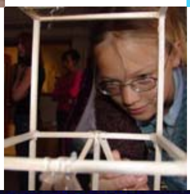
Research Highlights 2006

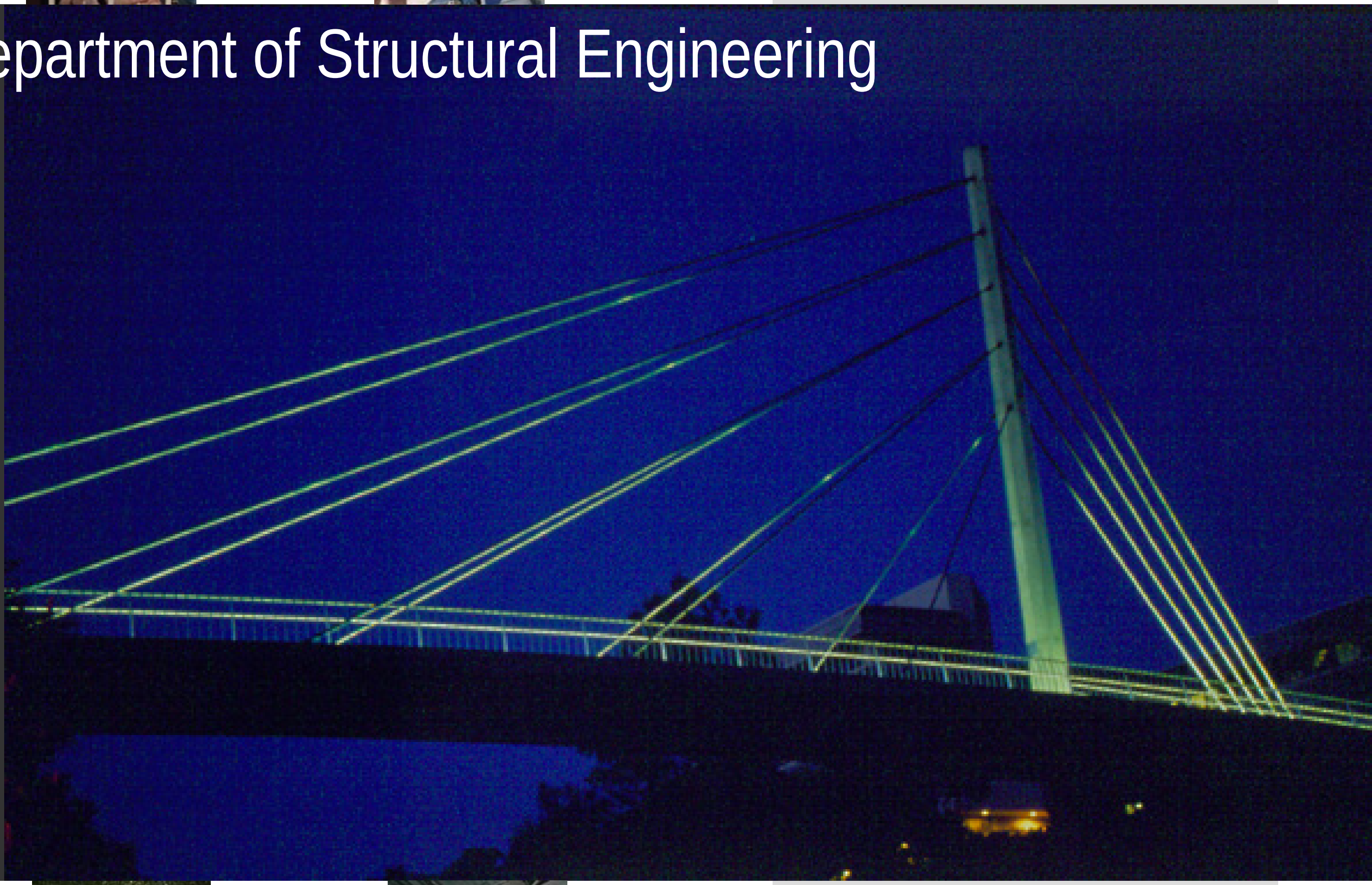
- Earthquake Engineering
- Mitigation of Blast Loading
- Health Monitoring & Condition Assessment
- Composite Materials & Light-Weight Structural Systems
- Hydrodynamics & Fluid-Structure Interaction

