Civil and Environmental Engineering

R. H. Dodds Jr., Professor and Head
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Civil and environmental engineers plan, design, and construct sustainable facilities required for society to function, for enhancing the quality of the environment, and for mitigating the effects of earthquakes, floods, strong winds, and other natural and man-made hazards. Civil and environmental engineering is a very broad discipline encompassing activity in the following areas:

- construction processes and their management (planning, analysis, automation, and economics)
- environmental engineering (water treatment, control of air pollution, and bioprocessing)
- geotechnical engineering (foundations, tunnels, embankments, solid waste disposal, and remediation of contaminated ground)
- hydraulics and hydrology (dams, flood control, groundwater resources, stream and wetland remediation, and water resources management)
- materials engineering (understanding and improving the materials used for construction)
- structural engineering (buildings, bridges, aircraft, ships, space structures, offshore facilities, and all types of industrial facilities)
- transportation engineering, both facilities and systems (highways, airports, and railroads)
- complex systems and information technology (understanding the behavior of very large-scale natural and man-made systems, and development and use of modern computing)

The evolving needs of humanity require development and application of new approaches, concepts, and products to the design and construction of facilities and the effective management and sustainability of the environment. Research programs in the department add to fundamental knowledge and are directed toward developing and applying new technologies. Graduate and undergraduate students participate actively with faculty members in conducting research; strong integration of research and education has been a decisive factor in the distinguished reputation enjoyed by this department.

Funded by the National Science Foundation (NSF), the Mid-America Earthquake Center studies approaches to reduce the impact of earthquakes on infrastructure. The Advanced Transportation Research and Engineering Laboratory (ATREL), funded largely by the Illinois Department of Transportation and the Federal Aviation Administration, is home to the Center of Excellence for Airport Pavement Research and the Illinois Center of Transportation. The NSF-funded Science and Technology Center on Advanced Materials for Water Purification with systems (WaterCAMPWS) is a multidisciplinary effort focused on improving the effectiveness, improving the reliability, and reducing the cost of water treatment for the nation and the world.

Our Department of Civil and Environmental Engineering at the University of Illinois is one of the most distinguished civil and environmental engineering departments in the world. Many of the 20th century’s greatest civil engineering educators were former faculty members—Hardy Cross, Nathan Newmark, Ven Te Chow, Ralph Peck, Richard Engelbrecht, Chester Seiss, and William Hall to name a few. Since its founding 134 years ago, this Civil and Environmental Engineering Department has evolved to a large, comprehensive department with approximately 560 undergraduate students, 390 graduate students, and a faculty of 52.

Our program is characterized by world-class faculty, many of whom are among the best educators and researchers in their field; outstanding undergraduate and graduate students; a comprehensive curriculum; excellent support staff; a unique history and heritage; a tradition of outstanding scholarship and engineering leadership; strong demand for our graduates in industry and academia; research laboratories that are in some cases among the best in the world; and a strong association of more than 12,000 alumni.
Faculty and Their Interests

Daniel P. Abrams
Reinforced concrete, masonry, earthquake engineering

Imad L. Al-Qadi
Pavement material characterization, modeling, and performance prediction, nondestructive testing and evaluation, instrumentation, full-scale accelerated testing, geosynthetics in pavements, pavement fracture and reinforcement, modeling of pavement interlayer system, tire-pavement interaction

Christopher P. L. Barkan
Transportation safety and risk analysis, with particular emphasis on topics related to railroad train accidents, tank cars, and hazardous materials; railroad transportation energy efficiency and environmental impact; railway signaling, traffic control systems, and capacity

Rahim Benekohal
Traffic flow modeling and simulation, car following models, traffic signal systems, highway capacity modeling and analysis, transportation system analysis, traffic operation and management, transportation safety, accident studies

Tami C. Bond
Effect of human activities on global and regional atmospheric chemistry, including chemistry, physics, and optics of combustion aerosols; physical and socioeconomic factors that govern emissions

Frank Boukamp
Building information modeling, knowledge representation and reasoning, ontological engineering, construction quality and safety

William G. Buttlar
Mechanics of transportation facilities and materials, micromechanical simulation of creep and fracture in particulate composites, asphaltic materials

Ximing Cai
Water resources management and policy, international water resources development, large-scale system optimization, drought management

Samuel H. Carpenter, Emeritus
Bituminous materials, pavement evaluation, climatic factors

Mark M. Clark
Membrane, colloid, and interfacial science; biomimetic membranes, flocculation and mixing

Barry J. Dempsey, Emeritus
Climatic effects on pavements and materials, drainage, geosynthetic materials

Robert H. Dodds, Jr.
Fracture mechanics and fatigue, computational solid mechanics, structural engineering

Carlos A. Duarte
Computational mechanics, three-dimensional computational fracture mechanics, multiscale modeling, computational micromechanics of materials

J. W. Eheart
Environmental systems analysis and management, water quality modeling

Amr Elnashai
Testing, analysis, field observations, study of the effects of earthquakes on complex multiphysics civil engineering systems

Khaled El-Rayes
Optimizing the utilization of construction resources during the construction of critical civil infrastructure, optimal construction planning and control, multi-objective optimization, parallel computing, optimal lighting design for nighttime construction, optimizing recovery and reconstruction efforts after natural disasters

Larry A. Fahnestock
Earthquake engineering: behavior, performance, and design of steel structures; experimental evaluation of large-scale structural components and systems

Kevin T. Finneran
Anaerobic microbial ecology and physiology, biotransformation and bioremediation, contaminant fate and transport, bioenergy and biologically produced hydrogen, sustainable bioremediation

Douglas A. Foutch
Dynamic characteristics of full-scale structures, analysis and design of earthquake-resistant bridge and steel buildings, wind effects
<table>
<thead>
<tr>
<th>Name</th>
<th>Specialization</th>
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<tbody>
<tr>
<td>William L. Gamble, Emeritus</td>
<td>Structural concrete, prestressed concrete bridges, creep and shrinkage of</td>
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<td>concrete, reinforced concrete slabs, fire-resistant structures</td>
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<tr>
<td>Marcelo H. García</td>
<td>Environmental hydraulics, stratified flows, river mechanics, sediment</td>
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<td>transport</td>
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<td>Jamshid Ghaboussi, Emeritus</td>
<td>Structural and geomechanical computational mechanics, earthquake engineering,</td>
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<td>computational intelligence and soft computing, information technology in civil</td>
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<td>engineering</td>
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<tr>
<td>German R. Gurfinkel, Emeritus</td>
<td>Structural design, failure investigations and retrofitting of wood, reinforced</td>
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<td>concrete, prestressed concrete and steel structures including silos, tanks,</td>
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<td>tall buildings</td>
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<td>Jerome F. Hajjar</td>
<td>Structural analysis, experimental testing, and design of steel and composite</td>
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<td>steel-concrete structures; earthquake engineering</td>
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<tr>
<td>William J. Hall, Emeritus</td>
<td>Structural engineering, structural dynamics, earthquake engineering</td>
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<tr>
<td>Yousef Hashash</td>
<td>Numerical modeling, static and dynamic soil-structure interaction, deep</td>
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<td>excavations and tunnels, underground structures, geotechnical engineering,</td>
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<td>discrete element modeling, visualization, virtual reality and information</td>
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<td>Neil M. Hawkins, Emeritus</td>
<td>Reinforced, prestressed, and composite steel and concrete structures, fracture</td>
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<td>Edwin E. Herricks</td>
<td>Aquatic ecology, ecosystem management, water quality management standards and</td>
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<td>legislation</td>
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<td>Keith D. Hjelmstad</td>
<td>Structural mechanics, nondestructive evaluation of large structures, fluid/</td>
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<td>structure interaction</td>
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<td>Daniel A. Kuchma</td>
<td>Design, behavior, and numerical modeling of concrete structures, including</td>
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<td>bridges and buildings; experimental methods, advanced measurement systems,</td>
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<td>visualization of experimental test data, and model validation</td>
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<td>Praveen Kumar</td>
<td>Hydroclimatology, hydrogeomorphology, hydrologic information systems,</td>
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<td>knowledge discovery in databases, ecohydrology</td>
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<td>James M. LaFave</td>
<td>Experimental behavior and modeling of connections and joints in reinforced</td>
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<td>concrete, brick veneer, GFRP, and aluminum structural systems; earthquake</td>
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<td>engineering; seismic assessment of bridges; concrete durability</td>
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<td>David A. Lange</td>
<td>Construction materials, microstructure and properties of cement and concrete,</td>
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<td>airport pavement performance</td>
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<tr>
<td>Susan M. Larson</td>
<td>Air quality monitoring and modeling, aerosol physics</td>
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<td>Jon C. Liebman, Emeritus</td>
<td>Water resource and water quality systems, solid waste management and disposal</td>
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<td>Liang Y. Liu</td>
<td>Construction project controls, productivity analysis and improvements,</td>
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<td>information technology, sensors and field data collection, construction</td>
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<td>James H. Long</td>
<td>Soil-structure interaction, foundation engineering</td>
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<td>Benito J. Mariñas</td>
<td>Adsorption and membrane technologies for water quality control, disinfection</td>
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<td>and disinfection byproduct control processes</td>
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<tr>
<td>Arif Masud</td>
<td>Multiscale and stabilized finite element methods for multiphysics problems,</td>
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<td>computational fluid dynamics and fluid-structure interaction, multiscale</td>
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<td>computational methods for bio- and nanomechanics</td>
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<tr>
<td>Gholamreza Mesri</td>
<td>Geotechnical engineering, engineering properties, construction problems, and</td>
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<td>ground modification technology in relation to soft clays and silts, stiff clay</td>
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<td>s and soft rocks, expansive soils and swelling shales, as well as granular</td>
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<td>materials, especially in connection with onshore and offshore reclamation</td>
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<td>projects, landslides, and building foundations</td>
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Barbara S. Minsker
Environmental systems analysis and management; data mining and machine learning applications to environmental monitoring and management

Eberhard Morgenroth
Influence of dynamic reactor operation on the performance of biological treatment processes using activated sludge, biofilms, or membrane bioreactors

Thanh H. Nguyen
Waterborne pathogen removal for water and wastewater treatment, fate and transport of antibiotic resistant bacteria and pathogens in natural environment

Scott M. Olson
Geotechnical earthquake engineering, soil liquefaction, geohazards, paleoearthquake and paleoliquefaction, seismic and static slope stability, in situ testing, laboratory testing of sands, soil-structure interaction related to bridges, geotechnical instrumentation

Yanfeng Ouyang
Stability and efficiency of transportation systems, supply network operations, logistics system design, infrastructure system management, transportation safety, traffic flow

Ilinca Stanciulescu Panea
Nonlinear finite element methods, computational methods for stability analysis in multiphysics problems, nonlinear dynamics

Gary Parker
Sediment transport, river engineering, river morphodynamics, turbidity currents and deep-sea sedimentation

Glaucio H. Paulino
Structural analysis, computational mechanics, fracture mechanics and functionally graded materials

David A. Pecknold, Emeritus
Structural mechanics and dynamics, shell structures, composite materials, neural network material modeling

Feniosky A. Peña-Mora
Information technology support for collaboration, change management, conflict resolution, and process integration during design and development of large-scale civil engineering systems

John S. Popovics
Nondestructive evaluation and sensing for civil engineering materials and structures; corrosion; mechanical and dynamic properties of cement-based materials

Shaoying (Shawn) Qi
Water and wastewater treatment: PAC/GAC adsorption theories and applications for organic removal; packed-bed filtration/ultrafiltration for particle removal; chemical and biological reactions related to water quality control

Arthur R. Robinson, Emeritus
Structural mechanics, dynamic elasticity, numerical methods applied to nonlinear structural problems

Jeffrey Roesler
Concrete pavement analysis, design, and large-scale testing; fatigue and fracture of concrete materials; concrete slab curling; fiber reinforced concrete materials; continuously reinforced concrete pavements

Mark J. Rood
Environmental air quality: aerosol chemistry and physics, development of methods to separate and remove contaminants from gas streams, development of aerosol sampling instrumentation

A. R. Schmidt
Surface-water hydraulics and hydrology; hydrology and hydraulics related to urban stormwater drainage systems, including best management practices, risk-based design and real-time control; and reliability-analysis applications for in water-resources and environmental engineering

Murugesu Sivapalan
Climate-soil-vegetation controls on hydrological variability, land-atmosphere interactions and feedbacks, watershed hydrological modeling, human impacts on water quantity and water quality, flood frequency analysis and risk assessment

Vernon L. Snoeyink, Emeritus
Environmental chemistry, drinking water treatment, water reclamation

Junho Song
Structural reliability, reliability of complex systems, stochastic structural dynamics, performance of lifeline systems, systematic treatment of uncertainty, earthquake engineering, probabilistic structural mechanics, probabilistic strength models
B. F. Spencer, Jr.
Smart structures, pseudo-dynamic substructure testing, structural health monitoring, vibration testing and theory, fatigue and fracture reliability, stochastic and robust structural control and system identification, earthquake engineering, deterministic and stochastic structural dynamics, computational probabilistic methods, structural reliability.

Timothy D. Stark
Foundation engineering, static and seismic stability of natural and man-made slopes, soil liquefaction, geosynthetics

Timothy J. Strathmann
Environmental chemistry, catalysis of contaminant degradation in engineered treatment systems and natural environments, emerging aquatic micropollutants, anaerobic biogeochemical processes, photocatalysis

Leslie J. Struble
Materials, chemical, microstructural and physical properties of cement and concrete, rheology of fresh cement and concrete

Marshall R. Thompson, Emeritus
Flexible pavements, transportation, railroad track structure analysis and design, soil stabilization, paving materials, subgrade soils

Erol Tutumluer
Pavement materials, aggregates and soils, flexible pavements, mechanistic-based pavement design, railroad ballast, aggregate image analysis, geosynthetics, artificial neural networks, full-scale pavement testing, pavement materials stabilization and recycling

Albert J. Valocchi
Transport processes in porous media, groundwater contamination, mathematical modeling, computational methods

William H. Walker, Emeritus
Structural mechanics, structural dynamics, highway bridge dynamics, fatigue and fracture

Y. K. Wen
Vulnerability functions, systematic treatment of uncertainty, effect of redundancy in buildings under seismic loads, Hilbert Spectral Representation and simulation of nonstationary random processes, optimal seismic design based on lifecycle cost consideration

Charles J. Werth
Transport and fate of organic chemicals in soils, sediments, and groundwater, sorption, mass transfer, soil and sediment characterization

Julie Zilles
Microbial physiology and ecology, biological nutrient removal processes, antimicrobial resistance, herbicide degradation

Construction Management

CAREER: Distributed Multi-Objective Optimization for the Construction of Large-Scale Transportation Systems
K. El-Rayes,* W. Orabi
elrayes@uiuc.edu
National Science Foundation, CMS-0238470

Recent applications of performance-based contracting methods in the construction of transportation systems present decision makers in the construction industry with new and serious challenges that require optimizing the utilization of construction resources to satisfy multiple and conflicting contractual objectives; solving large-scale construction optimization problems; and maintaining optimality for the developed plans in a dynamic construction environment. This project addresses these new and vital challenges by developing an innovative Information Technology Framework for Optimizing Construction Utilization of Resources in Transportation Systems, named IT-FOCUS. The main research objectives of IT-FOCUS are to develop robust multi-objective optimization models; formulate scalable methodologies for solving large-scale optimization problems; and explore dynamic frameworks for revising optimal plans whenever and wherever needed.

The development and application of IT-FOCUS is expected to improve cost effectiveness of public expenditures on the construction and renewal of transportation systems, accelerate the revitalization of aging systems, minimize construction-related service disruptions, improve construction quality and safety, and reduce negative impacts of construction on the environment.

* Denotes principal investigator.
Nighttime Construction: Evaluation of Lighting Glare for Highway Construction
K. El-Rayes,* L. Liu, I. Odeh
Illinois Department of Transportation, ICT R27-2

An increasing amount of highway repair and construction work in Illinois is being performed during the off-peak nighttime hours. Nighttime construction is advocated as a way to mitigate the impact of construction operations on the traveling public, shorten the duration of construction operations, and reduce the potential for work zone-accidents. However, nighttime construction operations may in fact be more hazardous for both drivers and construction personnel. Drivers often find difficulty in adjusting to the extreme changes in lighting levels when entering a construction zone from a relatively dark roadway environment. The utilization and placement of lighting equipment to illuminate the work zone may cause glare for drivers and/or equipment operators. To address these challenges, the main objectives of this project are to survey existing types of glare measurement practices currently being used in the industry; develop practical tools for evaluating glare at nighttime construction sites and evaluate their performance with selected lighting arrangements that are common to nighttime construction; and evaluate and recommend acceptable levels of glare that take into account construction workers, the traveling public, and overall light reflection from the work zone. The results of this study will provide the Illinois Department of Transportation with a scientific and objective approach for specifying the required lighting standards in nighttime highway construction projects.

Optimizing Airport Construction Sites to Maximize Aviation Security and Safety
K. El-Rayes,* H. Said
National Science Foundation, CMS-0626066

A large number of major airport construction and expansion projects are ongoing and being planned in order to meet the current and expected increases in air traffic demand. These projects include the expansion of terminals, runways and taxiways and they are often performed in close proximity to critical airport areas. This close proximity increases the level of hazards to both aviation safety and airport security, and presents construction planners with critical and serious construction site layout planning challenges, including: how to optimize site layout planning in order to address the conflicting objectives of maximizing aviation safety, maximizing airport security, and minimizing construction site layout costs; and how to maintain optimality for the developed site layout plans in a dynamically changing construction environment. This project addresses these site layout planning challenges using original concepts that integrate multi-objective and dynamic optimization methodologies to enable construction planners to identify and frequently update a set of optimal site layout plans that provide optimal tradeoffs among the conflicting site layout planning objectives. A main research objective of this project is to develop novel multi-objective optimization models for airport construction site layouts that are capable of maximizing the control of construction debris hazards near critical airport areas, minimizing the hazards of attracting wildlife to airport construction sites, minimizing and eliminating all potential security breaches that may originate from construction sites, and minimizing overall site layout costs. A second research objective is to develop robust information technology frameworks that are capable of supporting dynamic optimization and the continuous updating of optimal construction site layout plans, and providing enhanced visualization of the generated optimal solutions. The project integrates advanced methodologies from several disciplines, including construction and airport engineering, evolutionary computations, information technology, and object-oriented modeling in order to address a fundamental and critical gap in the existing knowledge and understanding of multi-objective and dynamic site layout optimization. The research developments provide construction planners and airport operators with novel and robust models that are capable of minimizing the spread of hazardous construction debris to critical air traffic zones, minimizing construction-related attractions of hazardous wildlife species, maximizing airport security during construction to prevent unauthorized access to secure airport areas, and complying with all relevant Federal Aviation Administration safety and security requirements.

Optimizing Large-Scale Construction Resource Utilization Problems
K. El-Rayes,* A. Kandil
elrayes@uiuc.edu
National Center for Supercomputing Applications

Optimizing the utilization of construction resources, such as labor, material and equipment, can lead to significant savings in construction costs, thereby accelerating the completion and delivery of constructed facilities, minimizing construction-related service disruptions, and improving construction quality and safety. In order to realize these significant benefits, there is a need to explore and formulate scalable methodologies for solving large-scale construction optimization problems. The objectives of this research are to study the computational...
requirements for optimizing large-scale construction planning problems and devise parallel/distributed computing algorithms to enable efficient solutions for these problems. The findings of this study will provide better understanding of the capabilities of parallel computing in optimizing the construction of large-scale infrastructure systems, and can transform the optimization of large-scale construction resource utilization problems from an intractable problem to a feasible and practical one.

Web-Based Management of Multiple Interdisciplinary and Geographically Distributed Research Projects
K. El-Rayes,* L. Liu, F. Pena-Mora, W. Orabi
elrayes@uiuc.edu
National Science Foundation, Mid-America Earthquake Center; University of Illinois

The main objective of this project is to develop a robust IT-based management system for engineering research centers to ensure the accomplishment of their research and educational and outreach goals on time and within budget. To this end, a web-based system is being developed to enable remote and effective management of multiple interdisciplinary research projects that are located in different geographic regions.

Automated Productivity and Progress Assessments Using Digital Close-Range Photogrammetry
L. Y. Liu,* T. Trupp
lliu1@uiuc.edu
University of Illinois; Hewlett Packard; National Science Foundation

Construction productivity and progress assessments are among the most challenging tasks of a construction project. Accurate measurements of productivity and progress play a critical role in the success of a construction project. This research project integrates digital close-range photogrammetry, computer vision, image reasoning, 3D-CADD, and computer databases to provide an automated system for measuring construction productivity and progress.

This research will impact how we manage construction projects in the future.

Construction Object-oriented Process Simulation
L. Y. Liu*
lliu1@uiuc.edu
University of Illinois

Simulation provides a practical means of analyzing construction processes to identify resource utilization and idleness, operation bottlenecks, productivity, and operational costs. This research uses object-oriented programming to design a network-based discrete-event simulation system for construction process modeling. All modeling elements are implemented as objects with integrated functionality of interactive computer graphics and simulation. Models are constructed through a friendly graphical user interface. Simulation is accomplished by having active objects send messages to one another. This paradigm of simulation system design can provide many advantages over traditional design, such as realistic resource tracking, precise simulation control, and linkage with other knowledge-based expert systems.

This research will impact how we manage construction projects in the future.

Construction Project Productivity Time-Series Monitoring and Predictions
L. Y. Liu,* S. Hwang
University of Illinois

This project investigates new applications of time-series techniques to better predict future productivity performance and trends. By fusing historical and actual data and factors from on-going projects, project managers can better predict future performance and manage resources more efficiently for construction projects.

Construction Site Digital Data Collection Devices
L. Y. Liu*
lliu1@uiuc.edu
University of Illinois

This project develops a hardhat-mounted device that collects multimedia information, including video and sound, for construction inspection and documentation. The device uses voice-activated control and allows construction inspectors to walk hands-free at the project site to document site conditions or problems. Narration, pictures, and videos can be taken and stored digitally into the device and can be ported later into a database that supports project control and documentation. A heads-up display is used for synchronizing the camera direction with the eyes. This device allows wireless, two-way

* Denotes principal investigator.
communications where images can be transmitted to and from the host computer.

The project will lead to intelligent field automation in the future.

**Construction Time–Cost Trade-Off Decision Support**

L. Y. Liu,* S. A. Burns* (Indus. & Enter. Syst. Engr.)

lliu1@uiuc.edu

*University of Illinois*

Construction engineers face the challenge of selecting the most effective construction methods for tasks within a project. Different methods, equipment, and crew sizes can be chosen for tasks depending upon the contract time limit and budget. Not all tasks are of equal importance in a project. Some tasks carry floats and can be delayed without impacting the project duration. Some tasks are critical because any delay on those tasks delays the project. Construction engineers may choose alternative construction methods, smaller crew sizes, and less productive equipment at lower costs while maintaining the same project duration. The purpose of this research is to develop a generic algorithm for assisting construction engineers in selecting optimal time–cost strategies to complete a project.

This new algorithm will support analyses of construction planning and controls, by lowering overall construction costs.

**Real-Time Geometrical Tracking and Productivity Analyses**

L. Y. Liu,* Y. Su

*University of Illinois*

This project utilizes the real-time location data, via a wireless communication network, from construction equipment, materials, and personnel to support productivity analyses. The geometrical (x,y,z) and time data are analyzed to automatically obtain insight into resource bottlenecks and productivity problems.

**Sensor-Based Construction Quality Control and Monitoring**

L. Y. Liu,* C. Erickson, K. Trauth

lliu1@uiuc.edu

*University of Illinois*

This project investigates new applications of sensor devices (electrical, micro-electrical-mechanical, and fiber-optic) in construction quality control and monitoring. These sensors are imbedded in infrastructure components to collect data for monitoring the conditions and other properties relevant to safety and performance of a structure, such as a bridge, tunnel, or building.

The potential impacts of this research include a new and better approach to conduct construction inspections, more timely responses to repair needs, and lower costs for structure maintenance.

**Construction Materials**

**Formwork Pressure of Self-Consolidating Concrete**

D. A. Lange*

*Center for Advanced Cement Based Materials*

We have studied many aspects of self-consolidating concrete (SCC) under IDOT funding (with Prof. L. Struble), and this project provides visibility to our sustained investigation of formwork pressure. Our group collaborates with other researchers through the ACBM consortium, and interfaces with ACI Committee 237 “Self Consolating Concrete.” Annual funding from ACBM facilitates sustained attention toward this important topic.

SCC is a more fluid type of concrete for which conventional understanding of formwork pressure is unsuitable. Therefore, we are measuring formwork pressure and developing useful models that can be used by practitioners to calculate safe pouring rates for construction of tall walls and columns.

**Increasing Bond Strength and Extent of Bond of Cements for Masonry**

D. A. Lange,* B. Bicer

*Portland Cement Association*

The primary factors that affect bond and the degree of bond in masonry include water transport between fresh mortar and porous substrate within the first minutes of contact. This experimental study characterizes water retention capacity of fresh mortars, water absorption of porous substrates, and the behavior of water as it is depleted from a dense suspension of small particles.

The results will lead to a more fundamental understanding of masonry bond and a more rational approach to design of admixtures and additions that alter moisture retention and adhesion of fresh mortars to masonry units.

**Moisture Curling of Concrete Slabs for Airfield Applications**

D. Lange,* J. Roesler, C. J. Lee, Y. S. Liu

*Federal Aviation Administration*

Slab curling occurs when a gradient of thermal or drying shrinkage stresses exists through the thickness of a

* Denotes principal investigator.
concrete slab. Higher tensile stress at the top of the slab can be caused by cooling or drying of the top surface. In both cases, the material of the top surface contracts while physically restrained by the lower mass of concrete, thus creating a state of tensile stress in the top of the slab and corner curling. Severe problems from slab curling were observed in a large section of concrete pavement constructed at the National Airport Pavement Test Facility (NAPTF) in Atlantic City. We are working with FAA in the analysis of the existing data from the NAPTF, new laboratory tests, and computational material modeling to predict the magnitude of curling from material properties measured in laboratory tests.

**Optimized Blending of Aggregates for Improved Concrete Performance**

D. A. Lange*
E. Khasshoghi Industries, LLC

This study explores benefits gained from improved control of aggregate gradation, including blending of multiple aggregate sources (i.e. more than two). The targeted benefits are improved fresh workability, and improvement of hardened properties made possible by changes in concrete proportions to exploit the improved workability. Improved workability makes it possible to lower w/c, reduce cement content, and increase aggregate content while maintaining a target slump. Concrete strength can be increased, shrinkage can be reduced, and cost can be reduced by judicious control of aggregate gradations.

**Advanced Concrete Mix Designs for O’Hare Modernization Program (OMP)**

J. Roesler,* D. Lange, R. Rodden, C. Gaedicke, Z. Grasley, S. Villalobos
OMP; BPC Partners

Research is being funded by the O’Hare Modernization Program (OMP) to investigate concrete material properties required to achieve long-term concrete pavement performance at the Chicago O’Hare International Airport. The project will develop concrete material constituents and proportions to achieve the desired concrete pavement behavior over time. Laboratory studies are being conducted to determine the concrete volumetric properties (shrinkage and creep) and fracture properties (fracture energy and tensile strength) of the potential mixes. The effect of the concrete mix designs on saw-cut timing, joint spacing, and joint performance will also be explored.

**Cement Finishability**

L. J. Sruble,* C.-W. Chung
Cemex USA

Rheology and hydration chemistry are being used to understand why some commercial portland cements show premature stiffening. We are comparing stiffening measurements made using a test developed here with more basic measurements of static and dynamic rheology. Hydration chemistry is measured using powder x-ray diffraction and thermal analysis.

**Cement-Admixture Interactions**

L. J. Sruble,* C. T. Chen
lstruble@uiuc.edu
Center for Advanced Cement-Based Materials

The objective of this study is to understand how flow of fresh cement paste is affected by the composition of cement in the presence of chemical dispersing admixtures. We are using dynamic rheological techniques to measure changes in rheology as hydration takes place, and correlating these changes with hydration chemistry using powder x-ray diffraction scanning electron microscopy.

**Chemistry of Alkali-Silica Reaction in Concrete**

lstruble@uiuc.edu
Federal Highway Department

Alkali-silica reaction is usually caused by reaction of sodium and potassium in cement with reactive constituents in the aggregate. The reaction product is able to swell, causing expansion and deterioration of concrete. Its chemistry is not well understood, making it difficult to develop reliable tests for aggregate materials. This project is a study of the chemistry of the reaction and the molecular structure of the reaction products. We are using solid-state nuclear magnetic resonance, powder x-ray diffraction, and optical and scanning electron microscopy to characterize the reaction product, measure swell properties of the reaction product, and measure expansion of mortar and concrete samples.

**Extrusion**

L. J. Sruble,* G. Paulino, Y. Chen, L. Shen
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National Science Foundation

Extrusion of cementitious materials is being used to produce graded microstructures for application in residential construction. Both fiber reinforced materials and materials with high porosity are studied. One focus of this work is to understand the rheological behavior involved in extrusion. Another focus is to measure and

* Denotes principal investigator.
model the mechanical behavior of these graded cementitious materials.

**Flow Behavior of Cement Paste and Concrete**
L. J. Struble,* J. Hidalgo
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*Consolis Technology Oy*

The flow behavior of concrete is not seen to correlate well with the flow behavior of cement paste. In particular, the behaviors do not respond in the same way to dispersing admixtures. The objective of this study is to determine whether paste preshear that simulates the shear history of concrete brings the behaviors into conformance.

**Materials for O'Hare Modernization Project**
L. J. Struble,* F. Nelson
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*O'Hare Modernization Program*

Concrete materials are being studied to provide bases for specifying materials for the O'Hare Airport modernization.

**Nondestructive Testing to Measure Stiffening and Set of Hydrating Cement**
L. J. Struble,* C.-W. Chung
lstruble@uiuc.edu
*Currently unfunded*

Nondestructive testing is being used to measure stiffening as cement hydrates. We are comparing stiffening measurements made using ultrasonic reflection with standard test using needle penetration and basic measurements of static and dynamic rheology. Hydration chemistry is followed using powder x-ray diffraction, thermal analysis, and scanning electron microscopy.

**Segregation in Self-Consolidating Concrete**
L. J. Struble,* L. Shen
*Illinois Department of Transportation*

A new type of concrete, called self-consolidating concrete, has been developed for use when it is beneficial to achieve flow of fresh concrete without use of vibration or to enable concrete to flow into constricted formwork. We are studying the flow behavior of this concrete using a concrete rheometer. The objective is to understand rheological parameters associated with aggregate segregation.

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**Earthquake Engineering**

**Dynamic Tests of Low-Rise Building Systems**
M. Aschheim,* D. Abrams, D. Simsir
*National Science Foundation, Mid-America Earthquake Center*

This project investigates nonlinear dynamic response of structural systems typically used for low-rise essential facilities. Reduced-scale idealized structures will be subjected to simulated earthquake motions of a shake table. Tests will emphasize the dynamic response of flexible diaphragms and the interaction of in-plane and out-of-plane response of masonry walls. The project is coordinated with other projects of the Mid-America Earthquake Center.

Test data will be used to confirm or improve current computational methods for estimating response and will be correlated with results from analytical methods prescribed in FEMA 273 to suggest updated guidelines.

**Utility Software for Dissemination of Mid-America Earthquake Center Data**
M. Aschheim,* D. Abrams, M. Inel, E. Bretz
*National Science Foundation, Mid-America Earthquake Center*

The project develops a graphic-user interface to link current and anticipated data and software products to users of the center's research data. Catalogs of ground motions, recorded and synthetic ground motions, soil and structural materials properties, data obtained in structural and geotechnical studies, socioeconomic data, inventory data, and societal response data will be accessed. The central engine of the software will be a single-degree-of-freedom nonlinear dynamic analysis program that contains menus of recorded and synthetic ground motions and libraries of measured and simulated hysteresis relations. Interfaces to permit real-time ground motion synthesis, response computation, and searching of inventories will be developed.

**Multiobjective Seismic Design of Steel Frame Buildings**
S. Burns,* Y. Wen,* M. Liu
*National Science Foundation, CMS 9912559*

The goal of this project is to develop a new approach for structural seismic design that provides a distribution of seismic design alternatives, each of which has relative merit with respect to the others in terms of initial material cost/usage, expected lifetime seismic damage cost, design/construction complexity, and a system redundancy index.

* Denotes principal investigator.
This gives the decision maker a direct sense of tradeoffs associated with the various objectives, and the ability to select a compromise design that best meets the goals of all parties involved in the project.

A Generalized Modal Pushover Analysis for Estimating Seismic Drift Demands
S. Burns,* M. Liu
University of Illinois

Performance based seismic structural design methodology necessitates an accurate estimation of seismic deformation demands (roof and interstory drifts, plastic hinge rotations, and so forth) for civil structural systems. This study seeks to account for inelastic modal coupling effects using multiple standard pushover analyses. In the proposed procedure, modal seismic demands are modified, using invariant multiple modal load patterns in pushover analyses, to account for coupling effects before they are combined with the SRSS rule. Preliminary studies demonstrate that in some cases the method produces results comparable to the behavior predicted by a nonlinear time history analysis.

Transportation System Seismic Losses Test Bed
R. DesRoches,* A. S. Elnashai, B. F. Spencer
National Science Foundation, Mid-America Earthquake Center

Stochastic network flow models are developed and employed to estimate the efficiency of transportation networks before and after earthquake disturbance, including different retrofitting options. The effect of reduction or loss of function in the various links, representing bridges, on the total network travel time is assessed, and the different simulation approaches are compared to arrive at the best estimate in the least number of trials. The project is moving into dynamic traffic models that take into account the temporal variation in link capacities due to restoration efforts and rerouting. The project also includes derivation of fragility relationships for bridges with and without retrofit and soil-structure interaction effects.

Systematic Treatment of Uncertainty for Consequence-Based Risk Management
B. Ellingwood (Georgia Tech.),* J. Song,* L. Chang
National Science Foundation, Mid-America Earthquake Center, RM-2, EEC-97010785

The goal of the project is to develop efficient methods for modeling uncertainty in all aspects of Consequence-Based Risk Management (CRM) of the Mid-America Earthquake (MAE) Center, including representations of the seismic source and path, site response, structure and foundation response, damage and loss assessment, and social and economic impact. Based on interdisciplinary coordination efforts within the MAE Center, this project also develops a probabilistic framework that can aggregate in order to quantify the uncertainties in the estimated damages and losses that propagate from the aleatoric and epistemic uncertainties identified by the CRM.

Advanced Seismic Assessment of the Caruthersville Bridge on the Mississippi
A. S. Elnashai,* A. Mwafy, Y. Hashash, O.-S. Kwon
Jacobs Civil (Missouri Department of Transportation)

The work scope comprises developing complex models for an existing 59-span bridge with the aim of making decisions on its retrofit. The bridge model includes detailed representation of the foundations and the surrounding soil. The objective of the project is to assess the dynamic characteristics of the bridge system and its deforming response under realistic ground motion. A concerted effort is being allocated to the generation and scaling of the earthquake ground motion records, which represent scenario earthquakes in the Midwest. Detailed geotechnical site testing is undertaken by a companion team at the Georgia Institute of Technology, leading to the best possible estimates of soil parameters and their variation with depth. Several analysis platforms are used in the assessment, including ZEUS-NL, the Mid-America Earthquake Center analysis environment. Detailed inelastic dynamic analyses of the as-built structure as well as after the application of a number of retrofitting solutions are undertaken.

Catastrophic Earthquake Response Planning for the New Madrid Seismic Zone
A. S. Elnashai,* B. F. Spencer, A. Masud
Federal Emergency Management Agency; U.S. Army Corps of Engineers

The eight central United States are in peril from an earthquake nucleating on the New Madrid Seismic Zone, known to have generated three of the largest earthquakes in the history of the country. The project deals with all aspects of impact on the eight states and develops a number of scenarios on the state and regional levels. The impact includes losses to buildings, bridges, pipelines, roads, industry, utility networks, fires, spills, and critical facilities. The outcome assessment is used to develop detailed gap analysis, and response and recovery plans to improve the preparedness of the region. The project draws on collaboration with a number of universities in the region.

* Denotes principal investigator.
as well as with the Central U.S. Earthquake Consortium and Innovative Emergency Management Inc.

**Consequence-Based Risk Management Framework**
A. S. Elnashai*
*National Science Foundation, Mid-America Earthquake Center*

The project is the philosophical backbone of the Mid-America Earthquake Center programs in research, education, outreach and industrial technology transfer. It develops and further articulates the basic concept and operational steps of Consequence-Based Risk Management, a logical and transparent framework for integrated assessment of risk and consequences, mitigation measures, response, and recovery planning for complex societal systems. It is focused on, but not exclusive to, earthquake risk.

**Earthquake Impact and Disaster Response Planning for the New Madrid Seismic Zone (8 Central States)**
A. S. Elnashai,* and B. F. Spencer
*Federal Emergency Management Agency and IS Army Corps of Engineers; Mid-America Earthquake Center*

Impact of New Madrid and other known earthquake sources in the Central United States may be of catastrophic proportions. Current estimates of economic impact vary between $70 billion and $200 billion, with thousands of casualties and tremendous numbers of displaced people. The project is concerned with evaluating the impact on all societal systems using the best possible methods, models, and data, including social and economic impact. The Mid-America Earthquake (MAE) Center and George Washington University are working with the Federal Emergency Management Agency (FEMA), eight state Emergency Management Agencies, and the Central U.S. Earthquake Consortium (CUSEC, a partnership of states most affected by earthquakes in the central United States), to provide the best possible estimates of impacts with associated uncertainties to enable the development of state, regional, and national disaster response plans. The center is using both HAZUS (the FEMA impact assessment software system) and MAEviz (seismic risk assessment software developed by the Center over the past 7 years).

