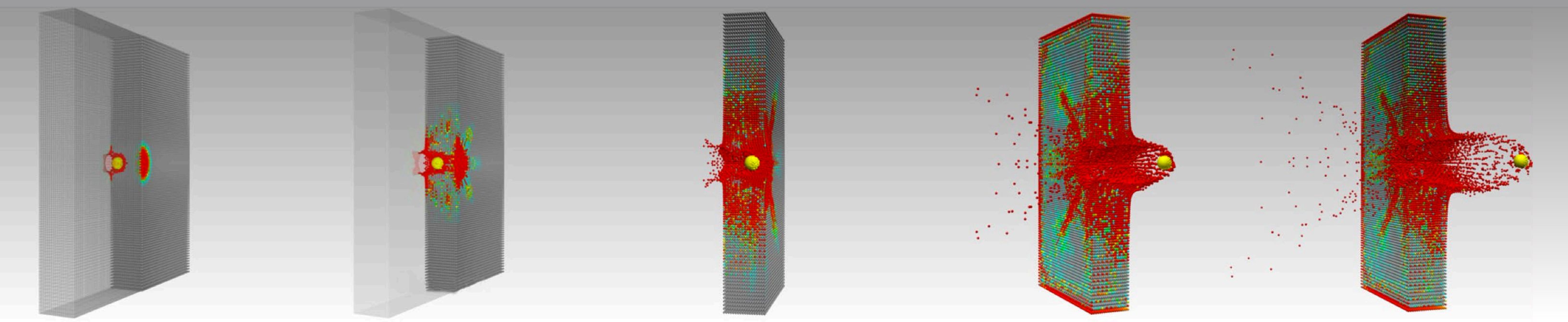
WEARABLE NANOCOMPOSITE FABRICS FOR HUMAN PERFORMANCE SENSING

Associate Professor Ken Loh

The safe, efficient, and reliable operations of land, air, and marine vessels and structural systems depend on the performance of the human operator. In fact, human error and fatigue have proven to be major causes of many historical catastrophes. Therefore, monitoring the physiological parameters and/or psychological state of the operator can facilitate early detection of problems and provide the necessary feedback for preventing potential accidents. One approach is to measure human vital signs (e.g., respiratory rate, body temperature, and bodily motions) using a wearable sensing system as a way of correlating and monitoring human physiological performance (e.g., fatigue or medical emergencies).

Instead of using conventional, bulky, wearable devices, the approach undertaken by the Active, Response, Multifunctional, and Ordered-materials Research (ARMOR) Lab and in collaboration with Prof. Helen Koo (UC Davis) is to design fabric-based sensors that are flexible, lightweight, low-cost, non-intrusive, washable, and comfortable to wear. Here, carbon nanomaterial-based thin film sensors are integrated with flexible fabric. The resulting fabric sensors can be readily tailored to form garments, chest bands, patches, and gloves, among others. They are by nature multifunctional, since fabric sensors can be worn on the body, while their electrical properties are tuned to be sensitive to changes in body temperature and deformation (e.g., due to chest movements during breathing), which have been successfully demonstrated in the lab. The vision is to establish a framework for designing and manufacturing different types of multifunctional fabrics for the military, emergency first responders, workers working in hazardous conditions, healthcare personnel, and patients, among many others.

ARMOR

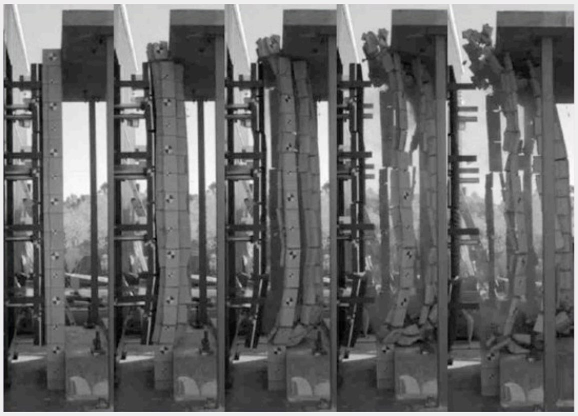


Bullet penetration simulation from Jiun-Shyan (JS) Chen's research group

CENTER FOR EXTREME EVENTS RESEARCH

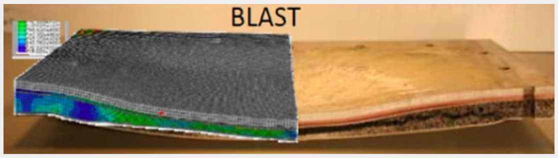
STRUCTURAL ENGINEERING R. Asaro, Y. Bazilevs (Associate Director), D. Benson, J. S. Chen (Director), G. Hegemier (Associate Director), A. Kim, H. Kim, K. Loh, MECHANICAL AND AEROSPACE ENGINEERING V. Nesterenko, A. P. Pisano, S. Sarkar, MATHEMATICS, R. Bank, L. T. Cheng, M. Holst, RADIOLOGY, S. Sinha, SAN DIEGO SUPERCOMPUTER CENTER, A. Majumdar, M. Tatineni