UCSD Jacobs






Department of Structural Engineering






- Reliability & Risk Engineering
- Renewal Engineering
- Civil Structural Design
- Bio-Mimetics
- Nano-Composites

University of California, San Diego

Structural Engineering Welcomes Four New Faculty Members in 2006

HUTCHINSON

Associate Professor **Tara Hutchinson** joined UC San Diego in July from UC Irvine. Hutchinson has a strong background in structural and geotechnical engineering, and her research is focused on information technology applied to the evaluation of structural damage. Hutchinson's IT research, combined with her expertise in earthquake engineering, strengthens the structural engineering department's efforts in sensing and monitoring of structural response, large-scale dynamic-model experimentation, and pre- and post-event characterization of structural integrity. Hutchinson works as both an experimentalist and theoretician, and has tackled issues in soil-foundation-structure analysis, seismic performance of structural and non-structural building components, and visual sensing for dynamic testing.

KIM

Associate Professor **Hyonny Kim** comes to UC San Diego from Purdue University, where his research interests include composite materials and durability research, and composite materials for aerospace structural applications. He is also interested in electro-mechanical multifunctional materials, carbon nanotubes and nano-materials, and adhesive bonding for composite joints. Kim's work compliments the department's existing strengths in composites design and mechanics with an emphasis on aerospace applications. His appointment begins November 1.

KUESTER

Falko Kuester joins UC San Diego as an Associate Professor of Structural Engineering, Adjunct Associate Professor of Computer Science and Engineering, and Calit2 Professor for Visualization and Virtual Reality. Kuester is an expert in scientific visualization and virtual reality, with specific emphasis on collaborative workspaces, multi-modal interfaces, and distributed and remote visualization. His focus is on developing new methods for acquisition, compression, streaming, synchronization and visualization techniques for large datasets. Kuester is applying these techniques to research challenges posed by distributed virtual environments and their application to earthquake engineering, earth system science, biomedical engineering and medicine. Joining us from UC Irvine, he directs the Calit2 research center for graphics, visualization and imaging technology, and will continue to be actively engaged in forging collaborations among Calit2, structural engineering, and computer science and engineering at UCSD. Kuester's appointment begins November 1.

QIAO

Associate Professor **Yu Qiao's** research focuses on high-performance infrastructure materials, failure analysis, and mechanics of materials. His leading-edge research in the areas of nano-fluidics and protective/energy absorbing materials provides synergy with the Department's ongoing work in blast mitigation, and his work on composite materials development and intelligent materials complements the Department's efforts in sensors, smart and multi-functional materials, and embedded actuators. Qiao joined UC San Diego in July from the University of Akron.

About our degree programs . . .

CLASS OF 2006

UC San Diego's Department of Structural Engineering offers B.S., M.S., and Ph.D. degrees. Our programs and curricula provide education and training through a holistic approach to structural engineering by emphasizing and building on the commonality in materials, mechanics, and analysis considerations across the disciplines of civil, aerospace, and marine engineering. The program features strong components in laboratory experimentation, basic theory, information technology, and engineering design. For admissions information, contact Student Affairs Coordinator, Ms. Linda Floyd, via email at lfloyd@ucsd.edu, or by telephone at (858) 822-1421.