**Earthquake Loss Assessment for Istanbul Buildings**
A. S. Elnashai*
*Istanbul Municipality; Istanbul Technical University*

The project develops an earthquake impact tool based on MAEviz, the Mid-America Earthquake Center loss assessment platform, specifically for Istanbul buildings. The hazard and fragility specific to Istanbul are developed and a unique data set for all buildings in the metropolitan Istanbul region is assembled. The tool will be used for rapid assessment of likely damage after an earthquake and for planning mitigation, response, and recovery activities.

**Earthquake Loss Assessment Model for Illinois**
A. S. Elnashai,* B. F. Spencer, Y. Hashash, others
*Federal Emergency Management Agency; Illinois Emergency Management Agency*

The scope of this project is to develop the most appropriate and representative comprehensive loss assessment model for the State of Illinois, for use in response and recovery planning. Three scenarios for New Madrid and Wabash Valley seismic zone earthquakes are used to evaluate the direct and indirect losses to buildings, bridges, utility and communication networks, critical facilities and businesses, including social and economic impact, housing needs, and all other consequences that should be mitigated and planned for in advance.

**Mid-America Earthquake Center—NSF Engineering Research Center**
A. S. Elnashai*
*National Science Foundation*

The Mid-America Earthquake Center, headquartered at the University of Illinois at Urbana-Champaign since 1997, is one of three centers of earthquake engineering research funded by the National Science Foundation. The mission of the MAE Center is to develop new approaches necessary to minimize consequences of future earthquakes. The Information Technology, Social Science, Engineering Engines and Consequence-Based Risk Management thrusts form the core research needed to develop consequence-based approaches for assessment, mitigation, and response and recovery strategies, and also to support stakeholder interests from a wide range of companies and state and federal agencies. More than 40 faculty researchers and 60 research assistants are included in interdisciplinary research at core institutions that include the University of Memphis, Washington University, Georgia Institute of Technology, Texas A&M University, University of Texas at Austin, University of Michigan at Ann Arbor, and the University of Puerto Rico at Mayaguez.

**Reconstruction of Hospitals and Schools in Pakistan following the Kashmir Earthquake of 2005**
A. S. Elnashai,* A. Masud, Y. Hashash, J. Hajjar
*U.S. Agency for International Development (through CDM International Inc.)*

The project deals with seismic design criteria, including hazard, geotechnical and structural aspects, for schools and

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* Denotes principal investigator.
hospitals in areas of Azad Jamu and the Kashmir district, that were affected by the October 2005 massive earthquake. The scope for the Mid-America Earthquake Center researchers includes review of existing hazard studies, review of geotechnical studies for selected regions, and quantitative assessment of seismic design criteria used in Pakistan. The assessment phase is followed by recommendations for near-future developments to improve public safety.

Seismic Fragility Assessment for Reinforced Concrete High-Rise Buildings
A. S. Elnashai,* D. Kuchma, J. Ji
National Sciences Foundation Mid-America Earthquake Center

Due to a lack of field and laboratory test data, fragility relationships for RC high-rise buildings can be derived only by purely analytical methods. A new framework was developed for conducting dynamic response history analyses (DRHA) using a lumped-parameter model that can accurately account for the complex behavior and interactions in RC high-rise buildings. The parameters for this model were selected using genetic algorithms to capture the structural behavior predicted from detailed inelastic frame and continuum models. To illustrate the effectiveness of this approach, this framework was used to derive fragility relationships for a 54-story dual-core wall structure. Fragility relationships were derived for this structure from the results of a large number of DRHA using both real and artificial ground motion records. Fragility curves for large, small, distant, and close events were produced. The success of this analysis framework is dependent on the simplicity, appropriateness, and reliability of the selected simplified model. The proposed framework is generally applicable for developing fragility relationships for high-rise building structures with frames, cores, and walls. As an extension to this project, a framework was developed for multiresolution distributed finite element analyses, in which parts of a high-rise structure were modeled using a nonlinear frame analysis program while other parts were modeled using a nonlinear continuum analysis program. The combined use of more than one analysis tool was made possible by the use of a simulation coordinator program called SIMCOR. This methodology provides the opportunity for conducting realistic and efficient nonlinear analyses in which more descriptive limit state definitions can be used.

Synthetic Earthquake Hazards
D. A. Foutch*
National Science Foundation, Mid-America Earthquake Center

A procedure for generating synthetic earthquake accelerograms is being developed. It will be based on the use of a finite source model. Seismic hazards in Mid-America will be emphasized.

Torsional Seismic Response of Structures
D. A. Foutch*
U.S. Army Construction Engineering Research Laboratory (USACERL); University of Illinois

One of the greatest uncertainties concerning calculating the inelastic response of a building for seismic loads is the torsional response resulting from nonsymmetrical stiffness, strength, and/or mass. A series of tests of one-story structures will be conducted on the earthquake simulator at USACERL. Each structure will have a different nonsymmetry and will be shaken by biaxial earthquake motions. This is possible as a result of the recent upgrade of the USACERL earthquake simulator.

A Rational Procedure for Determining R Factors for Seismic Design of Buildings
D. A. Foutch*
U.S. Army Construction Engineering Research Laboratory

One of the most significant and controversial parameters used for the design of buildings for seismic loads is the response modification factor, R. Although the R-value has a direct impact on the strength of a building, its value for each building system has been assigned in an ad hoc way without using a rational procedure. Analysis procedures developed for the FEMA-sponsored SAC program will be used.

The goal of this project is to develop a method for assigning R-values based on analytical and experimental studies.

Memphis Testbed Validation and Capstone Prediction
J. F. Hajjar*
National Science Foundation, Mid-America Earthquake Center

In this project, systemic validation of regional loss assessments will be performed by conducting risk assessments for three study regions that have been documented in the literature. A series of capstone scenario predictions of potential losses and associated risk mitigation strategies will then be conducted for a series of seismic events in Shelby County, Tennessee. The capstone scenario predictions will be based on risk assessment.

* Denotes principal investigator.
analyses utilizing the end products of research thrusts for hazard definition, with special attention paid to the unique geology and seismology of the New Madrid Seismic Zone and the Mississippi Embayment, advanced inventory collection technologies operating at a point-wise building stock level, vulnerability of structures constructed to common standards of quality and design requirements for the Central and Eastern United States, and social and economic losses such as direct casualties and repair costs, losses of function in lifelines, shelter requirements for displaced households, and business disruption.

Site Modeling and Nonlinear Seismic Site Response of Deep Soil Deposits
Y. Hashash*
National Science Foundation, Mid-America Earthquake Center

Ground motion simulations well constrained by geological and seismic data are an important resource for assessing hazard and designing earthquake-resistant structures, especially in urban areas of the central United States, where damaging earthquakes are largely unknown and where many buildings have poor seismic resistance. This project includes the development of new, simplified 1-D site response analysis techniques to examine the influence of very deep soil deposits in the Mississippi Embayment on ground motion propagation. The results of this study will provide valuable information for developing seismic risk maps and designing codes appropriate for the region.

This project is developing new approaches to estimating nonlinear soil response on propagation of earthquake motion. A new site response analysis software DEEPSOIL was developed. A new set of seismic site factors were developed for the Mississippi Embayment to assist engineers in evaluating the seismic hazard in Mid-America.

Network Economic Loss
T. J. Kim,* G. Hewings
National Science Foundation, Mid-America Earthquake Center, EEC-9701785-DS6

The goal of the project is to develop a framework to estimate the cost of disrupted transportation networks due to earthquakes. For the analysis, a 25-year span of the final demands for 84 earthquake analysis zones in the entire United States for 13 economic sectors are estimated starting from the base-year 1993. The cost approach incorporates several submodules. Transportation network loss functions by network and by zone are run to obtain the network disruption ratio. The estimated results of the transportation network loss function are entered into the final demand-loss function to obtain reduced final demand as well as into the integrated commodity flow model to obtain increased transportation cost. The 1812 New Madrid earthquake is used as the basic scenario in the analysis. Stochastic models combined with GIS will be a part of the framework for the analysis.

Evaluation of Existing Illinois Department of Transportation Priority Routes for Earthquake Response
J. M. LaFave,* K. W. Ryu, A. Barr
Illinois Department of Transportation

This study aims to identify and then collect key information for Illinois Department of Transportation bridges along priority emergency routes in southern Illinois. The information collected and organized in a database includes principal structural features, significant structural details, design specification(s) used, and existence and extent of retrofits. Based on the information collected, the likely vulnerable details are identified for each bridge, along with retrofit strategies (and possibly deficiencies that are outside the scope of retrofits considered). The reliability of all the information developed is verified through field-examination of two stretches of roadway.

NEESR-SG: Seismic Behavior, Analysis and Design of Complex Wall Systems
L. Lowes,* D. Lehman, D. Kuchma, J. Zhang, J. Ji, K. Marley, C. Hart
National Science Foundation

This research advances the understanding of, and simulation tools for, the seismic performance of slender walls through experimental and analytical investigations of wall systems with: configurations used in modern design; load distributions that are representative of earthquake loading; and consideration of soil-structure-interaction effects. The advanced experimental capabilities of the University of Illinois George E. Brown Network for Earthquake Simulation Multi-Axial Full-Scale Sub-Structures Testing and Simulation (MUST-SIM NEES) facility permit realistic simulation of these complex conditions. Instrumentation developed as part of the MUST-SIM facility makes possible high-resolution monitoring of test specimen displacement fields, and such data are necessary to support numerical modeling efforts. The collected data advance the state of the art for simulation of reinforced concrete structures through the development of fiber-shell elements that can be used to simulate the inelastic response, including localized damage mechanisms, of three-dimensional walls. A total of nine

* Denotes principal investigator.
large structural walls are being tested in the MUST-SIM facility, including planar, coupled, and C-shaped walls.

3-D Shaking Table Investigation of Methodology for Analysis, Design, and Implementation of Smart Dampers: Nonlinearity and Asymmetry
S. Sarkani,* L. Lutes (Texas A&M University), B. F. Spencer, Jr.
National Science Foundation, CMS-9908966

The focus of this project is to extend smart damping technology by considering the behavior of a smart damping system (SDS)—a system consisting of multiple smart MR dampers, controllers, and sensors—under realistic operational conditions. In particular, the study focuses on both nonlinear structural behavior and torsion and 3-D coupling induced by structural asymmetry. The consideration of nonlinearity is essential if one is to represent the behavior of a typical structure during a major earthquake and 3-D motion is also the norm, rather than an exception, in real structures.

Estimation of Post-Hazard Reliability and Availability of Lifeline Networks
J. Song,* L. Chang, W.-H. Kang
National Science Foundation, Mid-America Earthquake Center, EE-1, EEC-97010785

Urban lifeline networks such as power, water, and natural gas systems are critical backbones of modern societies. Natural and man-made hazards may cause not only physical damages to such lifeline networks, but also serious socio-economic consequences due to the disruption of urban infrastructure systems. The project aims to develop a new system reliability method that can estimate post-hazard reliability and availability of lifeline networks with accuracy and efficiency, which is essential for pre-hazard planning and rapid assessment of damages for optimal emergency responses.

Java-Based Virtual Laboratory for Earthquake Engineering
B. F. Spencer, Jr.*
National Science Foundation Multidisciplinary Center for Earthquake Engineering, Buffalo, N. Y., MCEER Task No. 03/5.5

The objective of this effort is the development of a suite of Java-based virtual laboratory (VL) experiments that will provide graduate students and practitioners with a means to interactively gain fundamental understanding and intuition regarding a wide range of structural dynamics and control topics via the World Wide Web. The VL experiments are based on the Sun’s platform independent Java programming language, providing access to these educational tools from any networked computer throughout the world with a minimum of administrative overhead.

Natural Hazard Mitigation Experiences in Japan
B. F. Spencer, Jr.,* Y. C. Kurama (Univ. of Notre Dame)
National Science Foundation, INT-0101111

The Natural Hazards Mitigation in Japan (NHMJ) Program is a supplement to the National Science Foundation Summer Program in Japan. This program provides unique opportunities to explore the state of research and practice in natural hazard mitigation in Japan to 12 U.S. graduate students. Each year, NHMJ participants attend activities prior to the summer program in Japan, including tours of Japanese research laboratories and site visits to design, construction, building, and bridge sites in the Kansai (Kobe, Kyoto, and Osaka) and Kanto (Tokyo and Tsukuba) areas. A student symposium is also held. This grant provides student support for the NHMJ activities, including housing, transportation, and meals.

Smart Damping Strategies for Seismic Protection of Urban Structures
B. F. Spencer, Jr.,* M. K. Sain (Univ. of Notre Dame)
National Science Foundation, CMS 9900234

This research is a U.S.–Japan collaborative investigation to develop a broad and integrated foundation for innovative smart structures concepts aimed at mitigating the effects of strong earthquakes caused by fault ruptures in heavily urbanized regions. The investigation focuses on the following: development of smart base isolation concepts, development of smart interconnected buildings concepts, development of control strategies that can exploit the unique features of the adaptive system in mitigating urban earthquakes, proof of concept experiments for several structural system configurations, and development of a 40 kip prototype magnetorheological fluid damper. This research has strong industrial support from the Lord Corporation, Takenaka Corporation, and Ishikawajima-Harima Heavy Industries (IHI).

Network Retrofit and Routing Strategies
D. Veneziano,* T. J. Kim, J. Sussman
National Science Foundation, Mid-America Earthquake Center, EEC-9701785-CM3

The goal of the project is to develop a set of tools that will allow stakeholders to trade-off pre- and post-earthquake investments designed to reduce earthquake losses across network systems both new and existing. Work to date has considered pre- and post-earthquake strategies

* Denotes principal investigator.
independently—this approach allows an integrated consideration of best strategies.

**Systematic Treatment of Uncertainty in Masonry and Wood Buildings**

Y. K. Wen,* Z. Li  
*National Science Foundation, Mid-America Earthquake Center, FD-2A*

A key goal of this research is to develop an efficient method for systematic treatment of uncertainty in all aspects of damage synthesis modeling, including representations of the seismic source and path, site response, structural and foundation response, damage and loss assessment, and social impact. A computationally efficient methodology for systematic treatment of both inherent uncertainty and modeling errors will be developed in seismic hazard and vulnerability analysis, including confidence levels based on sensitivity analyses to parameter estimate uncertainty.

The ultimate objective is to guide the Mid-America Earthquake Center program of research to invest where the return is highest in terms of quantifying and minimizing uncertainty.

**Vulnerability Function**

Y. K. Wen,* K. W. Liao, N. Svrakic  
*National Science Foundation, Mid-America Earthquake Center, DS-4A*

Vulnerability functions are keys in evaluating the seismic risks across a region with different populations of structures and/or networks and with different intervention measures. The project has two main components, namely the development of procedures and the application of these procedures to buildings, bridges, and networks-lifelines. A set of guidelines will be developed for general derivation of deformation-based limit states, specific vulnerability functions, and applications to civil systems.

This research will develop procedures for accurate and representative relationships between ground motion severity and the probability of a set of limit states being exceeded.

**Engineering Mechanics and Materials**

**CAREER: Rapid Nondestructive Assessment of Concrete Structures Using Elastic Waves**

J. S. Popovics*  
*The National Science Foundation*

This proposal offers an approach for rapid and accurate nondestructive evaluation (NDE) to assess the in-place condition of concrete structures for imaging structures that characterizes the location, type, and magnitude of damaged areas. The proposed approach makes use of several innovations including use of surface-guided waves; sensitive, noncontact wave reception techniques such as air-coupled transducers and laser interferometry; one-sided, point source, point receiver NDE measurements such as surface wave transmission and velocity scans; and an imaging approach that makes use of the developed measurement data. An educational plan is closely integrated with the proposed research.

Much of the concrete infrastructure in the United States is deteriorating, and agencies that govern these structures are shifting their priorities away from traditional analysis and design of new structures toward inspection, assessment, and maintenance of the existing infrastructure. Techniques that can detect, localize, and characterize damage within an existing concrete structure in a nondestructive fashion are of great value. However, the time and effort required to perform each test and analyze the results limit the amount of useful data that can be collected from a large structure. This proposal aims to develop a rapid and robust method to collect elastic wave data from a concrete structure and also an approach for imaging structures that characterizes the location, type, and magnitude of damaged areas, giving engineers an unparalleled tool for assessment of the condition of the concrete infrastructure.

**Development of Nondestructive Methods for Measurements of Slab Thickness and Modulus of Rupture in Concrete Pavements**

J. S. Popovics,* G. C. Clemena, M. K. Elfino  
*Virginia Transportation Research Council*

The proposed investigation aims to achieve the following: develop the basis and testing protocol of NDE for accurate measurement of concrete pavement thickness (with an accuracy of ± 3mm), regardless of surface roughness, base material type and surface condition, surface tining condition, and material internal moisture condition; develop the basis and testing protocol of NDE for determination of in situ flexural strength; and verify the performance of developed testing protocols on actual pavement structures in Virginia.

For a new portland cement concrete (PCC) pavement to reach its designed service life, it must be designed and built with a proper combination of adequate slab thickness and in-place strength, both of which are selected for the traffic load that the pavement is expected to bear. Therefore, as part of the quality control/assurance process, it is essential for every newly constructed PCC pavement to be inspected.

* Denotes principal investigator.
soon after construction is completed (within 21 days) to verify that the contractor has complied with specifications on thickness and strength of the concrete slab. With such nondestructive evaluation (NDE) methods, the inspection can be conducted at more sampling locations on a pavement for improved pavement quality assurance testing.

**Noncontact Ultrasonic Pulse Velocity Method for Concrete**

J. S. Popovic,* M. Hoag  
*James Instruments Inc.*

The ultrasonic pulse velocity technique (UPV) has been applied with success to locate defects and characterize concrete structures. However, effective UPV requires good contact between the sensor and concrete surface to obtain reliable data. Such contact measurements, which occasionally require concrete surface preparation, are time and labor intensive. One approach to speed up the data collection process is to eliminate the need for physical contact between the sensor and structure. Such sensing technology would enable continuous data measurement leading to rapid and more reliable concrete structure characterization with UPV. The work in this project focuses on characterizing conventional contact ultrasonic transducers and the design, development, and evaluation of a noncontact UPV testing system for concrete. The latter provides reliable and consistent through-thickness UPV data from concrete without the need for couplant or surface preparation. The primary design approach makes use of air-coupled ultrasonic transducers. This scheme has the advantages of low cost, portability, easy installation, no hazardous radiation or other phenomena, and fast scanning capability. These objectives are accomplished through a collaborative effort between the University of Illinois and an industrial partner.

**Research on Fresh and Early-Age Concrete**

J. S. Popovic*  
*Center for Advanced Cement-based Materials*

Research funds in the Center for Advanced Cement-based Materials (ACBM) are used to further research and study across a range of possible topics related to early-age hydration and performance of cement-based materials. In this case, the funds are used to investigate the role of specific hydration reactions that cause pre-mature stiffening of cement and concrete. Several analytical techniques, including ultrasonic wave reflection (UWR), are used to verify the development of specific hydration phases. This work represents the first known application of UWR to detect premature stiffening.

**Environmental Engineering and Science in Civil Engineering**

**Identification of Denitrifiers in Tile Drainage Biofilters**

J. M. Appleford,* J. L. Zilles, L. F. Rodriguez, R. Cooke, Y. Zhang  
*University of Illinois*

Although agricultural fields represent a significant source of nitrogen pollution, the diffuse nature of this source makes control difficult. However, in many areas with high water tables, tile drainage systems have been installed, and nitrate has been successfully removed from the runoff using wood-chip biofilters. The biological components of these reactors have not been investigated. To date, we have determined that the majority of the denitrification activity in the biofilters is bacterial, although there is also a significant fungal contribution. Current efforts are focused on quantifying these contributions and identifying the contributing microorganisms. This data will permit the development of monitoring and control tools and allow assessment of spatial and temporal variability.

**Reliability-Based Decision Making for Managing Reservoir Spill Water for Cyprus**

K. Aristeidou,* J. W. Eheart*  
*AMIDEAST (Fulbright); University of Illinois*

The rainy season on the island of Cyprus lasts from October to April. During the summer months, when water demand reaches its peak due to irrigation and the needs of the tourist industry, the inflow to the reservoirs is negligible. Many reservoirs on the island store water throughout the rainy season for use during summer when the demand of water is high (annual basis management) and so it is desired that these reservoirs be as full as possible at the end of the rainy season. During rainy years some of these reservoirs may spill over. If this spillover water could be predicted it could be used in advance for a "low value" purpose like groundwater recharge. However, such predictions will inevitably incur error, so any decision making must account for the competing risks of spilling water and allocating water early to low value purposes when it is needed later for high value purposes.

The purpose of this study is to develop a method for optimizing the strategy of water allocation on the basis of weather prediction that optimizes the tradeoff between those two risks. The approach taken is based on reliability of meeting a goal associated with the high value requirements and penalties associated with not meeting it. This goal could be that the reservoir be full on a specific
date at the end of the rainy season or meet a minimum storage that is needed for fulfilling the summer demand.

Adding Climate Relevance to World Bank Diesel Studies
T. C. Bond,* R. Subramanian
*U.S. Environmental Protection Agency, RD-83108501, and Clean Air Task Force

Understanding the properties of particles that affect atmospheric chemistry requires new kinds of measurements, which are costly to obtain. It is sensible and economical to “piggyback” these measurements with other programs. We are adding measurements to a study funded by the World Bank in Bangkok, Thailand, which had planned to measure only mass of emitted particles. Our measurements will provide additional information on chemical composition and other properties of the particles. This project will provide improved data on emissions and demonstrate how value can be added at low cost when studies of local and global atmospheric issues are connected.

CAREER: Carbonaceous Particles of Tarry Origin
T. C. Bond,* C. Roden, A. Kanu
National Science Foundation, ATM-0349282

We are characterizing the physical and chemical properties of carbonaceous particles generated by combustion or release of tar (heavy hydrocarbons) from solid fuels. These particles comprise about two-thirds of the carbon particles emitted globally. We examine the relationship between combustion conditions, fuel type, and emitted particles. Treating emissions as the sum of combustion conditions, we intend to develop profiles that represent different types of realistic combustion. We are also developing collaborations with international projects that provide samples for analysis and we are training nonprofit organizations in measuring particulate matter. This project will help to improve emission estimates and especially our understanding of the factors that affect emissions from burning wood. This information may be used in models of the atmosphere on local or global scales. It will also be used to help design better wood-burning stoves.

Incorporating Technological Change in a Global Carbonaceous Aerosol Emissions Forecasting Model
T. C. Bond,* S. Jung
Argonne National Laboratories, 5F-00427

Technological change is just as important as increased energy use in determining emissions of aerosols. We are examining the physical and economic factors that lead to dissemination and adoption of new emission-control technologies based on historical data. These drivers are incorporated into a model that forecasts the development of emissions by region. The model interfaces with future scenarios of energy consumption by region to estimate the role that aerosols will play in the global energy balance for the next 50 years.

Integrating the Thermal Behavior and Optical Properties of Carbonaceous Particles
T. C. Bond*
U.S. Environmental Protection Agency, RD-83108501

Monitoring funded by EPA and other agencies relies on special measurement techniques to assess the types of carbon particles in ambient air and in emissions from combustion sources. At present, different commercial analyzers give different results. We are improving the interpretation of the results by conducting systematic investigations of how the technique responds to well-known and well-characterized particles. We will develop new analysis procedures that can be applied to large existing national databases to reinterpret the results.

These results will lead to a greater understanding of the types of carbon particles in the atmosphere, their sources, and their impacts on air quality and global climate.

Measurement of Light Absorbing Carbon on Human Exposure Study Samples
T. C. Bond,* R. Subramanian
U.S. Environmental Protection Agency, 4D-6270-NAEX

We are investigating whether light absorption can be used to identify certain kinds of carbon on samples taken to assess human exposure to particulate matter. Previously, volatility analysis has been used; the light absorption method may allow smaller samples and faster analysis.

Reducing the Uncertainties in Carbonaceous Aerosol Emissions, Atmospheric Concentrations, and Climate Effects
T. C. Bond,* H. Sun
NASA-Goddard Institute for Space Studies

Aerosols are among the most uncertain and important elements of climate forcing, and the carbonaceous component of aerosols is responsible for a large fraction of the uncertainty. Observations indicate a very substantial carbonaceous aerosol load, and yet the best emissions estimates when used in global aerosol models seem to underestimate the observations in many regions. Thus there is at least an uncertainty of a factor of 2 in global carbonaceous aerosol load; the resulting uncertainty in climate forcing leaves even the net sign of aerosol forcing in question. This project is to reduce this uncertainty by
combining emissions, modeling, and observational expertise, and examining the sources of uncertainty. This project should result in improved representation of carbonaceous aerosols in global models and an enhanced ability to simulate the Earth system.

**Supporting EPA Inventory and Mitigation Analyses of Black Carbon and Organic Carbon Emissions**

T. C. Bond*

*U.S. Environmental Protection Agency, 4W-3384-NAEX*

Carbon particles affect climate and atmospheric chemistry, and reducing emissions of these particles is a way to mitigate human effects on the atmosphere. Because high emissions of these particles are thought to come from China, we are collaborating with Chinese scientists to improve emission estimates by collecting data on combustion practices. We also work with modelers who estimate future emissions based on socioeconomic variables, providing them with data on technology trends and emission coefficients. This project will help identify the most promising ways of reducing emissions that affect the climate of the near future.

**Understanding the Atmospheric Transformation of Anthropogenic Aerosol: Inferences from Satellite Data and Global Aerosol Modeling**


*National Aeronautics and Space Administration, NNG04GL91G*

We are developing up-to-date aerosol emission inventories and improving models that simulate the transport and radiative properties of aerosols in the atmosphere. Through statistical comparisons of the model results with satellite information on aerosols, we are investigating atmospheric processes that affect aerosol behavior. Results from this project will be used to improve the way that large models represent removal of aerosols from the atmosphere.

**Direct Fixed-Bed Biological Perchlorate Destruction Demonstration**

J. Brown,* E. Morgenroth, L. Raskin

*Department of Defense*

The objective of this work is to evaluate the efficacy of using fixed-bed (FXB) biological reactors (bioreactors) to remove perchlorate from drinking water. Using over six years of bench- and pilot-scale experience as a foundation, we are proposing to evaluate FXB biological perchlorate treatment at the demonstration scale. Specific project emphases include the demonstration of sustained removal capabilities, the identification and evaluation of process limitations and potential failure scenarios, and the development of realistic designs and cost estimates for full-scale drinking water FXB biological perchlorate treatment.

**Characterization of Membrane Fouling in Seawater Reverse Osmosis Desalination**

M. M. Clark,* D. Ladner

*United States Bureau of Reclamation; United States Environmental Protection Agency*

Desalted seawater is increasingly considered as a viable alternative water resource for water-scarce coastal regions. While reverse osmosis (RO) membrane systems are most widely used for seawater desalination, a major limitation to the productivity of these systems is fouling by dissolved and particulate constituents in the feed water. This is the first fundamental study to evaluate seawater composition from the perspective of membrane fouling. Advanced organic matter characterization is being applied to the raw feedwater and to materials deposited on the membrane after completion of filtration tests. Interrelationships between the composition of feedwater, the type of pretreatment, and the observed fouling are being explored.

**Characterization of U.S. Seawaters and Development of Standardized Protocols for Evaluation of Fouling in Seawater Reverse Osmosis (SWRO) Desalination**

M. M. Clark,* M. Kumar, D. Ladner

*WateReuse Foundation, MWH*

In this study, seawaters from three different locations in the United States are being extensively characterized and correlated to fouling behavior of SWRO membranes. The influence of membrane properties and pretreatment conditions on fouling is also being studied. The final goal of this project is to develop standard testing protocol for use by other researchers in evaluating fouling behavior of SWRO membranes and to characterize the composition of foulants in seawater and fouled membrane surfaces.

**Role of Metal Cations in Adsorption of Natural Organic Matter (NOM) on Polymer Membrane Surfaces**

M. M. Clark, A. G. Kalinichev,* W. Y. Ahn

*National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS); National Center for Supercomputing Applications*

Membrane fouling has been widely studied in the drinking water industry because it causes significant limitations on clean water productivity. Although various fouling models have been developed, the models cannot predict clean water flux for different feedwater chemistries. This study focuses on molecular-level understanding of fouling of

* Denotes principal investigator.
polymeric membranes by NOM. The interaction of calcium and magnesium with model NOM molecules and membrane surfaces is studied using computational molecular modeling techniques. In particular, this approach allows us to separately study two types of interactions, the binding of NOM molecules by metal ions and the interaction of NOM with membrane surfaces via metal ion complexation.

Cyberinfrastructure and Management System Development for the National CLEANER Network
W. Eheart,* B. Minsker, M. Welge
National Science Foundation, BES 041425, 2004-2006

This project focuses on developing a community consensus plan for the functioning and needs of the CLEANER Engineering Analysis Network (EAN). The EAN would implement the CLEANER vision through a system of instrumentation, data, and computational resources, shared by geographically distributed investigators and supported by cyberinfrastructure (a system of computers, digital data, networks, algorithms, and collaboration tools that support geographically distributed teams of researchers and educators). This project helped define requirements for the EAN, including the cyberinfrastructure and management plans necessary to bring the CLEANER vision into fruition, using a collaborative, community-based process supported by state-of-the-art information technology.

Nutrient Abatement Trading Using Constructed Wetlands as an Alternative to Conventional Point Source Wastewater Treatment
J. W. Eheart,* M. B. David
The Metropolitan Water Reclamation District of Greater Chicago

High nutrient loads in surface waters, particularly loads of nitrogen and phosphorus (N and P), are a cause of eutrophication in inland waters, high nitrate concentrations in raw water feedstocks, and hypoxia in coastal ecosystems. Constructed wetlands offer a possible method of cost-effective nutrient removal, but their performance is often complicated by environmental variability. The objectives of the research reported here were to develop a method to determine the cost-reliability tradeoff of such wetlands in comparison to that of nutrient removal (for N and P) in conventional wastewater treatment facilities (and thereby to assess the potential of a nutrient market) and to apply the method to an example watershed in Illinois. A modeling procedure was developed and used to determine the most cost-efficient wetland design, given the nutrient removal requirements. A nonsteady-state wetland model and a chance-constraint decision algorithm incorporating that model were developed. The chance-constraint algorithm was based on satisfying nutrient removal performance standards for a subset of the period of hydrologic and meteorological records. Several watersheds in Illinois were considered as examples, including Vermilion (of the Illinois River), LaMoine, Spoon, and Salt Creek of the Sangamon River. The latter was chosen because it lies in the heart of Illinois, is highly agricultural, and contains three cities with populations exceeding 10,000 residents. A second watershed was added later to examine the results from proposed wetland sites near Hennepin, Illinois along the Illinois River. The modeling procedure was applied to the two example cases. One compares the cost of conventional treatment at a Bloomington, Illinois facility, discharging to the Salt Creek of the Sangamon River in Illinois, to that of each of two hypothetical constructed wetlands (one at the treatment plant, and one downstream, 80 km. from the plant) and the two operating in concert. The other example compares the cost of conventional treatment for the Metropolitan Water Reclamation District of Greater Chicago to that of a hypothetical constructed wetland near Hennepin Illinois (177 km. downstream) taking water from and returning it to the Illinois River. Results showed that when there is an adequate supply of nutrients to be removed, the wetlands perform very cost effectively. However, it is not always the case that a riparian wetland, taking water from a river and returning it to the same river, can obtain, let alone remove, a sufficient quantity of nutrients to offset the discharge of a conventional wastewater treatment facility (this was found to be particularly true for phosphorus). The factors limiting wetland performance are low flow availability and low inflow nutrient concentrations. Because of the differences of these limitations and different locations, as well as high land prices at some locations, a two-wetland design was found to be more cost-effective than a single-wetland design. On average, wetlands have great potential for nutrient removal (certainly for nitrogen, possibly for phosphorus), but also have a higher risk of failure than conventional treatment and could, under unfavorable conditions, be either more expensive or altogether infeasible.

* Denotes principal investigator.
Uncertainties Associated with Market-Based Policies for Pollution Control
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In recent years, market-based environmental policies have been gaining popularity as an alternative means of pollution control. One market-based policy that has been the subject of much discussion lately is the use of tradable discharge permits to regulate polluters. Theoretical studies, as well as practical experience, have proven the tremendous potential that Tradable Discharge Permit (TDP) programs carry as a cost-effective means of achieving ambitious environmental goals that might not be achieved economically under the more familiar command-and-control policies.

However, there is still much uncertainty of the inner workings and implications of TDP programs that if not adequately addressed, might impair their success. These uncertainties, of which some are quantifiable but most are not, are as random as they are diverse. Concerns range from issues of market failure that prevents optimal trading, to political agendas that differ in their priorities, to modeling difficulties that might cause erroneous estimations of cost savings and environmental performance. It is therefore an interesting challenge to better understand these uncertainties, so that future implementations of TDP programs avoid mistakes that might thwart their full potential from being realized.

This project assesses and quantifies some of the uncertainties associated with a system of tradable discharge permits for controlling waterborne discharges into rivers. Uncertainties associated with the willingness to trade and the preservation of water quality in the face of trading, or lack thereof, are addressed.

Aerobic tert-Butyl Alcohol Biodegradation by a Bio-GAC Derived Microbial Culture
K. T. Finneran,* X. Yang (BP-ARCO)
BP-ARCO Project—Environmental Division

Granular activated carbon (GAC) is one physicochemical approach for removing groundwater contaminants in pump-and-treat systems. However, the technology is limited to contaminants that adsorb well to the carbon surfaces. Alcohols are miscible in water and have extremely low KOC values. Biofilms that develop on GAC can actively metabolize contaminants in the influent, which precludes the need for adsorption. This technology is referred to as Bio-GAC. Recently, field engineers have tracked degradation of one alcohol, tert-butyl alcohol (TBA), in a bio-GAC system in California. While TBA removal in the bio-GAC system is moderately efficient, the sponsoring agency is interested in identifying the microorganism(s) responsible and developing a liquid culture that can be used to inoculate field GAC units to decrease the lag time before TBA degradation ensues. In addition, they would like to understand degradation kinetics as environmental conditions change. A liquid enrichment culture was developed using GAC as the source of microbial biomass.

Anaerobic Methyl-tert Butyl ether (MTBE) and tert-Butyl Alcohol (TBA) Biodegradation under Shifting Biogeochemical Conditions: Degradation Kinetics and Mechanisms in Aquifer Material and Novel, Anaerobic Enrichment Cultures
K. T. Finneran*
American Petroleum Institute—Groundwater Task Force Research Board

Methyl-tert Butyl ether (MTBE) and tert-Butyl Alcohol (TBA) are two fuel oxygenate compounds that are problematic in groundwater. In addition, TBA is the first metabolic by-product of MTBE biodegradation. They are both extremely soluble and do not adsorb to aquifer solids; therefore MTBE and TBA plumes can become very large. The ideal bioremediation strategy would attenuate these compounds within the source area of the contamination. However, fuel spill source areas are anaerobic, and therefore any source area remediation strategies must encompass anaerobic conditions from nitrate reduction Fe (III) and Mn(IV) reduction sulfate reduction methanogenesis. This project will address MTBE and TBA biodegradation, and within this the critical problem of TBA accumulation in MTBE-degrading subsurface environments. The research will focus on specific degradation mechanisms and kinetics within the different terminal electron accepting processes (TEAPs). It will also identify the changes in degradation as these TEAP processes “shift” in situ; i.e., as one dominant microbial community, and therefore pathway, is replaced by another. It is within these shifting metabolic processes that degradation kinetics may change (to increase or decrease degradation). We will utilize experiments that mimic in situ conditions rather than pure culture models. Once degradation kinetics have been quantified across the shifting TEAPs, we will investigate whether the specific degradation pathway changes as TEAPs change. Recently, we have enriched three distinct anaerobic cultures that metabolize MTBE as the sole carbon and energy source. These cultures grow with Fe(III)/anthraquinone, sulfate, or fumarate as the electron acceptors, respectively. To date, no research group has reported enrichment cultures that

* Denotes principal investigator.
oxidize MTBE via anaerobic respiration. These cultures will allow us to characterize MTBE metabolism using defined and highly controlled experimental conditions. The tests that will be run will include microbial physiology, biochemistry, and molecular ecology. This work will lead to optimized bioremediation strategies for fuel contaminated anaerobic source areas in subsurface environments.

**Biodegradation of Nitramine Compounds by Stimulating Humic Substance- and Fe(III)-Reduction**

K. T. Finneran,* S. Drew (GeoSyntec Inc.), J. Davis (U.S. Army Corps of Engineers)

*DoD Strategic Environmental Research and Development Program, Project CU-1377*

Fe(III)- and humic substance-reducing microorganisms significantly transform organic and inorganic compounds, including contaminants. Humic substances (humics) are naturally occurring compounds that transfer electrons from microbial respiratory enzymes to solid phase Fe(III). Humics also transfer electrons directly to a variety of compounds. Humics-mediated electron transfer from microbial respiration to Fe(III), other metals, or contaminants is referred to as electron shuttling. Nitramine compounds are reported to be terminal electron acceptors for anaerobic microbial respiration. However, these processes may be inefficient in situ due to the poor distribution of nitramine-reducing microorganisms and the overall kinetics of the individual reactions. Recent evidence indicates that Fe(II) can abiotically transfer electrons to nitramine compounds, thereby altering their distribution and toxicity. These experiments were performed in pure phase or with pure cultures under artificial laboratory conditions. This project will determine if stimulating Fe(III) and humics reduction will increase the rate and extent of RDX reduction and biodegradation in RDX-contaminated aquifer material. The data will also determine if humics transfer electrons directly to RDX or if Fe(III)/Fe(II) are required as intermediate electron carriers. If humics and Fe(II) are both determined to increase the rate of RDX reduction, the experiments will further evaluate which of the two mechanisms is faster. Finally, the project will determine the microbial community or population enriched during humics- and Fe (III)-mediated RDX biodegradation using molecular techniques. Once the phylogenetic relationship of these microorganisms is compared to known microorganisms, the data may be used to develop molecular probes for this activity. Contaminated aquifer material from the Picatinny Arsenal, Massachusetts Military Reservation, or other suitable sites will be collected to conduct the experiments.

