

UC San Diego

JACOBS SCHOOL OF ENGINEERING
Structural Engineering

STRUCTURAL ENGINEERING



RESEARCH HIGHLIGHTS
2020–2021



2020-21 RESEARCH HIGHLIGHTS

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CHAIR'S MESSAGE



The Department of Structural Engineering at the University of California San Diego continues to be a leader in research and education related to all aspects of structural engineering, including civil structures, geotechnical engineering, structural health monitoring, computational mechanics, and aerospace structures. Our research plays a critical role in ensuring the safety and sustainability of the built environment and transportation means. Our Department reflects the interdisciplinary nature of structural engineering by bringing together civil, mechanical, and aerospace engineers to solve challenging problems at the forefront of research and practice. We provide an open, inclusive, diverse, and welcoming environment for our students, researchers, staff, faculty, and visitors to achieve their best and fulfill their professional goals, as we continue to actively recruit the best and most diverse faculty, staff and students.

The research highlighted here emphasizes both theory and experimentation while promoting discovery and innovation. Our research covers a broad range of structural materials and scales, from nano- and micro-structures consisting of particle assemblies or biological structures to large-scale structures, such as buildings, bridges, aircraft bodies, ship hulls, geotechnical structures, marine and naval structures. The research of our faculty, researchers, and students has provided solutions to some of the most challenging problems in the field, including the development of new design and assessment methods to improve the earthquake resilience of buildings and civil infrastructure systems, maximizing the structural efficiency and minimizing the societal impact of a major earthquake event; 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 and enhanced geothermal systems for renewable 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 and visualization of biological structures to understand the nature and help develop new treatment methods for diseases. Our research also addresses some of the emerging interdisciplinary challenges in the areas of artificial intelligence and data science in structural engineering, the use of digital twins, convergent systems engineering, visualization at different time rates and spatial scales, structural optimization, additive manufacturing, new sensors, smart materials, micromechanics, fluid-structure interaction, and multi-scale biomechanics. Our remarkable faculty members have received numerous awards and accolades; many hold highly respected positions within their professional societies, and are dedicated to mentoring their graduate students.

The experimental, computational, and visualization facilities in our Department are major assets that we continuously develop. Through these facilities, researchers, students and visiting scholars have access to some of the most innovative and productive research infrastructure in the world. The unique talents of the students, staff and faculty members in the Department of Structural Engineering along with our vast experimental facilities have been major resources to private industries and governmental agencies that have also contributed to our consistently high ranking within our field. Our research has made direct impacts on standards and practice in the structural, geotechnical, aerospace, and materials engineering fields. The Department is committed to pursuing excellence in research and public service and providing the best possible education and training for our students to be leaders in their profession.

John S. McCartney
Professor and Department Chair
Department of Structural Engineering, UC San Diego

FACILITIES

Major assets of our department are our experimental, computational, and visualization facilities. The Structural and Materials Engineering (SME) Building, where the department is located, has well-equipped teaching and research laboratories for geomechanics (soils and rocks), advanced composite materials, aviation safety, structural health monitoring and non-destructive evaluation, and computer visualization. In addition, our Department is home to the world-class Charles Lee Powell Structural Engineering Laboratories, which have unique experimental facilities to study the performance of large-scale structural systems and components under extreme loading, including earthquake, impact, and blast loads. Between the Powell Laboratories and the SME Building, the Caltrans Seismic Response Modification Device (SRMD) is another unique test facility capable of real-time 6-DOF dynamic characterizations of full-scale bearing devices and dampers. The SRMD building also houses a 50 g-ton geotechnical centrifuge used for physical modeling of geotechnical systems realistic self-weight and earthquake loadings. The Englekirk Structural Engineering Center (ESEC), located 10 miles east of the main campus, has the world's largest outdoor shaking table for seismic testing of large-scale structures, a blast simulator, and a soil-structural interaction testing facility. In addition, ESEC has unique large-scale experimental setups for field testing of non-destructive evaluation methods that detect defects in train rails, and for field testing of underground geothermal energy storage methods. Through these facilities, students and visiting scholars have access to some of the most innovative and productive research infrastructure in the world.

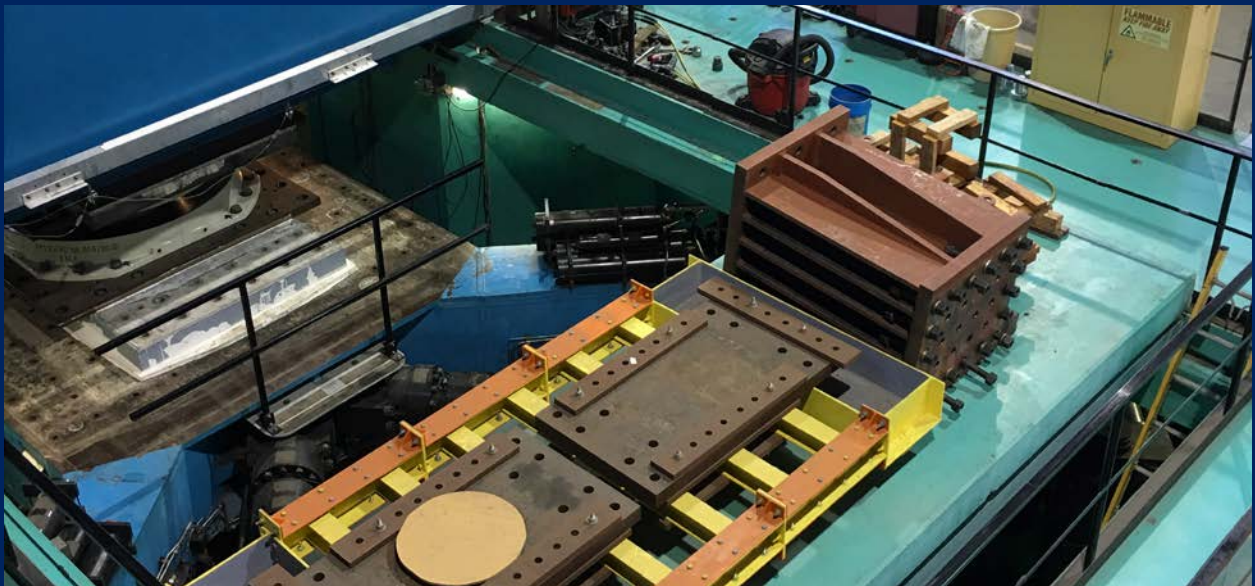


Photo courtesy of eeman agrama minert, Director of Residential Life & Associate Dean of Student Affairs at Thurgood Marshall College, UC San Diego and Owner of myownbeat photography.



STRUCTURAL AND MATERIAL ENGINEERING (SME) BUILDING

The 183,000-square-foot building houses the Structural Engineering Department, Nano-engineering, a Medical Devices group, the EnVision Maker Studio and parts of the Visual Arts department. The building includes 62 research and instructional laboratories, 160 faculty, graduate student and staff offices, Visual Arts studios distributed across all four building's floors, art exhibition and performance space, and ASML 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."



SEISMIC RESPONSE MODIFICATION DEVICE (SRMD) TESTING LABORATORY

Gianmario Benzoni, Director

A unique facility capable of real time 6-DOF dynamic characterizations of full-scale bearing devices and dampers. The UC San Diego geotechnical centrifuge is a 50 g-ton machine used for physical modeling of geotechnical systems under realistic self-weight and earthquake loading and has recently been used to test the pullout capacity of thermal suction caissons for offshore floating structures.

FACILITIES



THE ENGLEKIRK CENTER

Joel Conte, Director

The Englekirk Structural Engineering Center (ESEC), located 10 miles east of the main campus, has the world's largest outdoor shaking table for seismic testing of large-scale structures, a blast simulator, and a soil-structural interaction testing facility. The shaking table is currently undergoing a \$20 million upgrade project sponsored by NSF with matching from UCSD to simulate 6 degree of freedom motions that will be complete in 2021. ESEC has unique large-scale experimental setups for field testing of non-destructive evaluation methods that detect defects in train rails, soil pits to test full-scale foundations, and a facility to test geothermal energy storage. Through these facilities, researchers, students and visiting scholars have access to some of the most innovative and productive research infrastructure in the world.

CHARLES LEE POWELL STRUCTURAL RESEARCH LABORATORIES

Benson Shing, Director

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 strong-walls, actuators, and shake table in the Powell Laboratories are used daily to test full-scale transportation and geotechnical structures. 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.



WORLD-CLASS FACULTY AND RESEARCHERS



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.



TARA HUTCHINSON

Professor

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



GIANMARIO BENZENI

Research Scientist

Structural Analysis, Seismic response modification devices, Seismic Isolation; Earthquake engineering.



HYONNY KIM

Professor

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



JIUN-SHYAN (JS) CHEN

Distinguished Professor

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



HYUNSUN KIM

Professor

Structural and topology optimization, multiscale and multiphysics optimization of structures and materials, optimization for composite materials, aerospace structures.



JOEL CONTE

Distinguished Professor

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



JOHN KOSMATKA

Professor

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



AHMED-WAEIL ELGAMAL

Distinguished Professor

Information Technology, Earthquake Engineering, Computational Geomechanics.



PETR KRYSL

Professor, Vice Chair

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



CHARLES FARRAR

Adjunct Professor

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



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.

WORLD-CLASS FACULTY AND RESEARCHERS



FRANCESCO LANZA DI SCALEA

Professor

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



JOSE RESTREPO

Professor

Seismic design of buildings for improved response during earthquakes.



KEN LOH

Professor, Vice Chair

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



SHABNAM SEMNANI

Assistant Professor

Characterization and modeling of heterogeneous geomaterials across scales, microstructure and macroscopic behavior of materials.



JOHN MCCARTNEY

Professor, Department Chair

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



PUI-SHUM SHING

Professor

Earthquake engineering, structural dynamics, inelastic behavior of concrete and masonry structures, bridge structures, finite element modeling of concrete and masonry structures, and structural testing.



MACHEL MORRISON

Assistant Professor

Seismic safety, materials science, solid mechanics



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.



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.



INGRID TOMAC

Assistant Professor

Hydro-thermo-mechanical coupled processes in rocks; dense fluid-particulate systems micromechanics and rheology; rock mechanics; hydraulic fracturing and proppant flow and transport in geothermal reservoirs; induced seismicity and CO2 sequestration.



YU QIAO

Professor

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



GEORGIOS TSAMPRAS

Assistant Professor

Engineering mechanics; structural analysis; structural dynamics; structural connections; friction-based structural components; unified design methodologies; natural hazards; damage tolerance analysis; probabilistic mechanics.



CHIA-MING UANG

Professor

Earthquake engineering, seismic design of steel buildings and bridges.



LELLI VAN DEN EINDE

Teaching Professor



QIANG ZHU

Professor

Ocean engineering, biomechanics.



GILBERT HEGEMIER

Distinguished Professor Emeritus

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



DAVID BENSON

Professor Emeritus

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



ENRIQUE LUCIO

Distinguished Professor Emeritus

Earthquake engineering, strong motion seismology, soil structure interaction.