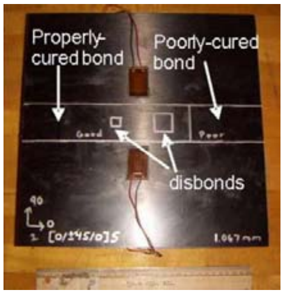
Simulating Bomb Blasts

The Explosive Loading Laboratory and Testing Program, funded by the Technical Support Working Group (TSWG), is the first program in the world to develop a hydraulic based blast simulator to simulate full scale, live explosive events up to 3000 psi-msec without the use of explosive materials, and without a fireball. Energy deposition, which takes place in time intervals of 2 to 4 ms, is accomplished via an array of ultra-fast, computer controlled hydraulic actuators with a combined hydraulic/high pressure nitrogen energy source based on blast physics models and codes. The blast simulator has been validated through comparison with the live explosive field test data, and computational blast physics models and codes are being improved and validated using the blast simulator and field test data. The simulator is being used to generate high fidelity data on the response and failure processes associated with critical infrastructure components subject to explosive loads, to evolve effective blast hardening/protective methodologies for existing and new structures, and to standardize test protocols for product validation. The simulator performs fully repeatable blast load simulations on structural elements such as columns, beams, girders, and walls; on nonstructural elements such as windows, masonry walls, and curtain walls; and on bridge components such as decks, piers, and towers.

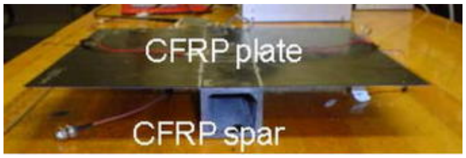
Development & Improvements in Unmanned Aerial Vehicles (UAV)

UC San Diego structural engineering researchers are actively improving the performance of existing UAV as well as developing new unmanned aircraft. Vibration tests were performed on the wings of the General Atomics Predator aircraft as well as on freely-suspended full-scale Northup-Grumman Hunter UAV using modal shakers and a scanning laser vibrometer. These results are being incorporated into the finite element analysis models used for flutter analysis and structural health monitoring. UCSD researchers are also working with Scripps Institution of Oceanography researchers in developing a new autonomous UAV for monitoring the atmosphere between Hawaii and Southern California.

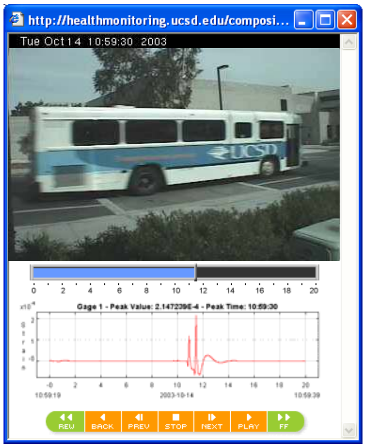
Structural Integrity Monitoring of Unmanned Aerial Vehicles: UAV Composite Wings



Researchers at UC San Diego are developing new sensing systems for the interrogation of adhesive bonds in aerospace structures, including composite Unmanned Aerial Vehicles (UAV). The technology includes the use of low-profile, flexible, ultrasonic sensors that can be integrated into the structure and probe the adhesive bond by ultrasonic waves with frequencies that are particularly sensitive to the state of the bond.



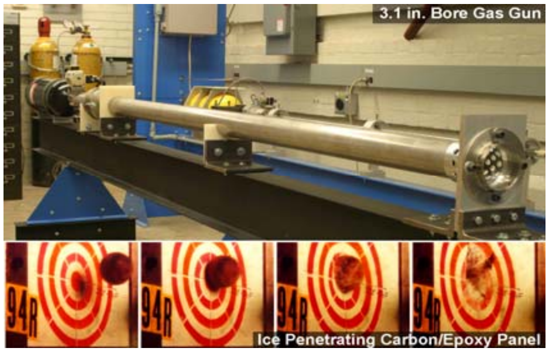
Bridge and Traffic-Pattern Monitoring



Information technologies are increasingly allowing for advances in monitoring and analysis of structural response. An integrated structural health monitoring analysis framework encompassing data acquisition, database archiving, and model-free/model-based system identification/data mining techniques has been created towards the development of practical decision-making tools. Bridge testbeds at UC San Diego are serving as an environment for development of such integrated structural health monitoring technologies. Instrumentation includes accelerometers and strain gages for measuring the bridge spatial response, and video cameras for tracking the related vehicle traffic. A hardware and software setup records synchronized video and sensor data, and allows real-time Internet transmission and data archiving. Image processing techniques are used to translate the recorded video into corresponding load time histories. Machine learning techniques are employed to correlate the input traffic excitation to the output bridge response. Anomalies in this correlation may be used as a basis for structural health monitoring and related decision making applications (http://healthmonitoring.ucsd.edu).