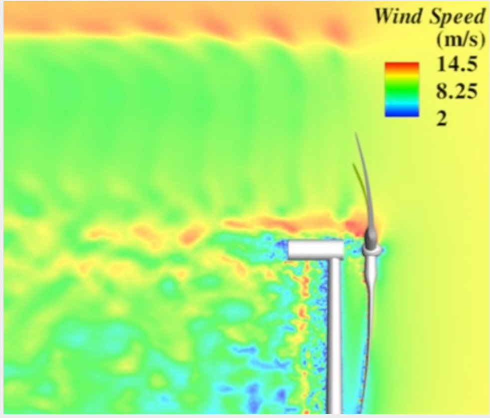
Center researchers are world-renowned experts in experimental and computational methods, design optimization, sensor technology and multifunctional materials for extreme events. We leverage this expertise to develop better ways to protect entire built infrastructures, as well as bio-systems, from extreme events such as blasts from terrorist attacks and mining explosions, car crashes, sports collisions, and natural disasters such as landslides. Challenges we address are: protecting the nation's built infrastructure, performing extreme event mitigation and recovery, and protecting bio-system injuries from extreme loading.



Unreinforced masonry wall under blast load

Extreme events simulator investigation of retrofitted wall response



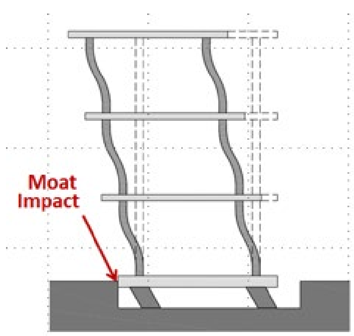


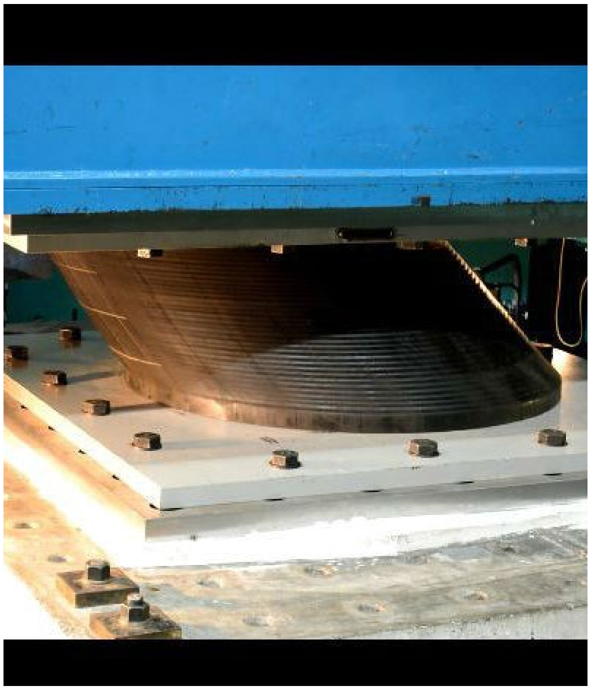
Simulation of wind turbines.

SEISMIC ISOLATION OF NUCLEAR POWER PLANTS

Professor Gilberto Mosqueda

Seismic isolation has been proven as an effective strategy to protect critical facilities including Nuclear Power Plants (NPPs) from the damaging effects of horizontal earthquake ground shaking. The increased flexibility and resulting elongation of the natural vibration period of the structure leads to significant reductions in acceleration and forces transmitted to the structure above the isolation level at the expense of large displacements in the isolation system. These large displacements need to be accommodated by the isolation bearings while sustaining the weight of the structure above. Further, the isolated structure requires a large horizontal clearance at the basement level that is often limited by a moat wall that can also function as a hard stop for the isolation system. In the case of an extreme earthquake, there is a potential for impact of the isolated structure to the hard stop or failure of the bearings that can be a significant safety concern. Through a combination of numerical and experimental studies, current research is examining the stability of seismic isolation bearings and the effects of moat wall impact on the response of seismically isolated NPPs. Experimental research is utilizing hybrid simulation with the SRMD facility to enable testing of full scale seismic isolation bearings under combined three dimensional seismic loads. This research is being carried out in collaboration with Professor Stephen Mahin at UC Berkeley with support from KEPCO and KAERI.