FRIEDER SEIBLE

Distinguished Professor Emeritus

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

BY THE NUMBERS

#8

UC San Diego Among U.S. Public Universities, by Center for World University Rankings CWUR.

#9

Division of Jacob School of Engineering Ranking among Public Institutions by 2020 US News & World Report.

8,900

Student enrollment at the Jacobs School of Engineering

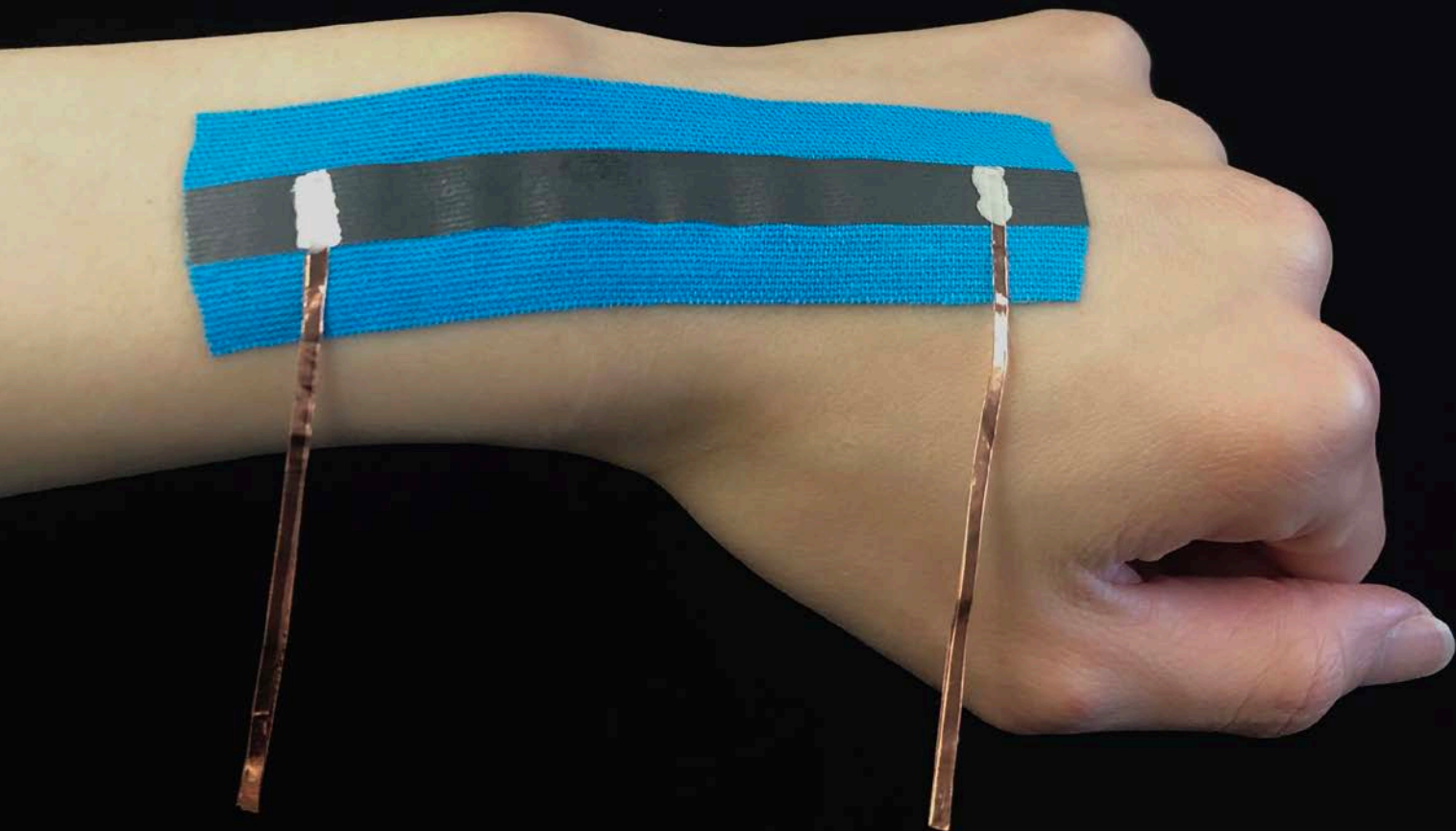
\$12M

in research per year

25

Ladder Rank Faculty

RESEARCH



WEARABLE SENSORS FOR WARFIGHTER PERFORMANCE MONITORING

PROFESSOR KEN LOH AND YUN-AN LIN

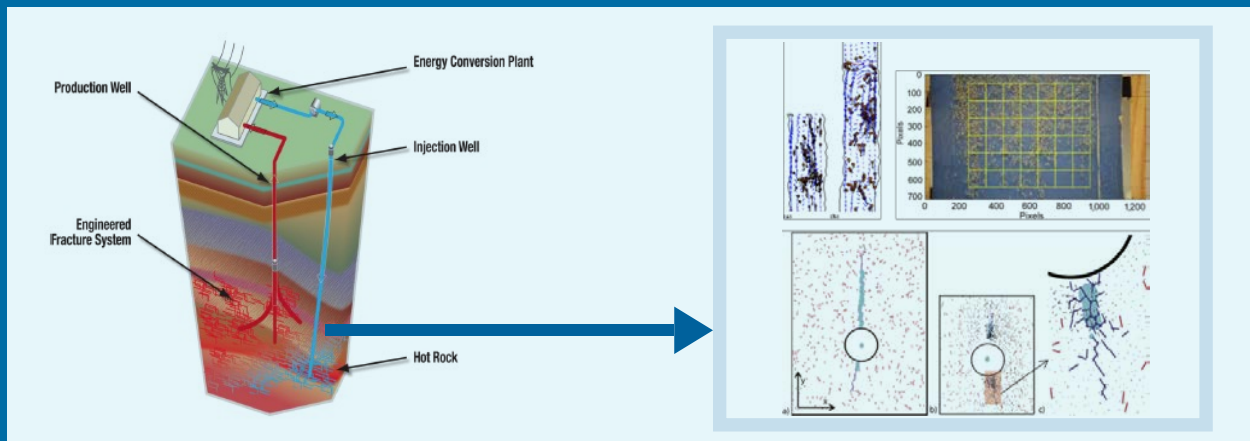
Wearable sensors have attracted considerable interest among the general public due to increased awareness in personal health and wellness management. In particular, wearable sensors that can capture the detailed movements and strains of muscles can facilitate a holistic assessment of muscle movement, performance, and precursors of musculoskeletal injuries. The objective of this Office of Naval Research project is to develop a multifunctional wearable sensing platform for warfighter performance monitoring. The Active, Responsive, Multifunctional, and Ordered-materials Research (ARMOR) Lab has designed "Smart K-Tape" sensors by integrating strain-sensitive nanocomposites with commercially available kinesiology tape. K-tape is a self-adhering, stretchable, fabric-based tape affixed onto the skin for supporting muscles and joints, as well as for relieving pain and swelling. The incorporation

of printed graphene-based thin films with K-tape enables the measurement of distributed strains as the warfighter (or athlete) undergoes different training and field exercises. Laboratory tests have shown that these Smart K-Tape sensors exhibit 15 to 100 times greater sensitivities than foil-based strain gages while exhibiting repeatable and high signal-to-noise ratio response. Human subject pilot testing has confirmed that these sensors are capable of measuring muscle and joint movements as individuals perform different types of motions. This project involves close collaborations with the Naval Health Research Center in Point Loma and the Naval Medical Center San Diego. The long-term goal is to deploy these sensors for warfighter performance and physiological monitoring while acquiring the data streams necessary for assembling a personalized Digital Twin for each warfighter.

THE EMERGENT FIELD OF ENERGY GEOTECHNICS

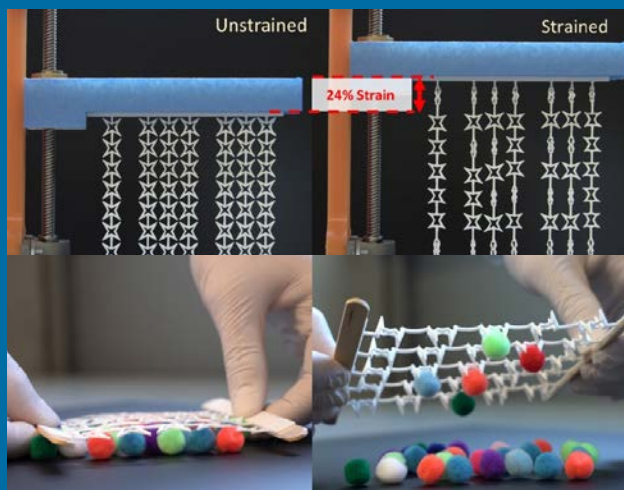
ASSISTANT PROFESSOR INGRID TOMAC

Energy geotechnics is an emergent field which relies on solving geomechanical problems for better extraction of renewable and sustainable energy from soils and rocks. Multi-scale and multi-physics problems are solved with aid of contemporary computational and experimental approaches, such as are Discrete Element Model coupled with computational fluid dynamics, micromechanical and laboratory scale experiments, Particle Image Velocimetry analysis of high speed camera images. Dr. Tomac team is putting experimental, theoretical and numerical effort to understand how dense-phase particulate fluid slurries flow in narrow, wavy, branched rock fractures. We will develop statistically supported theories for predicting placement of sand proppant in hydraulic fractures for efficient extraction of heat energy from deep enhanced geothermal systems (funded by NSF). Rock mass in 5 km deep geothermal reservoirs is subjected to coupled hydro-thermo-chemo-mechanical processes. Dr. Tomac and her team are developing novel failure and stress-strain theories for better predicting rock behavior during geothermal energy extraction.



SHAPE-MORPHING ACTIVE SKINS

PROFESSOR KEN LOH AND YUJIN PARK



Many of nature's creations, such as octopus and cuttlefish, can alter their skin properties to adapt and camouflage to their surroundings. Inspired by these biological systems, the Active, Responsive, Multifunctional, and Ordered-materials Research (ARMOR) Lab has designed Active Skins that can dynamically and reversibly morph their surface texture in a controlled manner. The objective of this project is to design skin-like structures that can shapeshift and alter their surface texture for camouflage. By designing the unit cell pattern of these flexible, 3D-printed, and planar structures, these Active Skins exhibit 2D to 3D deformations when tension is applied. In addition, the direction of these induced out-of-plane deformations can be reliably controlled by introducing instabilities or notches at selective locations in the structure. To harness these designs for specific functionalities, large arrays of these Active Skin unit cells have been fabricated. Each unit cell within the array can include, omit, or vary the placement of notch imperfections to elicit a specific out-of-plane deformation response. When assembled into an array, these Active Skins can function as a large-area gripper or be actuated to reveal an embedded "1 2 3" pattern, thus demonstrating the first concept of a dynamically variable camouflage system.