Advanced Sensor Networking Paradigms and Data Processing for Autonomous Structural Assessment

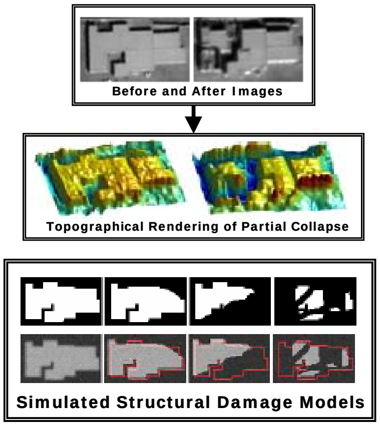
Damage assessment of large-scale structures (e.g., bridges, buildings, or dams) after an extreme event such as an earthquake or a blast load is a challenging task. In many cases, critical damage is not visible or obvious, human inspection poses serious life-safety concerns, and downtime for the structure equates with large economic losses. UC San Diego structural engineers, with partners in the Computer Science and Engineering Department, California Institute for Telecommunications & Information Technology (Calit2), and the Los Alamos National Laboratory, are developing components for a new systems approach that combines radio-frequency identification (RFID) -based wireless sensing, advanced networking and embedded system architectures, and autonomous network interrogation via unmanned platforms such as robots or unmanned UAV. The unmanned platforms are programmed to move to and query these wireless sensor networks and compute features that would facilitate structural health assessments after such extreme events.



High Velocity Impact on Composite Structures

Advanced composite materials such as graphite/epoxy laminates are especially vulnerable to transverse impacts which can result in damage that is difficult to detect. Damage that is barely visible, or not visible (e.g., delaminations, debonding in joints) can significantly reduce a structure's performance. High velocity impact tests onto composite structures are conducted to investigate the damage produced by projectiles such as hail ice, birds, or other foreign objects that pose a threat to aircraft structures. In addition to experimental investigations, numerical simulations and projectile material models are conducted to better understand the impact event and to provide predictive capabilities.

Image-based Damage Detection and Classification of Civil Infrastructure

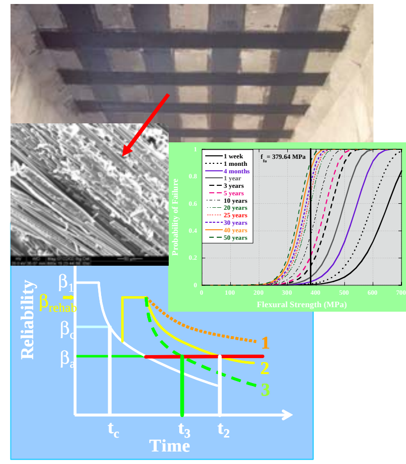


Rapid post-disaster damage assessment is critical to support optimum channeling of rescue efforts. High resolution digital images, whether captured during routine structural maintenance, or post-disaster reconnaissance, now provide a powerful tool for performing exterior damage assessment of existing infrastructure. In the context of post-disaster reconnaissance, UC San Diego researchers are developing fast, reliable detection and classification methods for evaluating the health of civil infrastructure regions affected by an extreme event, such as an earthquake or hurricane (see before and after images and topographical rendering). These tools are also being tailored toward surface structural damage identification, using supervised learning methods to develop local damage maps with associated probabilistic confidence levels embedded in the damage estimation. Validation is being conducted using scenarios of simulated damage (see image sequence).