THERMAL ENERGY IN GEOTECHNICAL ENGINEERING

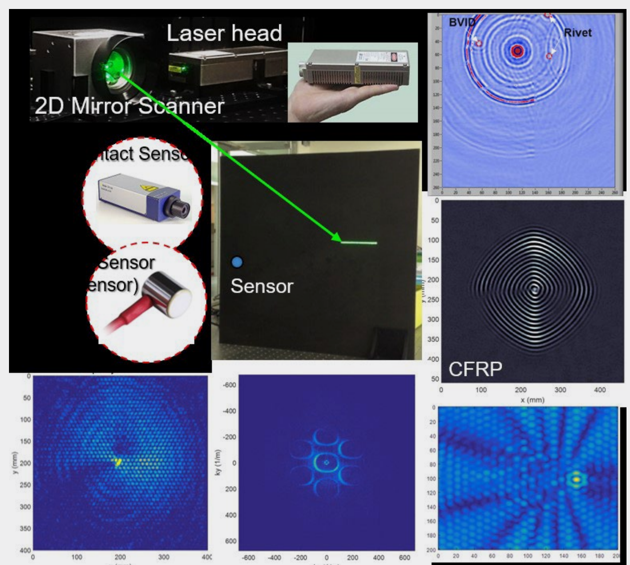
Associate Professor John McCartney

Although geothermal heat exchange is a well-understood approach to sustainably heat and cool buildings, it often comes with high up-front installation cost. Professor McCartney's research in geotechnical engineering seeks to understand ways that geotechnical engineering infrastructure can be used for geothermal heat exchange or storage, in part to reduce installation costs but also to pursue opportunities to use heat to improve the strength or stiffness of soils, or to achieve other objectives such as subsurface contaminant remediation. A major NSF-sponsored initiative has been the construction of a full-scale soil-borehole thermal energy storage system at Englekirk, which operates circulating water heated by solar thermal panels on the surface through an array of closed-loop heat exchangers embedded in 50 ft-deep boreholes in the ground. In this way, heat generated during summer days can be stored in the ground until it is needed later for community-scale heating. Innovative aspects of this project include consideration of multiphase flow processes in the soil above the water table to positively affect heat transfer and storage. These multiphase flow processes are also considered in another NSF-sponsored project focused on thermal improvement of unsaturated soils reinforced with geosynthetics, which has involved development of different laboratory tests to measure effects of heat on soil properties. Professor McCartney is also actively using UCSD's 50 g-ton geotechnical centrifuge to evaluate the pullout capacity of offshore piles in clay and to evaluate soil-structure interaction in energy piles in soft clay. Other ongoing geotechnical projects include the use of the Powell laboratory shaking table to investigate the seismic response of geosynthetic-reinforced wall bridge abutments for Caltrans, use of a large-scale direct/simple shear box to evaluate the shearing properties of tire-derived aggregates for CalRecycle, and development of new light-weight laminar containers for the centrifuge shaking table.

OPTIMAL DAMAGE DETECTION AND PROGNOSIS VIA ULTRASONIC SCATTERING

Professor Michael Todd

Ultrasonic guided wave interrogation using piezoelectric arrays and full-field laser ultrasonic inspection 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 in complex composite and metallic structures. Detection is accomplished using generalized likelihood testing, probabilistic imaging methodologies, and optimized data domain transformations.

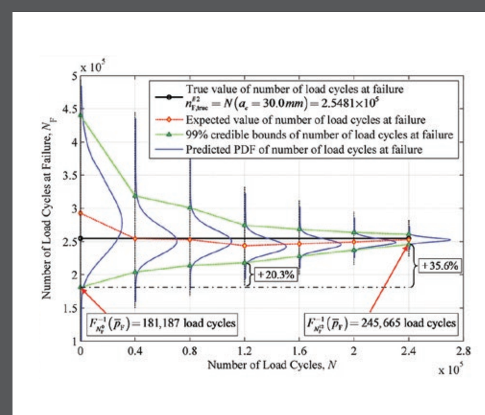


RESEARCH

REMAINING FATIGUE LIFE PREDICTIONS OF MONITORED STRUCTURAL SYSTEMS

Professors Joel. P Conte and John B. Kosmatka

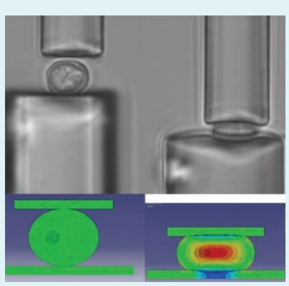
UC San Diego has developed a methodology for predicting and updating the Remaining Fatigue Life (RFL) of monitored aerospace structures and/or structural sub-components. According to this framework, NDE inspection results and Bayesian inference are used to (a) assess the current state of damage of the 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.