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**Degradation of Chlorinated Aliphatic Hydrocarbons under Fe(III)-Reducing Conditions: Role of Extracellular Electron Shuttles (EES) in Reductive Dechlorination**

K. T. Finneran*

*University of Illinois Research Initiative*

Chlorinated aliphatic compounds (CACCAC) are widespread marine sediment contaminants. They are extremely hydrophobic and therefore persist even in highly turbulent marine systems. Reductive dechlorination is one strategy that is applied to restore CAC-contaminated sediment, and success varies with each different environment. Meta and para substituted CAC congeners are generally more susceptible to reduction, and ortho substituted congeners may accumulate. Strategies to date have targeted organisms that directly reduce CAC compounds; however dechlorinating microorganisms are not present at sufficient cell density to catalyze these reactions in all CAC-contaminated environments. CACs can biodegrade under aerobic and anaerobic conditions. Anaerobic biodegradation is more relevant to contaminated marine sediment because aerobic metabolism is limited even in shallow systems. Oxygen may be transiently present, but it is not present at a high enough concentration to stimulate continuous aerobic CAC oxidation. Labile organic matter in sediment will be preferentially oxidized, which limits the extent of aerobic CAC degradation. Reductive dechlorination is the anaerobic strategy, whereby CACs serve as the primary terminal electron acceptor. Although this strategy has been successfully demonstrated in marine sediment, CACs still persist despite high electron donor concentration in many environments. Several chlorinated compounds are transformed by Fe(III)-reducing microorganisms and the associated reduction by-products such as soluble Fe(II), adsorbed Fe(II), and reduced humic substances. CAC reduction has been reported in marine sediments under conditions that may have been Fe(III) reducing, but iron-mediated CAC transformation was not the goal of the study and the iron chemistry was not investigated in detail. It is likely that several CAC congeners are transformed rapidly by various reduced iron and humic compounds, and directly by Fe(III)-reducing microorganisms. The objectives of this project are to: quantify the rate and extent of CAC transformation mediated by Fe(III)- and humics-reducing microorganisms in marine sediment; quantify the rate of CAC biotransformation with soluble Fe(II), adsorbed Fe(II), and reduced humic substances; and stimulate iron- and humics-mediated CAC reduction in contaminated marine sediment. These objectives will be met by testing the following three hypotheses: First, Fe

* Denotes principal investigator.
Microbial System

**Extracellular Electron Shuttle (EES) Mediated Hydrogen Overproduction in a Fermentative Microbial System**

K. T. Finneran*

*National Science Foundation Energy for Sustainability*

Biological hydrogen production has been considered one possibility for sustainable hydrogen-based fuel, but microbial metabolism limits the mass of hydrogen that can be produced in any single reactor. Research to date has focused on reactor optimization and reactor scale-up; building a larger and more efficient reactor increases the amount of hydrogen that will be produced in the fermentation. However, to increase the hydrogen yield, the reactors must be larger, and at a certain point the size of the reactor limits performance, as well as the feasibility of using the reactor at point-of-use operations such as a vehicle, lawnmower, or small electrical circuit in a residential or commercial setting. This research project focuses on optimizing the biological component of the pathway. Increasing the molar hydrogen yield per mole substrate fermented allows smaller reactors to generate more hydrogen. The biological reaction is the first step, and if made more efficient it would allow engineers to design small, point-of-use fuel cells fed by bioreactors that can generate more hydrogen per unit volume than larger reactors. Past reports suggest that different groups have identified “spikes” in molar hydrogen yield, but the actual physiological mechanism was not identified and the data were not repeated. The primary objective of this research is to develop a mixed culture (two species), continuous bioreactor for hydrogen overproduction using extracellular electron shuttles to increase the molar yield of hydrogen per unit substrate fermented. This objective fits into an overall larger project dealing with physiological approaches to increase hydrogen production using extracellular electron transfer molecules. A secondary objective is to determine the optimal concentration of the extracellular electron shuttle AQDS, pH, and hydrogen removal rate that will facilitate hydrogen overproduction in a mixed culture of *Clostridium beijerinckii* and *Geobacter sulfurreducens*. *C. beijerinckii* is the fermentative culture that will ferment glucose to acetate plus hydrogen; *G. sulfurreducens* will oxidize acetate with AQDS as the electron acceptor; this culture does not utilize H₂ as an electron donor. Based on preliminary data *C. beijerinckii* will reoxidize the 2QDS produced in a two-electron oxidation forming additional hydrogen. The AQDS/AH₂ QDS cycle is catalytic; therefore, a low concentration of AQDS will promote this reaction in perpetuity provided that substrate is maintained and hydrogen is continuously removed. The hydrogen yield in this co-culture will be greater than the expected stoichiometry based solely on glucose fermentation. Once the reactor dynamics have been established, the research will focus on the mechanistic biochemistry of EES mediated hydrogen production in fermentative cultures.

**Methyl- tert Butyl ether (MTBE) and tert-Butyl Alcohol (TBA) Biodegradation under Sulfate Reducing Conditions**

K. T. Finneran,* X. Yang (BP-ARCO)

*BP-ARCO Project – Environmental Division*

Sulfate reduction is an anaerobic terminal electron accepting process (TEAP) that dominates in sulfate rich subsurface environments. Sulfate-reducing microorganisms have been linked to biodegradation of numerous compounds, including benzene and other fuel contaminants. *Methyl- tert Butyl ether (MTBE) and tert-Butyl Alcohol (TBA)* are two fuel oxygenate compounds that are problematic in groundwater; TBA is also the first metabolic by-product of MTBE biodegradation. Recent data suggest that sulfate reduction may promote MTBE and TBA biodegradation; however, the rate and extent of MTBE and TBA biodegradation differ among environments even in which sulfate reduction is the dominant TEAP. This suggests that additional environmental controls influence MTBE and TBA degradation during sulfate reduction. One such possibility is the extent to which free sulfide accumulates in situ, which may become toxic to the cells at a high enough concentration. Fe(II) present in the aquifer will sequester free sulfide via precipitation, but the extent of Fe(II) is determined by Fe(III) reduction, which is an alternate TEAP. The pH effects may become important as pH influences the speciation of both iron and sulfur compounds. This project will investigate MTBE and TBA biodegradation in contaminated aquifer material at the fringes between Fe(III) and sulfate reduction and sulfate reduction and methanogenesis. Sulfate will be amended to specific incubations to increase sulfate reducer biomass, and the microbial community composition will be determined using molecular techniques.

* Denotes principal investigator.
**Phosphorus Removal in Retrofitted On-Site Wastewater (Septic) Systems by Stimulating Fe(III) Reduction: Insoluble Mineral Precipitation (Vivianite)**

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*Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET), a division of NOAA*

Phosphorus is a nutrient that accumulates in wastewater as a result of household and agricultural uses. Although it is not particularly toxic to human health, it is a significant ecological hazard when it reaches surface water bodies due to its eutrophication impacts. Current phosphorus removal methods rely on chemical precipitation or biological polyphosphate accumulation. Both of these methods are effective, but are not practical at all wastewater treatment facilities (e.g. biological accumulation needs specialized aerobic-anaerobic conditions that may not be present in all treatment systems). Biological Fe(III) reduction can lead to precipitation of the completely insoluble mineral vivianite, which would remain insoluble in secondary treatment sludge. It can be stimulated by adding bioavailable Fe(III) to promote Fe(III) reduction, and phosphate concentration dependent vivianite formation is favored at circumneutral pH or above. This is a simple amendment that can easily be “retrofitted” to any standard on-site wastewater (septic) system. This can be carried out by point of use individuals as the only functional aspect is to meter in bioavailable Fe(III) (as a liquid or amorphous semi-solid) to the wastewater. Fe(III) reduction in wastewater is limited due to low bioavailable Fe(III); therefore, this process will be easily stimulated by the addition. The objective of the proposed work is to quantify the rate of phosphorus (as soluble phosphate anion) removal from on-site treatment systems by stimulating Fe (III) reduction in the anaerobic portion of the septic system. Phosphorus will be removed as vivianite, and insoluble mineral with the formula Fe3(PO4)2-(H2O)8, which will precipitate and be removed by settling. Fe(II) will not accumulate as the reaction will be stoichiometric with respect to the phosphate concentration. Fe(III) reduction in wastewater is restricted by bioavailable Fe(III). It is a simple retrofit that can be implemented without additional infrastructure and negligible training or expertise. In the proposed research the microbial community will be monitored to identify an increase in Fe(III) reducer biomass; it is unlikely that bioaugmentation will be necessary to stimulate this process. This objective will be met by testing the following hypotheses: adding chelated Fe(III) (ligand bound-soluble Fe(III)) will stimulate vivianite formation and phosphorus precipitation in the aqueous volume of septic system waste; adding poorly crystalline Fe(III) plus electron shuttling compounds will stimulate vivianite formation in the flocculated and settled volume of septic sludge; 1.5 times stoichiometric Fe (III):PO43- addition (and subsequently Fe(II) to PO43-concentration) will completely remove PO43- without allowing soluble Fe(II) accumulation; vivianite will be the dominant mineral accumulated in the precipitate at several pH values; and the Fe(III) reducer population will increase without altering BOD removal by non-Fe(III) reducing heterotrophs; the increase can be monitored by basic molecular techniques. The proposed research is primarily a demonstration of the strategy; however, the data will be used as a baseline for scale up to the demonstration and validation level for the technology. The methods employed will include pure culture kinetics studies of vivianite formation with known Fe(III) reducing microorganisms, batch studies with material from phosphate-rich wastewater on-site treatment units, and sequencing reactor studies to mimic working on-site treatment systems with sporadic phosphorus input. The expected outcome of this research will be a strategy for phosphorus removal predicated on Fe(III) reduction that can easily be implemented at existing on-site treatment units without additional infrastructure.

**Sustainable Bioremediation: Distillers’ Dry Grains with Solubles (DDGS) and Wastewater Solids (WWS) as Novel Electron Donors for in situ Bioremediation**

K. T. Finneran*

*University of Illinois at Urbana-Champaign Research Board*

Distillers’ dry grains with solubles (DDGS) are a waste residual of the ethanol production industry. DDGS is an all-encompassing term that describes the conglomerate of soluble and insoluble mass that is leftover after the starch fraction of plant material has been fermented during ethanol production. The alcohol is recovered by distillation and the remaining fraction of fermented material is dried and recovered as bulk DDGS. It is referred to as a “co-product” rather than a waste product, but the limited number of markets available for DDGS versus the increasing production has generated a large amount of DDGS that is, in fact, wasted. Ethanol has been proposed as a “sustainable” biofuel, one that is particularly prevalent in the Corn Belt states, with Illinois among the top three producers in the nation. A significant amount of financial, political, and intellectual capital has already been invested in ethanol fuel in the United States, and all signs indicate that current and future administrations will pursue ethanol fuel as an alternative to refined petroleum. However, for a fuel to be truly “sustainable” it must be generated from
material that can be easily reproduced (which is still
debated but definitely possible), and it must not generate
waste materials that have no discernible use. DDGS negate
the second part of this equation for ethanol fuel. DDGS are
currently used as an animal feed supplement. The current
demand is smaller than the supply, as the United States
produces upwards of 12.5 million metric tons of DDGS
annually. This number is expected to increase at least three
times as ethanol production increases during the coming
decade. Given that the current market (animal feed) is too
small to deal with our existing surplus, it is fair to state that
DDGS will become a true waste of the ethanol industry,
which will limit its popularity amongst U.S. citizens and
have detrimental effects on ethanol fuel. Some ethanol
producers currently burn excess DDGS, which is not only
inefficient but also introduces CO2 directly to the
atmosphere. Ethanol may be an alternative fuel at the
moment, but it is far from sustainable. This need for DDGS
markets coincides with a need in another industry—the
bioremediation industry. This is a broadly defined
industry, which utilizes microbial activity to restore
contaminated environments, whether it is soil, sediment,
surface water, or groundwater. Bioremediation is often
predicated on adding a substrate (carbon and energy
source) to the contaminated environment to stimulate
microbial activity. There are three main issues to confront—
cost, raw material consumption to generate the
amendment, and efficiency with respect to the process
being stimulated. Many substrates are efficient; these are
typically the defined molecules such as acetate, lactate,
formate, vegetable oils, and hydrogen-generating
polymers that are sold under brand names by “electron
donor manufacturers.” The issue with these is cost and raw
material consumption; these substrates can cost several
dollars per pound to apply, which limits their use in a
number of applications, and they are produced only for
specific applications from raw materials. Many of these are
also short-lived, meaning they need to be continuously
applied, which increases cost and consumes more raw
materials. Other substrates are cheaper, but inefficient.
These include mulch and composted plant material. In
addition, these substrates have limited supply and require
that plant material be composted prior to use. The cost
savings are minimal when time and expense of production
are included. Data indicate that DDGS are as effective as
the more expensive, defined substrate molecules used for
bioremediation.

EcoLogically and Geomorphologically Based Methods
for Management and Regulation of Riparian
Anthropogenic Activities in Taiwan
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Taiwan, R.O.C.

In Taiwan, the annual precipitation reaches 2,510 mm,
which is about 2.5 times the world average. But, it is
concentrated in the period from May through October with
an amount of 75% of annual average. The peak discharge
per unit drainage area in Taiwan is the largest in the world
due to the high mountains and short drainage channel
lengths limited by shallow plains. These high discharge
events cause tremendous geomorphic changes in a
short period. Because of the diverse and plentiful
ecosystems, integrating the hydrological, ecologic, and
g geomorphic components for water resources
management is difficult.

The Taiwan Water Resources Agency (TWRA) has
made a commitment to the improvement of water resources
projects that must include ecological considerations to
protect the aquatic ecosystems. The primary activity in this
research is to develop hydrologic and ecological indicators
for Taiwan and to incorporate those indicators into the
decision-making framework for managing Taiwan's water
resources. The research accounts for the relations between
those indicators and geomorphic reactions and
incorporates adaptive management and other modeling
tools to protect and enhance environmental quality. It will
develop new methods of integrating ecological protection
schemes that are compatible with existing approaches that
protect water quality and the public health and safety.
Finally, the research will evaluate different policies under
high-flow events (e.g. typhoons) and low-flow events (e.g.
drought).

Development of Highly Efficient Aquaporin-Based
Membranes for Aqueous Separations
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University of Illinois, National Water Research Institute
(NWRI)

Aqueous separations are critical in several medical,
industrial, and municipal applications, including dialysis,
high quality process water preparation, ethanol
concentration, juice and aroma concentration, and
municipal drinking water and wastewater treatment
processes such as desalination. Reverse osmosis (RO) is a
common technology for such processes, but its use is
limited by the low productivities of existing membranes
and the corresponding requirements for high pressure and
investment of energy. We have recently demonstrated that

* Denotes principal investigator.
the bacterial water channel Aquaporin Z (AqpZ) can be functionally incorporated into an amphiphilic triblock (ABA) copolymer and that the productivity of this biomimetic membrane is up to two orders of magnitude higher than existing RO membranes. Optimization of synthesis of these membranes and evaluation of their stability is in progress. This study will advance fundamental knowledge in polymer chemistry and hybrid protein-polymer materials and enhance our ability to utilize and mimic efficient biological systems. At a more practical level, these biomimetic membranes have the potential to substantially reduce energy usage in desalination and other aqueous separations.

Carbon Monoxide Analysis for Highway Projects
S. M. Larson,* S. Peters
Illinois Transportation Research Center

A screening model is often a first step in analyzing potential air pollution problems, utilizing readily available data to make a conservative estimate of a source contribution to ambient pollutant concentrations. A more sophisticated model can be subsequently applied, if the screening model indicates its necessity. The screening model approach is not used for highway projects in Illinois now, but it could make the procedure for CO analysis for highways more efficient. In this project, screening and refined CO models for highway projects will be studied and validated. An acceptable CO screening model for Illinois highway projects will then be developed.

Climate Change and Atmospheric Chemistry
S. M. Larson,* Z. Tao, D. J. Wuebbles (Atmos. Sci.)
University of Illinois Critical Research Initiative

Changes in climate could alter rates of chemical reactions, paths of pollutant transport, and degree of pollutant removal. Emissions of pollutants may be indirectly impacted by climate variations due to adaptations, which, for example, change the amounts of fossil fuel burned. Researchers seek to predict the effects of climate change on the regional atmospheric environment. Objectives include outlining a suite of climate-change scenarios describing alterations in meteorological and emission parameters for selected regions in the Midwest, determining resulting equilibrium ambient concentrations of gaseous pollutants, and evaluating changes in compliance status and adaptation needs.

Improving the Novel Upflow Filter-Ultrafiltration (UF-UF) Process with Mathematical Modeling and Advances in Adsorbent Technology
B. J. Mariñas,* V. L. Snoeyink,* P. To, L. Ding, L. Schideman, S. Qi, G. Tang
National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS), University of Illinois at Urbana-Champaign

The objectives in this project are to improve the utility of UF-UF with mathematical modeling of key adsorption mechanisms and to improve UF-UF performance with new materials, configurations, and operating schemes. We have developed and tested a computerized adsorption model, COMPSORB, for a fixed granular adsorption bed that includes the effect background natural organic matter (NOM) has on trace compound (TC) adsorption. The model includes three key mechanisms observed to reduce an adsorbent’s capacity and uptake rate of TCs: direct competition by a strongly competing fraction of NOM, pore constriction by a pore blocking fraction of NOM, and reduction of the film diffusion coefficient. To test our model, we have completed experiments to determine model input parameters and longer-term model verification experiments. We have initiated work on the factors that affect desorption of trace compounds and the incorporation of these effects into our model.

Inactivation Kinetics of Adenovirus with Chemical and Photon-Based Disinfection Processes
B. J. Mariñas,* K. Sirikanchana, M. A. Page, T. vonder Haar
National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS); Royal Thai Government Fellowship; University of Illinois

Adenoviruses are viral pathogens of emerging concern in drinking water. Both respiratory and enteric types have been found to possess higher resistance to ultraviolet light (UV) disinfection compared to all other viral, bacterial, and protozoan waterborne pathogens. The objective of this project is to assess the occurrence of synergetic effects and to elucidate the kinetics of sequential inactivation of adenovirus type 2 when treated with monochloramine after primary disinfection with UV or free chlorine. Experiments are performed with synthetic solutions tested in batch reactors and the infectivity of adenovirus is assessed by a plaque assay method using a human cell culture.

* Denotes principal investigator.
Integrated Approach for the Control of Cryptosporidium parvum Oocysts and Disinfection By-Products in Drinking Water Treated with Ozone and Chloramines

B. J. Mariñas,* R. A. Minear,* H. Lei, J. Kim
U.S. Environmental Protection Agency, STAR Grant Program, EPA R826830-01-0

Experimental tasks are designed for the simultaneous study of C. parvum oocyst inactivation and selected DBP (bromate, formaldehyde, and cyanogen halides) formation in natural waters treated with ozone and chloramines in various reactor configurations. An integrated predictive model will be developed, calibrated with experimental results, used to determine optimum process design, and verified in full-scale systems using fluorescent-dyed polystyrene microspheres as surrogate indicators for C. parvum oocysts.

The overall goal of this project is to develop process design recommendations for the simultaneous control of Cryptosporidium parvum oocysts and disinfection byproducts (DBPs) in natural waters treated with ozone and chloramines.

Mechanisms for the Inactivation of C. parvum Oocysts with Chemical Disinfectants

B. J. Mariñas,* B. Corona-Vasquez
National Council of Science and Technology (CONACYT)-Mexico; University of Las Américas-Puebla Fellowship

The objective of this study is to investigate the mechanism of inactivation of C. parvum oocysts with chemical disinfectants applied singly or in sequential combinations. The chemical disinfectants of interest are ozone, chlorine dioxide, free chlorine, and monochloramine. More specific objectives are identification of inactivation target(s) for chemical disinfectants in the C. parvum oocyst; investigation of the interactions among chemical disinfectants and oocyst wall components of relevance to the presence or absence of synergism in sequential disinfection schemes; and development of a mechanistic model for the inactivation of this pathogen with single and sequential application of chemical disinfectants.

Reverse Osmosis/Nanofiltration (RO/NF) Membrane Systems with Enhanced Water Permeability and Contaminant Rejection Capability

B. J. Mariñas,* J. Moore, T. Suzuki
National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS), University of Illinois at Urbana-Champaign

The overall objective of this project is the development and characterization of RO/NF membrane materials and systems with enhanced capability for water permeability and rejection of water contaminants. Initial efforts are being directed at characterizing properties of commercial RO/NF membranes affecting solute/macromolecule permeation. Membrane samples are being analyzed by atomic force microscopy, scanning electron microscopy, gas adsorption/desorption, and Rutherford backscattering techniques. Experimental results are being evaluated to elucidate the mechanisms controlling the permeation of water contaminants through RO/NF membranes with the ultimate goal of providing information needed for developing new, more effective membrane polymers.

Solute Displacement and Pore Blockage Phenomena in Hybrid Sorption-Membrane Processes

B. J. Mariñas,* V. L. Snoeyink,* L. Ding, G. Tang
National Science Foundation, 0123281

The objective of this research is to develop a fundamental understanding of the pore blockage and solute displacement phenomena of competitive adsorption of trace organic compounds on powdered activated carbon (PAC) in natural waters. This information is applied to

* Denotes principal investigator.
develop mechanistic expressions for these effects that are incorporated into mathematical models of hybrid sorption-membrane processes. Adsorption studies are conducted using a mixture of atrazine as a trace contaminant and probes as surrogates for natural organic matter (NOM). The multicomponent kinetic model is validated with experiments performed with a flow-through PAC/microfiltration (MF) membrane reactor.

Strategies for Integrated Control of Surface Water Pathogens and Biological Agents
B. J. Mariñas,* M. Page
U.S. Environmental Protection Agency; The Midwest Technology Assistance Center for Small Public Water Systems

Small water systems are faced with the challenge of providing protection against a range of microbial contaminants, including opportunistic waterborne pathogens such as Cryptosporidium parvum oocysts as well as biological agents that could be used during acts of terrorism. In response to these new challenges, the overall objective of this project is to develop cost-effective strategies for the integrated control of surface water pathogens, and biological agents by small communities. The approaches considered focus on the modification of existing processes and/or the integration of new technologies into existing treatment systems in order to avoid high capital investment related to overall technology replacement. Additional important criteria are the robustness and automation capability of selected technologies with the goal of minimizing the operation and maintenance of the overall system, and the need for on-site operators.

Transport of Solutes and Macromolecules through Reverse Osmosis and Nanofiltration Membranes
B. J. Mariñas,* B. Mi, O. Coronell
National Science Foundation Award, BES-0332217

The mechanisms by which water contaminants permeate through reverse osmosis (RO) and nanofiltration (NF) membranes are being elucidated. Selected solutes and macromolecules are arsenious acid, Rhodamine WT, and three coliphages. The scope of work of the project is designed to develop a fundamental understanding for the mechanisms responsible for the permeation of water and solutes through RO and NF membranes, including elucidating the role of concentration polarization in the overall transport. Experiments are designed to characterize the contribution to overall solute permeation by adsorption/diffusion/desorption through membrane polymer matrix and advection through membrane nanopores. The size distribution of nanopores in the membranes is being characterized by atomic force and scanning electron microscopy and by gas adsorption/desorption techniques.

Adaptive Environmental Sensing and Information Systems (AESIS) Initiative
B. Minsker,* J. Braden, X. Cai, D. Fazio, J. Garcia, M. Ruiz, M. Sivapalan
University of Illinois, 2006-2009

The AESIS Initiative is exploring the role of adaptive sensing and information systems for enabling improved understanding and management of the urban environment, focusing on the Chicago metropolitan area. Six exploratory projects are focusing on developing digital watersheds, real-time stormwater information and management systems, and urban watershed models for Salt Creek watershed; data collection and research on water use and discharge to support decision-making tools for conservation-oriented water management policies; and using real-time sensing in stormwater catch basins to analyze the role of hydrologic conditions and catch basin design in mosquito prevalence and intensity of West Nile Virus.

Coalition for Creation of CLEANER Project Office
B. S. Minsker,* C. Haas, J. Schnoor, R. Hooper
National Science Foundation, 0533513, 2005-2008

This cooperative agreement establishes a project office to conduct planning and consortium development for this environmental observatory initiative. Key elements of the project office activities include collaborating with the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) to develop a preliminary program plan for the WATer and Environmental Research Systems (WATERS) Network, and identifying and broadly engaging the environmental engineering science and social science research and education communities in consensus-building activities. The program plan will include the research agenda, sensor and measurement plan, cyberinfrastructure and organizational plan, and the role and benefits for education.

Collaboration Support for Observation and Model-Based Decisions
B. S. Minser,* L. Marini

Our research is studying how to improve awareness among remote users during a crisis or for policy making. We are developing a software framework for scientific workflow * Denotes principal investigator.
management called Cyberintegrator together with other researchers at NCSA. This open system is being used to connect tools for accessing sensor data in near-real time to anomaly detection algorithms, numerical models, and data-driven hypoxia models in Corpus Christi Bay, Texas. We are investigating a suite of anomaly detection methods and visualization approaches for integrating data and modeling results to provide a real-time assessment of the state of the bay.

**An Environmental Information System for Hypoxia in Corpus Christi Bay: A WATERS Network Testbed**

B. Minsker,* J. Bonner, B. Hodges, D. Maidment, P. Montagna, T. Ojo  
*National Science Foundation, 0609545, 2006-2008*

This project is creating a prototype Environmental Information System (EIS) that couples sensor measurements with end-to-end cyberinfrastructure to improve understanding of hypoxia in Corpus Christi Bay (CCBay), Texas by: creating an Environmental Data Access System for CCBay data archives, leveraging CUAHSI Hydrologic Information System Web service developments to create data services that automatically ingest observed data in remote archives; leveraging NCSA’s cyberinfrastructure technologies to create an Environmental Modeling System for CCBay hypoxia, combining multiple numerical models with machine learning algorithms; and demonstrating the effectiveness of the EIS for supporting adaptive hypoxia sampling and collaborative research.

**A New Framework for Adaptive Sampling and Analysis during Long-Term Monitoring and Remedial Action Management**

B. S. Minsker,* B. Bailey, A. Valocchi, R. Johnson  

Federal agencies are making a significant investment in the development of new monitoring technologies that will have a profound impact on the way environmental monitoring is conducted. Designing and using these types of monitoring networks effectively will require development of a new paradigm for sampling and analysis of remedial actions. This project’s goals are to create an adaptive framework that will enable effective interpretation of nonintrusive monitoring data, improve predictions and assessment of remediation performance, develop decision rules for on-site adaptive sampling and analysis, and enable more informed decision making and risk analysis of long-term monitoring systems.

**CAREER: Detachment from Biofilms under Dynamic Operating Conditions—Integrating Fundamental Research and Practical Biofilm Modeling Education**

E. Morgenroth*  
*National Science Foundation, BES-0134104*

The overall objective of this proposal is to determine the influence of dynamic variations of shear stress on biofilm detachment. Mechanisms of biofilm detachment are poorly understood and procedures for the design and operation of biofilm reactors are mainly empirical. This project uses laser backscattering to continuously monitor the size of detached particles. Online techniques for measuring bacterial respiration rates within the biofilm reactor will be developed and used to correlate overall biofilm reactor performance with detachment dynamics. Detached particles will also be characterized for strength, surface hydrophobicity, surface charge, and abundance of nitrifying bacteria.

An improved understanding of how external conditions (i.e. shear forces) can be used to influence the microbial ecology of biofilms will help to improve the application of beneficial biofilms and help to develop strategies to reduce unwanted biofilms.

**Influence of Bioaugmentation Using In-Pipe on Sewer Processes and the Microbial Community in Sewer Biofilms**

E. F. Morgenroth,* J. Zilles  
*In-Pipe Technology*

The primary purpose of sanitary sewers is to collect wastewater and to transport it to biological wastewater treatment plants. During this transport, some of the contaminants are already degraded. This degradation is to a large extent based on bacteria attached to sewer pipes—so called biofilms. In the current project, we are evaluating methods to influence the composition and function of these microbial biofilms by bioaugmentation.

**Membrane Bioreactors for the Reuse of Wastewaters**

E. Morgenroth*  
*Illinois Agricultural Experiment Station, (HATCH) ILLU-35-0376*

We anticipate that membrane bioreactors (MBRs) will become a key technology in wastewater reclamation and reuse. New approaches for water management are needed as the United States and the world are facing real dangers of depleted aquifers, inadequate surface water supplies, and contamination from agricultural runoff, industrial emissions and spills, acid rain, and domestic sources. Today, direct reuse of wastewater and groundwater

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* Denotes principal investigator.
recharge using treated wastewater is applied in arid regions (e.g., Water Factory 21, Orange County Water District, California). The U.S. Department of Agriculture has made the reuse of treated urban wastewaters, recycled drainage waters, and other low-quality waters for irrigation and other agricultural an explicit part of its Action Plan for Water Resource Management. For MBRs to become more widespread in water reuse, they need to become more economical and more reliable. The proposed research will contribute to this goal and will provide a fundamental understanding of processes governing MBR operation. This project will evaluate mechanisms of membrane fouling and the practical implementation of MBR in agricultural, industrial, and municipal settings.

**Perchlorate Removal from Concentrated Wastewater Using a Hydrogen Enhanced Biofilm Reactor**

E. Morgenroth*

*U.S. Army Construction Engineering Research Laboratory, W9132T-05-2-0025, Grant A5635*

The objective of this project is to evaluate and compare three hydrogen-based technologies for the treatment of concentrated wastewaters containing perchlorate and RDX. The three technologies are gas-lift biofilm reactor, moving bed biofilm reactor, and biomass separating membrane bioreactors. Hydrogen gas is introduced into the reactors as the electron donor and gas will be recirculated to provide mixing. Results from continuous reactor operation and batch experiments will be used to provide kinetic parameters that can be used to model these reactor systems and as a basis for scale-up.

**The Influence of Shear on Membrane Fouling and Biological Processes in Anaerobic and Aerobic Membrane Bioreactors**

E. Morgenroth*

*National Science Foundation, CTS 01-20978 (3B.2a)*

Membrane bioreactors can produce water from wastewater that, in combination with further treatment, is suitable for potable or nonpotable reuse. The main objective of this project is to evaluate to what extent novel membrane materials with "antifouling" properties can allow for a long-term operation of membrane bioreactors without the need of frequent membrane cleaning? To answer this question, the following specific research questions are being addressed: What are the mechanisms leading to membrane fouling in anaerobic and aerobic membrane bioreactors? How does reactor operation influence the microbial production of foulants? To what extent can reactor operation be modified without harming the biological processes? Can new membrane materials reduce the rate of fouling, reduce the extent of fouling, change the dominant fouling mechanism, or improve the effectiveness of physical or chemical membrane cleaning?

**Effects of Discharge Permit Trading on Water Quality Reliability**

T. L. Ng, J. W. Eheart*

*Universiti Teknologi PETRONAS, University of Illinois*

Transferable discharge permit (TDP) programs show potential as cost-effective methods of pollution control. Nevertheless, there remain uncertainties that if not adequately addressed, might impair their success. Concerns include modeling difficulties that might cause erroneous predictions of cost savings and environmental performance. This study focuses on environmental modeling associated with the stochastic environment. Environmental quality reliability is defined as the probability of meeting a minimum dissolved oxygen (DO) concentration standard over the length of the river, given the uncertainty in the assimilative capacity of the river for discharges of material containing biochemical oxygen demand (BOD). The mean-value first-order second-moment (MFOSM) method is extended to demonstrate how changes, due to discharge permit trading, in the environmental quality mean and/or variance of a system, will cause the environmental quality reliability of the system to decrease, increase, or remain unchanged. The Willamette River in Oregon and the Athabasca River in Alberta, Canada, are used as example case studies and are simulated to predict how they might respond if trading were implemented.

**Development of Effective Removal Technology for Pathogenic Viruses without Creating Disinfection Byproducts: Iron Oxide Coated Fiberglass for MS2 Bacteriophage and Rotavirus Removal**

T. H. Nguyen,* J. Economy

*National Science Foundation Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS); Fulbright Foundation*

This research is intended to test the sorption capacity and inactivation of a glass fiber substrate coated with iron oxide for the removal of bacteriophage MS2 and rotavirus from water. The iron oxide tested is a hematite (2 to 20 nm particle size, 80 m2g-1 surface area) synthesized by J. Economy’s group.

**Interactions of Bacteriophage MS2 with Natural Macromolecules**

T. H. Nguyen,* S. Granick, G. Wong

*National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems*
We hypothesize that the interactions between virus particles with themselves and with background components such as natural organic matter, alginate, and algae chlorophyll affect the efficiency of disinfection. These interactions depend on the surface properties of the viruses and the solution chemistry, including solution pH, ionic strength, cation valence, and concentrations. We will use three complementary techniques to investigate interactions of bacteriophage MS2 with natural macromolecules (i.e. natural organic matter, alginate, and cellulase). The variables to be tested are solution ionic strengths, pH, and divalent cation concentration (Mg$^{2+}$ and Ca$^{2+}$). Fluorescent correlation spectroscopy (FCS) will be performed by Granick’s group to track diffusion time of fluorescent-labeled MS2 with and without NOM solution in the solutions of systematically varied composition. X-ray scattering will be performed by Wong’s group to study interactions of MS2 with silica nanoparticles functionalized with carboxyl groups, the most abundant functional groups of NOM. Nguyen’s group uses quartz crystal microbalance to study attachment of MS2 onto surfaces coated with NOM.

Investigating the Spread of Antimicrobial Resistance near Animal Facilities: Mechanisms of Extracellular DNA Transport and Transfer
T. H. Nguyen,* J. Zilles
Civil and Environmental Engineering Department

The dissemination of pathogens from animal production systems is an important public health concern, and it is compounded by the fact that many of these pathogens are resistant to antimicrobials. We propose to investigate the fate of the antimicrobial genes using an interdisciplinary approach to identify physical and chemical factors in the lagoon and soil environments that control their transfer to other microorganisms. The resulting relationships will be used to develop a model to predict the fate and transport of oocysts in the near-surface environment. The objectives of this project are: to determine the attachment and detachment rates of C. parvum oocysts on inorganic (i.e. quartz, aluminum oxide, iron oxide) and organic (i.e. coated with natural organic matter, alginate, and cellulase) soil surfaces on a microscopic scale; to investigate the role of oocyst wall macromolecules in the transport of C. parvum oocysts by systematically modifying the oocyst walls; to determine the transport of C. parvum oocysts in a near-surface environment on a macroscopic scale; and to develop a deterministic model to predict the loading of C. parvum oocysts in overland and near-surface runoff. The experimental approach ranges from a microscopic to a macroscopic scale.

Understanding the Spread of Antimicrobial Resistance around Animal Production Environments: Mechanisms of Extracellular DNA Transport and Gene Transfer
T. H. Nguyen,* J. L. Zilles
University of Illinois

We are investigating the fate of antimicrobial resistance genes in animal production environments through the identification of physical and chemical factors in the lagoon and soil environments that control their transfer to other microorganisms. The resulting relationships will provide a basis for evaluating risk and identifying novel measures with the potential to control the spread of antimicrobial resistance, such as timing the land application of manure or choosing fields with soil and water chemistry that minimizes transfer. We hypothesize the following: the persistence and mobility of extracellular DNA will depend on solution composition; and the transformation of extracellular DNA will be controlled primarily by physical and chemical parameters. These hypotheses will be tested using techniques from interfacial chemistry and pure culture transformation assays. The resulting relationships will be tested in more complex systems by evaluating the frequency of gene transfer in manure-amended soil columns and column effluent using fluorescent reporter genes and automated microscopic counts.

Roles of Cryptosporidium parvum Oocyst’s Surface Proteins on Attachment
T. H. Nguyen*
National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems

* Denotes principal investigator.
Capture of Emissions from Utilities
M. J. Rood,* M. Rostam-Abadi, Y. Liu
Electric Power Research Institute (EPRI), EP-P 17846
New methods to capture and remove pollutants from flue gas streams that are generated by the combustion of coal are developed for future potential applications.

Decision-Based Environmentally Conscious Design
M. J. Rood,* D. Thurston,* H. Emamipour, A. Kaldate
National Science Foundation, DMI 02-17491 MR
Certain design projects are vulnerable to decision biases that result in irrational and inconsistent decision-making. Environmentally conscious design (ECD) falls into this category. This project develops a rational decision-based design framework for ECD that overcomes current difficulties. An adsorption electrothermal-swing air pollution control technology is used as the testbed for this research.

Development of Emission Factors for the Dust Generated by Unique Military Activities
M. J. Rood,* K. Du
Engineering Research and Development Center, U.S. Army Construction Engineering Research Laboratory, W9132T-05-2-0006
There are numerous sources that emit particulate material to the atmosphere with unknown source strengths. Remote sensing techniques are under development to quantify the mass emission rates of particulate material from unique military sources.

Digital Optical Method Development and Certification
M. J. Rood,* K. Du
Engineering Research and Development Center, U.S. Army Construction Engineering Research, A 5755 Army W9132T-05-2-0022
A rapid response, accurate, and inexpensive optical sensing technique is under development to quantify the opacity of plumes caused by point source emissions and fugitive emissions. The method has the capability to be used as an alternative to Method 9 as established by the U.S. Environmental Protection Agency.

Microwave-Swing Adsorption to Capture Hazardous Air Pollutants and Volatile Organic Compounds from Gas Streams
M. J. Rood,* J. Bernhard, Z. Hashisho
National Science Foundation, A5783 NSF BES 0504385
A new microwave-swing adsorption system is under development at the bench scale to capture and recover or destroy organic vapors from gas streams. Valuable organic vapors will be captured from gas streams and converted into a liquid for reuse. Less valuable organic vapors will be destroyed in a more cost effective manner when compared to existing technologies.

Optimization of VaPRRS Technology for Commercialization
M. J. Rood,* D. Thurston, D. Ramirez
The Grainger Foundation Inc., 1-627565-251005-191100
An electrothermal-swing adsorption system is under development at the pilot-scale to capture and recover organic vapors from gas streams. Trace concentrations of organic vapors are readily captured from gas streams and converted into a liquid for reuse in the process that generated the organic vapor. This technology allows for a more sustainable environment when compared to destructive technologies such as thermal oxidizers.