STRUCTURAL STEEL RESEARCH

PROFESSOR CHIA-MING UANG

SEISMIC COMPACTNESS REQUIREMENT FOR STEEL MOMENT FRAME COLUMNS

Deep wide-flange columns are routinely used for the construction of multistory Special Moment Frames (SMF) in the United States because deep column sections are efficient to meet the story drift requirement specified in the building code. Although AISC Seismic Provisions for Structural Steel Buildings (AISC 341) require a check of strong column-weak beam condition, plastic hinging at column base is expected. To address the response and design of such columns, National Institute of Standards and Technology sponsored a research project at UCSD. A total of 48 deep columns were cyclically tested by using a shake table facility at the Structural Response Modification Device (SRMD) Laboratory.

Test results showed that the interaction between web and flange local buckling caused significant strength degradation and axial shortening. While some columns developed plastic hinges at member ends in the plane of bending, out-of-plane buckling as shown in Figure 1 was also observed in many column specimens. Based on results from both testing and finite element simulation, more stringent width-thickness limiting ratios (λ_{hd} for SMF and λ_{md} for IMF) have been proposed (see Figure 2). These recommendations are being considered by the AISC Specifications Committee for inclusion in the 2022 edition of AISC 341.

CONTINUITY PLATE DESIGN FOR STEEL MOMENT FRAMES

Continuity plates (i.e., horizontal stiffeners) have long been understood in playing an important role in stiffening the beam flange-to-column flange connection in an SMF. The 1994 Northridge, California earthquake resulted in brittle fractures at the complete-joint-penetration (CJP) weld adjoining the beam flanges to the column. Significant research effort conducted after the earthquake resulted in moment connection design requirements contained in AISC 341 and AISC 358 (Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications). These standards stipulate that continuity plates must match those of specimens tested in the past and, thus, expensive CJP welds are required to connect the continuity plate to column flanges. In this research project, sponsored by the American Institute of Steel Construction, we performed full-scale cyclic testing of more than ten beam-column subassembly tests to develop an alternate weld detail and a design procedure that allow the designer to use more economical fillet welds to replace CJP for such application.

Figure 3 shows the test setup for 2-sided moment connection testing. Eleven specimens that used fillet



Figure 1 Test Setup

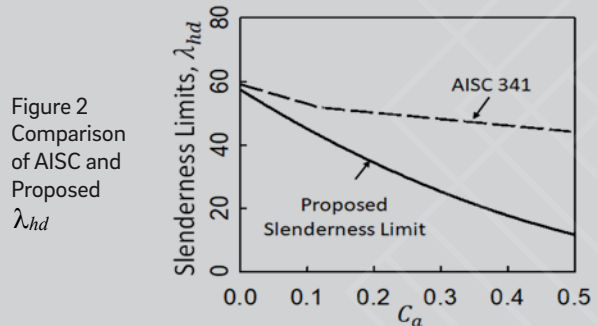


Figure 2 Comparison of AISC and Proposed λ_{hd}



Figure 3 Moment Connection Test

welds with the proposed design procedure met the acceptance criteria in AISC 341. Based on both testing and extensive finite element simulation, we proposed that continuity plates be permitted to be welded to column flanges using a pair of fillet welds with a weld size at least equal to 75% of the thickness of the continuity plate. In addition, we proposed a limiting width-thickness ratio for continuity plate design based on the observed buckling in this research program. These proposed requirements are being considered for inclusion in the 2022 edition of AISC 341.

TENSION-FIELD ACTION AND SHEAR STRENGTH OF END PANELS IN STEEL PLATE GIRDERS

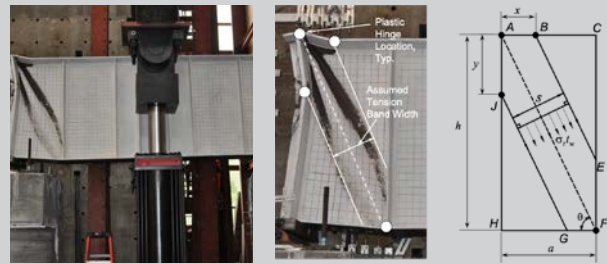
I-shaped steel plate girders with vertical stiffeners in the web are widely used for bridge construction. For economy, the web plate is very thin relative to the depth of the girder. Unlike typical rolled I-shape members, these girders rely on the development of tension-field action (TFA) after the web buckles to resist shear. Both the bridge design code (AASHTO Specifications) and building design code (AISC Specification) provide equations for calculating design shear that takes advantage of TFA in the past half century. But these equations are applicable for interior, but not end, panels. When performing evaluation of existing steel girder bridges in California, Caltrans engineer realized that end panels quite often do not have a sufficient shear strength in the end panels. Thus, Caltrans funded a research at UCSD to evaluate if end panels can also benefit from TFA such that expensive retrofit is unnecessary.

A total of eight large-size plate girders were tested in the Powell Laboratory. A TFA model was established based on the observed failure mode (see Figure 4), from which a shear

strength equation that reflects the partial TFA was developed based on plastic analysis:

$$V_n = 0.6F_y A_w \left[C_{v2} + \beta_v \left(\frac{1 - C_{v2}}{1.15\sqrt{1 + (a/h)^2}} \right) \right]$$

This shear strength is also being considered for adoption in the 2022 edition of AISC *Specification for Structural Steel Building*.



(a) Test Setup

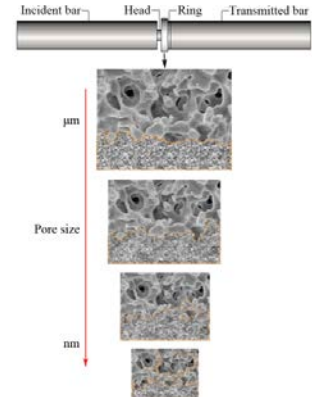
(b) Tension-Field Action Model

Figure 4 TFA in End Panels

STRESS WAVE MITIGATION IN POROUS MATERIALS

PROFESSOR YU QIAO

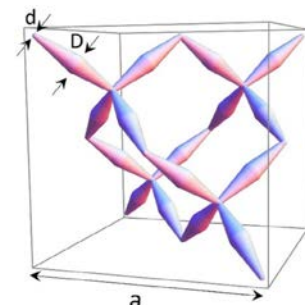
Stress wave mitigation in porous materials, such as silica monoliths and PTFE foams, are investigated. As shown in Figure 1, a hat-shaped setup on the SHPB testing system is used to induce force on the porous silica monoliths with different average pore sizes, from a few nanometers to a few hundreds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



MECHANICAL RESPONSE OF CONFINED PENTAMODE LATTICES FOR POTENTIAL USE AS NOVEL SEISMIC ISOLATION AND IMPACT PROTECTION DEVICES

DR. GIANMARIO BENZONI WITH UNIVERSITY OF SALERNO

The ability of pentamode lattices to have both very soft and very stiff deformation modes suggests they are potentially suitable for use as seismic isolators. Unlike most other seismic isolators, where the response depends entirely on the properties of the materials used, the response of pentamode lattices depends mostly on their geometry. This is advantageous, as their response can be easily tuned by altering the geometry to control the vertical and horizontal stiffness for each application.



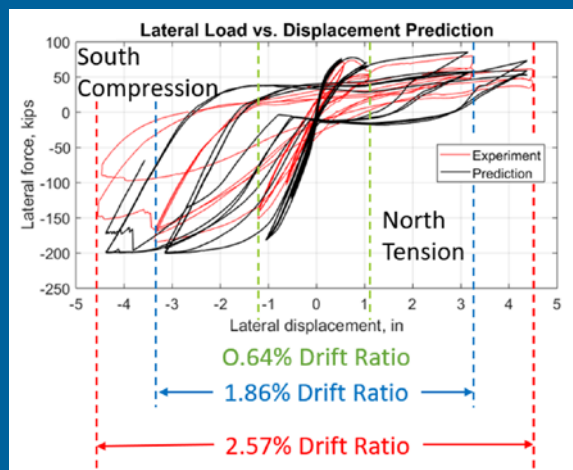


SEISMIC PERFORMANCE OF SUBMERGED BRIDGE PILES

PROFESSOR BENSON SHING

In older cross-bay bridges, submerged piles could experience significant structural deteriorations caused by the corrosion of the reinforcing steel and the cracking and spalling of the concrete after long-term exposure to the sea water. During a strong earthquake, these piles could be subjected to very high tension and compression in addition to lateral forces, all transmitted from the bridge pier supported by the pile group. Compounded by the fact that these piles were designed with older standards, their performance under extreme seismic events has been questioned. Little information is available on the shear capacity and failure mechanism of RC members subjected to lateral forces and high axial tension at the same time. In a project supported by Caltrans, a study has been carried out in the Powell Structural Engineering Laboratories of UC San Diego to evaluate the performance of prestressed concrete piles under alternate high axial tension and compression as the pile undergoes cyclic lateral displacements. The subject bridge was constructed in the sixties. In this research, five 0.78-scale models of a representative Type-II pile are tested. They represent an as-built pile as well as piles with different degrees of corrosion damage. A beam-column model that captures the interaction of the axial, flexural and shear responses of an RC pile has

been developed to analyze the behavior of a pile group as well as individual piles. The model is being validated by the test data. The study will determine whether the piles meet the target seismic safety requirements. Data obtained from this study can also be used to improve design specifications for prestressed concrete piles in general.



OPTIMAL SENSOR PLACEMENT AND BAYESIAN DECISION THEORY

PROFESSOR MICHAEL TODD

The primary objective of the structural health monitoring (SHM) system is to continuously monitor the state of the structure and evaluate the structural integrity at any time. Minimizing the losses due to failure, and the maintenance cost in the real-world structures requires the installation of an efficient and optimized SHM system. The first part of this research focuses on developing a framework for optimal sensor network design using Bayesian optimization concerning SHM applications using Bayes risk as an objective function. Bayes risk considers the costs of consequences associated with making decisions and design selection (extrinsic cost) in the monitoring process, as well as intrinsic costs (e.g., sensor costs and their maintenance costs), and hence, is a natural choice for the objective function. The optimal sensor network is obtained by minimizing Bayes risk. Solving this problem involves using advanced techniques of Bayesian inference, surrogate modeling using Gauss process regression (GPR), uncertainty quantification, and Bayesian optimization

The second part of this research is to arrive at the state of the structure, like to decide if the structure is damaged or undamaged, depending on the decision-maker's individual or organizational behavioral risk-profile using expected

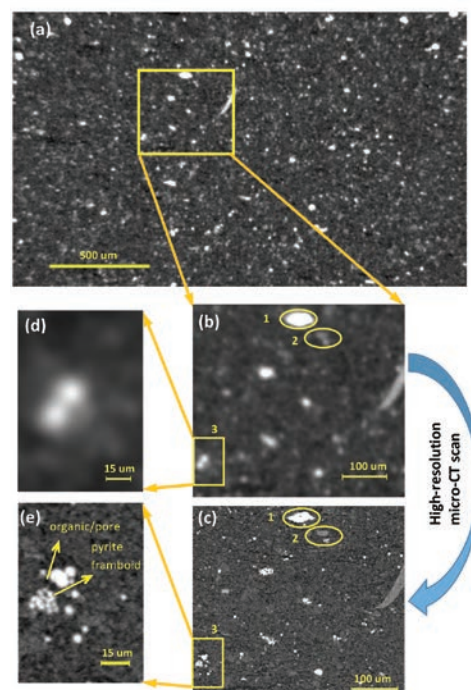
utility theory. Usually, SHM provides the distribution of the state-parameter from which the structural state is determined in probabilistic terms. The subjective actions corresponding to the state of the structure then consist of various maintenance strategies (like to inspect or not to inspect) that has an associated cost to it. This paper tackles the situation where the state of the structure is subjective to the decision maker's risk profile and is dependent on the uncertain state parameter (like crack length, and thickness of corrosion). It attempts to answer the question: Given the risk profile of the decision maker and the distribution of the state-parameter, which structural state must be chosen so that the consequence or the losses are minimized in an average sense? This involves understanding and designing individual and organizational risk-profiles, using the concept of the value of information, prior, posterior, and preposterior decision analysis. Both these investigations are applied to a miter gate problem.