New Concrete Construction Systems for Mid-Rise Residential Buildings

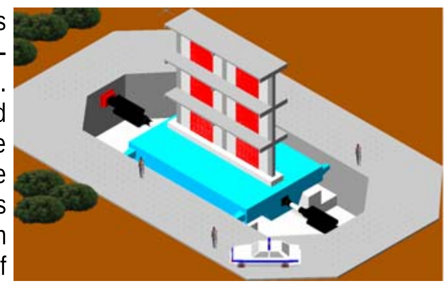
UC San Diego researchers and industry partners conducted an extensive series of earthquake simulations on the tallest structure ever built on a shake table. This experimental program supported the development of new reinforced concrete seismic design methodologies for medium-rise residential buildings such as condominiums and hotels. Researchers tested whether reducing longitudinal reinforcement in shear walls (see photo, right) by as much as 50 percent will increase earthquake safety, while at the same time, reduce construction costs. Such full-scale, dynamic testing has never been possible before because of space limitations of indoor shake tables. The tests took place on the new UCSD-NEES outdoor shake table at the Englekirk Structural Engineering Center. At 25 ft. by 40 ft., this is the largest shake table in the United States and the world's first outdoor shake table. The testing program is particularly targeted to housing needs in densely populated seismic regions in Los Angeles and throughout southern California.

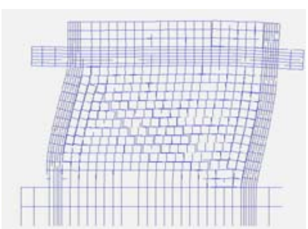
Investigation of Durability, Reliability and Security of Critical Infrastructure Using Fiber Reinforced Polymer Composites



Researchers from the Department of Structural Engineering and the Materials Science & Engineering Program, in conjunction with personnel from the California Department of Transportation, various materials suppliers, fabricators, and industry, have been conducting research aimed at the development of fiber reinforced polymer composite components and techniques for use in multi-threat mitigation and for the renewal of critical infrastructure. The use of unique, tailored structural components is being investigated for rehabilitation and new construction to decrease maintenance and increase speed of construction. Viability is being demonstrated through materials level, component level, and full-scale testing, as well as through implementation in the field. Unique accelerated tests combined with reliability techniques are being used to predict durability of the materials, components, and structural systems. Key components are monitored in the field using integrated materials-structural health monitoring techniques.

Improving Seismic Performance of Concrete and Masonry Structures





Assessing the seismic performance of older reinforced concrete (RC) frames that have masonry infill walls presents a most difficult problem for structural engineers. Currently, there are no reliable engineering guidelines. In a collaborative project sponsored by the National Science Foundation (NSF) under the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) program, UC San Diego researchers led an effort to develop advanced computational models as well as simple analytical methods to assess the performance of these structures, and to develop practical and effective techniques based on innovative materials to improve their seismic performance. Final proof-of-concept tests will be conducted on a full-scale three-story RC frame using the Large High Performance Outdoor Shake Table (LHPOST) at UCSD. Strength design of reinforced masonry (RM) structures has been under continuous development and evolution for many years. With structural design moving towards a performance-based approach, research is needed to have a better understanding of the performance of RM structures under different earthquake levels and to develop reliable predictive tools. UC San Diego researchers are also working on a second collaborative project sponsored by NSF's NEES program and the masonry industry to address these needs.

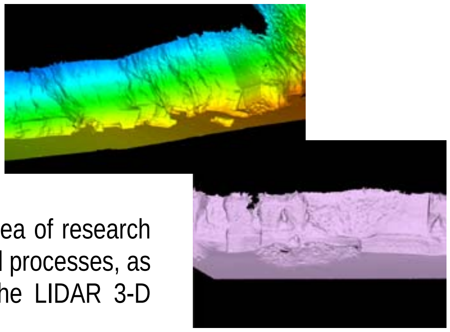
Seismic Rehabilitation of Steel Structures

Damage to welded steel moment-frame buildings occurring during the 1994 Northridge earthquake revealed a previously unrecognized welded beam-column connection fracture vulnerability. UC San Diego researchers worked with the California Department of General Services, Degenkolb Engineers, and the Crosby Group to perform full-scale laboratory testing and finite element analysis of moment connection rehabilitation schemes for the Caltrans District 4 Office Building located in Oakland, California. UCSD's test results were applied to the rehabilitation design of hundreds of moment connections for this 15-story steel moment frame building. The photo at left shows one rehabilitated steel moment connection specimen, 30 ft long and 14 ft tall, ready for laboratory testing. Two hydraulic actuators apply cyclic loading to simulate the seismic effect.