Steady-State Desorption of ACFC Adsorption/Desorption Systems
M. J. Rood,* H. Emamipour
Engineering Research and Development Center, U.S. Army Construction Engineering Research Laboratory, A5639 FA8651-04-1-0004
Many organic vapors are emitted into the atmosphere that need to be captured and either destroyed or recovered. This new technology will allow conventional organic vapor control technologies to capture those vapors more effectively and at much lower cost.

Vapor Recovery by Electrothermal Swing Adsorption
M. J. Rood,* H. Emamipour
Engineering Research and Development Center, U.S. Army Construction Engineering Research Laboratory, A5820 Army W9132T-05-2-0019
A novel electrothermal-swing adsorption system is underdevelopment to capture and recover and/or destroy organic vapors from gas streams before the vapors are emitted to the atmosphere.

Predicting Adsorption Isotherms Using Polyparameter Linear Free Energy Relationships
V. L. Snoeyink,* T. H. Nguyen, Q. W. Chow
Public Utilities Board in Singapore; University of Illinois at Urbana-Champaign
The goal of this research is to develop a model that is able to predict the adsorption capacity of activated carbon in natural water based on the molecular properties of the trace organic contaminant. We are exploring the use of polyparameter linear free energy relationships, which have been successful in predicting the equilibrium partition.

* Denotes principal investigator.
coefficients of organic compounds between water and Natural Organic Matter (NOM) in soils and sediments. The competitive effects of NOM with trace organic contaminants for activated carbon adsorption could be accounted for in this model by assuming that the molecular properties of NOM are similar to a specific polar trace contaminant (e.g. atrazine).

**Abiotic Reductive Transformation of Organic Contaminants by Iron(II)-Organic Complexes**

T. J. Strathmann,* D. Naka, D. Kim, A. Bussan

*American Chemical Society’s Petroleum Research Fund; University of Illinois Environmental Council; South Korean Military*

A number of aquatic contaminants are susceptible to reductive transformation processes, including nitroaromatic, nitramine, and halogenated organic contaminants. Contamination of soil and groundwater by these substances presents a serious environmental problem because many are persistent and toxic. Therefore, it is imperative to understand and predict the processes that control their fate in diverse environmental systems. This project examines the abiotic reductive transformation of organic contaminants in anoxic systems containing both iron(II) and natural organic constituents. It is hypothesized that iron(II)-organic complexes that form in these systems are potent reducing agents that promote the rapid reduction of aquatic contaminants. Reaction rates and products are systematically measured in solutions of varying composition (e.g., pH, [FeII]/[organic] ratio). Reaction rates are compared with the prevailing iron(II) speciation and contaminant structure to identify important mechanistic features of the reactions.

**Development of a Sustainable Catalytic Treatment Process for Perchlorate**

T. J. Strathmann,* C. Werth, J. Shapley (Chem.), J. K. Choe

*National Science Foundation, Division of Chemical, Bioengineering, Environmental, and Transport Systems*

Perchlorate (ClO4-) treatment is especially challenging because of the ion’s kinetic inertness and low affinity for common water treatment adsorbent materials. In this project we intend to advance our understanding of a novel Pd-Re bimetal catalyst system and its applicability for treating perchlorate-contaminated water and ion exchange regenerant brine solutions, and to evaluate the technology’s sustainability. These objectives will be met through a combination of efforts, including the following: synthesizing new catalysts that are more active under natural water conditions and are resistant to fouling by nontarget water constituents; developing a mechanistic-based heterogeneous kinetic model for predicting catalyst activity in source waters with varying composition; assessing the fouling/regeneration and long-term stability of the catalysts; and evaluating the environmental sustainability of catalytic treatment processes in comparison to conventional approaches.

**Metal-Catalyzed Reduction of Wastewater-Derived Organic Micropollutants**

T. J. Strathmann,* A. Frierdich, L. Knitt, C. Joseph, J. Shapley (Chem.)

*National Science Foundation, Center of Advanced Materials for Water Purification with Systems (WaterCAMPWS)*

Advances in analytical chemistry have led to an increased awareness in the water supply industry that a number of trace organic contaminants are present in treated drinking water and wastewater, as a result of either incomplete treatment (e.g., pesticides, pharmaceuticals) or as byproducts of treatment processes themselves (e.g., disinfection byproducts). A number of advanced treatment options are currently being examined by researchers, but the efficiency of many of these processes suffers from poor compound selectivity. Because of their inherent selectivity, reductive processes can be used to efficiently treat contaminants that contain highly oxidized functional groups within their structure (e.g., halogenated carbon atoms). This project examines the use of hydrogen-activated metal catalysts (e.g., Raney Ni, supported Pd) to reductively treat micropollutants of concern to the water supply industry, including disinfection byproducts and select pharmaceutical agents. Results may lead to a novel treatment strategy for producing higher quality effluent.

**Oxidation and Removal of Pharmaceutically Active Compounds during Water Treatment with Permanganate and Ferrate**


*American Water Works Association Research Foundation*

Widespread detection of pharmaceutically active compounds (PhACs), even at concentrations in the ng/L to μg/L range per liter range, has raised public concerns about the quality and safety of drinking water supplies. Several classes of PhACs have been detected in drinking water sources, including antibiotics, antiphlogistics, analgesics, lipid regulators, synthetic steroid hormones, and x-ray contrast media. This project aims to characterize the oxidation of representative PhACs by potassium permanganate (KMnO4) and ferrate (K2FeO4) salts, and to
assess the potential use of these reactions to degrade problematic PhACs during drinking water treatment operations. Results from experimental work will be used to develop a predictive model that can be used by the water treatment community to estimate the extent of PhAC removal from diverse source waters under different process operating conditions. PhAC oxidation byproducts will also be identified using advanced analytical techniques.

**Photocatalytic Transformation of Organic Micropollutants by Nanophase Titanium Oxide Materials**

T. J. Strathmann,* L. Hu, T. Paul, P. Miller (Rose-Hulman Instit. of Tech.)

*National Science Foundation, Center of Advanced Materials for the Purification of Water with Systems (WaterCAMPWS)*

Recent reports indicate that a number of emerging classes of organic pollutants (e.g., disinfection byproducts, pharmaceutically active compounds, personal care products) are pervasive in aquatic environments and recalcitrant toward conventional treatment technologies. As a result, there is growing interest in the development of novel treatment technologies that can efficiently destroy these compounds in waste streams. This project examines the aqueous photocatalytic degradation of emerging organic micropollutants using nanophase titanium dioxide materials. Special emphasis is being placed on characterizing pollutant transformations that occur when catalyst materials are exposed to visible light (wavelengths greater than 400 nm), since a larger fraction of the solar spectrum falls in the visible light range compared with the ultraviolet light range.

**Carbonaceous Material Fractions in Sediments and Their Effect on the Sorption and Persistence of Organic Pollutants in Small Urban Watersheds**

C. Werth,* P. Van Meter, B. Mahler (USGS); Y. Yang, S. Jeong

*National Institutes for Water Research; U.S. Geological Survey*

Particle-associated contaminants (PACs) are an important contributor to urban nonpoint source pollution across the nation. PACs, which include organochlorine compounds, metals, and PAHs, pose a threat to biota in aquatic systems and humans because many are persistent, bioaccumulative, and toxic. The overall goal of this work is to determine how carbonaceous material fractions in urban reservoir sediments affect the persistence of PACs. The study, a collaborative effort between the University of Illinois and the U.S. Geological Survey NAWQA program (RTNS team), will investigate the evolution of carbonaceous materials, and the associated PACs and sorption mechanisms, as they move from the land surface (soils and street dust) into the water column as suspended sediment, to their deposition in the receiving water body and subsequent burial. The study will focus on the Lake Como watershed in Fort Worth, Texas, because lake sediments cores have previously been collected and analyzed for PAHs by the RTNS team.

**Reducing Ammonia Volatilization and Odor Formation from Treated Swine Manure**

P. Walker, E. Morgenroth*

*Illinois Environmental Protection Agency*

Land application of residuals from animal production is limited by the regional and seasonal nutrient requirements for soil enrichment. Current residual management relies predominantly on direct land application. The overall goal of this project is to develop process technologies that provide farmers with greater flexibility and security in their animal residual treatment. Sequencing batch reactors will be evaluated as a biological treatment technology to reduce odor and ammonia volatilization and to selectively remove nitrogen. This technology will be integrated with the existing technology of process automation systems (PAS) of swine manure.

**Dissolution and Cleanup of Nonaqueous Phase Liquids in Heterogeneous Porous Media**

C. Werth,* C. Zhang

*National Science Foundation; University of Illinois Research Board; Shell Oil Company*

Predicting dense nonaqueous phase liquid (DNAPL) dissolution rates in the field is a critical first step to determining downgradient concentrations in groundwater, the risk that DNAPLs pose to potential receptors, design parameters for remediation technologies, and cleanup times and subsequent site management approaches. Recent studies indicate that the source zone configuration (or architecture) of DNAPLs is the primary factor governing dissolution. Scientists and practicing engineers do not currently have an adequate method or approach to account for the effects of source zone architecture on DNAPL dissolution in the field. The objectives of this work are to determine correlations between DNAPL distribution and permeability distribution for different spill scenarios, to determine the relationship between these correlations and the DNAPL dissolution rate, and to develop DNAPL distribution and scale-dependent mass transfer correlations that can be used to predict DNAPL dissolution using only

* Denotes principal investigator.
field measurable parameters. To achieve these objectives, we directly image residual NAPL saturation during dissolution in a 3-D heterogeneous permeability field packed into a flow cell. These measurements are used to calculate mass transfer rates, and correlate them to the distribution of permeability and NAPL saturation.

Gene Expression and Adaptation for Herbicide Degradation in Porous Media
C. Werth,* J. Zilles, R. Müller
United States Department of Agriculture

This work focuses on the interactions between physical and chemical gradients in porous media and their influence on gene expression, adaptation, and growth. C. Werth has developed a micromodel system for studying porous media, and he has characterized and modeled the flows and chemical gradients that develop in these systems. The current project aims to combine this work with fluorescently labeled microorganisms to investigate the relationship between the chemical gradients and gene expression, and to determine the relative fitness of specialist versus generalist strains in this heterogeneous environment. The project will focus on two chlorinated phenoxyalkanoic acid herbicides, 2,4-dichlorophenoxyacetate (2,4-D) and the R enantiomer of 2-(2,4-dichlorophenoxy) propionate ((R)-2,4-DP).

Preliminary results indicate that (R)-2,4-DP degrading microbes can evolve to express activity for 2,4-D.

Influence of Wetting and Mass Transfer Properties of Organic Chemical Mixtures in Vadose Zone Materials on Groundwater Contamination by Nonaqueous Phase Liquids
C. Werth,* A. J. Valocchi, H. Yoon, M. Oostrom
U.S. Department of Energy

Carbon tetrachloride was used to extract plutonium by the Department of Energy in Hanford, Washington. Used carbon tetrachloride was typically discharged to the ground surface with other chemicals and allowed to infiltrate into the vadose zone. As a result of this practice, over 750,000 kg of carbon tetrachloride was released. An estimated 64% of this amount remains as a nonaqueous phase liquid (NAPL) in the vadose zone. Despite this estimate, the presence of NAPL has not been observed in soil cores, and efforts to remove CCl4 using soil vapor extraction have resulted in removal of only 10% of the estimated original mass. These observations indicate that either the conceptual model used to calculate CCl4 mass is incorrect, or NAPL volatilization during SVE is far below what one would expect. As a result, it difficult to determine if CCl4 in the vadose zone contributes to groundwater contamination at the Hanford site, or if continued SVE efforts will mitigate this contribution. Previous studies have found that organic acids, organic bases, and detergent-like chemicals change surface wettability. The wastewater and NAPL mixtures discharged at the Hanford site contain such chemicals, and their proportions likely change over time due to reaction-facilitated aging. The objectives of this project are to determine the effect of organic chemical mixtures on surface wettability, determine the effect of organic chemical mixtures on CCl4 volatilization rates from NAPL, and accurately determine the migration, entrapment, and volatilization of organic chemical mixtures at the Hanford site.

Reductive Removal of Nitrate and Trace Contaminants from Water Using Metal Catalysts
C. Werth,* J. Shapley, B. Chaplin, E. Roundy
National Science Foundation, Center of Advanced Materials for Water Purification with Systems

Simpler, less expensive, and more efficient solutions are needed to remove nitrate from both public and (especially) domestic water supplies. One promising approach involves hydrogenation of nitrate to dinitrogen gas using supported bimetallic metal catalysts with dihydrogen or other reducing agents. A recent survey identified palladium on alumina as having the best combination of activity and selectivity for nitrate reduction to dinitrogen. Also, the selectivity for dinitrogen production from nitrate is markedly enhanced when palladium is combined with a second metal such as copper, tin, or indium. However, selectivity is still a problem, as nitrite and ammonia production can exceed mandated levels. Also, nitrate reduction in systems with multiple contaminants and microbial growth has not been adequately addressed. The overall goals of this work are to develop Pd/M/support catalysts for selective denitrification of nitrate to dinitrogen and to examine the catalysts’ performance under groundwater treatment conditions. The specific objectives of this work are to determine the effects of different Pd/M/support catalysts on nitrate reduction in natural waters, determine removal rates and the effects of co-contaminants on Pd/M catalyzed nitrate reduction, and develop a pilot-scale reactor capable of reducing nitrate in a groundwater well.

* Denotes principal investigator.
Fusing Information from Multiple Sources of Observation for the Identification and Calibration of Complex Environmental and Hydrological Models

H. Xie, J. W. Eheart,* B. Bailey, P. Kumar, Y. Chen, X. Cai
University of Illinois

The identification of conceptual environmental and hydrological models is subject to the amount and quality of data available. Nowadays, up-to-date complex models have the capability to simulate a range of processes occurring in a watershed simultaneously and modern monitoring technologies are providing more and more observations of these processes from various perspectives. Fusing the information from multiple sources will enhance the performance of identification but presents challenges in assessing the confidence to be placed in the model, since data from such multiple sources vary in quality. The ongoing study serves the purpose of developing the methodology to manage and utilize the data from multiple sources for identification and calibration of complex environmental and hydrological models. We follow Bayesian principles in statistical inference, which provide a natural and coherent conceptual framework for information fusing and allow exposing the potential deficiencies and inconsistencies in model structure. Furthermore, in view of the development of computation technology in recent years, more computationally efficient algorithms are also designed to implement the framework.

Thermo-Chemical and Biological Conversion of Biomass for Renewable BioEnergy in ACES

Y. Zhang,* S. Chen, T. Funk, A. Hansen, E. Morgenroth, X. Wang
Illinois Council on Food and Agricultural Research (C-FAR)

The overall goal of this project is to evaluate a range of processes to produce renewal energy from biomass derived from animal or crop production or processing. The specific aspect of this project that is addressed is the evaluation of biological hydrogen production from co-products generated during ethanol fermentation. An upflow anaerobic reactor will be developed to convert distillers dried grains with solubles into hydrogen gas with the specific objectives of increasing the yield and the reliability of hydrogen production.

Fate of Antibiotics and Antibiotic Resistance Genes in Swine Waste Treatment

J. Zilles,* L. Raskin, Z. Zhou, M. Robert
Agricultural Research Service, United States Department of Agriculture; National Pork Board

The application of antibiotic feed additives to enhance growth rate and feed efficiency is widely practiced in the swine industry. There is concern over the continued use of antibiotics for growth promotion and prophylaxis (prevention of disease) because of increased potential for colonization of the gut by pathogenic bacteria and the spread of antibiotic resistance in the wider environment through waste. This research investigates the levels of antibiotics and resistant microorganisms in swine waste treatment processes and manure amended soils to better characterize this potential hazard and identify practices to minimize it.

Microbial Ecology and Physiology of Enhanced Biological Phosphorus Removal Wastewater Treatment Processes

J. Zilles,* T. Greeley
University of Illinois

Although enhanced biological phosphorus removal processes are widely used, the microbiology of the process is poorly understood and likely contributes to long start-up times and, in some cases, unstable processes. This study includes operational, chemical, and microbial data from a full-scale start-up process and is designed to identify factors that limit phosphorus removal during the start-up period. The physiology of polyphosphate accumulation is being investigated using a metagenomic approach.

Environmental Hydrology and Hydraulic Engineering

Coupling Hydrologic, Economic, and Social Network Models to Improve Understanding of Surface Water–Groundwater Interactions for Protection of Instream Flows

N. Brozović,* J. Braden (Ag & Cons. Econ.); X. Cai; S. Gasteyer (Human & Comm. Dev.); A. J. Valocchi
National Science Foundation—Coupled Natural-Human Systems

In recent years, a major source of water conflict has been the increased extraction of groundwater from areas that are physically connected to rivers and streams, and the resulting loss of instream flows. Although hydrologists have long conducted field studies of the physical aspects

* Denotes principal investigator.
of groundwater-surface water exchange, little is known about the feedbacks operating between natural and human components of complex surface water-groundwater systems, which are uncertain, spatially variable, and may include nonlinear and threshold behavior. Two sites for studying surface water-groundwater systems where an understanding of the complex interactions between human and natural components is critical to effective policy design are the Kankakee River Basin in Illinois and the Republican River Basin in Nebraska and Kansas. The objectives of this research project are to quantify the economic and social impacts of uncertainty in coupled surface water-groundwater systems; to evaluate how variability in individual and social group behavior can affect modeling and policy design for surface water-groundwater systems; to analyze the impacts of decision making processes on the development of socially acceptable surface water-groundwater management policies; and to develop efficient and socially acceptable policies to manage surface water-groundwater systems in order to maintain instream water flows. The methods to be used in this study include numerical modeling and simulation, statistical analysis, the use of geographical information systems, interviews with stakeholders, and advanced visualization techniques. The research will address fundamental hydrologic and socioeconomic questions, while also integrating training and learning activities for K-12 and graduate students, as well as outreach activities to local and international stakeholders.

**Development of A New Global Hydrologic and Water Supply Model**

X. Cai,* P. Kumar  
*Int’l Water Management Institute*

This project is a continuous development of WaterSim, a global water and food model. The goal is to establish a solid scientific basis for WaterSim, and enable the model to conduct the analysis of integrated land and water management and interactions between socio-economic development and natural processes in the global context. The objectives are to update the existing hydrologic modeling component by a new global hydrologic model (GHM); add a land use and land cover (LULC) simulation/projection component; and improve the water availability and supply model (WASM).

**Hydraulic Modeling of the Tunnel and Reservoir Plan System—Phase I, Calumet TARP System and Phase I, Mainstream and Des Plaines TARP systems**

M. H. Garcia,* A. R. Schmidt*  
*Metropolitan Water Reclamation District of Greater Chicago*

The Tunnel and Reservoir Plan (TARP) system consists of 109 miles of deep, large-diameter, rock tunnels designed to capture and enable treatment of combined-sewer overflows from Chicago and 51 suburbs. During some storm events, large and potentially dangerous hydraulic transients have been observed in the system. The hydrodynamics controlling the formation and propagation of these transients are not clearly understood, particularly for such large-scale systems and for systems where transitions between open-channel and pressurized flow cause formation of transients. Furthermore, new understanding and approaches are needed to define the hydraulic behavior of such a large network of interconnected conduits and structures, particularly for future real-time control of the system. This project will result in improved understanding of hydraulic transients in sewer networks and new methods to simulate mixed flow conditions in such networks.

This will benefit society by allowing engineers to address formation and propagation of transients in the design of storm- and combined-sewer networks. In addition this research will provide a direct benefit to the communities served by TARP by providing tools that allow better use of the system’s capacity while avoiding conditions. This research benefits the University of Illinois in that detailed research on many smaller-scale topics (e.g., behavior of hydraulic structures, numerical methods for hydraulic simulation, behavior of two-phase flows) will be needed to achieve goals of the large-scale project.

**Finding Principles of Large-Scale Hydrologic Response: Linking Hydroclimatology and River Basin Dynamics**

P. Kumar*  
*National Science Foundation, EAR 97-06121*

The objective of this research is to develop principles of large-scale hydrologic response in different hydroclimatological regimes by coupling hydroclimatology and river basin dynamics. This will be accomplished by performing a joint analysis of the atmospheric-hydrologic cycle and streamflow to develop parameterizations to link hydroclimatology and basin response characteristics; developing a nondimensional formulation of large-scale basin response, which explicitly

* Denotes principal investigator.
incorporates the hydroclimatological influence; and performing validation studies.

Interactions between Water, Energy, and Carbon Dynamics as Predictors of Canopy to Ecosystem Scale Vegetation Pattern and Function in a Changing Environment
P. Kumar,* M. Sivapalan, S. Long, X.-Z. Liang
National Science Foundation

The goals of this research project are to use the eco-hydrologic approach as a framework for the interpretation of available observations on vegetation characteristics and functioning, and so develop a predictive understanding of the interactions between water, energy, and carbon dynamics, and the feedback relationship of these interactions with the spatial and temporal patterns of vegetation form and function, in addition to their links with climate variability and a change in atmospheric composition, scaling from the plant canopy to the ecosystem scale and beyond. Vegetation characteristics of interest include functional types, leaf area index, the magnitude and patterns of fractional coverage, and the vertical multilayer canopy characteristics. Vegetation functioning of interest includes variability of transpiration rates and CO$_2$ assimilation rates in space and time, and the nature of acclimatization strategies that plants adopt, such as deep root development, hydraulic lift, photosynthetic type, and so forth.

Interannual Variability of the Hydrologic Cycle over North America
P. Kumar,* M. Ting, X. Z. Liang
National Science Foundation, NSF EAR 02-08009

The goal of this research is to develop a better understanding of the coupling between the atmospheric and terrestrial (land) branches of the hydrologic cycle and identify the physical basis of their interannual variability. The underlying hypothesis of the proposed research is that the regional atmospheric moisture transport is governed by both the large-scale forcing as well as local recycling, and their relative contributions have important implications in the interannual variability of the hydrologic cycle. The relative contributions of advected and recycled moisture may depend on the season, region, and the memory of the various reservoirs such as the atmosphere, near surface, and subsurface storage. Two specific science objectives are to identify the modes of the observed interannual variability of the hydrologic cycle and the underlying causal mechanism and to identify the roles of land surface and subsurface storages (water and snow/ice) in regulating the interannual variability of the hydrologic cycle.

Knowledge Discovery from Spatial Data for Hydroclimatological Studies
P. Kumar*
University of Illinois Research Board

The objectives of the project are to develop a knowledge discovery system for hydroclimatological studies that uses voluminous spatio-temporal datasets and to apply the system to study seasonal to interannual hydroclimatic variability. The premise of the research is this: techniques for exploring large datasets are now becoming available but have not been extensively applied for the exploration of scientific data, and in particular, for hydroclimatological studies; scientific inquiry methods developed for small datasets or "few variable" problems may not be effective for large datasets or "many variable" problems; and pressing scientific questions need answers and can be answered by exploring the available observational data.

Multiscale Estimation, Error Propagation, and Scale Effects in the Dynamical Response of Soil-Moisture Data Assimilation System
P. Kumar*
National Aeronautics and Space Administration, NAG 5-8555

The objectives of this project are to develop a multiscale soil-moisture and temperature assimilation algorithm that utilizes observations obtained at multiple scales and to assess the impact of estimation errors and model scale on the dynamics of moisture and energy fluxes at the land-to-atmosphere interface. Researchers will first develop an algorithm for the estimation of near-surface soil moisture and temperature, at the model scale, along with the error estimates, using observations at different resolutions. The research team will then use an extended Kalman filter assimilation scheme to predict the vertical profile using the near-surface estimates. The errors in the near-surface estimates propagate to each model layer. Researchers will study the impact of these errors on the energy and moisture flux at the land-to-atmosphere interface.

Scalable Knowledge Discovery for Hydroclimatological Studies
P. Kumar*
National Center for Supercomputing Applications (NCSA), University of Illinois

The objective of this research is to develop a knowledge discovery system for hydroclimatological studies using a scalable architecture. The project is aimed at developing a
system for knowledge discovery, i.e. identification of implicit relationships and patterns between data elements, in spatial databases, particularly those that have raster representation. The primary emphasis of the proposed work is to utilize the parallel processing capability of the supercomputer to develop a scalable mining system.

**Hydrologic and Hydraulic Modeling for the Restoration of the Calumet Marshes: Assessment of Runoff Scenarios**

Y. Lian,* G. Roadcap (Illinois State Water Survey), X. Cai

*Illinois Waste Management Center*

This project includes four key goals: to construct hydrologic and hydraulic models that can be used as a basis for determining the best water management strategies for the Lake Calumet Cluster Site and the adjacent open spaces it affects: Indian Ridge Marsh, Big Marsh, Heron Pond, and Dead Stick Pond; to evaluate the hydrologic impacts of the different remedial options proposed for the Cluster Site as well as other upland properties in the marsh watersheds; to assess the adequacy of the existing marsh outlets in terms of the long-range ecological goals and the effectiveness in dealing with current problems, such as beaver dams; and to develop a benchmark plan which will include a combination of various measures for achieving water flow regime and water quality targets.

**Modeling Multiscale-Multiphase-Multicomponent Subsurface Reactive Flows using Advanced Computing**


U.S. Department of Energy, SciDAC

Predictive modeling of subsurface reactive flows is a daunting task for two key reasons. First is the wide range of spatial scales involved—from the pore to the field scale—spanning over more than six orders of magnitude. Second is the wide range of time scales involved—from seconds or less to millions of years. With uniform grids, large 3-D field-scale continuum models employing billions of nodes can only resolve features on the order of meters and cannot capture phenomena at much smaller scales on the order of millimeters or less. This work is aimed at developing the next-generation massively parallel, multiphase, multicomponent reactive flow and transport code based on the successful prototype code PFLOTRAN. We will extend PFLOTRAN to include a generic multiphase algorithm based on variable switching to incorporate phase transitions for which the user need only add appropriate physical properties for particular phases of interest.Capabilities for both unstructured grids and adaptive mesh refinement on structured grids will be incorporated within PETSc’s parallel framework and accessed by PFLOTRAN. Finally, multilevel solver and upscaling capabilities and subgrid scale models will be added to the code. These enhanced modeling capabilities will improve our understanding of radionuclide migration at the DOE Hanford facility and modeling sequestration of CO₂ in deep geologic formations.

**Estimating Shallow Recharge and Discharge in Northeastern Illinois Using a GIS and Pattern Recognition Tool**


U.S. Geological Service, National Competitive Grants Program

Estimates of natural groundwater recharge and discharge are crucial for assessment of long-term sustainability of groundwater resources. Since it is extremely difficult to measure these parameters directly, inverse groundwater models are often used. However, when applying these models it is necessary for the user to a priori specify the spatial zonation pattern of recharge. In this work we develop a tool that combines the well-know groundwater simulation model MODFLOW, the inverse modeling software, PEST, GIS, and a Pattern Recognition Tool to estimate the zonation and amount of natural groundwater recharge. The tool will be tested through application to shallow aquifers in northeastern Illinois, where population growth has lead to increasing pressures on the deep groundwater resources.

**A Generalized Flood Frequency Framework for Prediction of the Effects of Multiscale Hydroclimatic Variability**

M. Sivapalan,* S. W. Franks

Australian Research Council (Discovery Grant)

This project is aimed at investigating the effects of the multiscale variability in precipitation inputs—intra-annual, inter-annual and inter-decadal—on flood frequency estimation. It investigates the propagation of these variabilities through the catchment system via simple models that enable estimation of the resulting probability distributions of soil moisture, runoff generation and flood peaks, and the underlying process controls. In this way, it hopes to develop a framework for incorporating these multiscale variabilities in flood estimation practice in

* Denotes principal investigator.
Australia. Along the way, the project compares the behavior of catchments in diverse climatic regions: Perth, Newcastle, and Darwin.

**Linkage of the North American Monsoon and the Great Plains Summer Precipitation and Its Relation to the Pacific Sea Surface Temperature**

M. Ting,* P. Kumar, R. Joseph, X. Z. Liang
National Oceanic and Atmospheric Administration

It has been recognized recently that the North American monsoon (NAM) rainfall and the U.S. Great Plains precipitation in the summer are negatively related to each other on interannual, seasonal, and intraseasonal scales. Furthermore, it has been indicated that there is a linkage between tropical Pacific sea surface temperature (SST) and the extreme events (droughts and floods) in the Central United States. However, the physical mechanisms for these linkages are not completely understood. The objective of this project is to investigate the dynamics underlying the out-of-phase relationship between NAM and the Great Plains precipitation on seasonal and interannual time scales and furthermore, the influence of the north Pacific and tropical Pacific SSTs (sea-surface temperatures) on the NAM and the Great Plains precipitation. Diagnostic and regional climate model simulations will be used for the study.

**Effects of Pore-Scale Mixing on Reactive Transport**

A. J. Valocchi,* C. J. Werth,* T. Willingham, C. Knutson, R. Acharya
National Science Foundation

Natural and engineered in situ remediation rely on the mixing of reactive chemicals in porous media. For example, during in situ bioremediation, reaction rates often depend upon the degree of mixing between nutrients (e.g., oxygen, nitrate) and contaminants that are in groundwater. In general, reaction rates depend nonlinearly upon local concentrations of the reactants, which can vary dramatically at the pore scale due to the complex tortuous geometry of the flow paths and the different transport properties of aqueous and/or hydrocarbon species. In this research, a unique combination of micromodel experiments and Lattice-Boltzmann (LB) simulations will be used to quantify the effects of pore-scale geometry on reactive transport.

**High-Throughput Computing for the Analysis of Tracer Tests in Fractured Aquifers**

D. D. Walker* (Illinois State Water Survey), A. J. Valocchi, P. Cello
Sandia National Laboratories; Illinois Water Resources Center; National Center for Supercomputing Applications

Traditional approaches to characterization and modeling of fractured dolomite aquifers faces many technical challenges. One alternative strategy begins with the Generalized Radial Flow interpretation of hydraulic tests, which infers an additional parameter, the flow dimension, to describe the geometry of groundwater flow. This study examines the behavior and variability of the flow dimension, n, and transport for four stochastic models of heterogeneous hydraulic conductivity, K(x), using Monte Carlo simulation of numerical models simulating aquifer tests and converging flow tracer tests in two-dimensional systems. The heterogeneity models are: log Normal spatially correlated random field, uncorrelated log Normal field, fractional Brownian motion, and percolation network. Although limited to a small set of stochastic models and parameters, the project has identified characteristic flow dimension values for these models, and identified additional avenues for investigation. These results suggest that the flow dimension may be a useful diagnostic for selecting models of heterogeneity, and that flow dimensions n \( \neq 2 \) may be associated with unique tracer behavior. Follow-up research efforts are necessary to confirm these results across a range of parameters.

**Knowledge Discovery from Remote Sensing Data**

A. White,* P. Kumar
National Aeronautical and Space Administration, Graduate Student Fellowship, NASA NGT 5-30433

This research is aimed at using the KDD (Knowledge Discovery in Databases) techniques to identify seasonal and interannual variability of NDVI (Normalized Difference Vegetation Index). We use a telescoping methodology of studying the NDVI variability at several hierarchical levels for the continental United States. The methodology uses an embedded representational scheme or concepts, using the idea of concept hierarchy, to develop statistical measures that recognize the heterogeneity at several scales. We propose to study from large scale, such as broad ecoregion classification, to smaller scales, such as a finer scale ecoregion classification, to basin and pixel level correlation with topographic and hydrologic attributes. We will also identify appropriate hierarchically defined levels directly from the data rather than preimposed classification. Once a region of interest, i.e. that showing important interannual variability, is

* Denotes principal investigator.
identified, we will use finer scale (250 m) NDVI data from the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument to perform detailed study of the region.

**Flash Flood Runoff from Arid Lands**
B. Yen* (deceased), P. Kumar  
*Arid Lands Consortium, AG AZ Y702424-01R-02*

The main objective of this research is to use nonlinear instantaneous unit hydrograph (IUH) to develop a fast and accurate model for efficient applications to determine the flood runoff produced by rainfall on arid-land watersheds.

**Geotech/Information Technology**

**Visualization for Constitutive Relations in Geomechanics and Engineering**
Y. Hashash*  
*National Science Foundation; National Center for Supercomputing Applications*

Material constitutive relations or models are mathematical representations of the mechanical response of the material and relate stress and strain states of the material in a three-dimensional space. The relations also include descriptions of geometric shapes to represent yield and failure surfaces. This research explores the use of advanced computer visualization techniques and graphics to represent these relations. The visual representation will facilitate the interpretation of three-dimensional states of stress and strain and the influence of a constitutive relation on their evolution due to specified loading conditions.

A freely available web-based software VizCoRe was developed for visualizing constitutive models and stress and strain states in new and innovative ways.

**Geotechnical Engineering**

**Simulation of Machine-Medium Interaction in a Real-Time Virtual Reality Environment**
J. Ghaboussi,* Y. Hashash  
*National Science Foundation; Caterpillar, Inc.*

This project is a joint, multidisciplinary industry–academia research effort to develop an advanced virtual reality (VR) environment for modeling earthmoving equipment interaction with the surrounding medium, such as soil. The research team will develop an original neural network (NN) based on a real-time soil medium model that can be used to simulate soil response due to manipulation by earthmoving equipment. The proposed model will be mechanistically accurate and run in real-time. It will simulate the soil resistance and the interactive forces between the medium and the earthmoving equipment. The NN model will be trained using data sets developed from non-real-time simulations using the discrete element method. Data sets of soil and earthmoving equipment response will also be developed from full-scale field tests at the Caterpillar, Inc. proving ground in Peoria, Illinois.

**Collaborative Research: A Joint Northwestern University–University of Illinois Project for the Development of New Integrated Tools for Predicting, Monitoring, and Controlling Ground Movements due to Excavations**
Y. Hashash,* R. Finno, J. Ghaboussi  
*National Science Foundation*

This project will explore and develop new technologies that offer substantial promise for greatly enhancing the construction control process and attendant mitigation of ground deformations including field instrumentation and sensors with wireless communication capabilities; data storage and display, including the display of construction progress and ground and building movements in a virtual reality environment; and intelligent, self-updating numerical models to simulate the excavation and support process and to compute anticipated ground and structure movements. These new technologies and improvements will be field tested in real time during excavation projects.

This project is developing tools that enable engineers to better estimate and to control deformations around deep excavations in urban areas. This includes new simulation tools as well as data acquisition devices integrated within a GIS (Geographic Information System) environment.

**Measured Performance of Excavations and Jacked Tunnels for the Boston Central Artery/Tunnel Project**
Y. Hashash*  
*University of Illinois; Federal Highway Administration*

The Central Artery/Third Harbor Tunnel Project, under construction in Boston, Mass., is the largest public works project currently under way in the United States. The project includes placement of the highway underground and involves the construction of deep excavations using diaphragm walls and the largest jacked tunnels in the world below an operating railway line. This research project will use a vast electronic instrumentation database in conjunction with information that will be collected at significant construction stages to develop an understanding of the behavior of the diaphragm-wall-supported excavation systems and the jacked tunnels for CA/T.

* Denotes principal investigator.
A new method was developed to assist engineers in interpreting measurements of strut loads in braced excavations.

Axial Capacity of Drilled Shafts in Soil
J. H. Long*
Federal Highway Administration; The International Association of Foundation Drilling

Methods for predicting axial pile capacity for drilled shafts in soil are being evaluated. Several axial load tests conducted to failure are being collected and combined with a current collection to update relationships and design procedures. Both allowable and load and resistance factor designs are being considered.

Comparison of Three Different Methods for Determining Pile Bearing Capacities
J. H. Long,* J. Hendrix
Wisconsin Highway Research Program

The Wisconsin Department of Transportation (WDOT) often drives piling in the field based on the dynamic formula known as the Engineering News (EN) Formula. The Federal Highway Administration (FHWA) and others have provided some evidence and encouragement for state DOTs to migrate from the EN formula to a more accurate dynamic formula known as the FHWA-modified Gates formula. The main research objective for this project will be to quantify the ability of the three methods (EN, Gates, and PDA) for predicting pile capacity in a way that allows Wisconsin DOT to assess when or if it is appropriate to use each of the methods and to confidently estimate the reliability/safety and economy associated with each method.

Evaluation and Modification of IDOT Foundation Piling Design and Construction Policy
J. H. Long,* A. Baratta
Illinois Center for Transportation

Design of driven piling is unique among the foundations used by the bridge engineer because two different methods at two different times are used to define its axial capacity. First, allowable pile lengths are determined in the office and are based on soil properties and site stratigraphy. In the field, however, piles are driven to a depth at which they reach a prescribed resistance to penetration based on a second method. Using these two independent methods results in lengths of driven piling that rarely coincide. The main objectives for this study are to quantify and improve the method for determining pile capacity used by the Illinois Department of Transportation (IDOT), to quantify and improve IDOT’s method for estimating pile length, and to quantify and improve the agreement between the length of pile estimated for a site, and the length of pile actually driven.

Static and Cyclic Axial Capacity of Cast-in-Place Piles in Sand
J. H. Long,* S. Lee
University of Illinois

Numerical pile segment analyses are being used to investigate the development of side resistance and soil behavior around a micropile installed in sand and subjected to static and cyclic axial loading. A series of pile segment analyses are being performed for micropiles and conventional drilled Cast-In-Place (CIP) piles considering effects of pile installation, relative density of sand, and pile diameter. Effects of pile installation, relative density of sand, and diameter on static shear behavior of a micropile are being investigated, as well as their effect on changes in effective stresses and volumetric strains of soil adjacent to the interface. Effects are being quantified based on overall interface strength and t-z response.

Compressibility and Consolidation of Soils
G. Mesri,* F. Sarabia
University of Illinois

This research program is concerned with compressibility and consolidation of soft clay and silt deposits. The uniqueness principle of soil compressibility is being investigated by means of laboratory measurements of consolidation of half-a-meter thick natural soft clay specimens. This principle allows direct application of compressibility information from small-scale laboratory tests to full-scale field settlement problems. Surcharging of soft clays, peats, and silts for ground improvement is another subject of this investigation. Surcharging is used to speed up ground modification and minimize postconstruction deformation damage to structures.