MICROSTRUCTURE CHARACTERIZATION OF SHALE THROUGH MULTI-SCALE IMAGING

ASSISTANT PROFESSOR SHABNAM SEMNANI

Shale is a highly heterogeneous material at multiple scales. A typical shale has a complex microstructure comprised of nanometer-scale pores and minerals mixed with macro-scale fractures and particles of varying size. Computational modeling of this complex and highly heterogeneous rock requires detailed characterization of heterogeneities and microstructure of the material using imaging and visualization techniques. Advances in high-resolution imaging capabilities have made it possible to image heterogeneous materials down to the nano-scale resolution. However, it is generally not feasible to image a large sample of shale at a high resolution over a large field of view (FOV), thus limiting a full characterization of the microstructure of this material. We have developed a statistical framework that uses high-resolution images to enhance low-resolution images obtained over a large FOV. The approach has been demonstrated using X-ray micro-tomography images of organic-rich Woodford shale obtained at different resolutions and FOV.



Multiscale imaging of shale. A single slice of shale with pixel size of 4.14 µm, obtained using a low-resolution micro-tomography scan, is shown in (a), and the marked region is enlarged in (b). (c) Illustrates the same region shown in (b) obtained using a micro-tomography scan with a pixel size of 0.517 µm. Region 3 marked in (b, c) is enlarged in (d, e), respectively, showing small pyrite particles, framboids, pores/organics, and matrix of low-density minerals and clay, which appear as a blurred range of gray values in the low-resolution image (after Semnani and Borja, 2017)

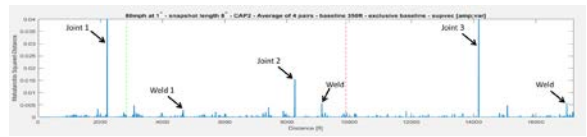


HIGH-SPEED INSPECTION OF RAILTRACKS BY PASSIVE EXTRACTION OF ACOUSTIC TRANSFER FUNCTIONS FROM WHEEL-GENERATED DYNAMIC EXCITATIONS

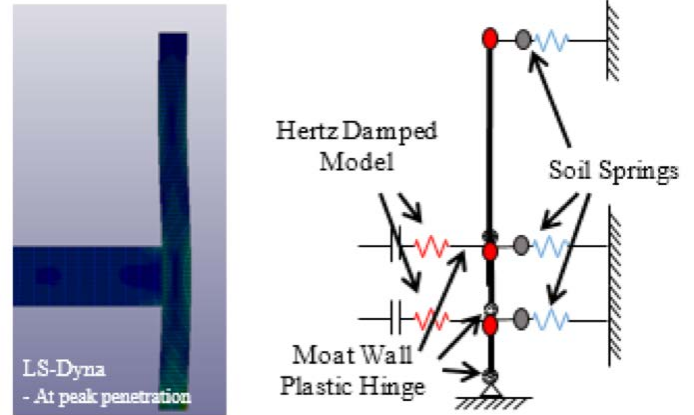
PROFESSOR FRANCESCO LANZA DI SCALEA

Internal defects in rails cause a number of train accidents worldwide, including derailments. Current rail inspection systems use ultrasonic transducers hosted in fluid-filled wheels to detect internal cracks before they reach critical size. These systems are operated at a maximum speed of 25-30 mph by dedicated inspection vehicles that need to be scheduled during normal train operations.

Under Federal Railroad Administration (FRA) funding, UCSD is working on a radically new method to inspect rails that can enable "smart trains" to conduct the inspection at regular traffic speeds (80 mph and beyond). The approach is based on the idea of passive reconstruction of an acoustic transfer function between two points of the rail by cross-correlating (and opportunely normalizing) apparently-random measurements of dynamic excitations naturally occurring in the rail due to the rotating wheels of a traveling train. A system based on this idea was designed and constructed using pairs of non-contact air-coupled acoustic receivers. Special signal processing algorithms are being developed to increase the stability of the passively-reconstructed transfer function, i.e. minimize the variance and bias of the transfer function's estimate. A prototype has been tested at the Transportation Technology Center (TTC) in Pueblo, CO, the premiere testing facility in the country for railroad engineering research. For these tests, the UCSD prototype was mounted underneath the FRA DOTX216 test car. Very promising results were obtained at speeds up to 80 mph, with positive identification of rail discontinuities (joints, welds, defects) from changes in the passively-reconstructed transfer function solely using the train wheels as the dynamic excitation of the rail.



Sample of inspection results at 80 mph test speed (TTCI RTT track)

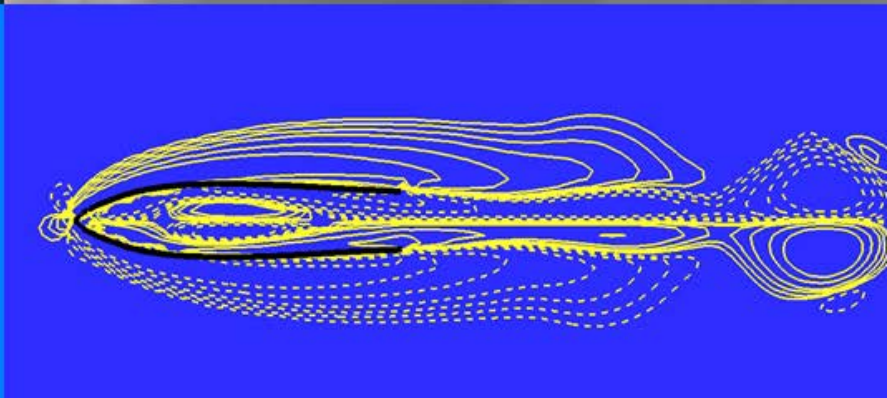
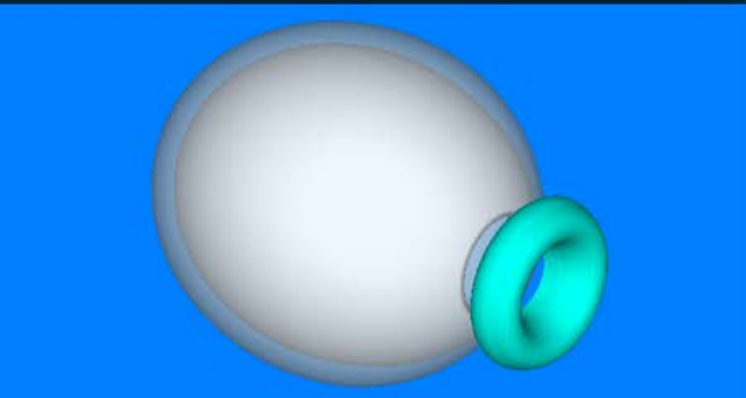


Finite element simulations of NPP base mat impact to moat wall and proposed macro model of moat wall for system level simulations

SEISMIC ISOLATION OF NUCLEAR POWER PLANTS

PROFESSOR GILBERTO MOSQUEDA

Seismic isolation is one of the most effective strategy to protect critical facilities including Nuclear Power Plants (NPPs) from the damaging effects of horizontal earthquake ground shaking. However, the behavior of the seismic isolation system under extreme earthquakes is not well understood and of significant safety concern. Recent research has focused on addressing the potential for impact of the isolated structure to the stop or moat wall after exceeding its clearance displacement limit. A moat wall model of the scale required for NPP applications was developed based on detailed simulations and previous experimental research. Simulation results indicate significant penetration into the moat wall is possible and the resulting increase in displacement demands on the isolation system should be considered in design.



SWIM LIKE A SQUID: A BIO-INSPIRED PROPULSION SYSTEM

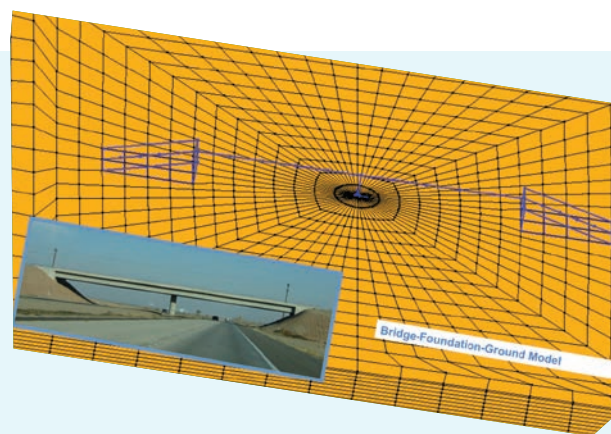
PROFESSOR QIANG ZHU

Relying on a unique hybrid locomotion system combining fin flapping and jet propulsion, squids are among the fastest swimmers in the aquatic world. Inspired by this ingenious design, we have developed a novel bio-inspired underwater propulsion system that can achieve high-speed swimming via body deformation and pulsed jetting. Numerical models have been developed to illustrate the underlying physical mechanisms and examine measures to optimize the propulsion performance. Based on these results a prototype has been developed through inter-departmental collaboration. In addition to high speed, this propulsion design also promises high maneuverability (via thrust vectoring) and low environmental footprint, useful features for potential environmental and scientific applications.

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

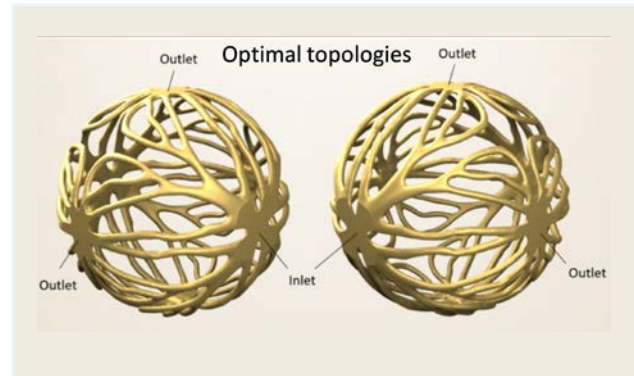
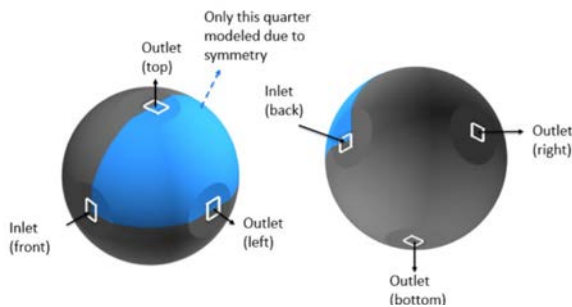


For more info, visit <http://www.soilquake.net/openseespl> and <http://peer.berkeley.edu/bridgepbee>

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.

