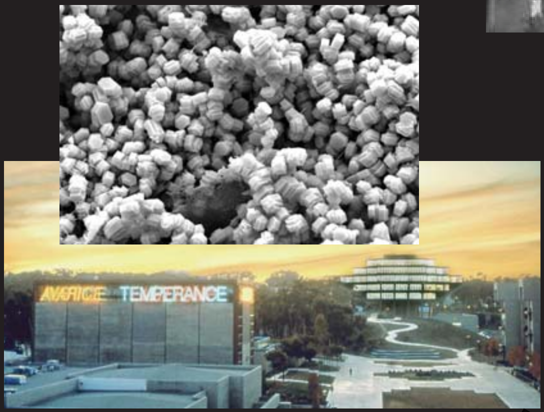
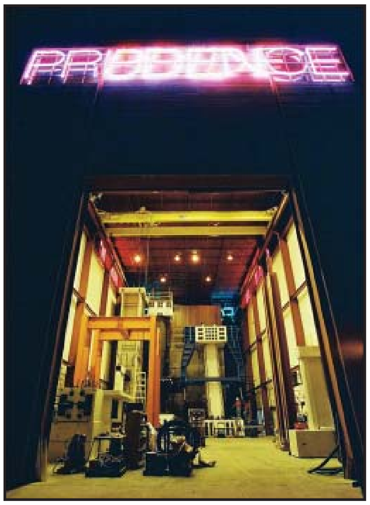


UCSD

Research Highlights 2008

Department of Structural Engineering
Jacobs School of Engineering

Over Twenty Years of Research Innovations . . .



Above: 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.

Founded in 1997, an off-shoot of the Department of Applied Mechanics and Engineering Sciences (AMES) at UC San Diego, the Department of Structural Engineering has enjoyed ten years of growth and success. To accommodate this growth, a new "Structural and Materials Engineering" building is scheduled to break ground in April, 2008. The new building (pictured at right) is slated to have approximately 50,000 sq. ft. of new office and laboratory Structural Engineering space.

The main testing facility of the Department of Structural Engineering, the Charles Lee Powell Laboratories, was dedicated in 1986. This multiple-location, multi-million-dollar facility committed to research at the materials, component, assembly, and systems levels features one of the largest assemblies of reaction wall/strong floor systems in the world 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. Pictured at right is the Caltrans Seismic Response Modification Device, capable of real-time, six-degrees-of-freedom, located adjacent to the Powell Laboratories.

In 2005, the Englekirk Structural Engineering Center opened as an expansion of the Powell Labs. This impressive facility is equipped a Blast Simulator (pictured at left) used to test technologies to harden structures against terrorist bomb attacks. The Center also boasts 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]), pictured at right, testing a 70-foot wind turbine.

The class of 2007

About Our Degree Programs . . .

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. Our programs features strong components in laboratory experimentation, basic theory, information technology, and engineering design. For admissions information, contact Graduate Student Affairs Advisor, Ms. Debra Bomar, via email at dbomar@ucsd.edu, or by telephone at (858) 822-1421, or Undergraduate Student Affairs Advisor, Ms. Sharon Gunderson at segunderson@ucsd.edu or by telephone at (858) 822-2273.

On the cover: *(Clockwise from top right) The new SF-OEB Bay Bridge, under construction; Prof. Restrepo, inside a Powell Lab; an iceball under testing; the DDG 1000 Destroyer; the new Structural and Materials Engineering building, as designed; Prof. Elgamal in the High Bay Physics Lab, with the centrifuge; Geisel Library, UC San Diego; Modular Hybrid Piers (U.S. Navy); Structural Health Monitoring of an aging bridge; ice impacat simulation; scanning of ancient buildings in Italy; looking west towards the Geisel Library, with the Powell Lab building in the foreground; silicalite crystals; UCSD Facility at Los Alamos National Laboratory; blast simulator testing;*

System and Damage Identification of a Seven-story Reinforced Concrete Building Slice Tested on the UCSD-NEES Shake Table