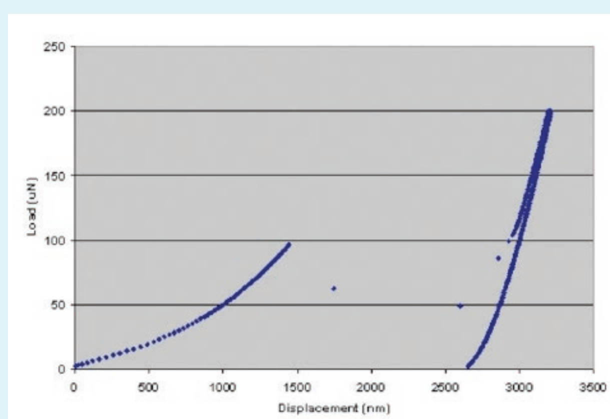


MODELING THE NANO-MECHANICS OF SINGLE-CELL STRUCTURES

Professor Robert J. Asaro

The cell wall of S. cerevisae 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.

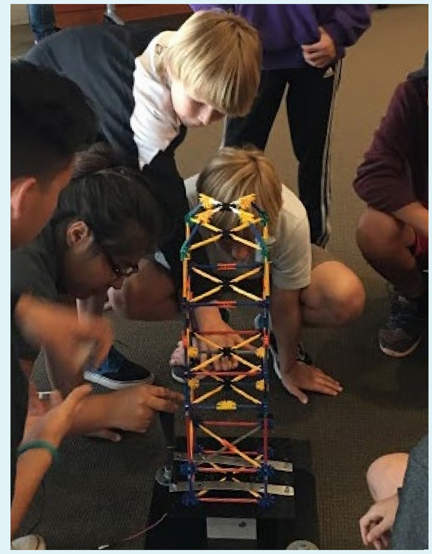




EARTHQUAKE ENGINEERING CURRICULUM FOR K-12

Professor Lelli Van Den Einde

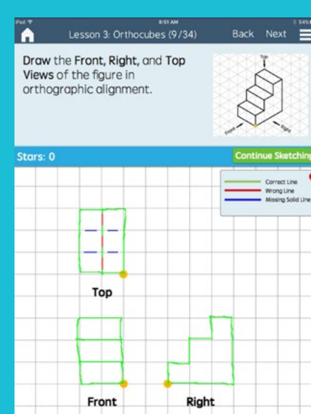
Current Next Generation Science Standards (NGSS) calls for introducing engineering design principles as early as Pre-K. Age appropriate, hands-on project based learning activities are being developed for K-12 that are aligned with standards, are well documented, and can be easily taught to a range of teachers for broad dissemination. The modules lead students through hands-on and research activities to learn basic earthquake engineering design principles and make use of an electronic instructional shaking table that allows students to test structures under representative earthquake loading. A project geared for 4th-6th grades requires students to build K'Nex™ buildings, while the high school curriculum requires students to design and build seismically sound timber, masonry and reinforced concrete structures, structures to avoid soft story mechanisms, base isolated structures, structures with tuned-mass dampers, and soil or foundation systems to avoid liquefaction. 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. These curricula allows students to learn about the engineering design process, to observe failure mechanisms and interpret data from testing, to learn how to define a design problem in terms of success criteria and constraints, to draw specific evidence-based conclusions about design and testing and iterate on the design.



SPATIAL VISUALIZATION TRAINING USING TOUCHSCREEN TECHNOLOGY

Professor Lelli Van Den Einde

A Spatial Visualization Trainer (SVT) App was developed for an iPad to enable students to freehand sketch isometrics and orthographic projections. The App consists of an algorithm that automatically grades each sketch. When errors are made, students can redraw their sketch or take a peek at the solution, which highlights the lines in their sketch that are correct or incorrect. The objective of the App is to teach spatial visualization and freehand sketching skills, which have been show to increase retention in STEM majors, especially among under-represented and women students. A unique aspect of this App compared to other eLearning tools is that the sketching assignments are not multiple-choice, and thus require students to synthesize their complete solution. As a result, data that tracks how engaged students are at different stages of an assignment can be collected. The App has been integrated into a 1-unit Spatial Visualization class to assess learning gains and provide feedback on it in terms of usability, functionality, and quality of sketching assignments. The goal of the study is to demonstrate the potential and provide guidance on how to further improve eLearning tools to teach spatial visualization as well as other topics. A K-6 version of the App is also under development.



UC San Diego
Structural Engineering
JACOBS SCHOOL OF ENGINEERING

2016–2017

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Irwin & Joan Jacobs School of Engineering

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