LEVEL SET TOPOLOGY OPTIMIZATION OF COOLING CHANNELS USING THE DARCY FLOW MODEL

SANDILIYA KAMBAMPATI, PROFESSOR H. ALICIA KIM



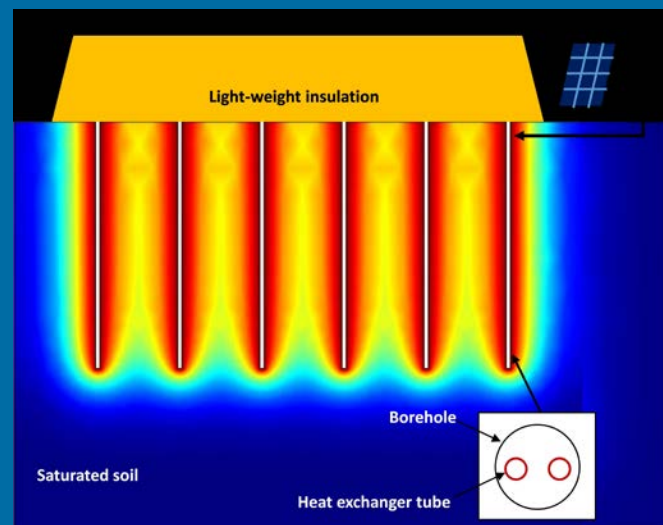
We developed a level set topology optimization method for 3D cooling channels, considering convective heat transfer for high Reynolds number flows. The Darcy potential flow is used to simulate the flow using the finite element method. The resulting velocity field is used in a convection-diffusion model to simulate the heat transfer using the finite element method. The pressure drop and the average temperature are considered as the objectives, which are minimized subject to a volume constraint and a maximum length scale constraint. Our results show that the pressure drop and the average temperature are conflicting criteria. We show an example in 3D where we optimize the cooling channel topology that conforms to the surface of a sphere.

THERMAL IMPROVEMENT OF NORMALLY CONSOLIDATED CLAYS

PROFESSOR JOHN MCCARTNEY AND RADHAVI SAMARAKOON

Cost-effective improvement of soft soil deposits encountered in civil infrastructure, offshore or river sediments, mine tailings dams and coal ash impoundments is a challenging geotechnical problem. This research assesses the feasibility of using solar thermal energy to improve the mechanical properties of soft soil deposits over different depth ranges. Specifically, heated fluid collected from solar thermal panels circulated through closed-loop geothermal heat exchangers in the subsurface is used to induce thermal volumetric contraction and a corresponding increase in shear strength of a targeted zone of soil. Advantages of this approach are that soil improvement can be gained in a targeted manner using renewable energy, after which the geothermal heat exchangers can be used for long-term underground thermal energy storage, yielding cost savings when compared to available soft soil improvement technologies. The results obtained from laboratory testing on kaolinite specimens subjected to a drained heating-cooling cycle show a clear increase in undrained shear strength. Further studies seek to better understand the fundamental processes governing the

thermal volume change of soft soils over different depth ranges and to improve constitutive models for soft soils needed in advanced computer simulations.



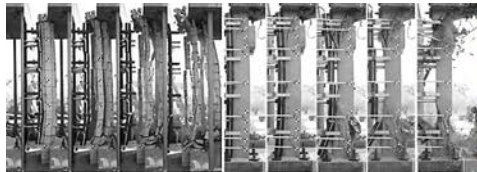
CENTER FOR EXTREME EVENTS RESEARCH

STRUCTURAL ENGINEERING ROBERT ASARO, YURI BAZILEVS, J. S. CHEN, VERONICA ELIASSON, TARA HUTCHINSON, GILBERT HEGEMIER, ALICIA KIM, HYOONNY KIM, FALKO KUESTER, KEN LOH, JOHN MCCARTNEY, S. SEMNANI, **MECHANICAL AND AEROSPACE ENGINEERING** DAVID KAMENSKY, BORIS KRAMER, VITALI NESTERENKO, ALBERT PISANO, SUTANU SARKAR, **RADIOLOGY** SHANTANU SINHA, **MATHEMATICS** RANDOLPH BANK, LI-TIEN CHENG, MICHAEL HOLST, **SAN DIEGO SUPERCOMPUTER CENTER** AMITAVA MAJUMDAR, MAHIDAR TATINENI

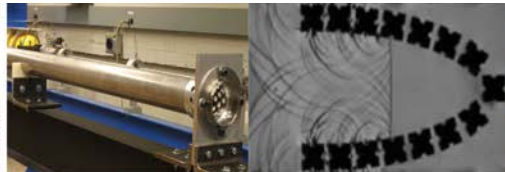
Center researchers are world-renowned experts in experimental and computational methods, design optimization, sensor technology and multifunctional materials for extreme events. We leverage this expertise to develop better ways to protect entire built infrastructures, as well as bio-systems, from extreme 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.



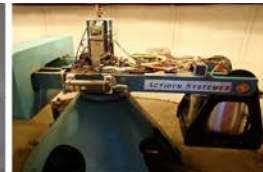
Data Fusion & Visualization



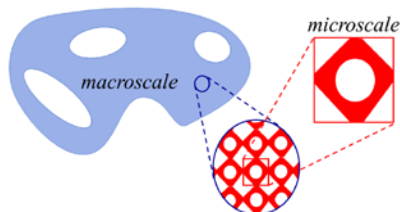
Blast Simulator



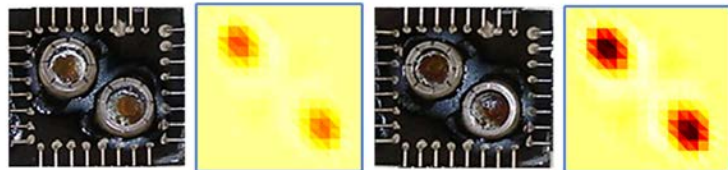
Impact Testing Facilities



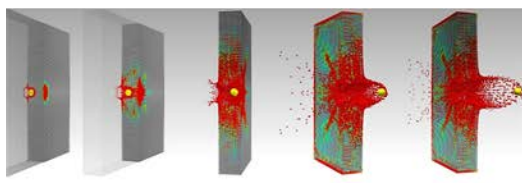
Geotechnical Centrifuge



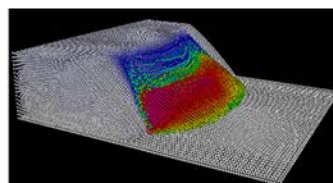
Topology Design Optimization



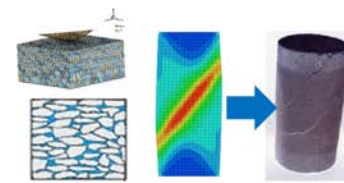
Multifunctional Materials & Sensors



Modeling of Man-made Disasters



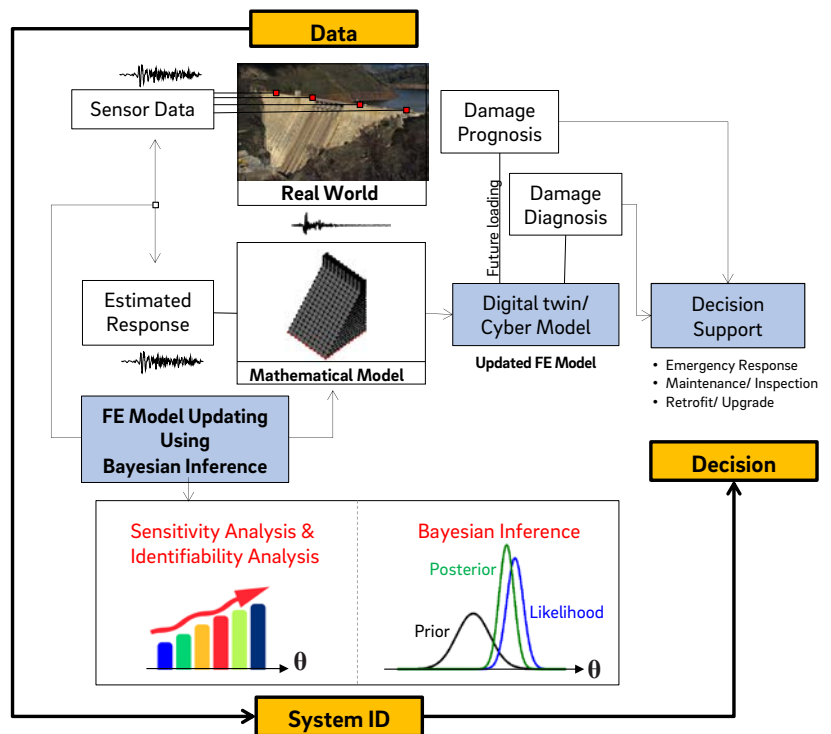
Modeling of Natural Disasters



Multi-scale Modeling

FINITE ELEMENT MODEL UPDATING FOR STRUCTURAL HEALTH MONITORING AND DAMAGE PROGNOSIS OF CIVIL INFRASTRUCTURE SYSTEMS

PROFESSOR JOEL CONTE AND
MUKESH RAMANCHA



A promising approach for performing SHM/ DP of civil infrastructure systems is through utilizing a calibrated finite element (FE) model. This involves collecting measurement data using heterogeneous sensor arrays (which may consist of accelerometers, GPS-based displacement sensors, LVDTs, string potentiometers, strain gauges, etc.) deployed on the system. Then, a FE model of the system is developed from design or as-built drawings of the system and using explicitly formulated assumptions and hypotheses. Due to the inherently complex nature of civil

engineering systems and due to the presence of wide-ranging uncertainties, it is extremely difficult to model these systems accurately. Often, FE models contain parameters that are unknown or known with significant uncertainty (e.g., inertial, damping, hysteretic material law, loading, boundary conditions, and geometric parameters). The process of FE model updating involves estimating the unknown parameters of the FE model accounting for numerous sources of real-world uncertainties (i.e., noisy output measurements, unknown/

partially known/noisy input measurements, uncertainty in FE model parameters, FE model form uncertainty) and probabilistically characterizing their estimation uncertainty. When a mechanics-based nonlinear FE model (able to capture the damage and failure mechanisms of concern) of the system is updated, it can be directly used to accurately or comprehensively perform damage detection, localization, classification, severity assessment and prognosis. Our lab is working on SHM/DP of concrete dams, miter gates, and bridge structures.

