2005 SUMMARY OF ENGINEERING RESEARCH

A Report of Activities during 2004

This .pdf is part of the larger 2005 Summary of Engineering Research, available on the Web at www.engr.uiuc.edu/research and on CD-ROM. The Summary of Engineering Research represents the extensive engineering research program conducted in 2004 at the University of Illinois at Urbana-Champaign. Detailed statistics about research in the College of Engineering are included in the Directory of Engineering and Engineering Technology Programs and Research, published by the American Society for Engineering Education, Washington, D.C.

How to Use the Summary of Engineering Research: Research projects are listed by title, followed by the names of the investigators and the sponsoring agencies. Projects are sorted by major topic areas. Project descriptions are brief. Additional information on each project may be obtained from the investigator in charge (denoted by an asterisk). Mailing addresses are provided on the introductory page.

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Civil and Environmental Engineering

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Civil and environmental engineers have responsibility for the planning, design, and construction of facilities necessary for society to function, for enhancing the quality of the environment, and for mitigation of the effects of earthquakes, floods, strong winds, and for 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, 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, all types of industrial facilities)
• transportation engineering, both facilities and systems (highways, airports, and railroads)

The needs of humanity continually require development and application of new approaches, concepts, and products to the design and construction of facilities and the effective management 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 132 years ago, this Civil and Environmental Engineering Department has evolved to a large, comprehensive department with approximately 500 undergraduate students, 390 graduate students, and a faculty of 50.

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, traffic flow theory and control, capacity analysis, traffic safety

Tami C. Bond
Aerosol chemistry, physics, and optics that govern the environmental impacts of particles from combustion

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

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

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

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

Robert H. Dodds, Jr.
Fracture mechanics, computational solid mechanics, structural analysis

C. Armando Duarte
Computational mechanics, three-dimensional computational fracture mechanics, multiscale modeling, computational micromechanics of materials

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

Khaled El-Rayes
Optimization and information technology in construction, including optimal construction planning and control, multiobjective optimization, distributed computing, parallel computing, optimal lighting design for nighttime construction, optimal construction site layout planning, optimizing recovery efforts of critical infrastructure systems after major disasters, impact of weather on construction

Douglas A. Foutch
Dynamic characteristics of full-scale structures, analysis and design of earthquake-resistant bridge and steel buildings, wind effects

William L. Gamble, Emeritus
Structural concrete, prestressed concrete bridges, creep and shrinkage of concrete, reinforced concrete slabs, fire-resistant structures

Jamshid Ghaboussi
Structural and geomechanical computational mechanics, earthquake engineering, computational intelligence and soft computing, information technology in civil engineering

German R. Gurfinkel, Emeritus
Structural design, failure investigations and retrofitting of wood, reinforced concrete, prestressed concrete and steel structures including silos, tanks, tall buildings

William J. Hall, Emeritus
Structural engineering, structural dynamics, earthquake engineering

Yousef Hashash
Numerical modeling, static and dynamic soil-structure interaction, deep excavations and tunnels, underground structures, geotechnical engineering, discrete element modeling, visualization, virtual reality and information technology

Neil M. Hawkins, Emeritus
Reinforced, prestressed, and composite steel and concrete structures, fracture mechanics

Edwin E. Herricks
Aquatic ecology, ecosystem management, water quality management standards and legislation

Keith D. Hjelmstad
Structural mechanics, nondestructive evaluation of large structures, fluid/structure interaction

Nicholas P. Jones
Structural dynamics, flow-induced vibration, and wind engineering
Praveen Kumar  
Hydroclimatology, hydrogeomorphology, hydrologic information systems, knowledge discovery in databases, ecohydrology

James M. LaFave  
Reinforced concrete building and bridge structures, light-frame construction, innovative structural framing systems

David A. Lange  
Construction materials, microstructure and properties of cement and concrete, airport pavement performance