Principal Investigator: Prof. Joel P. Conte

A full-scale, seven-story reinforced concrete building slice was tested on the UCSD-NEES shake table from October, 2005 through January, 2006. Six different state-of-the-art system identification algorithms including three input-output and three output-only methods were used to estimate the modal parameters (natural frequencies, damping ratios, and mode shapes) based on the measured response of the building subject to ambient as well as white noise base excitations at different damage states. The identified modal parameters obtained using different methods were compared to study the performance of these system identification methods, and also to investigate the sensitivity of the estimated modal parameters to actual structural damage. The results obtained in this study were then used to identify damage in the building based on a sensitivity-based finite element (FE) model updating algorithm. The damage identification results were verified through comparison with the actual damage observed in the test structure. Furthermore, the performances of the three output-only system identification methods as well as the FE model updating for damage identification were (numerically) investigated due to variability of different input factors such as amplitude of input excitation, spatial density of measurements, measurement noise, length of response data used in the identification process, and the modeling error.

New Concrete Construction Systems for Mid-Rise Residential Buildings

Principal Investigator: Prof. Jose Restrepo

Prof. Restrepo and other 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, left) 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.

Simulating Bomb Blasts

Principal Investigator: Prof. Gilbert Hegemier

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.

San Francisco-Oakland East Bay Bridge Replacement Project: Precast Prestressed Concrete Skyway

Principal Investigator: Prof. Frieder Seible

Professor Seible led the proof-testing of the new San Francisco-Oakland East Bay Bridge, including the 2.5 km long precast-prestressed concrete skyway (pictured at left). Joints between superstructure segments and the skyway piers were tested at 1/4 scale under simulated seismic loads to establish performance limit states.

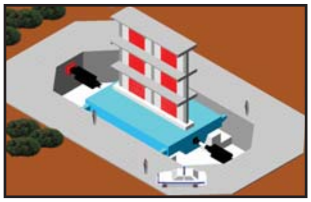
Seismic Rehabilitation of Steel Structures

Principal Investigator: Prof. Chia-Ming Uang

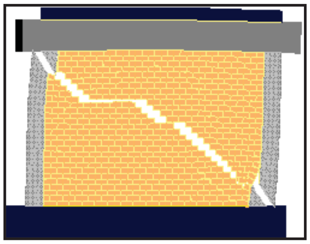
Damage to welded steel moment-frame buildings occurring during the 1994 Northridge earthquake revealed a previously unrecognized welded beam-column connection fracture vulnerability. Prof. Uang and other UC San Diego researchers worked with the California Department of General Services, Degenkolb Engineers, 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. UC San Diego'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 right 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.

Improving Seismic Performance of Concrete and Masonry Structures

Principal Investigator: Prof. P. Benson Shing



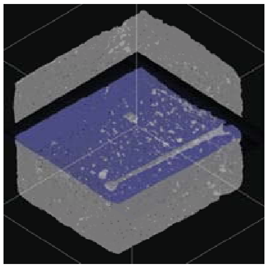
Assessing the seismic performance of older reinforced concrete (RC) frames that have masonry infill walls presents a most difficult problem for structural engineers. Currently, there are no reliable engineering guidelines. In a collaborative project sponsored by the National Science Foundation (NSF) under the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) program, Prof. Shing is leading an effort to develop advanced computational models as well as simplified 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 UC San Diego.



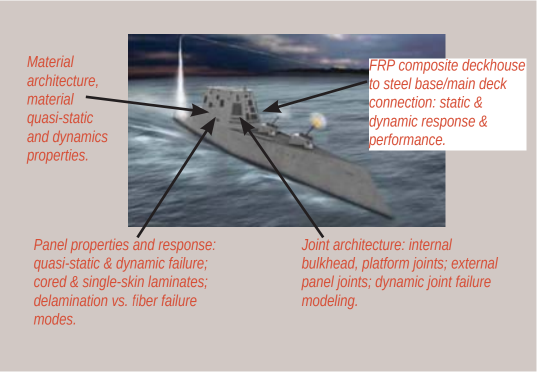
Strength design of reinforced masonry (RM) structures has been under continuous development and evolution for many years. With structural design moving towards a performance-based approach, research is needed to have a better understanding of the performance of RM structures under different earthquake levels and to develop reliable predictive tools. Prof. Shing is working on a second collaborative project sponsored by NSF's NEES program and the masonry industry and led by the University of Texas at Austin to address these needs. The project will involve large-scale testing on the LHPOST and computational simulation.