The objective is to develop a methodology for engineering surcharging operations.

Electrical Treatment of Soils
G. Mesri,* V. Schifano
University of Illinois

Electrical flow of pore fluid and associated electrochemical reactions have been used for permanent or temporary stabilization of soft clay and silt deposits. Important manifestations are consolidation and associated deformations, improvement of mechanical properties resulting from consolidation and electrochemical hardening, and favorable porewater flow resulting in an increase in effective stress. Although considerable

* Denotes principal investigator.
attention has been directed recently to electrokinetics as a means of cleaning contaminated ground, important uncertainties remain in relation to electrokinetic processes in soils as well as practical details of treatment. The physical and chemical processes are under detailed review and analyses for developing a formulation for predicting time-rate of electrochemical ground modification.

**Embarkment Stability Following Reservoir Drawdown**

G. Mesri,* M. Alzoubi  
*National Science Foundation, CMS 95-30464*

Embankment dams or dykes may experience undrained instability during rapid drawdown of the reservoir. Drainage may not occur in compacted clay of a homogeneous embankment or a core upon rapid drawdown. Undrained shear strength at yield of the compacted clay, consolidated under predrawdown shear stress and effective stress conditions, is required for stability analysis. Undrained strength may be expressed in terms of postdrawdown effective stress condition and strength parameters (ESSA), or in terms of predrawdown effective stress conditions and undrained shear strength ratios (USSA). Both approaches are being evaluated in laboratory undrained shear tests on saturated compacted clays and by full-scale stability analyses.

**Geotechnical Properties of Peat**

G. Mesri,* M. A. Ajlouni  
*University of Illinois*

Peatlands constitute 5% to 8% of the world's land. Peat deposits, the remains of plants, have a chemical composition and structure significantly different from those of inorganic soils. Peat exists at very high water contents and displays very large compressibility. It is no longer economical to avoid peat deposits in siting of infrastructure, including transportation facilities. Innovative engineering requires a fundamental understanding of peat behavior. Undisturbed samples of Middleton peat from Wisconsin and James Bay peat from Quebec are being used in a detailed laboratory study of geotechnical characteristics of peat.

**Granular Soils Improved by Dynamic Methods**

G. Mesri,* B. Vardhanabhuti  
*National Science Foundation, CMS 95-30464*

Geostatic horizontal stress plays a dominant role in ground response to in situ penetration tests that are frequently specified for the control of granular soil improvement by dynamic methods. These include densification by impulse loading, such as explosives or heavy tamping, and by steady vibration, such as vibrocompaction. Each compaction method produces a different history of preshearing, resulting in different magnitudes of horizontal stress in densified ground. Laboratory measurements of horizontal pressure in sand specimens that are densified by different impulse or steady vibration methods are intended for a better interpretation of postdensification penetration resistance.

**Lime Stabilization of Clay Slopes**

G. Mesri,* D. Rydeen,* N. Schwanz,* M. C. Hallman, V. C. Schifano, S. Keisel  
*U.S. Army Construction Engineering Research Laboratory, DACW37-98-M-0458*

Stability of levees and banks of the Red River has a profound influence on land use in adjacent communities. Slope movements damage adjacent structures, and during the spring 1997 flood, overtopping of levees caused catastrophic flooding in North Dakota and Minnesota. Programs are under way to stabilize riverbanks and improve the levee system. One scheme is lime treatment of riverbank clays. Adsorption of calcium hydroxide, together with formation of calcium silicates and aluminates, may lead to aggregation of clay particles. Direct shear testing is being used to investigate a possible permanent increase in frictional resistance of lime-treated Brenna and Sherak formations.

**Movement of Reactivated Landslides**

G. Mesri,* N. Huvaj  
*University of Illinois*

The objective of the proposed research is to establish baseline displacement rates for reactivated landslide masses, and minimum shear displacement required to reach residual shear strength condition on stratigraphic discontinuities. Relationships between shear displacement rate and factor of safety are being developed using field observations of reactivated slope movements, together with the laboratory measurements. The results of this investigation should allow interpretation of field observations of reactivated slope movements in terms of baseline shear displacement rate data for shear surfaces of different effective normal stress- and shear stress-histories, and selection of slip surfaces at residual condition for first-time slope failures in stiff clay and shale deposits with lithologic discontinuities.

* Denotes principal investigator.
Residual Shear Strength Mobilized in First-Time Slope Failures
G. Mesri,* M. Shahien, N. Huvaj
University of Illinois

In a first-time slope failure, part or all of the slip surface is unsheared prior to the occurrence of the landslide. For many of the first-time slope failures, part of the slip surface is at the residual condition. For excavated slopes, the residual condition could be present before the final slope is formed, or it may develop in response to excavation by progressive deformation along nearly horizontal surfaces. In addition to the rise in porewater pressure and softening, delayed first-time failure of slopes in stiff clays and clay shales is caused by propagation of the residual condition into the slope. The residual condition is present on the entire surface of reactivated landslides.

Secondary Compression of Peat
G. Mesri,* M. A. Ajlouni
University of Illinois

Secondary compression is most important in peat deposits because they exist at high void ratios and exhibit high values of compression index $C_c$, display the highest values of $C_u/C_c$ among geotechnical materials, and primary consolidation is completed in weeks or months in typical field situations. Secondary compression of Middleton peat was investigated by oedometer tests on undisturbed specimens. The observed secondary compression behavior of this fibrous peat, without or with surcharging, is completely in accordance with the $C_u/C_c$ law of compressibility. It is possible to predict settlement of embankments on peat without and with surcharging. The next phase of the research concerns primary consolidation of peat.

Settlement of Granular Soils Subjected to Static or Dynamic Loading
G. Mesri,* M. M. Shahien
National Science Foundation, CMS 95-30464

This research program is developing methodologies for settlement analysis of structures on granular soils subjected to repeated loading. Two independent methods based on in situ penetration tests are being evaluated using field performance records. One empirical method is based on the drive sampler penetration test (DSPT), and the second method uses push cone penetration test (PCPT) measurements. Settlements taking place during static or dynamic external loading and those that follow with time are being evaluated. Variables other than the condition of granular soil and nature of loading include depth of foundation and adjacent structures.

Settlement Resulting from Flow of Soil
G. Mesri,* M. Smadi
National Science Foundation, CMS 95-30464

Settlement of structures on soft clay deposits results from flow and consolidation of soil. In the latter case, water squeezes out from under the structure, whereas in the former case, soil squeezes out. Settlement resulting from flow of soil depends on the factor of safety against undrained instability. In construction situations where the factor of safety is small, an accurate prediction of settlement resulting from flow of soil is required. Field measurements of horizontal deformation of soft clays during construction of embankments and storage facilities are being used to develop a practical procedure for computing settlements resulting from flow of soil.

Soil Improvement by Vertical Drains
G. Mesri,* M. M. Shahien, M. A. Ajlouni
University of Illinois

The computer program ILLICON-I for settlement and pore water pressure analyses, which is based on a theory of consolidation developed at the University of Illinois, has been used successfully for designing dykes on highly compressible clays and for analyzing case histories of test fills on soft ground. Embankment construction on deep deposits of highly compressible soils generally requires the use of vertical drains to speed up the hydrodynamic consolidation stage. The new generation of the program, ILLICON-II, includes all the features of ILLICON-I and incorporates partially or fully penetrating vertical drains with well resistance and smear zone. The program is being used to analyze case histories of embankments on soft ground with sand or prefabricated drains.

Surcharging of Soft Ground to Reduce Secondary Settlement
G. Mesri,* M. A. Ajlouni, T. W. Feng
University of Illinois

Soft ground can be improved by precompression. Preloading with a surcharge is required to produce sufficient preconsolidation with respect to the final permanent structure load in order to reduce secondary settlement. Secondary settlement without surcharging is especially significant when duration of primary consolidation is small and secondary compression index is large. For any surcharging effort, values of $C_u/C_c$ are larger and values of $t_\ell/t_{pr}$ are smaller for peats than for soft clay and silt deposits. In other words, although surcharging

* Denotes principal investigator.
can reduce postconstruction secondary settlement for both clay and peat deposits, surcharging is less effective for peats.

**Building Capacity in the Pakistani Engineering Community to Employ Seismic Hazard Characterization, Mapping, and Analysis**
S. M. Olson,* Y. M. A. Hashash
*U.S. Agency for International Development*

As part of this collaborative effort with counterparts at the University of Engineering and Technology in Peshawar, Pakistan, we are working to accomplish the following: develop one or more courses on geotechnical earthquake engineering to provide engineering students at University of Engineering and Technology Peshawar with the knowledge needed to evaluate seismic hazards throughout Pakistan; develop a short course on geotechnical earthquake engineering that targets practicing engineers; install a downhole accelerometer array in Pakistan to measure local seismic shaking; and evaluate topographic amplification effects.

**Development of a New Laboratory Ring Shear Device for Testing Contractive Sandy Soils**
S. M. Olson,* A. Sadrekarimi
*University of Illinois*

In this study, we are developing an improved laboratory ring shear device for testing contractive sandy soils. The proposed device will overcome many of the difficulties associated with ring shear testing of sands including the impact of side friction, difficulties associated with undrained testing, and measurement of shearing resistance. The results from this study will be used to evaluate yield and liquefied shear strength ratio concepts for liquefaction analysis of sloping ground.

**Experimental Study of Yield and Liquefied Strength Ratios of Contractive Sandy Soils**
S. M. Olson,* A. Sadrekarimi, B. Mattson, D. Servigna
*University of Illinois at Urbana-Champaign*

In this study, we are collecting a database of triaxial extension and simple shear test results to verify the applicability of the yield strength ratio and liquefied strength ratio concepts, evaluate the effects the mode of shear on yield and liquefied shear strengths, and evaluate empirical field correlations between standard and cone penetration test data and liquefied strength ratios.

**Geotechnical Earthquake Instrumentation at the Bill Emerson Bridge**
S. M. Olson,* Y. M. A. Hashash
*U.S. Geological Survey, Advanced National Seismic Systems*

This project involves installing geotechnical instrumentation consisting of piezometers and dense downhole accelerometer/inclinometer arrays to measure ground response in soils that are predicted to liquefy and laterally spread in the event of a strong earthquake, as well as in soils that have been remediated to prevent liquefaction. The new instrumentation will complement the array of structural engineering instrumentation already existing at the bridge and will provide unprecedented opportunities to capture strong, near-field ground motions in the central and eastern United States, observe how soils liquefy and spread laterally, and record and study soil-structure interaction for a major bridge.

**Liquefaction Analysis of Sloping Ground**
S. M. Olson,* A. Sacks
*University of Illinois at Urbana-Champaign*

Liquefaction is one of the most prevalent consequences and sources of damage resulting from seismic activity. Predictions of the liquefaction potential of loose saturated deposits of cohesionless material are an important activity in earthquake preparedness in any seismic region. In this study, finite element analyses of several statically, seismically, and dynamically induced liquefaction flow failures are being studied to develop revised relations for estimating yield strength ratio using normalized penetration resistance. These relations also utilize available laboratory data from triaxial compression, torsional shear/triaxial compression, direct simple shear, and ring shear tests on isotropically and anisotropically consolidated specimens.

**Modification of IDOT Integral Abutment Design Limitations and Details**
S. M. Olson,* J. H. Long, J. LaFave
*Illinois Center for Transportation/Illinois Department of Transportation (IDOT)*

In this study, we evaluate the performance of deep foundations used for the support of bridges that do not use construction joints at the abutment, i.e., integral abutment bridges under extreme conditions of long bridge sections and high skew angles. The results of this study should lead to expanded use of cost-effective integral abutment bridges in the state of Illinois.

* Denotes principal investigator.
Quantifying Uncertainty in Paleoliquefaction Studies
S. M. Olson,* Y. K. Wen, J. Song
U.S. Geological Survey

In this study, we outline many of the uncertainties that are involved in conducting a paleoliquefaction study. We use a combination of rigorous and approximate methods of uncertainty and reliability analysis to quantify many of the uncertainties that are routinely encountered in paleoliquefaction studies. The purpose of quantifying these uncertainties is to incorporate them in a seismic hazard analysis, particularly probabilistic seismic hazard analysis. As a testbed case, we perform a quantitative uncertainty analysis for a paleoliquefaction study performed by others of the Vincennes earthquake that occurred in the Wabash Valley seismic zone circa 6100 BP.

Soil Improvement Strategies to Mitigate Impact of Seismic Ground Failure Via Novel Integration of Experiment and Simulation
S. M. Olson,* Y. M. A. Hashash
National Science Foundation, Network for Earthquake Engineering Simulation

Induced ground failures are a pervasive and growing source of economic loss from earthquakes. Concurrently, the nation’s growing infrastructure needs demand more and larger bridges with increased spans and traffic volumes, thus requiring the use of large, stiff foundations such as large diameter shaft groups or gravity caissons. When seismically induced ground failures occur, these foundations must contend with large, but unknown lateral forces. A common solution is to conservatively remediate large blocks of soil susceptible to failure, which involves high construction costs, increased construction time, and greater environmental impacts. This project will evaluate novel ground improvement geometries, such as chevrons and arches, to “deflect” laterally moving soil thereby reducing: lateral loads on large foundation elements; ground improvement costs; and time and environmental impacts. This will be accomplished via an innovative integration of centrifuge experiments (performed at the NEES equipment site at Rensselaer Polytechnic Institute) and Self-Learning Simulations (SelfSim) using the Open System for Earthquake Engineering Simulation software. This integration is termed “Simulation-designed Experiment–Experiment-driven Simulation” (SDE-EDS). This novel integration will result in robust mitigation strategies for seismically induced ground failure that can be implemented in a performance-based earthquake engineering environment. Besides reducing societal impacts from ground failures by reducing ground improvement costs, environmental impacts, and construction time, other broader impacts include the following: opening new avenues for future performance-based earthquake engineering studies involving foundation performance and ground improvement; and initiating an educational exchange between Valparaiso University and the University of Illinois at Urbana-Champaign to expand student exposure to research and better prepare them for practice.

A New Approach to Paleoliquefaction Analysis
S. M. Olson*
University of Illinois at Urbana-Champaign

A new methodology is being developed for the geotechnical analysis of strength of paleoseismic shaking using liquefaction effects. The proposed method provides recommendations for selection of both individual and regionally located test sites, techniques for validation of field data for use in back-analysis, and use of a recently developed and verified energy-based solution to back-calculate paleoearthquake magnitude and strength of shaking. The proposed method allows investigators to qualitatively assess the influence of post-earthquake density change and aging. The proposed method also describes how the back-calculations from individual sites should be integrated into a regional assessment of paleoseismic parameters. In addition, the procedure is being demonstrated for the largest Holocene earthquake that occurred roughly 6100 years ago in the Wabash Valley seismic zone of Indiana-Illinois.

Beneficial Use of Shredded Tires in Covering Abandoned Landfills
Department of Commerce and Community Affairs

Approximately 279 million used automobile, truck, and specialty tires are discarded each year nationwide. The unshredded tires disposed in landfills tend to "float" to the surface, breaking the landfill cover and causing increased leachate production that could contaminate groundwater. Therefore, many states have banned disposal of whole tires in landfills. The objectives of this research are to perform a comprehensive study involving both field and laboratory testing and to investigate the feasibility of using shredded tires as a drainage material in cover systems for waste containment systems.

* Denotes principal investigator.
Guidelines for Geofoam Applications in Roadway Embankments
T. D. Stark,* J. M. Horvath,* D. Leshchinsky,* D. Arellano
National Cooperative Highway Research Program, 24-11
The main objective of the proposed research is to develop guidelines for the use of geofoam, an expanded polystyrene, as a super-lightweight fill in roadway embankments and bridge approaches over soft ground. These guidelines will facilitate the use of geofoam in civil engineering projects by providing engineers with design procedures, historical data, and durability information.

Guidelines for Slope Stabilization Using Geofoam
T. D. Stark,* J. M. Horvath,* D. Leshchinsky,* D. Arellano
National Cooperative Highway Research Program, 24-11b
The main objective of the proposed research is to develop guidelines for the use of geofoam, an expanded polystyrene, as a super-lightweight fill in slope stabilization applications such as landslides. These guidelines will facilitate the use of geofoam in slope stabilization civil engineering projects by providing engineers with design procedures, historical data, and durability information.

Importance of Three-dimensional Slope Stability Methods
T. D. Stark,* O. Hungr,* D. Arellano
National Science Foundation, BCS 93-00043
The 1988 slope failure at the Kettleman Hills Waste Repository forced engineers to consider 3-D slope stability analyses. However, 3-D slope stability analyses are new and not readily available to practicing engineers or government agencies. The main objectives of the research are to develop improved understanding of the accuracy and applicability of existing 3-D slope stability methods to field conditions; to clarify the parameters or assumptions that significantly affect the 3-D factor of safety; and to identify field situations, if any, where 3-D factors of safety are less than 2-D factors of safety.

This research will lead to improved understanding of 3-D effects on 2-D back-calculated shear strength parameters and the importance of including 3-D effects in 2-D stability analyses.

Liquefaction-induced Permanent Deformations
T. D. Stark*
National Science Foundation, Mid-America Earthquake Center
This study will evaluate the mechanisms that lead to liquefaction-induced permanent deformation in soils and embankments, namely liquefaction flow failure and liquefaction-induced lateral spreading. The study will focus on determining procedures to evaluate the shear strength of liquefied soils and their deformation characteristics from in situ test results. New and existing field case histories and high-quality laboratory test results will be evaluated to study these phenomena and will be used to investigate the application of a shear strength ratio to liquefied soils.

PVC Geomembrane Institute Technology Program
PVC Geomembrane Institute
A technology program was established for the PVC Geomembrane Institute to develop and disseminate information on PVC geomembranes. The PGI is a nonproduct, industry-based consortium founded in 1988 to convey the advantages and disadvantages of PVC geomembranes. The research that is conducted involves thermal seaming, interface strengths, durability, and chemical compatibility. The information dissemination involves publishing technical bulletins, reports, and papers; establishing and maintaining a website; conducting workshops and short courses; and incorporating the information into existing courses.

Stability of Colluvial Slopes
T. D. Stark*
National Science Foundation, CMS-9802615
This research project will address a number of objectives, including determining the shear strength that is mobilized in a colluvial slope using natural and man-made case histories. Researchers also will investigate the geologic and/or environmental conditions that result in development of a residual strength; the importance of soil plasticity, clay-size fraction, effective normal stress, and so forth on the mobilized shear strength of colluvium; and the importance of strain incompatibility on the development of a residual strength condition in colluvial slopes. Another goal is to develop design recommendations for the construction and expansion of natural and constructed slopes founded on colluvium.

* Denotes principal investigator.
Static and Dynamic Geosynthetic Interface Strengths
T. D. Stark,* R. Hillman
Illinois Office of Solid Waste Research, OSWR-07-001; PVC Geomembrane Institute

The stability of a composite liner or cover system for landfills and reservoirs is dependent upon the interface strength between the various components within the system. This study is developing a test methodology and a database of interface strengths for the various interfaces in a composite system. Torsional ring shear tests, instead of reversal direct shear, are being performed to investigate the interface strength and its degradation with shear displacement. The effects of displacement rate and flexible geomembranes are also being investigated to evaluate the dynamic interface strength. Case histories are being used to estimate the magnitude of the laboratory strength that is actually mobilized in the field.

Railroad Engineering

Measuring Dielectric Constant of Ballast to Enhance Railroad Assessment by GPR
I. L. Al-Qadi,* W. Xie
American Association of Railroads

Railroad ballast plays an important role in supporting heavy rail loading, preventing the deformation of track, and providing drainage of water from the track structure. However, ballast fouled by infiltration of fines, which undermine the ballast functions, may result in damage to the rail system. Measuring the intact ballast thickness and early detection of fouled ballast are vital safety issues and can optimize the life-cycle cost of the ballast system. Ground penetrating radar (GPR), a nondestructive method, can be used to rapidly and effectively assess railroad ballast conditions. Using true ballast dielectric constant is essential to accurately predict the ballast thickness, degree of degradation, and fouling. The objective of this project is to determine the dielectric constant of different ballast materials utilizing GPR.

Affiliated Laboratory for Railroad Engineering
C. P. L. Barkan*
Association of American Railroads (AAR)

The AAR Affiliated Laboratory Program is intended to attract faculty and students to work in areas of interest to the railroad engineering profession; assist the railroad industry in the solution of technical problems related to the railroad operation and related industries; develop a pool of experts familiar with railroad engineering problems and willing to assist the industry in the solution of those problems; and develop courses and research programs to entice highly qualified students to work and study in areas related to railroad engineering. Most of these objectives will be accomplished by expanded programs of research on engineering problems related to the railroad industry.

This program supports projects in the departments of Civil and Environmental Engineering, Electrical and Computer Engineering, Industrial and Enterprise Systems Engineering, Mechanical Science and Engineering, Natural Resources and Environmental Sciences, and Physics as well as the Grainger Engineering Library.

A listing of the AAR Technology Scanning Projects and the faculty members follows. More information on these projects may be found by referring to each investigator's individual listings in departmental sections of the Summary of Engineering Research.

- Freight Car Truck Rotational Friction—T. Conry (Indus. & Enter. Syst. Engr.)
- Environmental Fate of Creosote—R. Larson (Nat. Res. & Environ. Sci.), R. Sanford (Civil & Environ. Engr.)
- Improved Fatigue-Resistant Design of Thermite Rail Welds—F. Lawrence (Civil & Environ. Engr.)
- Fracture Analysis of Broken Rails—F. Lawrence (Civil & Environ. Engr.)
- Railroad Engineering Library and Information Retrieval Service—W. Mischo, M. Schlembach (Grainger Engr. Library)
- Vibration Measurement of Rail Stress—R. Weaver (Physics)

Other railroad engineering projects include the following:
- Railroad Crosstie Accelerated Wear and Durability Testing, Including Use of Alternative and Recycled Materials—P. Chow (Nat. Res. & Environ. Sci.), various industry sponsors

* Denotes principal investigator.
Risk Analysis of Factors Affecting Railroad and Hazardous Materials Transportation

C. P. L. Barkan,* C. T. Dick
Burlington Northern and Santa Fe Railway Company

Risk analyses of accidents most likely to lead to serious hazardous materials releases are being conducted. Statistical analyses have shown that a fairly small group of causes accounts for a high frequency of the most serious accidents. Broken rail derailments are the most frequent cause of derailments occurring at high speed and involving a large number of railcars. These characteristics are strongly correlated with hazardous materials releases. Multivariate statistical techniques are being used to understand these relationships and to develop predictive models that use railway engineering data to predict the conditions in which a broken rail is most likely to occur.

Risk Analysis of the Effect of a Mid-America Earthquake on the Rail Transportation Network

C. P. L. Barkan,* K. Day
National Science Foundation, Mid-America Earthquake Center

Researchers are investigating the extent to which the rail network, and particularly critical features of the infrastructure, may be affected by a severe mid-America earthquake. GIS and various databases are being used to develop probabilistic estimates of the extent of critical infrastructure exposure to various levels of ground acceleration. This information and knowledge of the response of the infrastructure should enable researchers to determine how badly the rail network is likely to be damaged. A model evaluating the cost-effectiveness of retrofitting railroad bridges for enhanced seismic resistance compared to the cost of detouring is being developed.

RPI-AAR Railroad Tank Car Safety Research and Test Project

C. P. L. Barkan*
Railway Progress Institute (RPI); Association of American Railroads (AAR)

The RPI-AAR Tank Car Project has been collecting data on the performance of tank cars in accidents for 30 years and has developed a database of approximately 35,000 damaged tank cars. This database records detailed information on the accident, the nature of the damage suffered by the tank car, and whether or not there was a release of its contents. It enables detailed statistical analysis of the performance of tank cars in accidents. This has proved invaluable in identifying strengths and weaknesses of various designs and resulted in a number of safety improvements in tank car design.

Optimizing the Placement of Railcar Inspection Installations

Y. Ouyang*
Association of American Railroads

Railroads have invested millions of dollars installing wayside technology to monitor the health and performance of railcars. This technology has benefited the railroads greatly by helping to reduce derailments and damage to equipment and infrastructure. The problem of where to optimally locate new wayside inspection sites was identified. The objective of this project is to develop a method railroads can use to optimize the placement of these installations so as to maximize the efficiency of their use.

An analytical approach will be used for the optimal selection of installation sites for wayside detection systems. We will build upon existing literature within the network design field (i.e., location theory) to develop optimization models. Mathematical programming and systematic optimization methods will allow railroads to quantitatively select the best installation locations (and types of installations) on the network level.

Tank Car Reliability Design and Analysis

D. A. Pecknold,* H. Sehitoglu,* C. Barkan,* O.-C. Lee,
S. Kibey
Federal Railroad Administration, DFTRDV-00-G-60019

Railway tank cars with stub sills are particularly susceptible to fatigue cracking in weldments in the area where the tank is supported on the sill, which may eventually lead to component failure or even derailment. Improvements to the current damage tolerance analysis (DTA) methodology are being developed that allow more realistic estimates of fatigue life.

This project will develop improved methods for establishing safe inspection intervals for stub sill-type railway tank cars transporting hazardous materials, leading to higher levels of assurance against catastrophic accidents.

* Denotes principal investigator.
Development of GPR Based Railway Track Subsurface Condition Indices from Estimates of Track Bed Materials’ Physical Properties
E. Tutumluer,* I. Al-Qadi,* C. P. L. Barkan*
Federal Railroad Administration

The objective of the project is to automate and test previously demonstrated methods of collecting ground penetrating radar data, which was found to be suitable for the development of a quantitative assessment of the ballast and sub-ballast condition, including accurate assessment of its physical state and potentially indicative of the degree of ballast fouling, the main indicator of ballast degradation. The project work is broken down into three areas: Equipment procurement and setup; data collection; and algorithm development. The University of Illinois team will be responsible for the evaluation of modified common midpoint (Modified CMP) approach and ballast thickness algorithm tasks.

Discrete Element Modeling of Ballast for Strength, Stability, and Improved Manufactured Crosstie Design
E. Tutumluer,* H. Huang
Association of American Railroad (AAR)

A large portion of the annual budget to sustain the railway track system goes into maintenance and renewal of track ballast. A better basic understanding of the ballast behavior is essential for mitigating track problems and failures due to ballast breakdown, powdering, and fouling; ballast deformation and degradation due to compaction and repeated loading; and ballast lateral movement and instability causing track buckle. The primary objective of this project is to apply discrete element modeling (DEM) concepts to railroad ballast and study conditions needed to: improve ballast strength, stability, and resistance to lateral and permanent deformations, minimize ballast fouling and deterioration; and improve manufactured crosstie design.

Structural Engineering and Design

Aging Mesenchymal Stem Cells: A Link to Anemia
A. Barthalomew,* A. Masud
National Institute for Health

Stem cells can be viewed as the ultimate “smart material” as they can adapt to a multitude of conditions in response to the cellular microenvironment via site-specific differentiation. These cells are multipotential and have the properties of self-renewal, thereby providing a potentially unlimited source of material for “self-repair and regeneration.” Although some factors that initiate stem cell differentiation have been identified through cell studies in vitro, no known predictive profile exists that takes into account the behavior of the material as a whole. This work is aimed at experimental studies that can help develop a model of stem cell differentiation in which the process of stem cell adaptability or “smart material” characteristics could be defined. The model for stem cell differentiation will be implemented in a nonlinear finite element framework so that it can then be used in clinical applications requiring tissue regeneration and repair.

Optimal Seismic Design Based on Life Cycle Cost Consideration
S. A. Burns,* Y. K. Wen, M. Liu
National Science Foundation, CMS 99-12559

A genetic algorithm (GA)-based procedure for design of steel moment resisting frames considering expected lifecycle costs is developed. Current code procedures are used to check the validity of the design. Practical design/construction constraints are taken into account. A GA code is utilized to find a Pareto front for the resulting multiobjective optimization problem. Results of a numerical example of a five-story steel frame building show that a wide range of design alternatives exists, from which a decision maker selects the one that balances different objectives in the most preferred way.

The goal is to facilitate the decision making process.

Behavior of Bolted Steel Slip Critical Connections with Fillers
J. F. Hajjar*
American Institute of Steel Construction

This research is exploring the behavior of bolted steel slip critical connections with thick shim plate fillers and oversized holes, such as are used in the construction of long-span roof structures. The response of these structures to large loading has not been documented in prior literature. This project seeks to document the slip critical strength and bolt shear strength of these connections through a series of experimental tests of specimens that vary the thickness of the filler plate. Through this work, new national design provisions may be developed to ensure safer and more effective steel connections.

Cyclic Axial Testing of Buckling-Restrained Braces
J. F. Hajjar*
Nippon Steel Corporation

Buckling-restrained braces are providing an exciting new lateral-resistance system when used as the primary diagonal braces in steel buildings in high seismic zones. This research documented the cyclic response of an innovative new type of buckling restrained braced that is
characterized by a thin steel plate inside of a steel tube filled with mortar. Through optimizing the dimensions of the brace, this research is documenting the robustness and resilience of these economical new bracing components.

Assessment of the Seismic Vulnerability of Wall-Type Piers (and Abutments) for Bridges on Priority Emergency Routes in Illinois
J. M. LaFave,* J. L. Bignell
Illinois Department of Transportation

This study aims to identify the number and characteristics of bridges on priority emergency routes in southern Illinois that utilize wall-type piers, and then to assess the seismic vulnerability of those wall-pier bridges. Systematic assessments are made of the damage to be expected for specific bridges, accounting for the existing structural details as well as the characteristic earthquake ground motions for the bridge sites. Cost-effective retrofit techniques are under consideration, with the likely reduction in damage being predicted.

Seismic Performance of Light-Frame Construction
J. M. LaFave,* W. Clarke, D. J. Renetskie, Y. H. Choi
National Science Foundation, Mid-America Earthquake Center; State Farm Insurance

This project investigates the performance of brick veneer used in residential light-frame construction. Research objectives are to characterize typical design and construction of brick veneer systems, as well as to evaluate "local" performance of brick-tie-backup subassemblies and "global" performance of complete brick veneer-tie-backup wall systems. A series of brick-tie-backup subassemblies are tested to determine strength and stiffness under monotonic and cyclic loading. Static and dynamic tests of brick veneer-tie-backup wall systems are also being conducted. Experimental data from the tests are analyzed and used for verification of simple analytical models. Fragility curves for damage limit states are developed.

Seismic Performance of Reinforced Concrete (R/C) Eccentric Beam-Column Connections
J. M. LaFave,* M. Shin, and J. Kim
University of Illinois

This project investigates the seismic performance of R/C beam-column connections where the main beam centerline is at a substantial eccentricity from the column centerline. Large-scale R/C eccentric beam-column connection subassemblies (typically including a transverse beam and slab) are constructed and subjected to cycles of reversing lateral displacements, to a maximum story drift of 6%.

Connection damage, relative joint shear and torsion performance, floor slab effects, and stiffness deterioration, all as a function of connection eccentricity, are determined. Design recommendations are under development.

Development of Computational Mechanics Infrastructure and Human Resources for Advancing Engineering Design Practices
A. Masud*
U.S. Agency for International Development

This proposal is aimed at developing the infrastructure to promote application of advanced engineering analysis and design methodologies in the contemporary product development. The short-term objective of the proposed effort is to enhance the application of computers and computer tools in engineering curriculum, train the future generation of students with expertise in application of computers in engineering analysis and design, and establish a modern computational platform for large-scale simulation of engineering systems. The long-term objective of the effort is to bring about awareness among the industry practitioners to acquire and implement the modern design and analysis methodologies in the industry practices.

Elastoplastic Modeling and Analysis of the Coaxial Cable Systems Using Nonlinear Finite Element Method
A. Masud*
Andrew, Corp., Orland Park, Illinois

The coaxial cable LDF5-50A is composed of an inner noncorrugated copper tube and an outer corrugated copper tube. The volume between the two conductors is filled with polymer foam, and the outer core is protected via a black polyethylene coating. An accurate estimate of the mechanical strength of the cable requires a nonlinear material model that can account for large strain elastoplastic deformations, and a nonlinear finite element framework for the analysis of the system. The objective of this work is to reduce the usage of copper in the coaxial tubing system while maintaining the requirements on the strength of the cable system strength in tension, in crushing, and in bending. Consequently, this research aims at developing a nonlinear constitutive model for copper/copper-alloys, embedded in a nonlinear finite element formulation to help optimize the design of the coaxial cable system.

* Denotes principal investigator.
Multiscale/Stabilized Finite Element Methods and Large Scale Computing for the Simulation and Analysis of Clot Formation and Dissolution in Flowing Blood
A. Masud*
National Center for Supercomputing Applications

About 500,000 people in the United States suffer from strokes annually. Of these, 80 percent are caused by a blood clot that reduces the blood flow and oxygen to the brain. There are multiple interacting mechanisms that control the formation and dissolution of clots and thus maintain blood in a state of a delicate balance. In addition to a myriad of biochemical reactions, rheological factors also play a crucial role in modulating the response of blood to external stimuli. This research is aimed at developing a model for transformation of viscoelastic fluid into viscoelastic solid. Clot formation and dissolution is modeled as the growth/diminishment of a singular (viscoelastic liquid clot) front in a (shear-thinning viscoelastic) whole blood region. We introduce convection-reaction-diffusion equations that account for platelet activation, the extrinsic coagulation pathway and fibrinolysis, and a shear-rate enhanced diffusivity of platelets. The clot itself can also undergo dissolution due to either fibrinolysis being well advanced or due to very high shear stresses. We hope that a model that could predict regions susceptible to clot formation and also track the extent of clotting, once initiated, can be of immense value not only to doctors seeking to diagnose and treat their patients, but also bioengineers working to minimize such an occurrence within a cardiovascular device.

System Reliability Assessment for Risk-Quantified Design
J. Song,* W.-H. Kang
Caterpillar, Inc., RPS 06-077

The failure of an engineering product is often a system event constituted by component events such as the malfunctions of its physical parts or the occurrences of failure modes. Various types of uncertainties are inherent in the component events, which eventually lead to the unquantified risk of the system failure. Although system reliability is a well developed field, it is still challenging to quantify the system risk in many practical situations because of the complexity of system configurations, the existence of statistical dependence between the components, and the lack of data or information that conforms to the existing analysis methods. The project develops a new system reliability assessment framework that can quantify the risk of system failures in a wide range of practical situations.

Integrated Structural Health Monitoring and Control Employing Wireless Sensing Technology
B. F. Spencer, Jr.*
CUREE-Kajima Foundation

This research effort seeks to use smart sensing technology in combination with innovative structural health monitoring and structural control concepts and is aimed at extending the life of civil structures, helping to ensure the safety and performance of the structural system. Efforts are being conducted in cooperation with the Kajima Corporation in Japan to develop appropriate hardware, software, and networking components to support this effort.

Effect of Redundancy in Buildings Under Seismic Loads
Y. K. Wen,* D. A. Foutch, K. W. Liao, X. Ting
National Science Foundation, CMS 02-18703

Redundancy factor for design under seismic load is examined. In addition to structural configuration, the randomness of ground excitation, inelastic structural response behavior, uncertainty in structural resistance, and torsional effect are all considered. The results are compared with NHERP redundancy factor $\rho$, which is a function of the structural configuration only. The results obtained thus far indicate that the $\rho$ factor generally produces inconsistent results. It overestimates the effect of configuration and underestimates those of nonlinear dynamic response, 3-D dynamic motion, and structural ductility capacity. Rational uniform-risk design procedures for redundancy will be developed.

Hilbert Spectral Representation and Simulation of Nonstationary Random Processes
Y. K. Wen,* P. Gu
University of Illinois Research Board

A new method is proposed for characterization and simulation of nonstationary random processes based on samples of the process. The theoretical background is that of the Hilbert Huang Transform (HHT). Samples of a random process $X(t)$ can be decomposed into a summation of modal functions whose Hilbert transforms can be used to describe the amplitude and frequency changes with time. A Hilbert energy spectrum is then defined to describe the time-varying spectral content of the sample process. The method is also extended to characterization of vector processes. It can be conveniently applied to simulation of nonstationary random processes based on observed sample functions.

* Denotes principal investigator.
Structural Engineering and Structural Dynamics

NCHRP 12-75: Design of FRP Systems for Strengthening Concrete Girders in Shear
D. J. Belarbi,* O. Chaallal, A. Mirmiran, D. Kuchma, S. Sun
National Cooperative Highway Research Program

Fiber reinforced polymer (FRP) systems have been used for more than 15 years and are becoming a widely accepted method of strengthening concrete structures. FRP systems for strengthening reinforced or prestressed concrete girders consist of externally bonded laminates or near-surface mounted bars. These systems may contain either carbon or glass fibers. Extensive research has shown that FRP systems improve both short-term and long-term flexural behavior of concrete girders. The objective of this project is to develop design methods, specifications, and examples for the design of FRP systems for strengthening concrete girders in shear. The proposed specifications will be developed for adoption in the Load and Resistance Factor Design (LRFD) Bridge Design Specifications. In the work completed to date, the strengths, limitations, and differences between models of resistance were examined along with available experimental test data to develop an experimental testing program. The results from this program will provide the necessary data for the development FRP shear provisions for the LRFD specifications.

Field Tests and Analyses of Aluminum Sign Structures
D. A. Foutch,* J. LaFave,* D. A. Kuchma,* J. Zhang,* J. Bridge, S. Valdovinos
Illinois Department of Transportation

Aluminum sign structures span across interstate highways to display important information to drivers of personal and commercial vehicles. These structures are often over 75 feet in length and are subjected to dynamic loads created by trucks and wind. Past inspections have revealed cracks in structural members and a few actual failures. The purpose of this project is to determine the response characteristics of newly designed sign structures to passing trucks, wind loads, and erection procedures. The safety and life expectation of selected types of signs will also be evaluated.

A Study of Longitudinal Forces in Railway Viaduct
D. A. Foutch
Association of American Railroads

One of the most difficult problems in the design or evaluation of a railway bridge is determining the magnitude of the longitudinal load that will be transmitted to it through the tractive effort of the locomotives as they cross the bridge. Tests of single-span bridges demonstrated that the longitudinal forces carried by the bridge can be 30 times larger than the load used for design. This study will consider an 80-span viaduct. Experimental and analytical evaluations will be made.