San Francisco-Oakland Bay Bridge: Advancing Bridge and Seismic Design

UC San Diego researchers led the seismic proof testing for the new San Francisco-Oakland Bay Bridge East Span, a 1,850-ft long span currently under construction. The self-anchored suspension design includes a novel steel single tower. The tower is comprised of four separate hollow shafts, interconnected by horizontal links, which are designed to dissipate energy and stiffen the tower during an earthquake. Illustrated at right is the proposed bridge.

Understanding Coastal Bluff Erosion

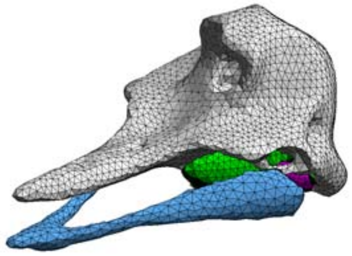


Erosion of our coastal bluffs and beaches has reached a crisis point in California. UC San Diego geotechnical engineers work with scientists and engineers at Scripps Institution of Oceanography on a variety of projects to develop a better understanding of the erosion process. This multi-disciplinary area of research requires interest in engineering, geology, and coastal processes, as well as advanced sensing technologies such as the LIDAR 3-D laser scans shown (right).

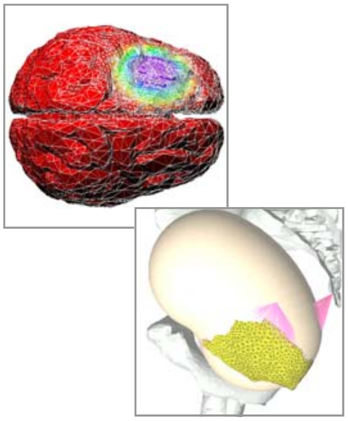
Liquefaction Using Controlled Blasting

In order to simulate seismically-induced liquefaction, UC San Diego geotechnical engineers use buried explosives to raise the water pressure in the soil. This method of controlled blasting has led to testing of deep foundations in liquefied ground all over the world. This type of full-scale testing gives ground truth to many of the numerical modeling efforts carried out by UCSD students and other researchers worldwide.

Analysis of the Structural Response of Biological Systems

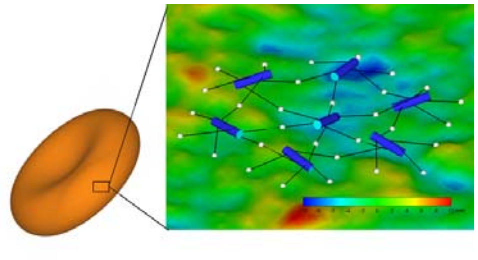


Advanced computational techniques are beginning to enable *in silico* investigations of biological systems. Recent projects include investigation of the interaction of sound waves with the anatomy of beaked whales (left) to test hypotheses concerning both pathways for sound reception, and pathways for sound generation (echolocation), adaptive finite element inverse brain EEG (right, upper) and computational non-rigid registration guided neurosurgery, and simulations of the musculature of the pelvic floor during natural birth (right, lower).



Machine Vision, Vision-Based Sensor Networks, and Collaborative Environments

This research investigates vision-based sensor networks for monitoring of structural and non-structural systems with applications in the areas of real-time motion capture, situation awareness and emergency response. The concepts of "Office of the Future" and "Classroom of the Future" environments are being extended and have introduced a new foundation for the development of "Living Laboratories"—collaborative workspaces that draw from research in pervasive communications and computing, human computer interaction and interfaces, as well a scalable techniques for real-time visualization of massive data sets. The NSF-funded VizClass environment and its VizION middleware are the anchor stone for this research.