Concrete Damage-Transport Properties Correlations

Principal Investigator: Prof. Tara Hutchinson



Concrete is by far the most widely-used building material in the United States, with extensive use in the construction of our Nation's buildings, highways, tunnels, water supply and sewage systems and other infrastructure. The strong dependency of the service life of concrete on its transport properties means that investigations of the performance of concrete components need to link these transport properties to observed damage states. In collaboration with Los Alamos National Laboratories and supported by the National Science Foundation, Prof. Hutchinson and other UC San Diego researchers are developing damage-transport property correlations, using an integrated program of structural testing of concrete components, gas permeability testing, and X-ray computed tomography (see 3-D reconstruction at right).



Blast Resistant FRP Composite Designs & Verification

Principal Investigator: Prof. Robert Asaro

Hybrid joints are subject to complex internal stress states and are critical in terms of how they transfer loads between the (typically massive) steel hull structures and the lower density FRP composite deckhouse structure. UC San Diego has, in the past (and under DARPA support), designed highly optimized FRP deckhouse-steel main deck connections that were specifically intended to absorb the shock loading associated with the overpressure of blast loading. Our designs were based upon the extensive experience and expertise at UC San Diego in seismic design of building foundations *vis-à-vis* earthquake loading. We propose to develop concept designs for the DDX deckhouse-steel connections and propose them to the Navy for consideration in future DDX design/build programs.

Advanced Sensor Networking Paradigms and Data Processing for Autonomous Structural Assessment

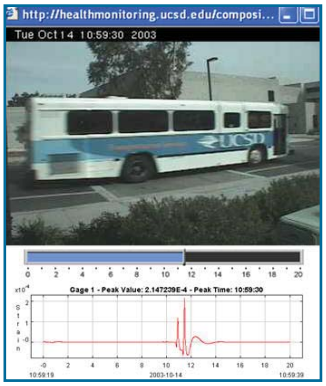
Principal Investigator: Prof. Michael Todd

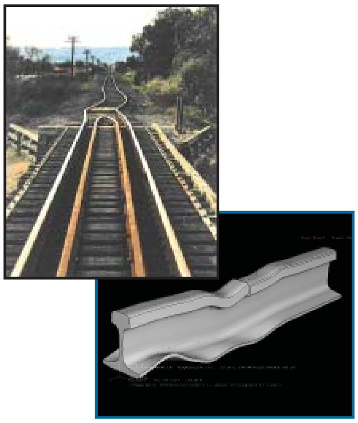
Damage assessment of large-scale structures (e.g., bridges, buildings, or dams) after an extreme event such as an earthquake or a blast load is a challenging task. In many cases, critical damage is not visible or obvious, human inspection poses serious life-safety concerns, and downtime for the structure equates with large economic losses. Prof. Todd and other researchers at UC San Diego, 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.

Bridge and Traffic-Pattern Monitoring

Principal Investigator: Prof. Ahmed Elgamal

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).





Rail Monitoring Systems

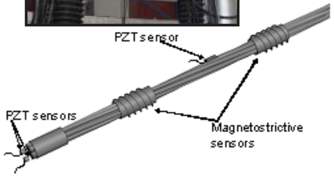
Principal Investigator: Prof. Francesco Lanza di Scalea

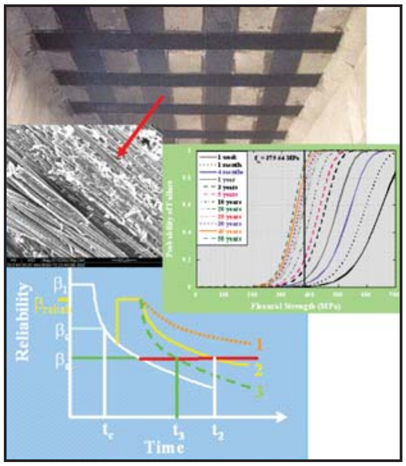
Railroad infrastructure is in need of technologies able to prevent derailments and perform repairs/replacements in a timely manner. Due to heavy tonnage and aging conditions, several structural problems affect railroads today, including the growth of cracks hidden from the surface of the rail. Prof. Lanza di Scalea and his graduate students, Stefano Coccia and Ivan Bartoli, are working with the Federal Railroad Administration (FRA) to develop a system which can detect cracks in rails while in motion, using ultrasonic waves and non-contact (laser) probing to detect the flaws. The system is being refined and plans are in place for installation in an FRA research car in late 2008. Additionally, in another FRA project, Profs. Lanza di Scalea and Uang are studying ways to detect incipient buckling of rails. Lateral buckling, a severe problem since the advent of continously-welded rail, is one of the most frequent causes of derailments worldwide today. UC San Diego researchers will extract high- and low-frequency dynamic signatures of rails in a non-contact manner as indicators of imminent buckling. Plans are for the development of an incipient buckling detection prototype working in motion at regular train speeds.