Gravity Dam



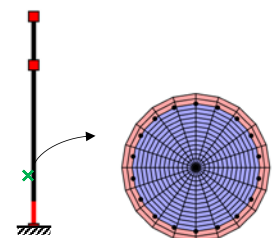
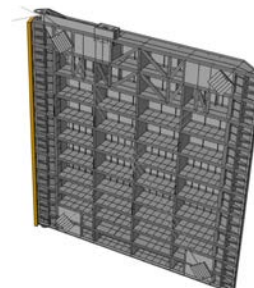
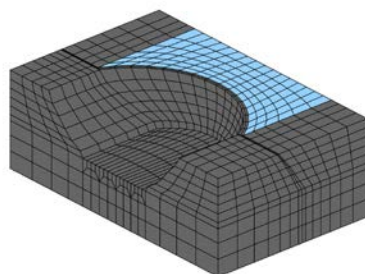
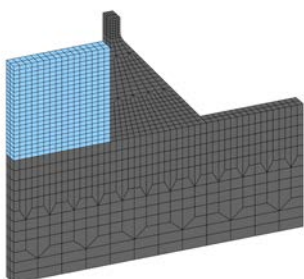
Arch Dam



Miter Gate



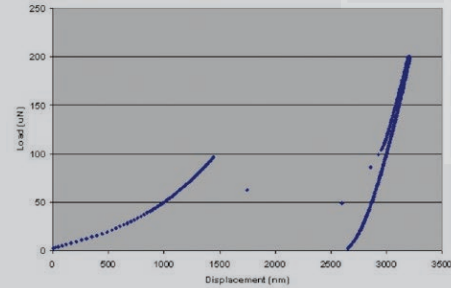
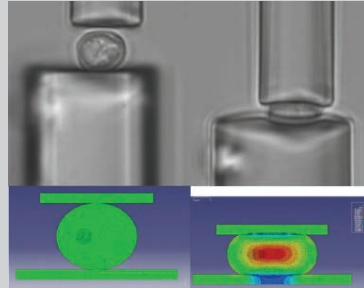
Bridge Column



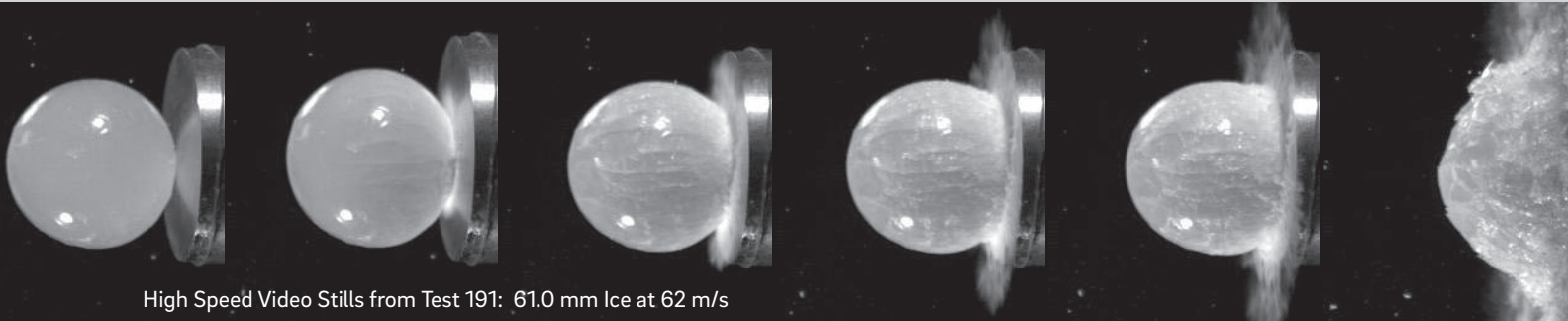
MODELING THE NANO-MECHANICS OF SINGLE-CELL STRUCTURES

PROFESSOR ROBERT J. ASARO

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



and their interconnections. A multi-scale model describing the cell walls nano-mechanical response to AFM tip indentation and the whole cell's response to high hydrostatic pressure, nano-indentation and micro-manipulation compression experiments is under development.



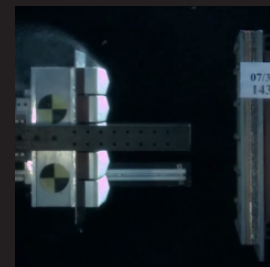
High Speed Video Stills from Test 191: 61.0 mm Ice at 62 m/s

HAIL ICE IMPACT ONTO COMPOSITE AIRCRAFT STRUCTURES

PROFESSOR HYONNY KIM

Impact damage to laminated composite aircraft structures, when subjected to in-flight impact by hailstones, can be extensive internally while exhibiting low external visual detectability. Basic research studies have established methods for determining minimum aircraft skin thickness to be resistant from hailstone impacts. Fundamental study of ice behavior and properties enabled establishment of finite element based modeling simulation which accurately represents the ice during impact.

Conventional methods for evaluating blast loads on structures require the use of explosives and remote test facilities. Although detonating charges provides the most realistic test conditions for understanding blast effects, non-explosive techniques such as shock tubes and gas guns are popular alternatives to recreate (simulate) blast events in a safe, controlled lab environment. Some advantages include repeatable, consistent application of loads, no fire and debris cloud obscuring high speed camera observation, and limited shockwaves which can damage sensors and equipment. Generally, these non-explosive methods test smaller specimens and/or produce limited impulse levels. This research activity has developed a non-explosive methodology for applying representative blast loads onto large-sized (e.g., 610 x 610 mm or greater) flexible composite panels using fast (25 m/s) servo-hydraulic actuators tuned to match the specific impulse of an equivalent explosive charge. Control of the applied impulse loading and time-dependent characteristics of the pulse are controlled using "pulse-shaping" techniques and spatial-tuning of the impact mass distribution.



Vehicle Armor Blast Response

MESHFREE METHOD FOR EXTREME EVENTS MODELING THROUGH MULTI-SCALE IMAGING

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 Reproducing Kernel Particle Method (RKPM) for modeling material damage in fragment-impact processes. RKPM is formulated with state-of-the-art stabilization and variationally consistent methods, which ensures the stability, accuracy, and efficiency in the numerical simulation. The in-house Nonlinear Meshfree Analysis Program (NMAP) developed based on RKPM by Chen's group has been successfully applied to the modeling of Empty Room Closure at the Waste Isolation Pilot Plant (sponsored by the Sandia National Laboratories) as shown in Fig. 1, where the shearband formation and damage accumulation associated with the closure of an underground disposal room (rock salt repository) under the natural compaction over hundreds of years are simulated. Funded by the National Research Council Canada, the RKPM capabilities have been applied to the simulation of reinforced concrete column under blast load as shown in Fig. 2, where RKPM simulation accurately captures the formation of diagonal cracks on the column's shaft as well as the post-blast intense spalling as observed by the UCSD blast simulator. Sponsored by the National Science Foundation, Prof. JS Chen's group has developed an efficient RKPM reduced-order modeling technique for the fast prediction of thermal fatigue behaviors of electronic devices as shown in Fig. 3, where only 2.62% computational time of the high-fidelity model is required with merely a loss of 0.7% accuracy

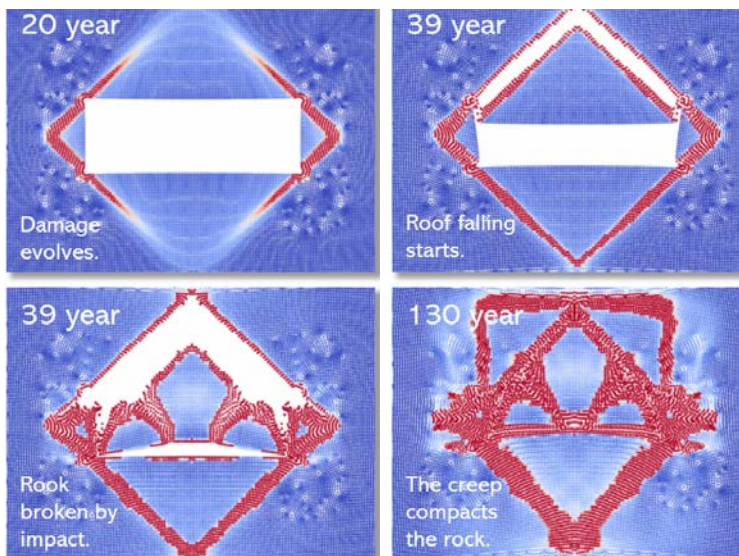


Figure 1. Process of an empty room closure: creep-damage evolution, roof falling, and rock compaction by RKPM simulation.

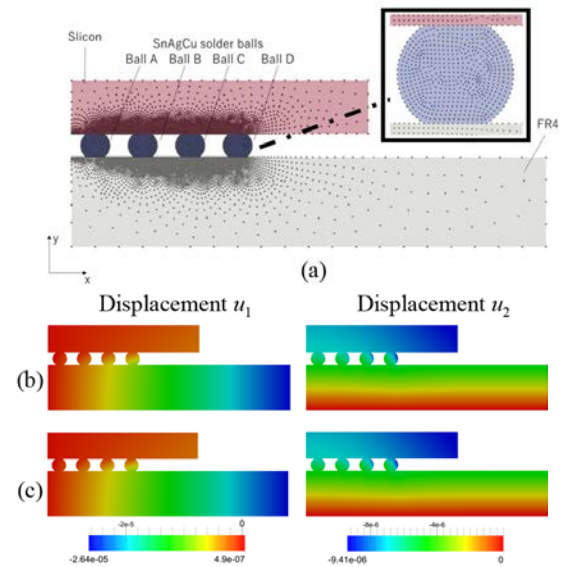


Figure 3 (a) RKPM discretization of the flip chip assembly; (b) displacement fields of high-fidelity analysis; (c) displacement fields of reduced-order hyper reduction analysis.

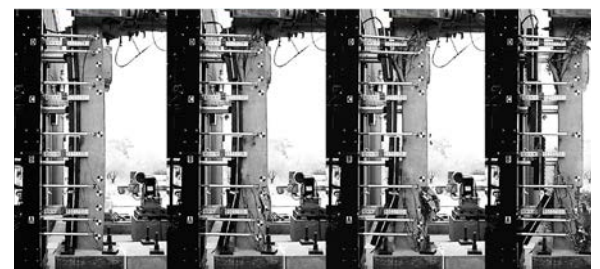
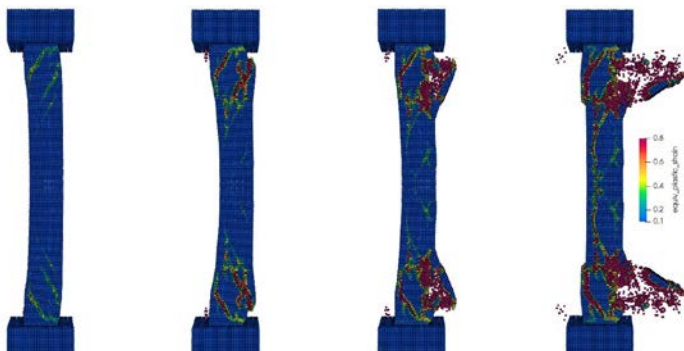
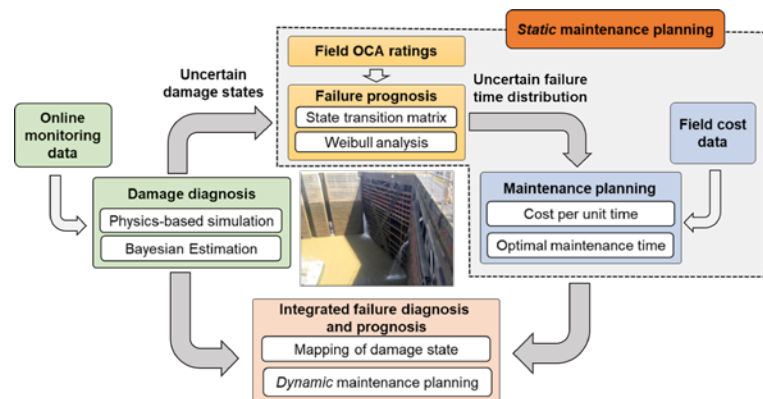


Figure 2. Comparison of the progressive deformation and fragmentation between the RKPM simulation (top) with the UCSD blast simulator experiment (bottom).