Analysis of Seismic Retrofit Measures for Major Bridges
J. Ghaboussi,* S. Nam
National Science Foundation, Mid-America Earthquake Center; University of Illinois

Methods are being developed for seismic analysis of major river-crossing bridges in the central United States. Evaluation of seismic behavior of existing bridges, as well as seismic evaluation of any proposed retrofit measure, will require nonlinear dynamic finite element analysis. It is

Advanced Simulation Tools
A. S. Elbashai,* J. Hajjar
National Science Foundation, Mid-America Earthquake Center (EE-3)

The objective of this project is to develop new and advanced response analysis tools for estimating peak structural response quantities for use in defining accurate vulnerability functions in an efficient manner. Both simplified procedures for estimation of seismic demand, including soil-structure interaction effects, and a detailed environment for seismic capacity estimation are provided.

National Pooled Fund Study on Thermal Cracking
W. G. Buttlar,* G. H. Paulino, H. Yin, A. Braham
Federal Highway Administration; Minnesota Department of Transportation

The fracture of asphalt pavements due to severe low temperature events, commonly referred to as thermal cracking, is a devastating form of pavement deterioration. Presently, national design specifications are based upon testing and analysis methods that do not directly address fracture. Researchers from the University of Minnesota, University of Illinois at Urbana-Champaign, Michigan Tech, and the University of Wisconsin have teamed up with experts from the Minnesota Department of Transportation to evaluate new fracture tests and models for asphalt concrete. A comprehensive laboratory and field investigation endeavors to use cutting edge fracture tests and fracture mechanics principles to advance the state-of-the-art in asphalt pavement design for cold climates.

* Denotes principal investigator.
especially important for these long-span structures to include the effects of soil-structure interaction and multiple support excitation caused by seismic waves traveling in the ground. Several methods of soil-structure interaction modeling and analysis will be developed, and their performance will be evaluated. A fully evaluated, simplified method of analysis for practical applications will be developed.

**Applications of Neural Networks in Structural Engineering**

J. Ghaboussi,* A. S. Elnashai
*University of Illinois*

In this project, fundamental developments aimed at representing multidimensional inelastic material response using neural networks have been made. The new “inner product” neural network has proven to achieve simulation results far superior to existing approaches. This new development, alongside other neural network representations, has been used to represent the complex 3-D behavior of steel and composite beam-column connections, thus enabling the analysis of very large structural systems in seconds.

**Field Calibration of Creep Model in Segmented Long-Spanned Bridges**

J. Ghaboussi,* S. Jung
*University of Illinois*

One common method of erecting long-span bridges is to use segmented post-tensioned sections. Creep of the reinforced concrete sections can often lead to excessive sagging of the central portions of these bridges. If the creep can be forecast accurately, then steps can be taken during construction to prevent excessive deformations from occurring later. We are developing a self-learning creep model that can be calibrated during the early stages of the construction to accurately predict deformation in the latter stages of the construction. This also allows us to more closely integrate the computer simulation of the structural response with the actual construction.

**Smart Fiber Optics System for Condition Monitoring of Railway Bridges**

*National Science Foundation, CMS-9908651*

A remote-sensing bridge condition monitoring system using advanced computational intelligence methods and specially designed fiber optics instrumentation will be developed. The proposed system will address high-speed rail safety concerns by continuously monitoring both short- and long-term aspects of bridge health. The first part of the system will allow continuous detection of major damage that would pose an immediate safety hazard and would require closure of the bridge. The second component of the system will be triggered by the approaching train and will monitor the condition of the bridge by using the train itself to perform a load test by using advanced computational intelligence methods.

**Advanced Simulation Tools: Analysis of Composite Building Frames**

J. F. Hajjar,* A. S. Elnashai
*National Science Foundation, Mid-America Earthquake Center*

Advanced simulation of composite (steel-concrete) frames with various types of composite connections is the focus of this project, with the ultimate objective of providing the community with the most advanced and realistic representation of this important structural form. Toward this end, advanced modeling of the various components of composite connections, including the RC slab, is undertaken. The interaction between the various components, as well as their failure modes, is accounted for in this research.

**NEESR-II: System Behavior Factors for Composite and Mixed Structural Systems**

J. F. Hajjar*
*National Science Foundation, George E. Brown, Jr. Network for Earthquake Engineering Simulation*

The objectives of this project are to develop system performance factors for composite frame structural systems and to provide practical guidelines for the analysis and design of such structures. The project includes testing of a series of 20 full-scale slender composite beam-columns in order to develop data on the evolution of the stiffness and strength of these elements when subjected to large lateral displacements. Advanced computational models for composite frames will also be developed to conduct parametric studies so as to develop simplified recommendations for the equivalent rigidities to be used for composite beam-column elements and their connections in braced and unbraced mixed and composite frames subjected to large cyclic drifts.

* Denotes principal investigator.
NEESR-SG: Controlled Rocking of Steel Framed Buildings with Replaceable Energy Dissipating Fuses
J. F. Hajjar*
National Science Foundation, George E. Brown, Jr. Network for Earthquake Engineering Simulation

This research aims to develop a new structural building system that employs rocking action and replaceable structural fuses to provide safe and cost-effective resistance of buildings to earthquakes. The system combines desirable aspects of conventional steel-braced framing with shear panel fuses. Materials that are being investigated for implementing the fuses are high-performance fiber reinforced cementitious composites and ductile low yield strength steel. Guided by performance-based capacity design principles, the fuses are easily replaceable and can be tuned to provide optimal performance. Through controlled rocking of the structure, concerns about damage to foundations and primary structural elements are avoided.

Analytical Assessment of Seismic Demands in Untopped Diagram Shear Connectors
D. Kuchma,* H. J. Lee
Prestressed Concrete Institute

Several issues regarding the design and behavior of precast parking structures require attention. These include how to design for composite action, the role of the topping, the selection and detailing of connectors, as well as the influence of overall geometry and localized connection behavior on the flow of forces within, into, and out of diaphragm systems. These issues are being addressed through an analytical investigation of global and localized behavior.

This work is expected to result in a plan for experimental work that is necessary in order to develop improved design practices.

Automated Nonlinear Finite Element Analysis (2004–Present)
D. Kuchma,* J. W. Park, S. Yindeesuk, T. Tjhin
National Science Foundation, CMS CAREER 0092668; Precast/Prestressed Concrete Institute; Royal Thai Scholarship Program

The last three decades have seen the development and advance of nonlinear finite element analysis tools for predicting the complete response of reinforced and prestressed concrete structures to static and dynamic loadings. These tools employ a large variety of constitutive relationships, behavioral models, failure theories, and solutions methods. These tools have enabled their

dominant users, researchers, to examine the impact of different modeling assumptions on behavior. Unfortunately, these tools do not provide practicing structural engineers with what they need, which is a unique prediction of response with quantified levels of uncertainty as is provided by design code provisions. In addition, the time required to model a structure is prohibitive for design practice. Through this research, an automated procedure is being developed for the nonlinear analysis of structural concrete in which the finite element model is generated from overall geometry and material properties and in which the impact of different modeling selections on response is quantified.

Brass Breakaway Couplers
D. Kuchma,* S.-H. Kim
Illinois Center for Transportation (IDOT)

A goal of this project is to evaluate the design of a free-cutting brass breakaway coupling device for use in supporting poles. These devices could be used to replace the currently used aluminum or steel couplings, and potentially save IDOT significant resources. An application process is also under way for a patent. The review, and as-needed or suggested modifications to this device, will be based on the results of physical testing and of calibrated finite element analysis (FEA). The physical testing will be contracted out by the University of Illinois research team, while the FEA will be performed by University of Illinois researchers.

Design of Lifting Loops for Precast Deck Panels
D. Kuchma,* C. Hart
Illinois Center for Transportation (IDOT)

Lifting loops for bridge decks typically consist of one or more 7-wire prestressing strands that have been bent into loops. Current national codes and handbooks do not provide guidance for the design of lifting loops for shallow members and, consequently, individual states and producers use a variety of different in-house methods. This has led to problems in the field, including the failure of loops, and this poses a significant safety hazard. To address this concern, current practices are being reviewed and a range of lifting loop arrangements is being tested to failure in order to develop a standard practice for IDOT that has potential national application.

* Denotes principal investigator.
Effect of Superstructure Flexibility on Bridge Deck Deterioration
D. Kuchma,* N. Hawkins
Portland Cement Association

Recent field research and observations suggest that concrete bridge decks may deteriorate faster when supported on steel girders than when supported on concrete (reinforced or prestressed) girders. It is not clear if this observation is a result of the materials used in the girders, the stiffness of the girders, temperature effects, shrinkage effects, or construction practices. This project addresses these questions through a literature search, analytical evaluations, field observations and a review of inspection records.

This is expected to result in improved criteria for the design and construction of more durable bridge decks.

Establishment and Mining of an Experimental Database of Shear Tests on Structural Concrete Members
D. Kuchma,* K. S. Kim, A. Kamat, K.-H. Reineck
National Cooperative Highway Research Program

A comprehensive database of experimental test data has been collected and is being mined to develop a better understanding of the capacity and behavior of concrete structures in shear. This work was motivated by the inadequacy of current design codes for which the strength of members as predicted by one code may be three times the capacity given by another code of practice. A primary reason for these differences is that shear design approaches are empirically based and derived from inadequate experimental test databases. The common database being developed will facilitate the development of a more unified and accurate approach for shear design and analysis.

ExVis: A Data-Visualization and Analysis Tool for Experimental Test Data
D. Kuchma,* S. Sun
Precast/Prestressed Concrete Institute; National Cooperative Highway Research Program; Various Donors; ICR

Through improvements in sensor and data-acquisition technologies and the use of noncontact measurement systems, the strain or displacements at hundreds or thousands of points on a reinforced or prestressed concrete test structure can now be measured. Traditional methods of data exploration and analysis, in which arrays of data are examined, are inadequate for the exploration and understanding of this dense data. In this project, a general data visualization and analysis tool, called ExpVis, was written for presenting and exploring the measured response of planar concrete structures. ExpVis integrates the details of the test structure with strain, displacement, and cracking data obtained from several different types of measurement systems. This program serves as a post-processor for experimental test data in a manner that is similar to a post-processor for presenting the results from finite element analyses. The added complication with experimental test data is that the measurement systems provide different densities, accuracies, and conflicting measurements of response. Consequently, the data must be fused and differences reconciled so as to provide a best possible description of the measured behavior with quantifiable levels of accuracy for all aspects of the response at all locations.

NCHRP 12-61 Simplified Shear Design of Structural Concrete Members
D. Kuchma,* N. Hawkins, S. H. Kim
National Cooperative Highway Research Program

A new method of shear design was introduced into the U.S. community with the AASHTO LRFD Bridge Design Specifications. This method provides a unified approach for the shear design of concrete bridges and enables members to be designed for higher shear stress levels. Unfortunately, the design methodology is unfamiliar to bridge engineers and is perceived by many as being more complex than the AASHTO Standard Specifications. To address this concern, the National Cooperative Highway Research Program funded project 12-61 to supplement the full LRFD method for shear design with a simplified procedure that provides a direct solution for transverse and longitudinal reinforcement of concrete structures of common proportions.

NCHRP Project 12-56: Application of the LRFD Shear Design Specifications to High-Strength Structural Concrete: Shear Provisions
D. Kuchma,* N. Hawkins, S. Sun
National Cooperative Highway Research Program

NCHRP Project 12-56 was established to overcome the 10 ksi limitation on the compressive strength of concrete that can be used in the LRFD shear provisions. In this research program approximately 24 shear tests are being conducted on 63-inch deep bulb-tee girders. The compressive strength of the concrete in these girders ranges from 10 to 18 ksi and these girders are designed for maximum shear stresses ranging from 700 to 2500 psi. The girders are 52 feet long, simply supported, and subjected to a uniformly distributed load using 44 individual jacks.

* Denotes principal investigator.
The product of this research will be a greater understanding of the shear behavior of prestressed concrete and provisions that enable the same size structural sections cast with high-strength concrete to span longer differences and thereby reduce construction costs and improve the long-term durability of bridges.

Use of Close-Range Digital Photogrammetric Methods for Measuring Structural Behavior
D. Kuchma,* J. Ji
*University of Illinois; ICR

One of the challenges in conducting load tests on structural components, such as beams, columns, and walls is to collect sufficient information about the measured behavior (patterns of deformation) so to fully understand the behavior. This is challenging due to the space and time required to attach traditional measurements. It is common practice to measure the deformations at a few dozen locations during an experiment, but it is really necessary to measure deformations and strains at many thousands of locations to fully understand behavior. The researchers are developing a measurement technique that uses high contrast targets and high resolution digital cameras to measure patterns of deformation at thousands of locations.

Validation of Computational Models for Structural Concrete
D. Kuchma,* H. H. Lee
*University of Illinois; ICR

Over the last couple of decades, advances in the development of computational models have made it possible to model (predict) the response of concrete structures to imposed loadings. Structural engineers have been reluctant to use these models in practice due to the variation in the predictions of different models and the lack of transparency of these tools. The objective of this research is to develop formal procedures and tools for assessing the capabilities and limitations of computational models, thereby enabling structural engineers to take advantage of these computational methods in practice.

Sandia Methods for Model Reduction
A. Masud*
*Sandia National Laboratories

This project investigates the Sandia methods for model reduction related to structural dynamics and joint nonlinearity. It develops a new strategy for nonlinear model reduction and evaluates its potential for scaling to problems of millions of degrees of freedom. Because model reduction always sacrifices precision, some method of assessing the loss of precision associated with model reduction techniques is important. Consequently, one of the tasks of the current project is to develop new methods for a posteriori error estimation that are most promising for application to reduced order models, and to assess the mathematical robustness and computational economy of these new approaches.

Boundary Element Methods for Functionally Graded Materials
G. H. Paulino,* A. Sutradhar
*University of Illinois

This work focuses on establishing the conceptual framework for applying the boundary element method (BEM) to functionally graded materials (FGMs). Boundary integral methods require a Green’s function (fundamental solution), and thus such methods have been limited to homogeneous, or piece-wise homogeneous, materials. To circumvent this limitation, special attention is given to the derivation of Green’s functions for exponentially graded materials in heat conduction (steady state and transient) and elasticity. Both collocation and Galerkin methods are investigated. In particular, the Laplace transform Galerkin BEM is explored for transient heat transfer problems, in which the time-dependence is restored by numerical inversion of the Laplace transform using the Stehfest’s algorithm.

Fracture Mechanics of Viscoelastic Functionally Graded Materials
G. H. Paulino,* Z. H. Jin
*University of Illinois

One of the primary application areas of functionally graded materials (FGMs) is high temperature technology. Materials will exhibit creep and stress relaxation behavior at high temperatures. Viscoelasticity offers a basis for the study of phenomenological behavior of creep and stress relaxation. This project focuses on the development of a fracture mechanics theory for viscoelastic FGMs. The correspondence principle is revisited and established for viscoelastic FGMs. The revisited correspondence principle, together with the existing fracture mechanics theory of nonhomogeneous materials constitutes the framework of viscoelastic fracture theory of FGMs. Stress intensity factors for various crack geometries under both traction and displacement conditions will be studied by means of the revisited correspondence principle of viscoelasticity.

* Denotes principal investigator.
Fracture of Functionally Graded Materials: Modeling, Synthesis, and Experiments
G. H. Paulino,* J. C. Gibeling, Z. A. Munir
National Science Foundation, CMS 9996378

This project involves an investigation of functionally graded materials (FGMs) within a framework that integrates modeling, materials processing, and mechanical properties experiments. Special emphasis is given to the influence of compositional distribution functions on the structural behavior and the mechanics of crack initiation and propagation in FGMs under mechanical and/or thermal loads. The FGM system MOSi$_2$/SiC and Nb/Nb$_5$Si$_3$ are investigated. A novel technique, developed at University of California-Davis and known as Field-Activated Combustion Synthesis (FACS), is used in the synthesis process. The fracture behavior of FGMs with crack faces parallel and perpendicular to the property gradient is investigated both experimentally and numerically. These configurations are analyzed using boundary integral equation (BIE) and finite element techniques, the choice of the technique being dictated by suitability for the problem at hand.

Functionally Graded Material Applications to Advanced Thermal Protection Systems
G. H. Paulino,* M. C. Walters
National Aeronautics and Space Administration, Ames Research Center

The complex microstructural features that make functionally graded materials (FGMs) different from more conventional composite materials also invalidate many aspects of standard solid-mechanics approaches used to quantify their response to loading. Thus an appropriate material model needs to be developed to capture a broad range of conditions and to address multiconstituent, multiscale, and multiphysics issues inherent to multiphase FGM systems. This investigation involves extension of evolving theories for the response of ceramic-ceramic and ceramic-metal FGMs in order to address critically important issues for thermal protection system (TPS) applications, including transient thermal response within a three-dimensional (3-D) framework that has material nonlinearities; damage tolerance under repeated quasi-static loading; and damage tolerance under high-velocity, low-mass impact events (cracking, pitting, and spalling). Such information will prove crucial to predicting the complex response of FGMs in the manufacturing process and during service.

Generalized Isoparametric Finite Elements for Fracture of Functionally Graded Materials
G. H. Paulino,* J. H. Kim
University of Illinois

Graded finite elements are developed within the framework of a generalized isoparametric formulation. Such elements possess a spatially varying material property field and are applied to model both isotropic and orthotropic materials. Stress intensity factors for mode I and mixed-mode, two-dimensional fracture problems are developed and compared through three different approaches tailored for functionally graded materials (FGMs). Research includes path-independent $J_k^*$ integral, modified crack closure integral, and displacement correlation. Crack tip singular elements and carefully designed transition elements emanating from the crack tip region are used to ensure accuracy of the methods. The framework described here will serve as the basis for further investigations, such as thermal and dynamic problems in FGMs.

High Order Gradient Theory for Fracture of Functionally Graded Materials
G. H. Paulino,* Z. Dong
University of Illinois Campus Research Board

The main objective of this project is to develop an anisotropic gradient elasticity theory for fracture of functionally graded materials (FGMs). To the best of the authors’ knowledge, this is the first application of strain-gradient theory to such materials. The theory accounts for two material constants having dimensions of length: one responsible for volumetric strain-gradient terms and another responsible for surface strain gradient terms. This approach allows precise monitoring of the crack profile and offers a framework to investigate the influence of microstructure on fracture behavior of FGMs (multiscale phenomena). Moreover, this investigation has the potential to shed light on the asymptotic behavior of fracture problems in nonlocal continua.

Multiscale Fracture Modeling of Functionally Graded Materials
G. H. Paulino,* Z. Zhang
University of Illinois Computational Science and Engineering Program

Rapidly advancing developments in the manufacture of ceramic and metal functionally graded materials (FGMs) have created exciting new possibilities for their application in large-scale structural systems requiring very high performance. Current examples include advanced thermal
protection systems for new air and spacecrafts and blast-resistant systems of critical structural components. The proposed project focuses on developing a verified multiscale numerical procedure for simulating spontaneous crack nucleation, initiation, and propagation in FGMs by means of visualization and parallel computing techniques. The fracture events will be represented by a novel three-dimensional interface element for FGMs with tractions across the interface that follow a nonlinear cohesive model driven by work conjugate displacement jumps.

**Transient Thermal Stress Analysis of Cracked Functionally Graded Materials**

G. H. Paulino,* Z. H. Jin  
*University of Illinois*

The knowledge of thermal fracture behavior of functionally graded materials (FGMs) is important in order to evaluate their structural integrity. The existing analytical studies in this aspect have been mainly related to thermal stress intensity factors (TSIFs) for FGMs with specific material properties. This investigation consists of a multilayered material model to deal with arbitrary variations of material properties. Mathematical techniques such as integral transforms and asymptotic analysis are used to obtain an analytical first-order temperature solution for short times, transient thermal stresses, and TSIFs. An in-house graphical interface program named TAP (Thermal Analysis Program) is developed to visualize the analytical results and to help engineers and students to better understand fracture behavior.

**Strength of Simple Joints**

D. A. Pecknold,* Y.-K. Chang, C. C. Ha, J. B. Park  
*Offshore Tubular Joint Research Center; Edison Welding Institute for the American Petroleum Institute, EDISON WELD 97-219*

Design formulas for the ultimate static strength of steel tubular joints in offshore petroleum production structures have, since the early 1970s, been based primarily on data from large-scale testing programs. Over the last two decades, there has been a dramatic increase in the use of nonlinear finite element analysis as a more economical means of addressing specific static strength issues, particularly in geometrically complex joints. The objective of the project is to develop comprehensive parametric design formulas for the ultimate static strength of planar X, T, and K joints of different geometries, subjected to brace axial and bending loads, and carrying chord axial and bending preloads, based on the available test database, as well as an extensive new series of nonlinear finite element analyses previously carried out as part of this project.

The ultimate static strength formulas developed in this project will form the basis of design guidance for X, T, and K tubular joints included in the 21st edition of the API RP2A Recommended Practice for Design of Offshore Structures (Working Stress Design).

**Design of Bridge Piers under Combined Action**

D. Sanders,* A. S. Elnashai, D. Belarbi, J. Zhang, S. Dyke  
*National Science Foundation, George E. Brown, Jr. Network for Earthquake Engineering Simulation Research (NEESR)*

The project develops design criteria for the deformation and failure of RC bridge piers subjected to combined axial, shear, and flexural loading. Both testing and analysis, within an integrated bridge system, are used to define and refine expressions to predict deformation and failure of RC circular and interlocking piers. In-depth investigation of the use of very small scale specimens and the effect of partial dynamic similitude are parts of the scope. The project also has large education and outreach components.

**NCHRP 12-77: Structural Concrete Design with High-Strength Steel Reinforcement**

B. Shahrooz,* R. Miller, K. Harries, H. Russell, D. Kuchma  
*National Cooperative Highway Research Program*

The American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications allow the use of reinforcing steels conforming to different AASHTO and American Society for Testion and Materials (ASTM) materials specifications, but limit reinforcement yield strengths to a maximum of 75 ksi. Reinforcement is now available that has yield strength in excess of 75 ksi. Typical reinforcing steels have well-defined yield plateaus, whereas high-strength reinforcements do not have a well-defined yield plateau. The higher strength and the lack of a well-defined yield plateau alter structural behavior and do not satisfy some of the design assumptions in the LRFD specifications. The objective of this project is to develop recommended revisions to the AASHTO LRFD Bridge Design Specifications and the AASHTO LRFD Bridge Construction Specifications to ensure the safe and economic use of high-strength steel reinforcement in structural concrete members. The project includes all types of steel bar reinforcement covered by current AASHTO or ASTM specifications.
Development of Hybrid Simulation Framework
B. F. Spencer,* A. S. Elnashai
NEES Inc. (Network for Earthquake Engineering Simulation)

New procedures for the development of hybrid (mixed testing and analysis) simulations are developed to enable the use of geographically distributed testing laboratories and analysis tools to represent complex structural and geotechnical interacting systems. The developed software is compatible with all NEES (Network for Earthquake Engineering Simulation) software platforms and is available on an open source basis.

Response of Skew Bridges
B. F. Spencer,* A. S. Elnashai
Civil and Environmental Engineering Department, University of Illinois

The global and local response indicators of RC bridges with different levels of skew are being investigated in this project. Several configuration of skew bridge are being analyzed using simplified and detailed models to estimate effective response periods and the interaction of modes as a function of the skew angle. Small- and large-scale tests are underway to determine the degree of skew and its effect on the imposed torsional moments and angles on RC bridge piers and are being investigated with a view to relating design criteria of skew bridges to their straight counterparts, as a function of skew angle.

Structural Engineering and Structural Mechanics

Advanced Modeling of Brittle and Ductile Fracture in Structural Metals
R. H. Dodds, Jr.,* X. Qian, J. Sobotka
U.S. Nuclear Regulatory Commission, N00167-02-C-0076

Large-scale numerical computations are employed to couple a micromechanics model for initiation of cleavage fracture with inelastic deformation at the structural level. Previous efforts along these lines have successfully resolved the specimen size and deformation dependence of cleavage fracture toughness, Jc, to the lower- to mid region of the ductile-to-brittle transition of ferritic materials. Experimentally verified models to scale cleavage fracture toughness with specimen size, relative crack size, strain hardening, and loading mode (tension versus bending) are now available. Current efforts focus on extending and calibrating the Weibull stress model to predict temperature and loading rate effects.

Models Delamination Fracture in Advanced Aluminum-Lithium Alloys
R. H. Dodds, Jr.,* S. Kalyanam
National Aeronautics and Space Administration, Marshall Spaceflight Center, NMM04AA37G

Strength, toughness, and weight design requirements for next-generation expendable and reusable cryotankage has spurred development of newer Al-Li alloys. This work executes a tightly integrated research plan to couple new, material-scale simulations of Al-Li alloys with engineering-scale simulations. The research goal is production of a delamination criterion and an anisotropic plasticity model focused on plane slip, both leading to a reduction of the empiricism in engineering-scale models.

Software for Large-Scale, Nonlinear 3-D Fracture Analysis of Solids
R. H. Dodds, Jr.,* A. Carlyle
National Aeronautics and Space Administration, Marshall Spaceflight Center, NMM04AA37G; University of Illinois

WARP3D is a research code for the solution of 3-D solid models subjected to static and impact loads. Specific features in the code oriented toward the investigation of ductile fracture in metals include a robust finite strain formulation, a general J-integral computation facility (with inertia and face loading), an element extinction facility to model crack growth, nonlinear material models including viscoplastic effects, functionally graded materials, and a dilatant plasticity model for void growth. Central features of WARP3D involve a linear-preconditioned conjugate gradient (LPCG) solver implemented in a blocked element-by-element format and modern sparse matrix solvers for parallel execution.

PAGFEM: Parallel Adaptive Generalized Finite Element Methods for Large Scale Fracture Mechanics Problems
C. A. Duarte,* D.-J. Kim, N. Sobh
National Center for Supercomputing Applications

This project seeks the parallelization of emerging simulation tools for three-dimensional crack propagation recently developed in the Department of Civil and Environmental Engineering (CEE).

Thermo-Mechanical Effects of Spatially Localized Large Thermal Gradients on Aircraft Structures
C. A. Duarte,* P. O’Hara, T. Eason
Air Force Research Laboratory Air Vehicles Directorate, Midwest Structural Science Center

In order to resolve large thermal gradients and attendant thermal stresses in aircraft structures, we propose to

* Denotes principal investigator.
develop a computational framework using the generalized finite element method to address the multiscale nature of the problem. This process can be thought of as a traditional element formulation that is augmented with enrichment functions to capture the local (fine scale) events of interest. A-posteriori error indicators will be used to automatically detect the location and orientation of internal layers and to guide the adaptive enrichment of elements.

An hp Adaptive Generalized Finite Element Method with “Face Offsetting” for Three-Dimensional Crack Propagation
J. Pereira, C. A. Duarte,* J. Jiao
University of Illinois

This project aims at developing a computational method able to simulate arbitrary three-dimensional crack growth in complex geometries. The technique is based on an hp adaptive generalized finite element method (GFEM) coupled with a Lagrangian representation of the crack surface that is completely independent of the finite element mesh. Hp adaptive algorithms will be used to create discretizations that can deliver highly accurate solutions with the minimal number of degrees of freedom. The resulting technique will be able to model the evolution of complex crack surfaces using only the physics of the underlying problem without introducing any artificial bias from the underlying discretization. The second major component of this interdisciplinary project is a robust geometric engine capable of representing evolving complex three-dimensional crack surfaces including their interactions with the boundary of the domain.

Uncertainty/Risk Quantification Methods for Spatially Tailored Aero-Thermal Structures
J. Song,* Y. J. Lee
Air Force Research Laboratory, Midwest Structural Sciences Center, FA8650-06-2-3620

The project develops efficient methods for quantifying the uncertain responses and the risks of spatially tailored aero-thermal structures (STATS) by use of computational simulations. Also developed are the methods to identify important input uncertainties through sensitivity analyses, which will allow us to focus on the dominant uncertainties during the risk-quantified structural design (RQSD). The project aims at developing system reliability methods for efficient RQSD of aircraft structure systems as well.

Structural Mechanics and Dynamics

Fracture Driving Forces in Offshore Tubular Structures with Mismatched Welds
R. H. Dodds,* X. Qian
Offshore Technology Center (National University of Singapore); University of Illinois

Very large-scale offshore structures for petroleum production are constructed using hollow tubular sections. The X- and K-type joints have extraordinarily complex geometric configurations and are now often fabricated with mismatched welds (yield strength of base plate and weld metals do not match). Very high fidelity, linear, and nonlinear analyses conducted in this project provide the first quantification of elastic (K) and inelastic (J) driving forces for stationary cracks located at critical weld positions for a wide variety of joint configurations currently employed in offshore structures.

Cyclic Plasticity Models for Low-Cycle Fatigue Analysis
K. D. Hjelmstad,* R. H. Dodds,* K. Bergeron
National Aeronautics and Space Administration, NAG 8-1751

High performance structures (such as space shuttle main engines) are often vulnerable to low-cycle fatigue (on the order of 10,000 cycles at intensities higher than would be typically associated with high-cycle fatigue). In this project researchers intend to model low-cycle fatigue using computational fracture mechanics tools. One of the key features required to solve this problem is a model that accurately captures the cyclic plasticity of the background material. This project aims to develop and implement better cyclic metal plasticity models in the context of continuum inelasticity.

Domain Decomposition Methods that Couple Variable Time Integration Schemes
K. D. Hjelmstad,* A. Prakash
DOE Center for Simulation of Advanced Rockets

In very large-scale simulations, it is convenient to use methods based upon partitioning of the computational domain because it simplifies mesh preparation, it allows different treatment of different domains, and it allows the implementation of an efficient parallel algorithm. During a certain simulation, the response in a given region may have particular features (e.g. a propagating crack) that demand using a finer time step to resolve it than is warranted in other regions.

* Denotes principal investigator.
This project is focused on developing and improving methods to consistently couple domains that are being integrated with different numerical schemes.

**Finite Element Modeling of Contact**  
K. Hjelmstad,* G. Haikal  
*Fulbright*

Unilateral contact between solid bodies occurs in many engineering applications. This project is aimed at the modeling of the nonsmooth contact of moving solid bodies. The goal is to develop a new approach to the formulation and implementation of the contact constraints that allows for a simpler and at the same time more general treatment of potential contact scenarios. Our approach will enable the formulation of contact without any restriction on the elements used in the finite-element modeling of a structure, as has been the case in the contact formulations adopted to-date.

The results of this research, once implemented, in a nonlinear finite element framework, will potentially lead to a robust and widely applicable contact resolution algorithm.

**Fluid-Structure Interaction**  
K. D. Hjelmstad,* D. Turner  
*DOE Center for Simulation of Advanced Rockets*

The capability to perform large-scale three-dimensional numerical simulations of fluid-structure interaction (FSI) problems has opened the possibility of exploring questions in FSI that had been previously beyond our reach. The computer codes developed in the Center for Simulation of Advanced Rockets provide this simulation environment required to carry out this work. In this project we are investigating the effects of structural motion on the FSI problem. In particular, we are examining the effects of structural motion on vortex shedding in the classical problem of flow past a cylinder.

**Implicit Computational Methods for Fluid/Structure Interaction**  
K. D. Hjelmstad,* K. Nakshatrala  
*DOE Center for Simulation of Advanced Rockets*

Simulation of the burn-back of a solid propellant rocket motor is a complicated fluid/structure interaction problem. Some phenomena associated with these simulations require relatively long-time computations. In these cases, implicit time integration methods are essential because of their favorable stability properties.

This project is focused on developing implicit finite element algorithms for both the solid and fluid domains using multiscale methods based on bubble functions.

**Implicit Computational Methods for Modeling Mechanical Contact**  
K. D. Hjelmstad,* W. Xu  
*DOE Center for Simulation of Advanced Rockets*

Mechanical contact between parts is an important feature of many problems in solid mechanics from bolted joints to rocket O-rings. Many methods are available for simulating contact, but carrying out these computations in an implicit time-integration setting remains a challenge.

This project is focused on developing alternative descriptions of the contact problem, potentially leading to numerical algorithms that are more robust than those available in commercial codes now.

**Numerical Stability of Staggered Fluid-Structure Interaction Algorithms**  
K. D. Hjelmstad,* D. A. Tortorelli, K. Nakshatrala  
*DOE Center for Simulation of Advanced Rockets*

Staggered schemes for fluid-structure interaction (FSI) problems advance the solution by performing independent computations in the fluid and solid domains, coupling them together by passing state information back and forth. These algorithms are important because they allow independent (legacy) codes to work together to solve FSI problems. Computational evidence suggests that staggered schemes can suffer from numerical instability. This project is focused on better understanding the numerical stability characteristics of staggered schemes through detailed analysis of simple benchmark problems.

**Transportation Facilities and Systems**

**Effectiveness of Geogrid-Reinforcement in Flexible Pavements: A Full-Scale Testing**  
I. L. Al-Qadi,* E. Tutumluer,* J. Baek, S. Dessouky, J. Meister  
*Tensar Earth Technologies, Inc.*

Geogrids are believed to enhance the performance of flexible pavements by providing reinforcement to the pavement structure. The effectiveness of geogrid reinforcement appears to be more pronounced when used in roads designed for low to moderate traffic volumes, especially when the pavement structure consists of a thin hot-mix asphalt (HMA) layer on top of a granular base/subbase layer. The primary objective of this research is to quantify the effectiveness of geogrid-reinforced flexible pavements.
pavements. To achieve that, an instrumented full-scale flexible pavement test section will be constructed at ATREL, and ATLAS will be used to apply different loading patterns. The pavement response to traffic and environmental loading will be incorporated to develop transfer functions for predicting pavement distress and quantifying geogrid effectiveness.

**Analysis of Flexible Overlay Systems for Airport Pavements**
W. G. Buttlar,* D. Sherman
*Federal Aviation Administration, Center of Excellence for Airport Pavements*

The Federal Aviation Administration is in the process of developing advanced tools for the design and analysis of airfield pavements. The primary objectives of this project are to evaluate current design procedures utilizing the powerful 3-D nonlinear finite element analysis technique and realistic material models and to make recommendations toward the feasibility of incorporating such a tool in future design procedures. The present scope of the work is focused on the analysis of flexible (asphaltic) overlays placed on either flexible or rigid bases.

**Evaluation of Potential Applications of End-Result and Performance-related Specifications**
W. G. Buttlar,* S. Aref, X. He, A. Manik, Z. You
*Illinois Department of Transportation*

The primary objective of this study is to provide support to IDOT in the development of End-Result Specifications for asphalt concrete paving. This is being accomplished through demonstration projects, data analysis using statistical principles and simulations (ILLISIM), and laboratory testing. New testing devices to support the new specifications are also under investigation. Fundamental materials testing and field performance monitoring are being conducted to support future development of performance related specifications.

**Characterization of Asphalt Concrete for Airport Pavement Design**
S. H. Carpenter,* K. Ghuzlan, S. Shen
*Federal Aviation Administration, Center of Excellence for Airport Pavement Research*

New aircraft are producing loading conditions that have not been present before. This project will examine the impact of these new loading conditions on the performance and characterization of the asphalt concrete to develop appropriate testing methodology for use in new pavement design methodologies. Beam fatigue evaluations will illustrate the effect of the load pulse duration and shape on the fatigue life of asphalt concrete, which may change for different pavement structures. Viscoelastic characterization will be required to account for the duration of the load pulses for stiffness determinations. Constitutive testing technology developed for asphalt concrete in highway applications will be evaluated for adaptation to airport conditions.

**Developmental Work on Cold Patching Mixtures**
S. H. Carpenter,* L. Diaz, A. Johnson
*Gas Technology Institute*

This is a laboratory investigation into the performance of proprietary cold mix patching products used by the gas utilities. This project will establish quality levels and identify tests that can indicate the required quality in the laboratory and in the field, allowing construction crews to test their finished patch before leaving the construction site.

**Highway Problems: Illinois Cooperative Highway and Transportation Research Program**
S. H. Carpenter*
*Illinois Department of Transportation*

Two separate projects were included in the Illinois Cooperative Highway Research Program in 2002. They include a study on bridge column rehabilitation and an early cracking analysis of continuously reinforced concrete pavements.

**Validation of Design Considerations for Extended Life HMA Pavements**
S. H. Carpenter,* C. Dunbar, S. Behrman, S. Beranet, P. Dalbey
*Illinois Department of Transportation*

New pavement construction recommendations include multilayered asphalt pavements designed to provide an extended life. This project will validate current Illinois Department of Transportation mechanistic-empirical design procedures as they apply to the new Extended Life HMA Pavements (ELHMAP). Laboratory testing of field produced mixes for dynamic modulus and fatigue will be conducted. Test sections for the ATLAS test machine will be developed and constructed for response testing during the next fiscal year. Fatigue testing will be conducted to establish the existence of a fatigue endurance limit for asphalt pavements.
Anti-Icing Coating Self-Cleaning Properties and Wearing Characteristics Study at Chicago O’Hare International Airport
B. J. Dempsey,* N. M. Carroll
Center of Excellence for Airport Technology, Federal Aviation Administration, DOT 95-C-001

The purpose of this project was to observe a pavement test section that was designed with an anti-icing textured aggregate system. This test section is located at O’Hare International Airport at the intersection of Taxiway K and Taxiway 11. The objective of the study was to produce a thorough analysis of the pavement in relation to durability, surface friction characteristics, and anti-icing performance during the 2004-2005 winter season. A 24-hour, 7-days-per-week video system was used to monitor all snowstorm events and deicing activities at the test site. A draft final report on the study findings has been submitted to the FAA for review.

The Development and Evaluation of Antioxidants in Asphalt Pavement Materials
B. J. Dempsey,* A. K. Apeagyei
Center of Excellence for Airport Technology Federal Aviation Administration, DOT 95-C-001

This study relates to the identification and evaluation of physical and/or chemical additives that will mitigate the oxidation of the bituminous binders used in asphalt concrete mixtures for pavements. To date a broad range of materials have been researched and evaluated for use as antioxidant additives. Several materials, used individually or in combination, have been identified that are showing substantial promise in mitigating the oxidation process. The benefits of the various antioxidant additives are being evaluated in the laboratory by use of asphalt super-pave testing methods.