Health Monitoring of Post-Tensioned Concrete Bridges

Principal Investigator: Prof. Francesco Lanza di Scalea

Ninety-percent of California's bridges are post-tensioned concrete structures. There is a need to develop technologies able to monitor the state of health of the prestressing tendons which carry most of the loads. Recent bridge collapses have further highlighted the problem of the deteriorating conditions of the transportation infrastructure which require information on weak components. Prof. Lanza di Scalea, graduate student Ivan Bartoli, and post-doctoral Salvatore Salamone are working with Caltrans to develop an ultrasonic-based monitoring system for the prestressing tendons of post-tensioned concrete structures. The method is based on embedded sensors and ultrasonic guided waves which can provide information on the level of stress as well as the presence of defects such as corrosion or broken wires. Laboratory tests have indicated the suitability of the guided-wave method to achieve these goals. If further laboratory tests are favorable, the tendon monitoring system will be installed and tested on an operational post-tensioned bridge in California later in 2008.





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

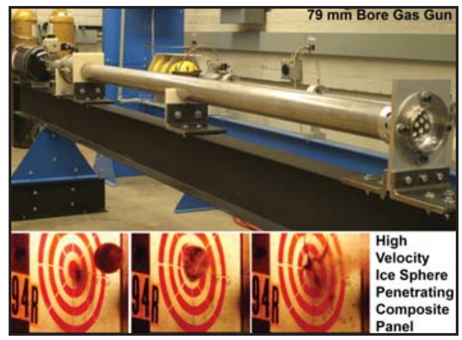
Principal Investigator: Prof. Vistasp Karbhari

Prof. Karbhari and other 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.

High Velocity Impact on Composite Structures

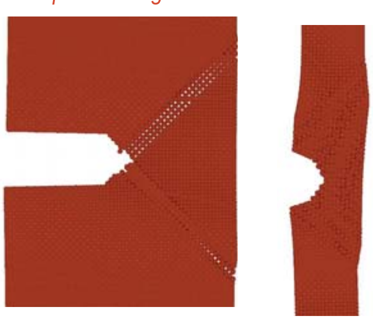
Principal Investigator: Prof. Hyonny Kim

High performance composite aircraft structures are exposed to various impact threats such as bird, hail ice, and ground maintenance damage. Ongoing research projects are particularly focused on the development of damage to carbon and glass epoxy structures as a result of impact by hailstones traveling at high velocities, e.g., equivalent to aircraft flight speeds. A gas gun is used to launch ice projectiles onto composite test panels to determine the threshold at which impact damage develops in the structure, thereby defining the resistance of these structures to the formation of damage under such threats. Such tests are also used to determine the morphology of the resulting damage. This latter information is critical in the definition of the impact-created flaws that the aircraft structure must be tolerant to since impact damage to composites is often difficult to detect.



Testing Biomineralized Composites for Greater Toughness

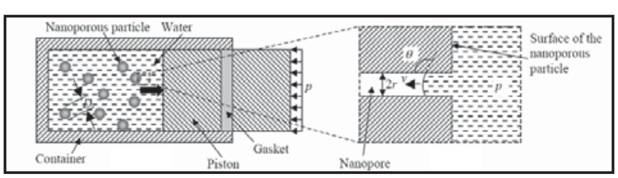
Principal Investigator: Prof. Robert Asaro