OPTIMAL MAINTENANCE DECISIONS FOR DETERIORATING COMPONENTS IN MITER GATES SUBJECT TO UNCERTAINTY IN THE CONDITION RATING PROTOCOL

PROFESSOR MICHAEL TODD

Operational condition assessments are frequently used by field engineers to assess inland navigation assets and components. These assessments are reported using a discrete rating system. The goal of these assessments is to initiate effective risk-informed budget plans for maintenance and repair. However, some of the components in the navigation infrastructure (such as navigational locks) cannot be inspected when the water is at operational levels. In many of these cases, ratings due to protocols are sometimes given to components even when they are not inspected. This leads to highly abstracted inspection data. On the other hand, navigational locks are equipped with structural health monitoring (SHM) systems to achieve effective and high-precision real-time damage diagnosis through online monitoring data. UCSD has developed a novel damage prognosis and maintenance planning framework for miter gates, one of the US Army Corps of Engineers (USACE) most important structural assets, by integrating highly abstracted inspection data with physics-informed simulations.



MEAN-STRAIN METHODOLOGY

PROFESSOR PETR KRYSL

Methodology for stabilizing mean-strain hexahedron and tetrahedron finite elements for applications to anisotropic deformation in the infinitesimal- and finite-strain was described in several papers by Krysl et al. The approach is based on a sampling of the stabilization energy using the mean-strain quadrature and the “full” integration rule. This combination is shown to guarantee consistency and stability. The stabilization energy is expressed in terms of input parameters of the real material, and the value of the stabilization parameter is determined in a quasi-optimal manner by linking the stabilization to the bending behavior of the elements.

The accuracy and convergence characteristics of the stabilized mean-strain formulations for both solid and thin-walled structures (shells) compare favorably with the capabilities of mean-strain and other high-performance hexahedral and tetrahedral elements described in the open literature and also with a number of successful shell elements.

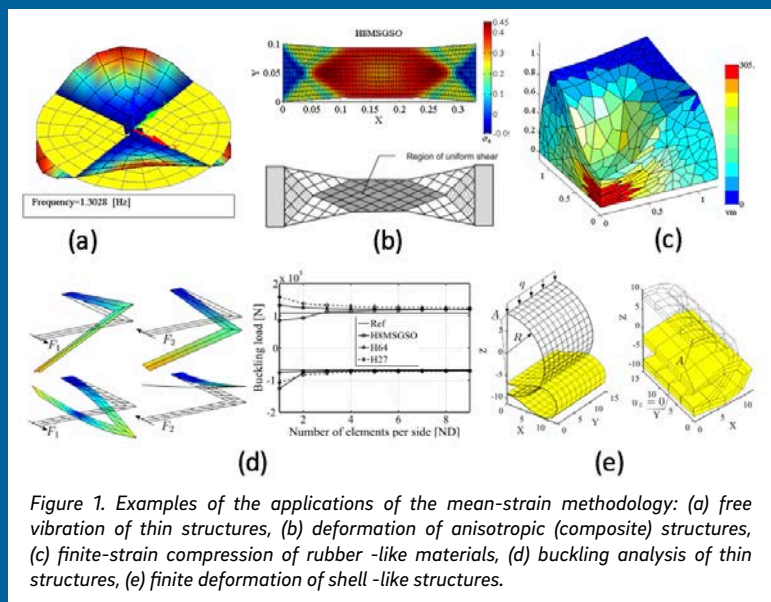


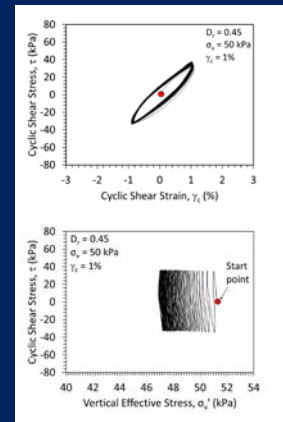
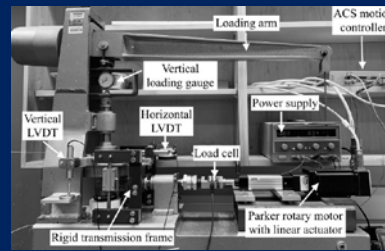
Figure 1. Examples of the applications of the mean-strain methodology: (a) free vibration of thin structures, (b) deformation of anisotropic (composite) structures, (c) finite-strain compression of rubber-like materials, (d) buckling analysis of thin structures, (e) finite deformation of shell-like structures.

Krysl, P. (2015). "Mean-strain eight-node hexahedron with optimized energy-sampling stabilization for large-strain deformation." *International Journal for Numerical Methods in Engineering* 103(9): 650-670. Krysl, P. (2015). "Mean-strain eight-node hexahedron with stabilization by energy sampling." *International Journal for Numerical Methods in Engineering* 102(3-4): 437-449. Krysl, P. (2016). "Mean-strain 8-node hexahedron with optimized energy-sampling stabilization." *Finite Elements in Analysis and Design* 108: 41-53. Pakravan, A. and P. Krysl (2017). "Mean-strain 10-node tetrahedron with energy-sampling stabilization." *International Journal for Numerical Methods in Engineering* 109(10): 1439-1460. Pakravan, A. and P. Krysl (2017). "Mean-strain 10-node tetrahedron with energy-sampling stabilization for nonlinear deformation." *International Journal for Numerical Methods in Engineering* 111(7): 603-623.

SEISMIC COMPRESSION MECHANISM IN UN-SATURATED SOILS AND ITS APPLICATION TO TRANSPORTATION SYSTEMS

PROFESSOR JOHN MCCARTNEY AND WENYONG RONG

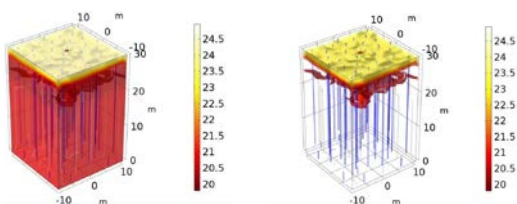
Unsaturated soils are widely encountered in engineered geotechnical structures like embankments or retaining walls involving compacted backfills, in near-surface natural soil layers above the water table, and even in natural soil deposits below the ground water table where occluded air bubbles are present due to ground water level fluctuations or decomposition of organic materials. In earthquake-prone areas, it is of great interest to understand the seismic compression mechanisms of unsaturated soil as well as its interaction with the transportation infrastructures. This research included innovative laboratory testing of unsaturated soils with controlled drainage conditions for pore water and pore air phases centered on the fundamental mechanics and physical model tests focused on the application of unsaturated soil mechanics to transportation infrastructure to lessen the impacts of earthquakes. The results in this study can provide sound experimental data for model development and constitutive model calibration for unsaturated soils, as well as to provide a design guideline which better addresses the geotechnical engineering problems consisting of unsaturated soils.



ENERGY PILES THERMAL EFFICIENCY IN UNSATURATED SOIL

PROFESSOR JOHN MCCARTNEY AND FATEMAH BEHBEHANI

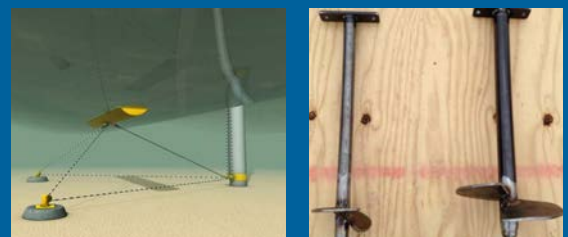
Energy piles are deep foundations that are used for supporting buildings and providing a clean renewable energy by exchanging heat between the ground and an overlying building. Energy piles are often installed in unsaturated soil deposits. Soil saturation conditions, properties and energy piles dimensions and spacing can influence the efficiency of the energy piles. The objective of this study is to simulate the long-term response and the efficiency of energy piles in unsaturated soils during heating and cooling cycles. The Model is implemented in COMSOL Multiphysics, a finite element analysis, solver and multiphysics simulation software. The model calculates the coupled behavior of the heat transfer and water flow considering nonequilibrium phase change and water vapor diffusion in unsaturated soil. Sensitivity analysis was used to highlight the effect of the soil saturation condition and parameters for a one pile case. Results show that the nonequilibrium phase change have a significant effect on soil temperature and the saturation levels.



LONG-TERM CYCLIC AXIAL LOADING OF HELICAL ANCHORS FOR OFFSHORE WIND

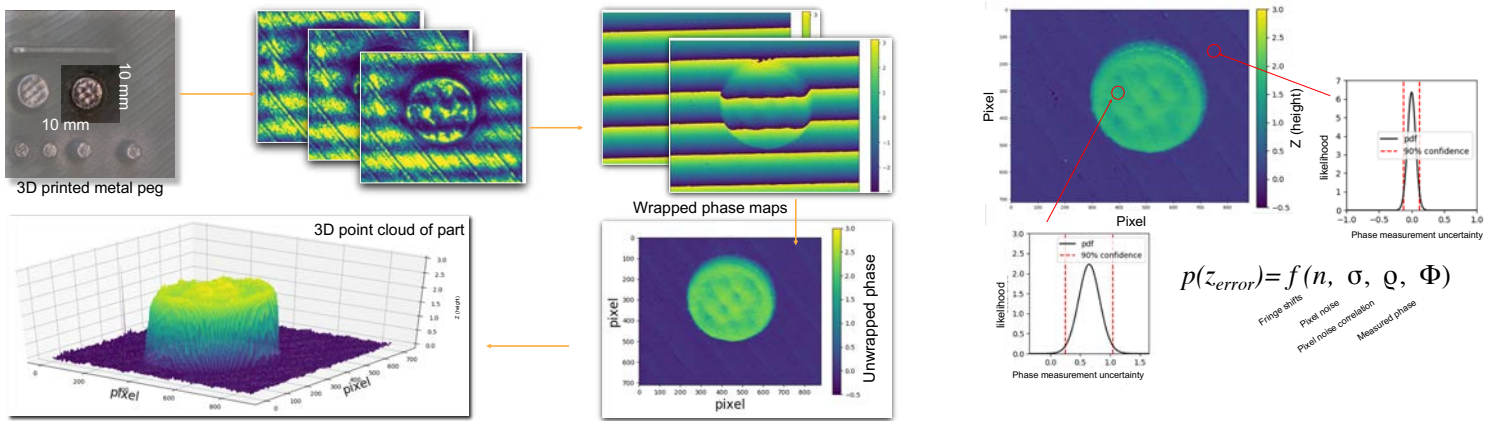
PROFESSOR JOHN MCCARTNEY AND JEFFREY NEWGARD

The USA has a tremendous untapped renewable energy resource in the form of offshore wind and wave energy, industries that are now well-developed in other parts of the world. According to the Department of Energy, more than 2,000 GW of capacity, or 7,200 TWh of generation per year (nearly double our country's current electricity use) could be harvested via offshore wind alone. Yet the cost remains prohibitively high and a large portion of installation cost is embedded in the foundation or anchoring elements for these offshore energy structures. Helical anchors (shown at bottom left) can be installed relatively easily by screwing a load-bearing plate into the seafloor, after which it serves as an anchor for floating wind turbines or wave energy generators (shown at top left, courtesy of Nemos). Our research centers around performing long term-cyclic loading tests on model helical anchors to develop more rigorous design guidelines and ensure their reliable serviceability over many years in the chaotic ocean environment.