It is proposed that the performance life of the pavement can be significantly extended by decreasing the oxidation process in asphalt concrete pavements.

Behavior of the End Regions in Prestressed Concrete Girders
D. Kuchma,* T. Nagle
Prestressed Concrete Institute

The manner in which loads are carried in the ends of prestressed concrete girders is quite complex and influenced by many details including the shape of the member cross-section, the anchorage of the prestressing strands, the location of the end support, and the end reinforcement detailing. End regions are often the weak link in prestressed girders and yet there are few guidelines in codes of practice for their design. Through experimental and analytical investigations, the researchers are developing a better understanding of these end regions and developing improved design guidelines.

Tools and Research to Advance the Use of the Strut-and-Tie Method for the Design and Analysis of Concrete Structures
D. Kuchma,* T. Tjhin, Y. Zhai
National Science Foundation, CMS CAREER 0092668

For the purpose of designing structural concrete, it is useful to divide a structure into regions in which engineering beam theory applies and so-called D-Discontinuity Regions wherein there is a complex variation of internal straining. While building codes have historically provided little guidance for the design of D-Regions, the main 2002 design code introduced the strut-and-tie method (STM) as a general approach for the design of D-Regions. The University of Illinois research is developing computer-based approaches for the design and analysis of concrete structures by the STM. It is also using experimental test data and conducting nonlinear finite element analyses to validate, improve, and extend design code provisions for the STM.

Center for Excellence for Airport Technology
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Federal Aviation Administration, DOT 95-C-001; Chicago O’Hare Modernization Program

The Federal Aviation Administration established an Air Transportation Center of Excellence in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign on April 12, 1995. Starting in 2004, the O'Hare Modernization Program (OMP) became a major sponsor of CEAT with a research and outreach program focusing on support of their $6.6B expansion program.

CEAT has developed a strong working partnership with the FAA in providing new technologies for airport facilities. Seven CEAT projects are presently in progress and include Materials Testing and Evaluating for the NAPTF, Fatigue and Fracture Behavior of Airport Concrete Slabs, Design of Flexible Overlay Systems for Airport Pavements, Energy Based Fatigue in Airport Pavements, Moisture Curling of Concrete Slabs in Airfield Applications, Wildlife Hazard Abatement Systems, and the CEAT Summer Research Program targeted at students from disadvantaged groups. Individual CEAT project summaries can be found elsewhere within this report. New

* Denotes principal investigator.
technology from the studies will support the development of pavement designs adequate for accommodating the new generation of larger aircraft, such as the Boeing 777-300 and Airbus 380.

CEAT research supports the OMP with research focused at needs specific to their expansion program at O'Hare International Airport. Projects for OMP include soil stabilization and modification, raw material analysis, and portland cement concrete pavement design. In addition, an outreach program has been developed to provide technology transfer through a seminar series held on-site in Chicago, student internships, and support for minority contractors to better participate in OMP contracts.

Twenty six Ph.D. theses and approximately 200 technical reports and technical journal papers have been prepared from COE research activities since it was established in 1995. Many of the publications can be obtained from the CEAT website at http://cee.uiuc.edu/research/ceat

Detection of Recycled Asphalt Pavement (RAP) in Bituminous Mixtures
W. G. Buttlar,* W. Nassar, G. Rebholz (Bradley Univ.)
Illinois Transportation Research Center

The economical use of pavement milling in recent years has resulted in the availability of significant amounts of recycled asphalt pavement (RAP). The use of RAP in new bituminous mixtures can result in cost savings for both aggregate and asphalt binder. When properly utilized in the mix design and production, lower costs are realized without a loss in serviceability of the pavement. However, cost savings may not be realized by the owner and there may be a loss in serviceability of the pavement when unauthorized use occurs. This project will investigate methods for monitoring plant inputs to ensure production quality and consistency and make recommendations for requirements along these lines for agency quality assurance.

The project also seeks to identify laboratory tests that can be used to determine the presence and amount of RAP in post-production mixtures for use as a practical quality assurance tool for the Illinois Department of Transportation.

Crash Data Analysis Engineering Solutions for Local Agencies
Y. Ouyang,* Z. Li (Illinois Inst. Tech.)
Illinois Department of Transportation

This project will evaluate other states’ safety service programs for local agencies and develop a plan to establish a successful Illinois program based upon findings; create a searchable database of local roads crashes and locate all crashes; analyze crash data and develop reports useful to local agencies; and provide crash analysis to local agencies, including a list of improvements to reduce the incidence of crashes, when requested. This research will enable local agencies to construct data-driven roadway improvements to reduce the number and severity of crashes on their system. A searchable local roads database will be created that allows local agencies to locate crashes on rural roads, and analyze and report crash data to develop engineering solutions.

Update Condition Rating Survey (CRS) Calculation/Prediction Models
Y. Ouyang,* L. Heckels
Illinois Department of Transportation

The state planning and programming process utilizes the Condition Rating Survey (CRS) and the pavement needs that are calculated from the CRS. The CRS calculation/prediction models are outdated and no longer cover all surface/pavement types, thus there is a need to revisit the current CRS models and develop new ones for new surface/pavement types. This project will revisit and revise the state's outdated Condition Rating Survey (CRS) calculation/prediction models, and ensure the CRS models include all surface/pavement types. The outcome of this project will produce more finely-tuned Condition Rating Survey (CRS) calculation/prediction models and develop new models for any missing pavement/surface types.

GOALI: Reflective Crack Control Treatment and Design Procedures—A New Integrated Approach
G. H. Paulino,* W. G. Buttlar,* P. B. Blankenship
National Science Foundation; Koch Materials Company

The University of Illinois and researchers from Koch Materials Company are collaborating on this project under the National Science Foundation Grant Opportunities for Academic Liaison with Industry (GOALI) to vigorously expand fundamental knowledge of damage mechanisms in reflective crack control systems for asphalt pavements. The project involves advanced laboratory testing, field instrumentation, and finite element simulation using new constitutive models, including cohesive zone fracture models. As the industry partner to this venture, Koch Materials Company is providing annual matching funds; technical expertise, including access to field installation and performance data; laboratory and field materials for laboratory testing at the U of I, and mentoring of U of I students through extended site visits at the national laboratory in Wichita, Kansas, and by serving on doctoral thesis committees. The university's world-class

* Denotes principal investigator.
computational and laboratory facilities that can be brought to bear upon the proposed research include the National Center for Supercomputing Applications (NCSA) and the Advanced Transportation Research and Engineering Laboratory (ATREL).

**Accelerated Pavement Testing of Continuously Reinforced Concrete Pavement Sections**

J. Roesler,* E. Kohler  
*Illinois Department of Transportation*

With the increase in traffic loading and repetitions, agencies are requiring longer design lives for their new pavement designs. The Illinois Department of Transportation is interested in designing and constructing extended-life concrete pavements with 40-year service lives. This study will design, instrument, and construct continuously reinforced concrete pavement sections at the Advanced Transportation, Research, and Engineering Laboratory in Rantoul, Ill. These sections will allow for monitoring and analyzing of early-age cracking in continuously reinforced concrete pavement (CRCP). A new accelerated transportation loading assembly (ATLAS), which can simulate 40 years of traffic in several months, will load and fail the test sections.

The full-scale testing data will allow for better understanding of the failure of CRCP sections and for extrapolation to new, extended-life CRCP sections on highway systems in Illinois.

**Analysis of HVS Rigid Pavement Response Data from Palmdale, Calif.**

J. Roesler,* S. Rao  
*University of California–Berkeley, Pavement Research Center*

A full-scale concrete pavement test section was constructed on State Route 14 in Los Angeles County. The purpose of this test section was to determine the fatigue properties of field concrete pavements in California and the performance of several design options, such as widened lanes, tied concrete shoulders, and doweled transverse joints. Accelerated pavement testing of the sections has been completed on 24 test sections. Analyses of the results will be conducted to compile a concrete fatigue equation for California rigid pavements. The effects of temperature and moisture curling on the load response of concrete pavement will be studied. A performance model will also be developed to relate load level and repetitions to the joint deterioration of plain and doweled transverse joints.

The full-scale field results will help improve existing rigid pavement design procedures and enable better prediction of the service life of concrete pavements.

**Fatigue and Fracture of Airfield Concrete Slabs**

J. R. Roesler,* S. Shah (NW Univ.), C. Gaedicke  
*Federal Aviation Administration, Center of Excellence for Airport Technology*

With the introduction of the Boeing 777 aircraft for commercial service, the Federal Aviation Administration has been exploring what effects this aircraft has on existing design procedures and pavement performance. Laboratory slab fatigue testing is under way to determine the fatigue resistance of airport concrete pavements to the tridem gear on the B-777 aircraft. A more fundamental understanding of concrete slab fatigue is also being researched to assist in applying fatigue algorithms in design. The results of the research will assist the FAA in establishing the damaging effects of new, multiple-wheel-gear aircraft and how it can be incorporated into their existing concrete pavement design procedure.

**Mechanistic-Empirical Rigid Pavement Design Procedure for Caltrans**

J. Roesler,* J. Hiller  
*University of California–Berkeley, Pavement Research Center*

California has more climatic and material type variations than any other state in the United States. The proposed AASHTO 2002 Pavement Design Guide does not cover the majority of distresses occurring on Caltrans rigid pavement systems. Research has begun to develop a supplemental concrete pavement design process, which predicts fatigue cracking at transverse joints and along the longitudinal edge. The transverse joint fatigue algorithm will allow for design of a concrete pavement at any location in California, given a set of input parameters such as traffic, material properties, and slab geometry. An existing finite element program is being used to calculate the critical pavement responses and reduce the complexity of problems due to the wide range of conditions in California.

This research project will improve the design of rigid pavement highways in California and will supplement the existing national standards for design concrete pavements.

**Mechanistic-Empirical Rigid Pavement Design Procedure for Caltrans**

J. Roesler,* J. Hiller, D. Wang  
*Illinois Department of Transportation*

With the recent release of the Mechanistic-Empirical (M-E) Pavement Design Guide (DG2002), many states are

* Denotes principal investigator.
evaluating its applicability against their existing design methods. IDOT already has an existing jointed plain concrete pavement (JPCP) design based on M-E principles, but does not have an M-E based continuously reinforced concrete pavement (CRCP) design procedure. This project will review DG2002, other current research findings, and develop new design algorithms in the area of traffic, climate, concrete fatigue, built-in curling, and crack width prediction for both JPCP and CRCP.

This research project will improve the design and performance of rigid pavement systems in Illinois.

**Cold-In-Place-Recycling with Asphalt Products**

M. R. Thompson,* S. H. Carpenter, L. Garcia  
*Illinois Department of Transportation*

Cold-In-Place-Recycling with foamed asphalt and “engineered emulsions” has emerged as a viable procedure for recycling flexible pavements. This project will conduct an “information/data” survey and summarize Best Demonstrated Available Technology (BDAT)/State of the Practice; document and evaluate selected Illinois projects; prepare a summary report; and present recommendations for IDOT implementation.

**Mechanistic Design Implementation and Monitoring for Flexible Pavements**

M. R. Thompson*  
*Illinois Department of Transportation*

Mechanistic-based thickness design concepts and procedures for rigid and flexible pavements were developed by the University of Illinois in previous projects sponsored by the Illinois Department of Transportation. IDOT implementation activities are completed for jointed concrete and full-depth asphalt concrete (AC) pavements. Implementation activities for continuously reinforced concrete, conventional flexible (AC granular base), and AC high-strength stabilized base pavements are in progress. Selected rigid and flexible pavements are being monitored to develop data for future refinements or modifications to the mechanistic-based procedures.

This project is to provide technical support to IDOT and to cooperate with IDOT in implementation and monitoring activities associated with the mechanistic-based design of flexible and rigid pavements.

**Analysis of NAPTF Trafficking Dynamic Response Data for Pavement Deformation Behavior**

E. Tutumluer,* P. Donovan  
*Federal Aviation Administration Center of Excellence for Airport Technology*

This research utilizes the Federal Aviation Administration’s National Airport Pavement Test Facility trafficking dynamic response database, as well as the response tests conducted in association with the trafficking tests, for detailed analyses and better understanding of the construction cycles 1 and 3 flexible pavement test section deformation trends (both recovered and unrecovered deformations). To achieve this objective, deformation trends are investigated with respect to the various combinations of applied load magnitudes and loading sequences (application order and stress history effects); trafficking speeds (load duration effects); traffic directions (shear stress reversals); gear spacing and gear/wheel interaction; and wander positions and sequences. Validated rutting models will be developed to evaluate and predict potential rutting in variable thickness unbound base and subbase courses due to realistic full-scale aircraft gear loading.

**Characterization of Illinois Aggregates for Subgrade Replacement and Subbase**

E. Tutumluer,* D. Mishra  
*Illinois Department of Transportation*

The overall objective in this project is to characterize strength, stiffness, and deformation behavior of various types and qualities of aggregate commonly used in Illinois for subgrade replacement and subbase. The project focus is on pavement construction working platform issues. The project will develop aggregate thickness correlations with aggregate properties to modify and improve the thickness requirement curve in Figure A-2 of the Subgrade Stability Manual based on laboratory and field performances. This way, aggregate characteristics will also be used when determining cover thicknesses.

**Laboratory Characterization of the Engineering Behavior of Oil Sands**

E. Tutumluer,* S. H. Carpenter,* J. Anochie-Boateng  
*Caterpillar, Inc.*

The primary objective is to determine from laboratory testing material properties of selected oil sand samples. The oil sand samples were obtained from Canada’s natural deposits and are currently being studied by Caterpillar, Inc. for modeling their response and engineering behavior under off-road haul trucks, shovels, and other construction equipment. The goals of the experimental program are to

* Denotes principal investigator.
determine strength, modulus, compaction and damping properties, and deformation (elastic and plastic) characteristics under simulated close to field densities and loading stresses; to study effects of different loading frequencies, temperatures, and density levels or void contents; and finally, to provide the laboratory determined material properties/oil sand test data to ultimately evaluate field rutting accumulation for trafficability (mobility) and subgrade stability purposes.

**Nondestructive Pavement Evaluation Using ILLI-PAVE Based Artificial Neural Network Models**
E. Tutumluer,* M. R. Thompson, O. Pekcan
*Illinois Department of Transportation*

Evaluating structural condition of existing, in-service pavements is a part of the routine maintenance and rehabilitation activities undertaken at the Illinois Department of Transportation (IDOT). In the field, the pavement deflection profiles (or basins) gathered from the nondestructive Falling Weight Deflectometer (FWD) test data are typically used to evaluate pavement structural conditions. This kind of evaluation requires the use of backcalculation type structural analysis to determine pavement layer stiffnesses and, as a result, the estimate of remaining life of pavement. According to IDOT’s mechanistic-based pavement analysis and design procedures, recent use of artificial neural network models trained with ILLI-PAVE finite element solutions has proved to give much better results than the statistical algorithms currently in use.

**Project 4-34: Application of LADAR in the Analysis of Aggregate Characteristics**
E. Tutumluer,* H. Huang
*National Cooperative Highway Research Program*

The objective of this project is to develop and evaluate a LADAR (laser detection and ranging) system capable of precise and accurate measurement of the aggregate characteristics of shape, volume, angularity, surface texture, specific surface area, and volumetric gradation. The LADAR system will be applicable to aggregate in each of three size categories, coarse (2 in. to No. 4), fine (No. 4 to No. 200), and microfine (P200), and will be suitable for routine use in research, central, and field laboratories for PCC and HMA mixture design and quality control and acceptance (QC/QA). This nationwide research is aimed at developing the best methodology based on LADAR to measure aggregate shape properties in an effort to address the impact of aggregate shape selection on building more durable and longer lasting pavements.

**Subgrade Soil Support and Stabilization**
E. Tutumluer,* M. R. Thompson,* B. Harkanwal
*O’Hare Modernization Project; Center of Excellence for Airport Technology*

The objectives in this research are to: establish pavement design inputs for subgrade support, establish soil stabilization requirements with respect to need for stabilization, stabilization admixture(s) selection, and stabilization depth, and estimate subgrade support for various combinations of subgrade stabilization treatments and prepared subgrade conditions. Based on the representative soil samples received from the new O’Hare North Runway (9-27) site, laboratory testing at the University of Illinois Advanced Transportation Research and Engineering Laboratory (ATREL) is undertaken to recommend subgrade stabilization treatments and prepared subgrade conditions.

**Tensar Mechanistic Based Design for Geogrid Reinforced Flexible Pavements**
E. Tutumluer,* J. Kwon
*Tensar Earth Technologies, Inc.*

Geogrids enhance the performance and design of flexible pavements by providing reinforcement to the pavement structure. With the latest AASHTO move toward designing pavements using mechanistic concepts, research efforts have focused on developing a mechanistic model and a mechanistic based design procedure for Tensar Earth Technologies, Inc. to evaluate the benefits of including Tensar geosynthetic products in flexible pavement construction. The project is a multiyear research effort to deliver the analytical tools and the design procedure needed to help design and thereby facilitate increased use of Tensar geogrids in pavements.

This analytical research advances modeling and design of geogrid reinforced flexible pavement structures to reduce base course thickness and extend pavement life with enhanced structural performance.

**Transportation Systems**

**Development of Performance-Based Guidelines for Hot-Poured Crack Sealants**
I. L. Al-Qadi,* S. Yang, E. Fini, S. Dessouky
*Federal Highway Administration; 12 state-level Department of Transportation agencies in the United States*

* Denotes principal investigator.
Preventive maintenance is the most effective approach to delay road deterioration, extend its service life, and save public funds. While crack sealing is one of the most common preventive maintenance techniques, sealant failure is common within the first three years of application. This research is geared toward developing performance guidelines for hot-poured crack sealants. The project outcome includes the development of testing procedures to predict sealant performance in the field utilizing rheological behavior of sealants at a wide range of temperatures; to quantify the effect of aging on sealant performance; and to investigate the adhesion capability of sealants to crack walls. In addition, the project will result in developing performance specifications to identify and categorize sealants based on crack parameters and environmental conditions.

Development of Predictive Design Models to Determine Pavement Damage Due to Different Tire Configurations
I. L. Al-Qadi,* P. J. Yoo
Michelin Americas Research & Development Corp.

A 3-D finite element parametric study is conducted to quantify the viscoelastic pavement responses due to different tire loading configurations: dual and wide-base tires, at different temperatures and speeds. The study investigates factors that affect pavement responses including type of moving wheel loading amplitude (continuous, trapezoidal, and total cumulative), interface layer condition (simple friction and elastic stick models), and lateral surface forces. The asymmetric nonuniform stress magnitude and shape at the entrance and exit of the tire using continuous loading amplitude can more accurately simulate pavement responses to moving wheel vehicular loading than the currently used trapezoidal loading amplitude. Results of this study will be compared to field measured responses obtained from instrumented pavements.

Effectiveness of Steel Reinforcing Nettings as a Reinforcement for Hot-Mix Asphalt
I. L. Al-Qadi,* J. Baek
Bekaert Corporation

In recent years, interlayer systems have received considerable attention as viable solutions to enhancing flexible pavement performance. Steel reinforcing nettings have been used successfully in Europe and tested recently in the field by the PI in the U.S. In this study, a theoretical approach is being developed utilizing 3-D finite element modeling to quantify the effectiveness of steel reinforcement netting in flexible pavement applications. The model accurately simulates steel reinforcement netting as a nonhomogeneous interlayer with openings. The concept of cohesive zone model in the FE analysis was used to monitor the evolution of damage resulting from cyclic loading and to determine the contribution of interlayer systems to the pavement structure. The initiation and propagation rate of the reflection of cracks into the overlay can be determined for pavement with and without reinforcement.

Evaluation of Pavement Damage Due to New Tire Designs
I. L. Al-Qadi,* S. Dessouky
Illinois Center for Transportation

While a majority of pavements have performed satisfactorily in the past on a wide range of roads, it is evident that pavements are now failing more rapidly, and that the rate of failure appears to be increasing. Some of the most important factors that contribute to rapid pavement deterioration stem from loading by heavy trucks. These factors include: changes and increase in truck loading, varying the axle weight and configuration, tire type and pressure, and suspension systems. This research focuses on quantifying pavement damage due to different tire and axle configurations commonly used in Illinois, based on accelerated pavement testing and numerical modeling using the FE Method. This will include standard and overweight axle loads. Tire configurations to be considered will include traditional dual tire setup as well as original and new generation of wide-base tires. In addition, the study will conduct a detailed analysis to determine the damage caused by overweight vehicles and their impact on the pavement.

Structural Assessment of Concrete Bridge Piers Using Ground Penetrating Radar, Ultrasonic Pulse Velocity and Impact-Echo
I. L. Al-Qadi,* J. S. Popovics, K. Jiang, W. Xie
Illinois Center for Transportation; Illinois Department of Transportation

The integrity of a concrete pier located at the proposed ramp “J” interchange between Interstate 80 eastbound and Illinois route 394 northbound (Chicago) is evaluated. This evaluation followed a construction accident that occurred several months prior. The objective of the evaluation was to assess the capacity of the structure for continued construction operation. The current condition of pier cap number six was assessed using visual survey and nondestructive testing (NDT) techniques. Ground
penetrating radar (GPR), ultrasonic pulse velocity (UPV), and impact-echo (IE) were applied to reveal any internal abnormality in the structure.

Tack Coat Optimization for Overlays
I. L. Al-Qadi,* S. Carpenter, H. Ozer, Z. Leng  
* Illinois Center for Transportation

In this study, different tack coat types, rates, and interface conditions will be evaluated to illustrate the impact of these variables on the performance of the overlay. Coordinated lab, computer simulation, and accelerated full-scale testing to optimize tack coat type and application rate on PCC having different surface textures will be conducted. Effect of HMA mix design will also be investigated.

Comprehensive Crosswalk Safety Study for University of Illinois Urbana-Champaign Campus
* University of Illinois

The overall goal of this study is to analyze pedestrian safety issues on campus crosswalks and make suggestions to improve them. On-street yield to pedestrian crosswalk signs are used on the University of Illinois Urbana-Champaign campus; however, effectiveness of signs and whether or not they provide a false sense of security for pedestrians has not been determined. An Internet survey of pedestrians and drivers will be conducted to identify crosswalk safety issues and assess pedestrians’ knowledge and interpretation of the signs. Focus group meetings and pedestrian conflict counts will also be conducted. An assessment of the signing and marking of crosswalks at the Urbana-Champaign campus will be made and compared to campuses with similar environments and student populations.

Effects of Temperature on Performance of Uninterruptible Power Supply Systems
R. F. Benekohal,* M. Chitturi, M. Maestranzi  
* Illinois Department of Transportation

Uninterruptible power supply (UPS) systems installed at the traffic signals are subject to a wide range of weather conditions. Consequently they were evaluated at the extreme hot and cold temperatures that are experienced in Illinois. This study evaluated the performance of four different systems at hot and cold temperatures. Effects of temperature on runtime of the systems were determined. The finding provided very valuable insights into the performance of the UPS systems and how to increase the utility of these systems in adverse weather conditions.

Evaluation of Speed Photo Enforcement in Illinois Work Zones
R. F. Benekohal,* M. Chitturi, J. Medina  
* Illinois Department of Transportation; Federal Highway Administration

Work zone safety and efficiency of operation is important to road users and roadway authority. The Illinois Department of Transportation (IDOT) is interested in evaluating the effects using speed photo enforcement (SPE) systems on traffic flow characteristics and safety in work zones. A vendor will provide the equipped vans to IDOT and will train the Illinois State Police and IDOT personnel on how to use the system. The overall goal of this study is to determine the effectiveness of SPE in work zones. Data will be collected on speed, speed variation, speeding tickets issued, and fraction upheld as valid in courts.

Evaluation of Video Detection Systems for Traffic Signal Operation at Intersections
R. F. Benekohal,* M. Chitturi, J. Medina  
* Illinois Department of Transportation; Federal Highway Administration

Video detection systems are increasingly used in operation of traffic signals at intersections. They have potential to improve safety and efficiency intersections. This study will evaluate the performance of three VD systems under a wide variety of traffic and weather conditions. The findings from this project would help to decide how to optimize the operation of the systems and what system is appropriate for a given condition. The Illinois Department of Transportation (IDOT) is a partner in this study and will use the findings in developing a specification for video detection systems.

Methodology for Delay-Based Passenger Car Equivalencies for Urban Transit Buses
R. F. Benekohal,* J. D. Rodriguez  
* Federal Highway Administration

The adverse effects of heavy vehicles on traffic flow are considered using passenger car equivalents (PCE). For signalized intersections, the 2000 Highway Capacity Manual uses a constant PCE value, regardless of the difference between urban buses and trucks. Operational effects of urban transit buses that stop to pick up and alight passengers on signalized intersections are analyzed. The study develops a delay-based methodology that accurately determines PCEs for transit buses that stop within the confines of the signalized intersections. It establishes the relationship between PCE for transit buses and the different factors contributing to additional vehicular delay. These
factors are the bus dwell time, bus frequency, and average number of cars queued behind the bus while it is stopped at the bus stop.

**Modern Roundabout Evaluation and Design**
R. F. Benekohal,* V. Atluri  
*Illinois Department of Transportation*

Modern roundabouts are considered as an alternative intersection design and they may be effective in reducing the severity and injury associated with crashes at intersections. Roundabouts have been used in several states in the United States and IDOT is interested in promoting the use of roundabouts at appropriate locations to improve safety. IDOT does not have design guides for roundabouts. The objectives of this study are: to identify intersections in Illinois that have a potential to reduce fatalities and injuries using a roundabout design; to evaluate existing roundabout design software and recommend one for use by IDOT; to obtain feedback from IDOT district and central offices about roundabouts; and to develop a design and selection guideline for roundabouts that may be used by IDOT staff for developing a policy for design of roundabouts in Illinois.

**A Methodology for Estimating Operating Speed and Capacity in Work Zones**
R. F. Benekohal,* M. Chitturi  
*Illinois Department of Transportation; Federal Highway Administration*

This study develops a new methodology for estimation of operating speed and capacity in work zones. The operating speed is determined considering the adverse effects of work zone intensity and roadway and traffic conditions. The work intensity is quantified and a relationship between work intensity and speed reduction in work zones is developed. Speed flow curves are developed for work zones to estimate capacity for an operating speed. A new methodology to estimate work zone capacity is developed. The study is based on extensive traffic flow data collected in eleven work zones with single lane closures on interstate highways in Illinois.

**A Wireless Embedded Sensor System to Monitor and Assess Corrosion in the Tendons of Prestressed Concrete Girders**
J. Bernhard,* D. Kuchma, H. Reis  
*National Science Foundation, NSF0201305*

The results of this project have the potential to deliver advanced, accurate information about the internal condition of steel reinforcement as well as the efficacy of new materials and rehabilitation methods. Therefore, cost savings for maintaining the nation’s transportation infrastructure could be significant. The research plan consists of three thrust areas and a demonstration project. In thrust one, a corrosion detection and monitoring method will be developed that uses embedded sensors. Thrust two will integrate the internal sensors with wireless systems for the harsh, embedded environment of a concrete girder. Thrust three involves the development of a software program for relating embedded sensor data to changes in significant structural characteristics.

**Cost-Effectiveness and Performance of Overlay Systems in Illinois**
W. G. Buttlar,* I. L. Al-Qadi,* S. Dessouky, J. Bael, M. Kim  
*Illinois Center for Transportation*

Hot-mix asphalt (HMA) overlays are typically applied to existing flexible and rigid pavements when the structural or functional conditions of the pavement system have reached an unacceptable level of service. However, adequately designed overlays may still show cracking or joint patterns similar to the ones that existed in the old pavement after a short period of time; i.e., "reflection cracking" occurs. Evaluation of different rehabilitation methodologies, including interlayer systems, will be performed using theoretical, laboratory, field evaluations, and a combination of these approaches. Up-to-date life cycle costs and a rehabilitation guidance document will be produced.

**Reflective Cracking and Improved Performance of Grooved Asphalt**
W. G. Buttlar, I. L. Al-Qadi  
*Chicago O'Hare Modernization Program*

A major consideration in safe aircraft operations is to ensure that adequate friction is present at the tire-pavement interface on runways, similar to skid resistance requirements on highway pavements. In order to enhance skid resistance at airport pavements, grooves are often sawn into concrete and HMA surfaces in areas where low friction is experienced or where high friction is needed, particularly on runway takeoff and touchdown areas. However, the insertion (sawing) of grooves into an HMA surface can accelerate several forms of deterioration, including rutting, thermal cracking, reflective cracking, and raveling. As a result, surfacing materials having high fracture-resistance would likely be needed in order to resist thermal and reflective cracking in overlays. The study will focus on modeling reflective cracking of HMA overlays, evaluate asphalt binder properties to design materials that

* Denotes principal investigator.
are more resistant to cracking, and evaluate stability of grooves in HMA surfaces.

Evaluation of Uninterruptible Power Supply (UPS) Systems at Signalized Intersections
M. Chitturi, R. F. Benekohal*
Illinois Department of Transportation

Uninterruptible Power Supply (UPS) systems are being used at critical signalized intersections to power traffic signals in the event of a power failure. The performance characteristics and runtime of UPS systems from four manufacturers were evaluated. The runtime and operation of certain features of the systems were compared to IDOT interim specification. The findings were used in finalizing the IDOT specifications for UPS systems. All four systems were found to satisfy a majority of the specifications.

Lane Width Effect on Speeds of Cars and Heavy Vehicles in Work Zones
M. Chitturi, R. F. Benekohal*
Illinois Department of Transportation; Federal Highway Administration

Speed reductions due to narrow lanes and reduced lateral clearances on a regular basic freeway section are given in the Highway Capacity Manual (HCM). However, similar data for work zones are not available. The reductions in FFS of vehicles in work zones are not available. The reductions in FFS of vehicles in work zones due to narrow lanes are higher than the reductions given in the HCM for normal freeway sections although the reduction due to narrow lateral clearance was comparable. The narrower the lane, the higher was the speed reduction. The reduction in FFS of heavy vehicles is greater than the reduction in FFS of passenger cars. Further data are being collected to quantify this effect.

Evaluation of HCM Back of Queue Predictions
M. Maestranzi, R. F. Benekohal*
Illinois Department of Transportation

Inaccuracy in queue length estimation for signalized intersections may lead to a lane blocking problem. Entry to a left turn lane may be blocked by the through traffic waiting in the queue. Through lanes may be blocked by the spilled back left turning vehicles. Both cases will adversely affect intersection operation and capacity. An analyst may use the HCM models in five different ways to compute queue length depending on field data available. This study compares field data from three intersections to the estimated values from five different methods of using the HCM back of queue model. Advantages and disadvantages of each method are discussed.

Evaluative Study of Non-FWD, Nondestructive Testing and Evaluation (NDTE) Technologies for Airport Pavement Maintenance and Acceptance Activities
J. S. Popovics,* I. L. Al-Qadi
Federal Aviation Administration (FAA)

Test methods for controlling the construction quality of airport pavement layers and assuring the quality of new pavements have changed little over the past several decades. Nondestructive testing and evaluation (NDTE) methods are thought to be the most useful techniques for measuring the quality of individual pavement layers during or immediately after construction because of the noninvasive nature of the techniques and the anticipated rapidity of the measurements. The research focuses on determining the effectiveness and practicality of selected NDTE technologies for maintenance, evaluation, quality control, and acceptance of airport pavements; and on providing recommend appropriate optimized technologies to the FAA based on the field evaluation results.

A Bi-level Programming Formulation and Heuristic Solution Approach for Traffic Control Optimization in Networks with Dynamic Demand and Stochastic Route Choice
D. Sun, R. F. Benekohal*
University of Illinois

This study develops a bi-level programming formulation and heuristic solution approach for traffic signal optimization in networks with time-dependent demand and stochastic route choice. The upper level represents the decision-making behavior (signal control) of system manager, while the traveler behavior is addressed in the lower level. The heuristic solution approach consists of a genetic algorithm (GA) and a cell transmission simulation (CTS) based incremental logit assignment (ILA) procedure, where GA is used to find the upper level signal control variables, while ILA is developed to find user optimal flow pattern in the lower level problem, and CTS is implemented to propagate traffic and collect real-time traffic information.

Uniform Delay Models for Left Turn Lane Group for Signalized Intersections
M.-H. Wang, R. F. Benekohal*
University of Illinois

This study develops new models for estimating uniform delay for the left turn lane group with various combinations of protected and permitted operations. For the protected phasing, delay is computed relatively straightforward; for the permitted phasing, the delay is dependent on traffic volume and arrival type of opposing approach and subject

* Denotes principal investigator.
lane. For those operations with permitted left phasing, the effect of opposing traffic is a complex factor for estimating delay for signalized intersections. The models consider the platooning effects of both left turn and opposing approaches. Platoon duration and queue clearance time of the left turn and opposing traffic are used to estimate the uniform delay. Models are validated using field data and a microscopic simulation model.

### Journal Articles

#### Construction Management


#### Construction Materials


#### Earthquake Engineering


Environmental Engineering and Science in Civil Engineering


Characklis, G. W., Reed, P. M., and Minsker, B. S.  *The role of the systems community in the National Science Foundation's environmental observatories* [editorial material]. *Journal of Water Resources Planning and Management, 133:*1, 1-3 (Jan.-Feb. 2007) (http://dx.doi.org/10.1061/(ASCE)0733-9496(2007)133:1(1)).


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Cai, X. and Ringler, C.  
Balancing agricultural and environmental water needs in China: Alternative scenarios and policy options.  

Cai, X. M., De Fraiture, C., and Hejazi, M.  
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Cantelli, A., Wong, M., Parker, G., and Paola, C.  
Numerical model linking bed and bank evolution of incisional channel created by dam removal [art. no. W07436].  
Water Resources Research, 43:7, 7436 (Jul. 2007).

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Cantero, M. I., Lee, J. R., Balachandar, S., and Garcia, M. H.  
On the front velocity of gravity currents.  

Catano-Lopera, Y. A. and Garcia, M. H.  
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Ocean Engineering, 34:5-6, 856-869 (Apr. 2007) (http://dx.doi.org/10.1016/j.oceaneng.2006.05.001).

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Self-burial of short cylinders under oscillatory flows and combined waves plus currents.  

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Two-dimensional concentration distribution for mixing-controlled bioreactive transport in steady state.  

Garcia, C. M., Cantero, M. I., Nino, Y., and Garcia, M. H.  
Closure of "Turbulence measurements with acoustic Doppler velocimeters" by Carlos M. Garcia, Mariano I. Cantero, Yarko Nino, and Marcelo H. Garcia.  

Garcia, C. M., Oberg, K., and Garcia, M. H.  
ADCP measurements of gravity currents in the Chicago River, Illinois.  
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Kostic, S. and Parker, G.  
Conditions under which a supercritical turbidity current traverses an abrupt transition to vanishing bed slope without a hydraulic jump.  

Kusumastuti, D. I., Struthers, I., Sivapalan, M. and Reynolds, D. A.  
Threshold effects in catchment storm response and the occurrence and magnitude of flood events: Implications for flood frequency.  

Laurent, R. and Cai, X. M.  
A maximum entropy method for combining AOGCMs for regional intra-year climate change assessment.  

Lee, H., Zehe, E., and Sivapalan, M.  
Predictions of rainfall-runoff response and soil moisture dynamics in a microscale catchment using the CREW model.  


Geotechnical Engineering


Railroad Engineering


Structural Engineering and Design


Structural Engineering and Structural Dynamics


Han, S. W., Kim, W. T., and Foutch, D. A. Seismic behavior of HSS bracing members according to width–thickness ratio under symmetric cyclic loading. *Journal of Structural Engineering, 133*:2, 264-273 (Feb. 2007) (http://dx.doi.org/10.1061/(ASCE)0733-9445(2007)133:2(264)).

Han, S. W., Kim, W. T., and Foutch, D. A. Tensile strength equation for HSS bracing members having slotted end connections. *Earthquake Engineering and Structural Dynamics, 36*:8, 995-1008 (Jul. 2007) (http://dx.doi.org/10.1002/eqe.665).


**Structural Engineering and Structural Mechanics**


**Transportation Facilities and Systems**


Transportation Systems


Books

Structural Engineering and Design


Book Chapters

Structural Engineering and Design


Papers Presented at Conferences and Symposia

Construction Management


Construction Materials


Environmental Engineering and Science in Civil Engineering


Bell, C. and Finneran, K. T. Concurrent Fe(III) reduction and complete dechlorination of chlorinated ethenes in contaminated marine sediment. 2007 American Society for Microbiology General Meeting (Toronto, ON, May 2007).


Coronell, O., Mariñas, B. J., Zhang, X., and Cahill, D. G. Quantification of functional groups in the active layer of nanofiltration (NF) and reverse osmosis (RO) membranes. 2007 American Water Works Association Membrane Technology Conference (Tampa, Florida, Mar. 2007).


Hatch, J., and Finneran, K.T. Physiological approaches to increase molar H2 yield in fermentative cultures: Use of extracellular electron shuttles. 2007 American Society for Microbiology General Meeting (Toronto, ON, May 2007).


Li, X., Choi, Y. C., Morgenroth, E., and Raskin, L. Optimization of backwash strategy to maintain continuous perchlorate reduction with a fixed bed biofilm reactor. 4th American Society for Microbiology Conference on Biofilms (Quebec City, QC, Mar. 2007).


Luh, J. and Mariñas, B. J. **Inactivation of Mycobacterium avium with free chlorine.** 2007 American Chemical Society Spring National Meeting, Division of Environmental Chemistry (Chicago, IL, Mar. 2007).

Menniti, A. and Morgenroth, E. **The time scale of shear and its importance to fouling potential in MBRs.** 80th Water Environment Federation Technical Exhibition and Conference (San Diego, CA, Oct. 2007).

Menniti, A. L. and Morgenroth, E. **Influence of shear on floc structure development and fouling potential in MBRs.** 2007 American Chemical Society Spring National Meeting (Chicago, IL, Mar. 2007).