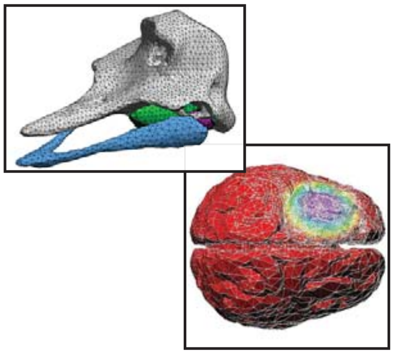
Are biomineralized composites tougher due to their nano-scale size? Atomistic studies of the resistance to crack propagation in nano-sized ceramic platelets that exist in teeth, bone, or the shells of mollusks, reveal that they are far more ductile than their bulk counterparts. The principal reasons are concerned with the increased ease of crack tip blunting and the inability for cracks to sustain the stress concentration required for brittle fracture. Examples of crack tip response are shown for cracked plates of thickness 4 nm and 16 nm, subjected to uniaxial tension; the former displays ductile rupture whereas the latter demonstrates more brittle like crack growth. At left, cross-sections of cracked plates with thickness 16 nm (far left) and 4 nm (left) shows crack propagation in the 16 nm thick plate, while section at left shows crack tip blunting in the 4 nm thick plate due to profuse dislocation nucleation.

Developing High-Performance Energy Absorbing Liquids

Principal Investigator: Prof. Yu Qiao



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. Prof. Qiao, post-doctoral Aijie Han, and other 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, among others.



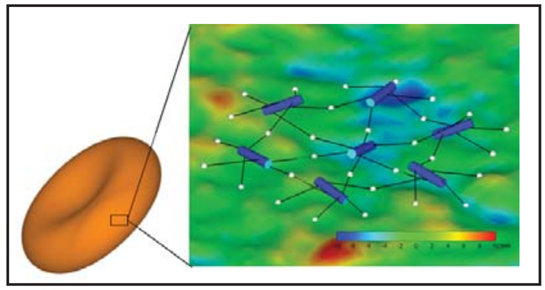
Analysis of the Structural Response of Biological Systems

Principal Investigator: Prof. Petr Krysl

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 (upper left) to test hypotheses concerning both pathways for sound reception, and pathways for sound generation (echolocation), adaptive finite element inverse brain EEG (left) and computational non-rigid registration guided neurosurgery.

Molecular-based Modeling of Red Blood Cell Membrane

Principal Investigator: Prof. Qiang Zhu



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.

Development & Improvements in Unmanned Aerial Vehicles (UAV)

Principal Investigator: Prof. John Kosmatka

Prof. Kosmatka and other UC San Diego 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. UC San Diego 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.

Virtual Vecchio: Creating a Digital Clinical Chart for a Landmark Building of the Renaissance

Co-Principal Investigator: Prof. Falko Kuester

Prof. Kuester, in collaboration with Maurizio Seracini, is developing a “digital clinical chart” for the Palazzo Vecchio in Florence, Italy, part of Calit2’s cultural heritage preservation initiative. His team spent three weeks in late 2007 laser-scanning the interior of the Palazzo’s main hall. The goal: to understand the structure’s performance and changes over time, and hopefully, to help find Leonardo da Vinci’s long-lost masterpiece mural, “The Battle of Anghiari.” Kuester’s team is creating an interactive, 3-D model based on 25 gigabytes of data collected in Florence, including x-y-z coordinates for 500 million points generated from the laser scans, and color values for each point (based on high-resolution photography). This model will serve as the baseline and reference for a broad range of multi-spectral imaging techniques that will be applied over the next year. Prof. Kuester’s team is currently developing algorithms and techniques needed to visualize and analyze this massive model, on the 220-million-pixel resolution HIPerSpace display, the highest-resolution such display in the world. This research is made possible, in part, through generous support by Natalie and Robert Englekirk.

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

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

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

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

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

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

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

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

Associate Professor Tara Hutchinson, Ph.D., P.E.—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.

Professor and Vice-Chair Vistasp M. Karbhari, Ph.D.—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.

Associate Professor Hyonny Kim, Ph.D.—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.

Professor John B. Kosmatka, Ph.D.—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.

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

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

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

Professor J. Enrique Luco, Ph.D.—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.

Professor Emeritus M. J. Nigel Priestley, Ph.D.—Seismic design of concrete and masonry structures. Seismic design philosophy.

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

Professor José I. Restrepo, Ph.D.—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.

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

Professor P. Benson Shing, Ph.D.—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.

Associate Professor and Vice-Chair Michael Todd, Ph.D.—Structural health monitoring methodologies. Applied nonlinear dynamics and chaos. Structural dynamics and vibrations. Time series analysis. Fiber optic sensors for structural monitoring.

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

Assistant Professor Qiang Zhu, Ph.D.—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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