STRUCTURED LIGHT PROJECTION FOR ADDITIVE MANUFACTURING

PROFESSOR MICHAEL TODD



This figure shows the progression of measurement from the structured light sensor. From top left: 3D printed part feature to be measured; projected patterns on measurement surface; measured wrapped phase; unwrapped phase; 3D point cloud of part.

This figure shows an example height map, where each height measurement point has an estimated uncertainty distribution, allowing for confidence criteria to be established.

The field of additive manufacturing (AM) is a quickly-growing area of research and industrial development, experiencing double-digit annual growth percentage rates, and currently valued at an estimated \$9 billion. AM enables the incorporation of complexities within parts such as internal cooling channels, lattice structures, and topology optimized features which can be impossible to fabricate with traditional, subtractive techniques. Most present quality control (QC) approaches for metallic additive manufacturing are performed post-production, including ultrasound, thermography, penetrant testing, eddy current, and x-ray computed tomography and provide either quality assessment after the part is already fully constructed, resulting in wasted fabrication time and materials if the part does not pass inspection. More importantly, the access of these inspection techniques is limited to the external faces of the manufactured part, making the quality of the internal features unknown, which may have been the driving reason for the part to be produced by AM.

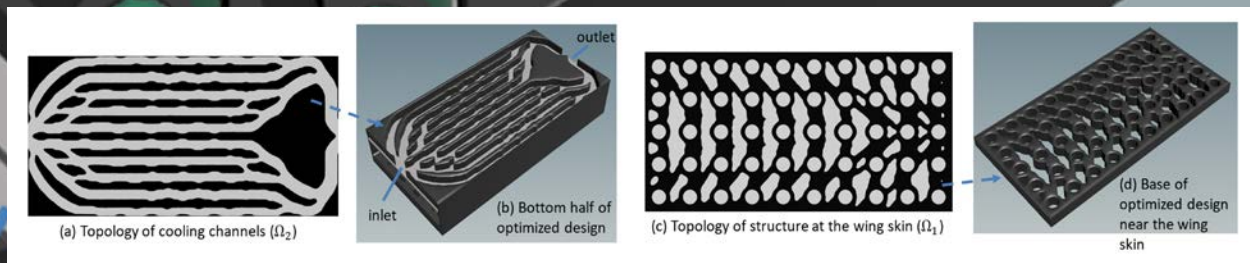
We are developing a structured light sensing technique specifically tailored for in-situ part monitoring in additive

manufacturing. This technique is used to measure layer-by-layer features such as powder coating layer health, sintered metal layer height, porosity, and overall part dimensions. The sensing method works by projecting patterns of light into the part chamber, and capturing images which are combined to create a high resolution height map. The sensing method will be used for closed feedback communication integrated into the print routine.

We are also developing a statistical model which estimates the uncertainty of each height measurement point from noise statistics on the input (pixel intensity). This model will ultimately be used in the closed feedback decision making routine, allowing for statistical confidence levels of build-terminating defects.

We are currently reaching out to a variety of companies in the AM industry to test the sensing technique. On the schedule is a test with an on-campus start-up, Additive Rocket Corporation, where we plan on performing initial height measurements on powder coating layers, and powder coating defects such as clumping and streaking.

NEW COURSES

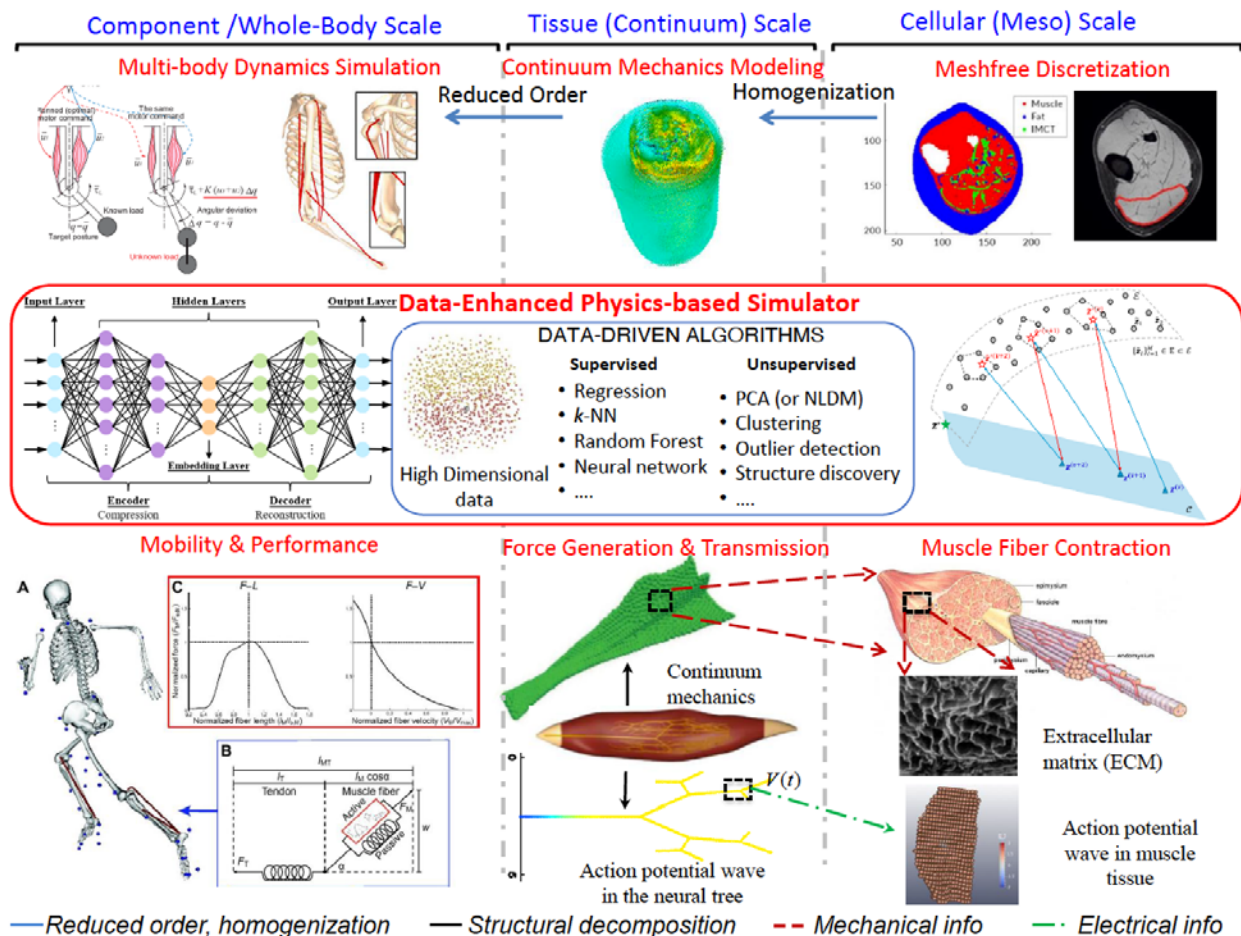


CONVERGENT SYSTEMS ENGINEERING

Convergent Systems Engineering is a school-wide effort to address the challenges in design of complex multidisciplinary systems. It is widely recognized that the traditional engineering methods and tools are not well-equipped to engineer complex systems which are becoming increasingly hyper-connected. The relationships and consequences of a decision are not intuitive or predictable in a complex system and the unintended consequences arising at the interfaces are often missed. Academics from Structural Engineering (Prof. H Alicia Kim), Electrical and Computer Engineering (Profs. Richard Gessener, Todd Hilton, Truong Nguyen, David Whelan) and Mechanical and Aerospace Engineering (Profs. Carlos Coimbra and Jorge Cortes) are building up a transdisciplinary engineering team and we are hiring new academics, Profs. Jon Wade and Boris Kramer in 2019-2020 and Profs. Sylvia Herbert and Yuanyuan Shi in 2020-2021. We envision providing engineering solutions to complex societal problems by taking a three pronged approach: (1) establishing strong research basis to investigate and develop new engineering sciences and methods for complex systems; (2) Initiating new graduate degree programs to train new convergent systems engineers; and (3) creating an ecosystem to engage and collaborate closely with industry for immediate impact. We are investigating the system of connectedness of people, information and goods, particularly in the context of sustainability and resiliency (e.g. Covid-19). We are also developing a new multiscale systems approach to design and discover new material with novel multifunctional properties. One application area of focus is to create a new multifunctional design methodology for a thermally managed load carrying battery system for electrical aircraft, an example of which is shown in the figure below. We are creating a new master program that crosses all engineering disciplines in convergent systems engineering and actively engaging with various engineering industry in defining the challenging research spaces.

MACHINE LEARNING FOR STRUCTURAL ENGINEERING

Machine learning (ML) and artificial intelligence (AI) are now broadly used techniques that have become indispensable for solving complex problems in science and engineering. Structural Engineering Department researchers are making contributions to the advances in research and curriculum in these emerging fields. Research activities in ML/AI in the Structural Engineering Department include hybrid simulations with large-scale experimental substructure and complex numerical models by Prof. Gilberto Mosqueda's group, scour monitoring for powering USACE civil asset digital twins by Profs. Ken Loh's and Mike Todd's groups, multi-scale data integration for microstructure characterization of heterogeneous materials by Prof. Shabnam Semnani, data-driven computational mechanics and digital twin models for musculoskeletal systems (Fig. 1) by Profs. J. S. Chen's and Ken Loh's groups, among others. In addition, Profs. Shabnam Semnani and J. S. Chen are developing a new undergraduate course for Spring 2021, titled "SE 132 Machine Learning for Structural Engineering," to introduce concepts of machine learning and its applications to structural engineering. The SE Department of UCSD is teaming up with Northwestern University, Stanford University, Brown University, Columbia University, and Arts et Métiers Institute of Technology of France in co-organizing the 1st IACM (International Association for Computational Mechanics) Conference for Mechanistic Machine Learning and Digital Twins for Computational Science, Engineering & Technology to be held in September 26-29, 2021 at the Hyatt Mission Bay Hotel in San Diego (website: iacm-mltd-cse.ucsd.edu).



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