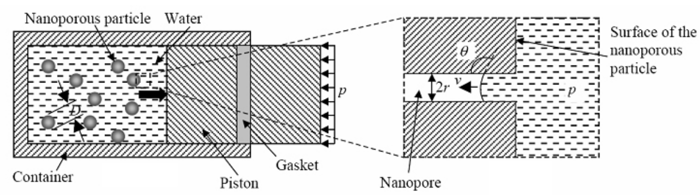


Molecular-based Modeling of Red Blood Cell Membrane

Erythrocytes (red blood cells) routinely squeeze through capillaries much smaller than their own size. Essential to this remarkable deformability is a composite cell membrane consisting of a lipid bilayer strengthened by a protein skeleton. Researchers at UC San Diego are launching an inter-disciplinary effort to create molecular-based dynamic models of this bio-structure. The objective is to understand the detailed relationship between molecular architecture and its mechanical/physiological performance. This knowledge may pave the way to potential applications in biomimetics.

Developing High-Performance Energy Absorbing Liquids

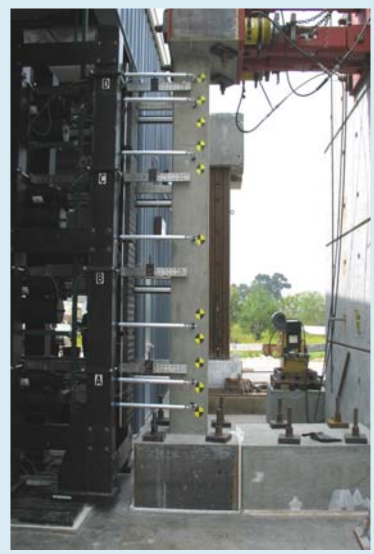
By immersing nanoporous materials in a non-wetting liquid phase, the system becomes an energy absorbing liquid, or a "liquid super-sponge." When a sufficiently high pressure is applied, the liquid can be forced into the nanopores, leading to a significant energy dissipation characteristic. UC San Diego researchers are exploring ways that these liquids can be used for protection and damping applications, such as liquid armors, healthcare products, and protective layers for buildings, amongst others.



About the Charles Lee Powell Laboratories

1986-2006—Twenty Years of Research Innovations

The Charles Lee Powell Laboratories at UC San Diego are a multiple-location, multi-million-dollar facility dedicated to research at the materials, component, assembly, and systems levels. The Powell Labs feature one of the largest assemblies of reaction wall/strong floor systems in the world. The main testing facility was dedicated in 1986, and includes over 12,000 assignable square feet of space. Additional facilities have been added as the scope and nature of Powell Labs research has expanded. The laboratories, with their test area dimensions, load capacities, state-of-the-art computer controlled servo-hydraulics, and data acquisition systems, represent a unique tool for large and full scale testing of structures. In 2005, the Englekirk Structural Engineering Center opened (nine miles east of the UC San Diego campus) as an expansion of the Powell Labs. This impressive facility is equipped with the world's first outdoor shake table (funded in part by the National Science Foundation's George E. Brown, Jr. Network for Earthquake Engineering Simulation [NEES]), a Soil Foundation-Structure Interaction Facility (SFSI), and a Blast Simulator.



Above left—the Powell Lab's North building features a neon sculpture, "Vices and Virtues" by Bruce Nauman, part of UC San Diego's Stuart Art Collection. Above right—the Blast Simulator at the Englekirk Structural Engineering Center. At far left—the High Bay Physics Building, home of the Caltrans Seismic Response Modification Device (SMRD) with tested columns in foreground. At left, overlooking the SMRD.

> faculty <


Robert J. Asaro, Professor—Experimental and computational studies of nonlinear material behavior. Marine civil structural design. Advanced structural materials.


Scott Ashford, Professor—Geotechnical earthquake engineering, soil dynamics. Foundation engineering. Soil-structure interaction. Slope stability. Landfill linear design.


Joel P. Conte, Professor—Structural reliability and risk analysis. Probabilistic design. Computational structural mechanics. Experimental structural dynamics. System identification. Structural health monitoring.