Milferstedt, K., Pons, M. N., and Morgenroth, E. **Spatial organization of biofilms: The effect of controlled disturbances (e.g., shear and particle addition).** 2007 American Society for Microbiology General Meeting (Toronto, ON, May 2007).

Minier-Matar, J., Coronell, O., Mariñas, B. J., Zhang, X., and Cahill, D. G. **Concentration polarization dynamics in high-pressure membranes.** 2007 American Chemical Society Spring National Meeting, Division of Environmental Chemistry (Chicago, IL, Mar. 2007).


Page, M., and Mariñas, B. J. **Improving the control of pathogenic viruses in drinking water treatment.** 2007 American Chemical Society Spring National Meeting, Division of Environmental Chemistry (Chicago, IL, Mar. 2007).


Reinauer, K. and Finneran, K.T. **Aerobic biodegradation of tert-butyl alcohol (TBA) by cultures derived from granular activated carbon.** 2007 American Society for Microbiology General Meeting (Toronto, ON, May 2007).


Sirikanchana, K., Shisler, J. L., and Mariñas, B. J. **Inactivation of adenovirus with UV and chlorine.** 2007 American Chemical Society Spring National Meeting, Division of Environmental Chemistry (Chicago, IL, Mar. 2007).


Environmental Hydrology and Hydraulic Engineering


Geotechnical Engineering


Structural Engineering and Design


Jung, S., Ok, S.-Y., and Song, J. **Multi-objective optimization based structural condition assessment.** 18th Engineering Mechanics Division Conference of the American Society of Civil Engineers (Blacksburg, VA, Jun. 2007).

Kang, W.-H., Song, J., and Gardoni, P. **Matrix-based system reliability method and applications to bridge networks.** 10th International Conference on Applications of Statistics and Probability in Civil Engineering (Tokyo, Japan, Jul. 2007).


Song, J. and Kang, W.-H. **Matrix-based system reliability method and applications to structural systems.** 18th Engineering Mechanics Division Conference of the American Society of Civil Engineers (Blacksburg, VA, Jun. 2007).


**Structural Engineering and Structural Dynamics**


**Transportation Facilities and Systems**


Dessouky, S. H., Al-Qadi, I. L., and Yoo, P. J. Full-depth pavement response to different truck tire loading. 86th Transportation Research Board Annual Meeting (Washington, DC, Jan. 2007).


**Theses**

**Earthquake Engineering**


Environmental Engineering and Science in Civil Engineering


Structural Engineering and Design


Transportation Facilities and Systems


Patents

Geotechnical Engineering


Awards and Honors

Daniel P. Abrams
William and Flora Hewlett Fellowship, 1989
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1992
Hanson Engineers Professorship in Civil Engineering, University of Illinois, 1997
President's Award, The Masonry Society, 1997
Scalzi Research Award, The Masonry Society, 1997
D. B. Willett Professor in Engineering, University of Illinois College of Engineering, 2002
Bob Y-K Wong Distinguished Visiting Professor of Civil Engineering, University of Hawaii, 2003-2004

Imad L. Al-Qadi
STS Research Award, Best Paper by an Academic Researcher, 5th International Conference on Structural Faults and Repair, 1993
Young Investigator Award, National Science Foundation, 1994
Dean's Award for Research Excellence, Virginia Tech College of Engineering, 2001
Charles E. Via, Jr. Professor of Civil and Environmental Engineering, Virginia Tech, 2002
D. Grant Mickle Award, runner-up, Best Transportation Research Board Paper, 2002
Fellow, American Society of Civil Engineers, 2002
International Geosynthetic Society Award, 2002
Selected Researcher of the Week, Virginia Tech and WVT, 2003
Founder Professor of Engineering, University of Illinois, 2004
Limoges Medal of Merit, Limoges, France, 2004
D. Grant Mickle Award, Best Transportation Research Board Paper, 2006
Outstanding Instructor Award, American Society of Civil Engineers, 2006
Profiled in the TRNews of the National Academies, November-December 2006, Number 247, 2006
Honorary Member, Societa Italiana Infrastructure Viarie, Rome, Italy, 2006

Rahim Benekohal
Honorary Professorship in Transportation Engineering, Harbin University of Civil Engineering and Architecture, China
Certificate of Appreciation for Outstanding Service, Illinois Institute of Transportation Engineers, 1989
Faculty Honor Member, Chi Epsilon, University of Illinois, 1989
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1991, 1993
IBM Innovations Award for Teaching, University of Illinois Educational Technologies Board, 1991
Arthur M. Wellington Prize, American Society of Civil Engineers, 1993
Advisors List for Excellence in Advising, University of Illinois College of Engineering, 1994, 2006
Faculty Honor Member, Phi Kappa Phi, University of Illinois, 1994
Certificate of Recognition for Outstanding Mentoring of Graduate Students (finalist), University of Illinois Graduate College, 1997
Past President's Award, Institute of Transportation Engineers, 1998
Guest Professor, Harbin Institute of Technology, China, 2006

**Tami C. Bond**
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2004
Postdoctoral Fellowship, Climate and Global Change, National Oceanic and Atmospheric Administration, 2000-2002
Fannie and John Hertz Foundation Award, Outstanding Doctoral Dissertation, 2000
Arthur & Virginia Naumann Endowed Faculty Scholar, 2006

**William G. Buttlar**
General Electric Scholar Award, University of Illinois College of Engineering, 1997
Outstanding Poster Award, International Society of Asphalt Pavements, 8th International Conference on Asphalt Pavements, 1997
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1999
Fred Burggraf Award, National Academy of Sciences, Transportation Research Board, 2000
Prix Earl Kee Award, Canadian Technical Asphalt Association, Best Technical Presentation by New Authors, 2001
Instructor of the Year, Department of Civil and Environmental Engineering, American Society of Civil Engineers Student Chapter, 2003
Rose Award for Teaching Excellence, University of Illinois College of Engineering, 2004

**Ximing Cai**
Best Paper Award, International Water Resources Association, 2005
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 2006

**Samuel H. Carpenter, Emeritus**
D. Grant Mickle Award, Transportation Research Board, 1989
Andersen Consulting Award for Excellence in Advising, College of Engineering, University of Illinois, 1992
Everitt Award for Teaching Excellence, University of Illinois College of Engineering, 1994
Advisors Lists for Excellence in Advising, University of Illinois College of Engineering, 1997, 2002

**Mark M. Clark**
Research Initiation Award, National Science Foundation, 1988
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1994
Presidential Young Investigator Award, National Science Foundation, 1990-1996
Associate, Center for Advanced Study, University of Illinois, 1999-2000

**Barry J. Dempsey, Emeritus**
Emeritus Member of Transportation Research Board Committee AFS60, Subsurface Drainage, 2005

**Robert H. Dodds, Jr.**
Distinguished Alumni Award, University of Memphis, 1989
Burlington Northern Foundation Faculty Achievement Award, University of Illinois, 1990
Walter L. Huber Research Prize, American Society of Civil Engineers, 1991
Nathan Anne M. Newmark Professor of Civil Engineering, University of Illinois, 1997-2000
Distinguished Visiting Professor, University of Sao Paulo, 1998
Distinguished Visiting Professor, Imperial College of Science and Technology, 1999
Honor Member, Chi Epsilon Chapter, University of Illinois, 2000
M. T. Geoffrey Yeh Endowed Chair in Civil Engineering, University of Illinois, 2000
Award of Merit and Fellow, American Society for Testing and Materials International, 2001
Nathan M. Newmark Medal, American Society of Civil Engineers, 2001
Distinguished Visiting Professor, National University of Singapore, 2002
Southwest Universities Mechanics Speaker, 2002
Honorary Fellow of the International Conference on Fracture, 2005
Distinguished Alumnus Award, Tau Beta Pi, University of Illinois Alpha-Chapter, 2006
Carlos A. Duarte
Professional Development Award, University of Texas at Austin, 1996
Young Researcher Fellowship Award, Exemplary Research in Computational Mechanics, First MIT Conference on Computational Fluid and Solid Mechanics, 2001
Faculty Fellow, National Center for Supercomputing Applications (NCSA), University of Illinois, 2006
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, Fall 2006, Spring 2007, Fall 2007
Advisor of Jeronymo Pereira, Best Student Presentation, Meshfree Methods; 9th U.S. National Congress on Computational Mechanics, San Francisco, 2007
Chairman-elected of the U.S. Association for Computational Mechanics Specialty Committee on Meshfree Methods, August 2007-July 2009

J. W. Eheart
Distinguished Professor Award, Council for International Exchange Scholars, 1988

Amr Elnashai
Unwin Prize, Best Ph.D. in Civil and Mechanical Engineering, Imperial College, 1985
Armstrong Medal, Best Paper, Institution of Structural Engineers, UK, 1989-
Fellow, Institution of Structural Engineers, UK, 1989-
Visiting Professor, Institute of Industrial Science, Japan, 1990, 1992, 1995
Visiting Professor, University of Southern California, 1990-1995
Visiting Professor, University of Surrey, UK, 1995-
Founder and Editor, Journal of Earthquake Engineering (Taylor and Francis), 1996-2006
Fellow, American Society of Civil Engineers, 1997-
Visiting Professor, University of Pavia and Politechnic of Milan, Italy, 1998
Visiting Professor, McMaster University, Canada, 1999
Armstrong Medal, Best Paper in the Institution of Structural Engineers, 2000-
Fellow, Royal Academy of Engineering, UK, 2000-
Donald Biggar Willett Professor in Engineering, University of Illinois College of Engineering, 2003-2008
First Bill and Elaine Hall Endowed Professor, University of Illinois, 2006-

Khaled El-Rayes
Competitive Scholarship Award, American Association of Cost Engineers, 1991, 1992
Excellence Award, Project Management Institute, 1993
External Grant Holder Doctoral Scholarship, Concordia University, 1993-1996
Excellence Award for Graduate Studies and Integration of Research, Nature and Technologies Research Foundation, Quebec, Canada, 1993-1996
Scholastic Scholarship Award, American Association of Cost Engineers, 1994
Teaching Assistantship Award, School of Graduate Studies, Concordia University, 1996
Doctoral Prize in Engineering and Computer Science, Concordia University, 1999
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2003-2008
Thomas Fitch Rowland Prize, American Society of Civil Engineers, 2007

Larry A. Fahnestock
Outstanding Instructor Award, University of Illinois American Society of Civil Engineers Student Chapter, 2007

Kevin T. Finneran
Best Student Paper Award, Association for Environmental Health Sciences Annual Meeting, Amherst, 2007
List of Teachers Ranked as Excellent by their Students, Spring 2007, Fall 2007

Douglas A. Foutch
Arthur M. Wellington Prize, American Society of Civil Engineers, 1990
Haliburton Award for Engineering Education Leadership, University of Illinois College of Engineering, 1992
Norman Medal, American Society of Civil Engineers, 1992
Arthur M. Wellington Prize, American Society of Civil Engineers, 1998
Norman Medal, American Society of Civil Engineers, 2003
Best Paper, Earthquake Spectra, Earthquake Engineering Research Institute 2004

Marcelo H. García
Hokkaido River Institute Lectureship, Japan, 1990
MUCIA International Development Travel Grant, 1992
Invited Professor, Instituto di Idraulica, University of Genoa, Italy, 1993
Invited Professor, Universidad Nacional del Litoral, Argentina, 1995
Guest Lecturer, University of Essen, Germany, 1995  
MUCIA International Program Development Award,  
Argentina, 1995  
Karl Emil Hilgard Hydraulic Prize, American Society of  
Civil Engineers, 1996  
Advisors List for Excellence in Advising, University of  
Illinois College of Engineering, 1997  
Invited Professor, California Institute of Technology, 1997  
Walter L. Huber Research Prize, American Society of Civil  
Engineers, 1998  
Karl Emil Hilgard Hydraulic Prize, American Society of  
Civil Engineers, 1999  
Invited Professorship, Universidad de Castilla-La Mancha,  
Spain, 2000  
Supervised and Supported Research of Emmauelle Gira,  
exchange student from France, 2000  
University Scholar Award, University of Illinois,  
2000-2001  
Honorable Mention for Excellence in Graduate and  
Professional Teaching, University of Illinois, 2003  

**Jamshid Ghaboussi, Emeritus**  
Research Fellowship, Royal Norwegian Council for  
Scientific and Industrial Research, 1972-1973  
Best Theoretical Paper Award, International Conference  
on Intelligent Engineering Systems through Artificial  
Neural Networks in Engineering, 1997  
Guest Chair Professorship, National Research Council of  
Taiwan, National Taiwan University, Taipei, Taiwan,  
2000  
Short Term Invitation Fellowship, Japanese Society for  
Promotion of Science, 2000  

**German R. Gurfinkel, Emeritus**  
Fellow, American Society of Civil Engineers  
First Prize, Bridge Design Competition, Commission for  
National Development of Cuba, 1959  
Danforth Teacher Award, Danforth Foundation, 1964  
James F. Lincoln Arc Welding Foundation, nine awards,  
Innovative Design, Structural Engineers Association of  
Special Recognition, Technical Council on Forensic  
Engineering, American Society of Civil Engineers, 1988  
Certificate of Achievement, U.S. Army in Europe, 1990  
Outstanding Civil Engineering Undergraduate Teaching  
Award, American Society of Civil Engineers,  

Harriet and Charles Luckman Undergraduate  
Distinguished Teaching Award, University of Illinois,  
1992  
Most Outstanding Paper Award, *American Society of Civil  
Engineers Journal of Performance of Constructed  
Facilities*, 1997  

**Jerome F. Hajjar**  
Minnesota Young Civil Engineer of the Year, American  
Society of Civil Engineers, Minnesota Section, 1995  
Minnesota Young Engineer of the Year, Minnesota  
Federation of Engineering Societies and Minnesota  
Society of Professional Engineers, 1995  
Outstanding Instructor Award, Department of Civil  
Engineering, Institute of Technology Student Board,  
University of Minnesota, 1995, 1996  
Bonestroo, Rosene, Anderlik and Associates  
Undergraduate Faculty Award, University of Minnesota  
Department of Civil Engineering, 1996, 1997  
Taylor Career Development Award, University of  
Minnesota Institute of Technology, 1998  
UPS Foundation Visiting Professor, Department of Civil  
and Environmental Engineering, Stanford University,  
2000-2001  
Norman Medal, American Society of Civil Engineer, 2000  
Charles E. Bowers Faculty Award, University of  
Minnesota Institute of Technology, 2001  
Walter L. Huber Civil Engineering Research Prize,  
American Society of Civil Engineers, 2003  
Special Achievement Award, American Institute of Steel  
Construction, 2004  
T. R. Higgins Lectureship Award, American Institute of  
Steel Construction, 2005  
Narbey Khatchaturian Faculty Scholar, University of  
Illinois Department of Civil and Environmental  
Engineering, 2005  
Fellow, American Society of Civil Engineers, 2007  

**William J. Hall, Emeritus**  
Member, National Academy of Engineering  
Honorary Member, American Society of Civil Engineers  
Fellow, American Association for the Advancement of  
Science  
Howard Award, American Society of Civil Engineers,  
1984  
Nathan M. Newmark Medal, American Society of Civil  
Engineers, 1984  
Distinguished Engineering Service Award, University of  
Kansas School of Engineering, 1986  
Senior University Scholar, University of Illinois, 1986  
C. Martin Duke Lifetime Earthquake Engineering Award,  
American Society of Civil Engineers, 1990
John Parmer Award, Structural Engineers Association of Illinois, 1990
Norman Medal, American Society of Civil Engineers, 1992
Daniel C. Drucker Tau Beta Pi Eminent Faculty Award, University of Illinois College of Engineering, 1993
Houser Medal, Earthquake Engineering Research Institute, 1998
National Honor Member, Chi Epsilon, 1998

Yousef Hashash
James Croes Medal, American Society of Civil Engineers, 1994
Thomas Middlebrooks Award, American Society of Civil Engineers, 1997
Faculty Fellow, National Center for Supercomputing Applications, University of Illinois, 1999
Arthur Cassagrande Professional Development Award, Geo-Institute, American Society of Civil Engineers, 2000
Representative, First International Young Geotechnical Engineers Conference, U.S. delegate selected by GeoInstitute, Southampton, U.K., 2000
Presidential Early Career Award for Scientists and Engineers, National Science Foundation, 2000
American Bridge Faculty Scholar Award, University of Illinois Civil and Environmental Engineering Department, 2001-2003
Beckman Fellow, Center for Advanced Studies, University of Illinois, 2002-2003
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2003
Delegate, National Academy of Engineering 11th Annual Frontiers of Engineering Symposium, 2005
Faculty Fellow, National Center for Supercomputing Applications Faculty Fellow (NCSA), University of Illinois, 2005

Neil M. Hawkins, Emeritus
Edward Noyes Prize, Institution of Engineers, Australia, 1965
Wason Medal for Research, American Concrete Institute, 1969
State-of-the-Art Award, American Society of Civil Engineers, 1974
Raymond C. Reese Structural Research Award, American Society of Civil Engineers, 1976
Raymond C. Reese Award, American Concrete Institute, 1978, 1981
T. Y. Lin Award, American Society of Civil Engineers, 1988

UNESCO Distinguished Visiting Scientist, International Institute of Seismology and Earthquake Engineering, BRI, MOC, Japan, 1988
Structural Research Award, American Concrete Institute, 1991
Charles C. Zollman Award, Precast/Prestressed Concrete Institute, 1994
Joe W. Kelly Award, American Concrete Institute, 1996
Erskine Scholar, University of Canterbury, New Zealand, 1997
Precast/Prestressed Concrete Institute, Educator of the Year, 2001
Honorary Award for Outstanding Achievements in the Field of Concrete Technology and Structures, International Federation of Concrete, 2002
Howard Award, American Society of Civil Engineers for Special Merit in Research and Education, 2004
Titan, Innovation and Change, Precast/Prestressed Concrete Industry, 2004
Fellow, Precast/Prestressed Concrete Institute, 2005
Turner Medal, American Concrete Institute, 2005
Boase Award, Concrete Research Council, American Concrete Institute, 2005
Charles C. Zollman Paper Award, Precast/Prestressed Concrete Institute, 2005

Edwin E. Herricks
Fulbright Distinguished Professor, Yugoslavia
Guest Professor, University of Essen, Germany
Education and Public Services Award in Water Resources, Universities Council on Water Research, 1992

Keith D. Hjelmstad
Alfred Noble Prize, American Society of Civil Engineers, 1987
President Young Investigator Award, National Science Foundation, 1987
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1993
University Scholar, University of Illinois, 1993
Advisors List for Excellence in Advising, University of Illinois College of Engineering, 1995
Robert E. Miller Award for Teaching Excellence in Mechanics, University of Illinois Theoretical and Applied Mechanics Department, 2002
Campus Award for Excellence in Advising Undergraduate Students, University of Illinois, 2002
Engineering Council Award for Excellence in Advising, University of Illinois College of Engineering, 2003
Honor Member, Chi Epsilon Chapter, University of Illinois, 2005

Daniel A. Kuchma
Faculty Fellow, National Center for Supercomputing Applications (NCSA), University of Illinois, 2001
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001-2006
Design Practice Award, American Concrete Institute, 2003
Fellow, American Concrete Institute, 2004
Burton and Erma Lewis Faculty Scholar, 2007

Praveen Kumar
New Young Investigator Award, NASA, 1996

James M. LaFave
Outstanding Instructor Award, University of Illinois American Society of Civil Engineers Student Chapter, 2002, 2005
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2005
Alan H. Yorkdale Memorial Award, American Society for Testing & Materials, 2006

David A. Lange
Sigma Xi, 1994
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 1996
Narbay Khachatryan Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1998
Faculty-Student Fellowship Award (with student, Anne Werner), Portland Cement Association, 1998
Faculty-Student Fellowship Award (with student, Zach Grasley), Portland Cement Association, 2002
Fellow, American Concrete Institute, 2002
Wason Medal, Most Meritorious Paper, American Concrete Institute, 2003
Fellow, American Ceramic Society, 2005

Susan M. Larson
Lilly Endowment Teaching Fellowship, 1989
Everitt Award for Teaching Excellence, University of Illinois College of Engineering, 1991
Presidential Young Investigator Award, National Science Foundation, 1991
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1993
Finalist, Harriet and Charles Luckman Undergraduate Distinguished Teaching Award, 1993
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1994
Advisors List for Excellence in Advising, University of Illinois College of Engineering, 1995

Jon C. Liebman, Emeritus
Fellow, American Association for the Advancement of Science
Outstanding Civil Engineering Teacher Award, University of Illinois Student Chapter, American Society of Civil Engineers, 1976, 1986, 1996
Daniel L. and Irma Evans Visiting Distinguished Lecturer, University of Washington, 1988
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1989
Rose Award for Teaching Excellence, University of Illinois College of Engineering, 1997

Liang Y. Liu
Scholar, W. E. O’Neil Faculty, University of Illinois College of Engineering, 2002-2006
Teaching Award, University of Illinois College of Engineering, 2003

James H. Long
Shell Faculty Award, 1987
Newmark Scholar Award, University of Illinois, 1991-1992
Rose Award for Teaching Excellence, University of Illinois College of Engineering, 2003

Benito J. Mariñas
Fellowship, Abraham Rosenberg Research, University of California, Berkeley, 1984
Fellowship, University of California Regents, University of California, Berkeley, 1986, 1987
Harold Munson Outstanding Teacher Award, School of Civil Engineering, Purdue University, 1992
Ross Judson Buck ’07 Outstanding Counselor Award, School of Civil Engineering, Purdue University, 1992
Arthur and Virginia Nauman Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1998-2004
Parsons Engineering Science Doctoral Thesis Award (advisor to doctoral student: Qilin Li, co-advised with V. L. Snoeyink), Association of Environmental Engineering and Science Professors (AEESP), 2003
Ivan Racheff Professorship, University of Illinois Department of Civil and Environmental Engineering, 2005
Chemical Sciences Poster Award, Annual Biomedical Research Conference for Minority Students (ABRCMS) (Summer Research Opportunity Program Student: Wanakee Carr), 2006
Second Place Academic Achievement Award, Best Doctoral Dissertation (doctoral student: Lance C. Schideman), American Water Works Association, 2007
Student Best Paper Award (doctoral student: Orlando Coronell), American Water Works Association Membrane Technology Conference, 2007

**Arif Masud**
Mian-Iqbal Gold Medal, University of Engineering and Technology, Lahore, Pakistan, 1986
Teaching Recognition Program Award, Council for Excellence in Teaching, University of Illinois at Chicago, 1999
Visiting Professor, The Swiss Federal Institute of Technology (EPFL) Lausanne, Switzerland, 2001
Faculty Distinguished Research Award, University of Illinois at Chicago College of Engineering, 2002
Edward M. Burke Teaching Award, University of Illinois at Chicago Department of Civil and Materials Engineering, 2003
Chair of the American Society of Civil Engineers (ASCE) Computational Mechanics Committee, 2006
Associate Editor, *ASME Journal of Applied Mechanics*, American Society of Civil Engineers, 2006
Fellow, International Association of Computational Mechanics (IACM), 2006
Chair, ASME Technical Committee on Fluid Mechanics, 2007
Faculty Fellow, National Center for Supercomputing Applications, University of Illinois, 2007

**Gholamreza Mesri**
Fellowship, Royal Norwegian Council for Scientific and Industrial Research, 1970
Norman Medal, American Society of Civil Engineers, 1988

**Visiting Norwegian Council for Scientific and Industrial Research (NTNF) Senior Scientist, Norwegian Geotechnical Institute, 1981
Visiting Senior Scientist, National Defense Academy of Japan, 1988
Thomas A. Middlebrooks Award, American Society of Civil Engineers, 1992
Visiting Renowned Foreign Scholar and Scientist, Republic of China, 1994
Kersten Lecture, Minnesota Geotechnical Society, 1997
Ralph B. Peck Professorship, 2000
International Scientific Advisor to the Norwegian Geotechnical Institute Center of Excellence on Geohazards, 2003
Norman Medal, American Society of Civil Engineers, 2004
Beyer Distinguished Lecture, University of Houston, 2005
Honor Member, Chi Epsilon Chapter, University of Illinois, 2006

**Barbara S. Minsker**
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 1998
Faculty Fellow, National Center for Supercomputing Applications, 1999
Army Young Investigator Award, U.S. Army Research Office, 2000
*Presidential Early Career Award for Scientists and Engineers (PECASE)*, National Science and Technology Council, 2000
Fellow, Center for Advanced Study, University of Illinois, 2001
Nauman Faculty Scholar, University of Illinois, 2001-2002
Fellow, Japan Society for the Promotion of Science, 2003
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 2003
Environmental and Water Resources Institute Outstanding Achievement Award, American Society of Civil Engineers, 2005
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2006

**Eberhard Morgenroth**
Ulrich Finsterwalder Award, Outstanding Ph.D. Thesis, Dykerhoff & Widmann, Technical University of Munich Department of Civil Engineering, 1998
Collins Scholar, Academy for Excellence in Engineering Education, University of Illinois, 2001
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2002
Editor, *Water Research*, 2002-
Incomplete List of Teachers Ranked as Excellent by Their Students, 2003
Beckman Fellow, Center for Advanced Studies, University of Illinois, 2003
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2004
Harold E. Babbitt Faculty Scholar in Civil and Environmental Engineering, 2007-

Thanh H. Nguyen
Gaylord Donnelley Environmental Postdoctoral Fellowship, Yale University, 2005-2006
German Academic Exchange Service (Deutscher Akademischer Austausch Dienst, DAAD), Scholarship declined, 2005-2006
German Academic Exchange Service (Deutscher Akademischer Austausch Dienst, DAAD), Scholarship declined, 2006

Scott M. Olson
R. M. Quigley Best Paper Award, Canadian Geotechnical Society, 2003
Arthur Casagrande Professional Development Award, American Society of Civil Engineers, 2004
Outstanding Teaching Commendation Award, University of Missouri at Rolla, 2005
Incomplete List of Teachers Ranked as Excellent by their Students, University of Illinois at Urbana-Champaign, 2005, 2007

Yanfeng Ouyang
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 2005, 2006
Gordon F. Newell Award, Institute of Transportation Studies, University of California, Berkeley, 2005

Glaucio H. Paulino
Collins Scholar, University of Illinois, 2000
Xerox Award for Faculty Research, University of Illinois College of Engineering

David A. Pecknold, Emeritus
Outstanding Civil Engineering Undergraduate Teaching Award, University of Illinois Student Chapter, American Society of Civil Engineers, 1978, 1992

Outstanding Paper Award, American Society of Civil Engineers Journal of Performance of Constructed Facilities, 1997
Special Paper Award, American Society of Mechanical Engineers Ocean, Offshore and Arctic Engineering Division, 2000

John S. Popovics
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2000
University of Illinois American Society of Civil Engineers Outstanding Teacher Award, 2004
Accenture Outstanding Advisor Award, 2004

Shaoying (Shawn) Qi
Recipient, Editor's Award, Journal of Environmental Engineering, American Society of Civil Engineers 129 (12), 1076, 2003

Arthur R. Robinson, Emeritus
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1969
Moisseiff Award, American Society of Civil Engineers (with Harry H. West), 1970

Jeffrey Roesler
Marlin J. Knutson Award, Technical Achievement (shared with University of California-Berkeley, WSCACPA, Caltrans), American Concrete Pavement Association, 2001
Incomplete List of Teachers Ranked as Excellent, University of Illinois, 2003, 2004, 2005
Bengt F. Friberg Award, International Society for Concrete Pavement, 2005
Young Author Award (with Jacob Hiller and Paul Littleton), “Large-Scale Airfield Concrete Slab Fatigue Tests,” 8th International Conference on Concrete Pavement, 2005

Mark J. Rood
Valle Scandinavian Exchange Program Scholarship, 1985
James M. Montgomery Thesis Award to advisee Joseph Wood, Association of Environmental Engineering Professors, 1992
Distinguished Service Recognition as Treasurer and Executive Board Member, Association of Environmental Engineering Professors, 1993-1995
Community Recycling Center, Executive Board Member, Champaign, Illinois, 1993-1997
Community Recycling Center, President of the Board, Champaign, Illinois, 1994-1996
Richard A. Glenn Best Paper Award, 214th American Chemical Society National Meeting Fuel Chemistry Division, 1997
Associate Editor, Journal of Air and Waste Management Association, 1994-2004
Associate Editor, Journal of Environmental Engineering, 1998-2004
Editor-in-Chief, Journal of Environmental Engineering, 2002-2004
Thesis Award to advisee Katherine Dombrowski, Montgomery-Watson-Harza, Association of Environmental Engineering Professors, 2002
Editor-in-Chief, Journal of Environmental Engineering, 2002-2004
Keynote Lecture, Carbon 2003 Conference, Spain, 2003
Environmental Engineering Committee Member, U.S. Environmental Protection Agency, Science Advisory Board, 2003-
Ivan Racheff Professor of Environmental Engineering, University of Illinois, 2005-
Board Certified Member (BCM), American Academy of Environmental Engineering American Academy of Environmental Engineering, 2005-
Outstanding Cooperators Award, Illinois State Geological Survey, 2006

A. R. Schmidt
University Council on Water Resources Ph.D. Dissertation Award in the field of Natural Science and Engineering, 2003

Murugesu Sivapalan
Certificate of Commendation for Achievement in Postgraduate Supervision: Guild of Students, The University of Western Australia, 1994

Member, Editorial Board, Hydrological Processes (John Wiley & Sons), 1996-2004
Associate Editor, Journal of Hydrology (Elsevier Science), 1996-2004
Lise Meitner Fellow (Austrian Science Foundation), Vienna University of Technology, 1995-1996
Fellow, The International Water Academy, Oslo, Norway, 2000
Member, Editorial Board, Environmental Modelling & Software (Elsevier Science), 2000-2005
Visiting Professor, Delft University of Technology, The Netherlands, 2000-2001
Biennial Medal (Natural Systems), Modelling and Simulation Society of Australia and New Zealand, 2001
Fellow, Modelling and Simulation Society of Australia and New Zealand, 2001-
Associate Editor, Encyclopedia of Hydrological Sciences (John Wiley & Sons), 2001-2005
Member, Editorial Board, Advances in Water Resources (Elsevier Science), 2001-
Fellow, Australian Academy of Technological Sciences and Engineering, 2001
Winner, WA Water Industry Awards, Farm Water Supply (along with Matthew Hipsey and Iain Laing), 2002
Chair, Science Steering Group, Decade on Predictions in Ungauged Basins, International Association of Hydrological Sciences, 2002-2005
Fellow, American Geophysical Union, 2003
John Dalton Medal, European Geophysical Society, 2003
Centenary Medal, Commonwealth Government of Australia, 2003
Member, Editorial Board, Hydrological Sciences Journal, International Association of Hydrological Sciences, 2004-
Member, Editorial Board, Benchmark Papers in Hydrology, International Association of Hydrological Sciences Press, 2004-
Member, Editorial Board, Nordic Hydrology, 2004-
Executive Editor, Hydrology and Earth System Science, European Geophysical Union, 2004-

Vernon L. Snoeyink, Emeritus
Member, National Academy of Engineering
Past President, Association of Environmental Engineering Professors
Nalco Award, Significant Chemical Research in Industrial Waste Treatment, 1981
Outstanding Civil Engineering Teacher Award, University of Illinois, American Society of Civil Engineers Student Chapter, 1982
Best Paper Award, Research Division, American Water Works Association, 1983
Campus Award for Excellence in Undergraduate Teaching, University of Illinois, 1983
Fuller Award, American Water Works Association, 1986
Best Paper Award, Illinois Section, American Water Works Association, 1987
Association Research Award, American Water Works Association, 1988
Thomas R. Camp Lecture, Boston Society of Civil Engineers, 1989
Halliburton Engineering Education Leadership Award, University of Illinois College of Engineering, 1990
Best Ph.D. Thesis Award, (advisor to doctoral student: I. Najm), American Water Works Association, 1992
Second Prize, Ph.D. Thesis Competition, (advisor to student: F. Cannon), American Water Works Association, 1994
Distinguished Monsanto Lecturer, Purdue University, 1994
Samuel Arnold Greeley Award, American Society of Civil Engineers, 1995
Tau Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 1996
Honor Member, Chi Epsilon, 1998
Ambassador Award, American Water Works Association, 1999
Best Paper Award, Research Division, American Water Works Association (with F. Cannon), 1999
Founders Award, Association of Environmental Engineering and Science Professors, 1999
Life Member, American Water Works Association, 1999
Excellence in Advising Award, University of Illinois College of Engineering, 2001, 2002
Best Paper Award, Water Science and Research Division, American Water Works Association (with J. Brown and M. J. Kirisits), 2003
Honorary Knight of St. Patrick, 2003
Athalie Richardson Irvine Clarke Prize, National Water Research Institute, 2004
Henske Distinguished Lecture, Yale University, 2004

Junho Song
Outstanding Graduate Student Instructor Award, University of California, Berkeley, 2004
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 2006, 2007

B. F. Spencer, Jr.
Honorary Professor, Harbin Institute of Technology, Harbin, China
Schmidt Distinguished Visiting Professor, Florida Atlantic University, Boca Raton, Florida
President-elect, Asia-Pacific Network of Centers for Research in Smart Structures Technologies (ANCRiSST), 2003

Timothy D. Stark
Summer Research Fellow, U.S. Army Corps of Engineers, U.S. Army Waterways Experiment Station, Mississippi, 1988, 1991
Outstanding College of Engineering Professor, San Diego State University Tau Beta Pi Honor Society, 1989
Meritorious Performance and Professional Promise Award by President of San Diego State University, 1990
Timeos Award, Outstanding Assistant Professor at San Diego State University, Phi Eta Sigma Honor Society, 1990
Edmund Friedman Young Engineer Award for Professional Achievement, American Society of Civil Engineers (ASCE), 1991
Arthur Cassagrande Professional Development Award, American Society of Civil Engineers, 1992
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1993
Presidential Citation for Outstanding Alumni Achievement, University of Delaware, 1993
DOW Outstanding New Faculty Award, American Society for Engineering Education, 1994
William J. and Elaine F. Hall Scholar Award, University of Illinois Department of Civil and Environmental Engineering, 1994-1996
News Correspondent Award, American Society of Civil Engineers, 1995
Outstanding Section Campus Representative Award, American Society for Engineering Education Illinois/Indiana Section, 1998
University Scholar, University of Illinois, 1998-2001
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1999
Standards Development Award, American Society for Testing and Materials, 2002
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 1995, 1996, 2004, 2005
Elected Fellow, American Society of Civil Engineers (ASCE), 2005

**Timothy J. Strathmann**
Graduate Fellowship, United States Environmental Protection Agency S.T.A.R., 1997
Graduate Fellowship, Society of Environmental Toxicology and Chemistry, 2000
Graduate Student Paper Award, American Chemical Society, 2000
List of Teachers Ranked as Excellent by Their Students, University of Illinois, Spring 2007, Fall 2007

**Leslie J. Struble**
Young Investigator Award, National Science Foundation, 1992
Fellow, American Ceramic Society, 1996
Honorary Member, American Society for Testing and Materials (ASTM) CO1, 2001
Sanford E. Thompson Award, Outstanding Paper, ASTM CO9, 2003
Honorary Member, ASTM Committee CO9 on Concrete and Concrete Aggregates, 2004

**Marshall R. Thompson, Emeritus**
Ronald D. Kenyon Research and Education Award, National Asphalt Pavement Association Research and Education Foundation, 1997
Distinguished Research Award, Aggregates Foundation for Technology, Research and Education, 1998
K. B. Woods Award, Transportation Research Board, National Research Council, 1999

Hall of Fame Inductee, National Asphalt Pavement Association, 2005
Best Paper Award, International Society for Asphalt Pavements Meeting, Quebec City, Canada, 2006

**Erol Tutumluer**
Gold Plate Award, Top Ranked High Honor Graduate, Bogazici University, 1989
Best Student Paper Award Recipient in Pavement Engineering, ERES Consultants, Illinois, 1995
Gene Boyd Vulcan Materials Scholarship, Civil Engineering, Georgia Institute of Technology, 1995
Outstanding Graduate Teaching Assistant Award, Georgia Institute of Technology Civil Engineering, 1995
General Electric Scholar, University of Illinois, 1997
General Electric Fellow, University of Illinois Academy for Excellence in Engineering Education, 1999
Collins Fellow, University of Illinois, 2000
Fred Burggraf Award for Excellence in Transportation Research, Transportation Research Board, National Academy of Sciences, 2000
Ronald E. McNair Research Institute Faculty Advisor, University of Illinois College of Engineering, 2002
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 2003
Paul F. Kent Endowed Faculty Scholar, University of Illinois, 2006

**Albert J. Valocchi**
Shell Faculty Career Fellow, 1984-1987
NATO Fellowship, Visiting Lecturer, Summer School on Environmental Dynamics, Venice, Italy, 1990
Invited Lecturer, NATO Advanced Study Institute on Migration and Fate of Pollutants in Soils and Subsoils, 1992
Danish Research Academy Fellowship, Technical University of Denmark, 1993
Invited Guest Instructor, Danish Center for Applied Mathematics and Mechanics, 2000
Collins Award for Innovative Teaching, University of Illinois, College of Engineering, 2002
Center for Advanced Study Associate, University of Illinois, 2003-2004
Editor-in-Chief, *Journal of Contaminant Hydrology*, Elsevier, 2003-

**William H. Walker, Emeritus**
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1989
Y. K. Wen
Fellowship, Japan Society for the Promotion of Science, 1986, 1996
Moisseiff Award, American Society of Civil Engineers, 1986
Walter L. Huber Civil Engineering Research Prize,
American Society of Civil Engineers, 1986
Research Prize, International Association of Structural Safety and Reliability, 1997
Raymond C. Reese Research Prize, American Society of Civil Engineers, 2002
Engineering Risk and Reliability Association (CERRA) Award, 2003

Charles J. Werth
Faculty Early Career Development (CAREER) Award,
National Science Foundation, 1988-2002
Environmental Engineering and Science Faculty Scholar, 2001-2004
Humboldt Research Fellowship, 2004-2005