Robert Dowell, Assistant Adjunct Professor—Non-linear seismic analysis of reinforced concrete. Bridge engineering. Bridge retrofit strategies.


Ahmed Elgamal, Professor & Chair— Health monitoring sensor networks, database and data mining applications. Computational and experimental simulation of soil/structure systems, and seismic load mitigation solutions.


Robert Englekirk, Adjunct Professor—Reinforced concrete. Design of buildings and bridges. Seismic response of mid-rise buildings. Large-scale structural analysis and design.


Charles Farrar, Adjunct Professor—Integrated approaches to Structural Health Monitoring. Damage detection. Damage prognosis technologies and solutions.


Gilbert Hegemier, Professor—Blast mitigation. Mechanics of composite materials with applications to aerospace and civil structures. Infrastructure renewal via composites. Large-scale experiments on structures.


Tara Hutchinson, Assoc. Professor—Experimental and analytical studies in earthquake engineering. Seismic performance assessment of structures. Soil-structure interaction. Seismic response of concrete and timber structures. Response of non-structural components.


Vistasp M. Karbhari, Professor—Mechanics of composites. Manufacturing/processing science of polymers and composites. Durability of polymers and composites. Damage and crash energy management. Infrastructure renewal and blast mechanics.


Hyonny Kim, Assoc. Professor—Mechanics of composite structures and materials. Failure prediction of adhesive joints. Multifunctional composite materials. Hail ice impacts. Characterization and modeling of ice material. Buckling and stability of composite structures. Nano-structured materials and modeling.


John B. Kosmatka, Professor—Advanced composites for aerospace, civil, and sports structures. Linear and nonlinear structural dynamics, stability, aeroelasticity, and structural health monitoring. Vibration control using embedded passive and electro-active materials.


Petr Krysl, Assoc. Professor—Computational analysis of solids and structures with finite element and element-free methods. Computer-aided geometric analysis and design. Computational biomechanics and bioacoustics.


Falko Kuester, Assoc. Professor—Tera-scale scientific visualization and virtual reality. Image-based modeling and rendering. Distributed and remote visualization.


Francesco Lanza di Scalea, Assoc. Professor—Nondestructive evaluation. Structural health monitoring. Wave-based diagnostic systems for smart structures. Time-frequency processing. Experimental mechanics.


J. Enrique Luco, Professor—Earthquake engineering. Strong motion seismology. Wave propagation in solids. Dynamics. Soil-structure interaction. Foundations. Active control of seismic response of structures. Effects of topography on earthquake ground motion.


Yu Qiao, Assoc. Professor—High performance infrastructural materials. Novel applications of nanoporous technology in damping and intelligent structures. Size effects in thin solid films. Energy-related materials.


José Restrepo, Assoc. Professor—Seismic design and retrofit of buildings and bridges. Development of construction alternatives suited to performance-based design. Large-scale shake-table tests, and nonlinear dynamic response of buildings and structural components.


Frieder Seible, Professor & Dean—Bridge design. Earthquake engineering. Structural concrete and advanced composite design. Large-scale structural testing.


P. Benson Shing, Professor—Theoretical and experimental investigations of nonlinear behavior of concrete and masonry structures under extreme static and dynamic loads, including nonlinear finite element modeling and large-scale testing. Development and applications of pseudodynamic and real-time hybrid test methods.


Michael Todd, Assoc. Professor—Structural health monitoring methodologies. Applied nonlinear dynamics and chaos. Structural dynamics and vibrations. Time series analysis. Fiber optic sensors for structural monitoring.


Chia-Ming Uang, Professor & Vice-Chair—Seismic design of steel structures. Earthquake engineering. Seismic design methodology. Large-scale testing. Seismic design of wood frame structures.


Qiang Zhu, Asst. Professor—Nonlinear free-surface waves, wave-body interactions. Dynamics of highly-flexible mooring systems. Computational simulation of offshore structures. Locomotion of aquatic creatures. Modeling of biopolymers.

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