Susan M. Larson  
Air quality monitoring and modeling, aerosol physics

Jon C. Liebman, Emeritus  
Water resource and water quality systems, solid waste management and disposal

Liang Y. Liu  
Construction project controls, productivity analysis and improvements, information technology, sensors and field data collection, construction modeling and simulation

Gholamreza Mesri  
Engineering properties, construction problems, and ground modification technology in relation to soft clays and silts, stiff clays and soft rocks, expansive soils and swelling shales, as well as granular materials

Barbara S. Minsker  
Environmental systems analysis and management, machine learning applications to remediation and monitoring

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

Scott M. Olson  
Geotechnical earthquake engineering, soil liquefaction, seismic stability of sloping ground, paleoseismology, in situ testing, field instrumentation

Stanley L. Paul, Emeritus  
Experimental and analytical studies of reinforced concrete

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

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

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

Lutgarde Raskin  
Biological treatment of water and wastewater, molecular microbial ecology, environmental microbiology

Chris R. Rehmann  
Environmental fluid mechanics, turbulence in stratified fluids; double diffusion, zebra mussel transport in rivers, environmental multiphase flows

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

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

Lucio Soibelman  
Construction management, civil engineering information systems, distributed artificial intelligence, data mining, design rationale, KDD, lean construction, text mining, image reasoning
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 constructed slopes, soil liquefaction, geosynthetics

Timothy J. Strathmann
Environmental chemistry, catalysis of contaminant degradation, sorption and speciation at mineral-water interfaces, metal microbe interactions, 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, image analysis, geosynthetics, artificial neural networks, full-scale pavement testing, railroad ballast, stabilization and recycling

Albert J. Valocchi
Transport processes in porous media, groundwater contamination, numerical 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

Jian Zhang
Seismic analysis and design of bridges and reinforced concrete structures, soil-structure interaction, earthquake engineering, structural dynamics and seismic protective devices

Construction Management

Integrated Design and Construction Planning of Steel Frame Structures
S. Burns,* L. Liu,* A. Nandula
lliu1@uiuc.edu
National Science Foundation, CMS 9912559

This research will seek to develop a structural steel frame design simulation system to improve communication among designer, fabricator, and erector. From the designer’s point of view, this software will serve to provide immediate feedback of estimated total project cost as the design evolves, permitting “what-if” scenarios to be conducted quickly and efficiently. One of the key features of the software will be its ability to suggest design alternatives that lower total project cost or otherwise improve on the design, considering complex interactions between material costs, labor costs, and structural behavior.

This research will lead to better design and construction integration.

CAREER: Distributed Multi-Objective Optimization for the Construction of Large-Scale Transportation Systems
K. El-Rayes,* A. Kandil
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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.

Evaluation of Lighting for Nighttime Highway Construction Operations
K. El-Rayes,* L. Liu,* L. Soibelman,* K. Hyari
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Illinois Department of Transportation, ITRC-VD-H1

An increasing number of highway construction and repair projects throughout the United States are being performed during the off-peak nighttime hours to alleviate construction-related traffic congestion. Despite the apparent advantages of nighttime construction operations, a number of challenges are often encountered during this type of construction, including decreased visibility for both workers and motorists, causing decreased levels of safety and quality; problems in implementing quality control procedures; adverse public reactions due to construction noise during nighttime; and increase in cost for nighttime operations. In order to address these challenges, this project explores the development of innovative design criteria and lighting arrangements for nighttime highway construction operations. The objectives of this research are to develop and recommend design criteria for lighting nighttime highway construction; develop a design and optimization model for lighting nighttime construction sites; and implement a practical and mobile computing tool for lighting design that can be utilized by contractors in design and implementation and by resident engineers in the inspection of lighting conditions on site.

The developed lighting standards in this research will be adopted by the Illinois Department of Transportation (IDOT) for state specifications for lighting of nighttime highway construction operations. Furthermore, the developed lighting design tool will provide much-needed support for contractors and resident engineers in the design and implementation of practical and effective lighting arrangements for nighttime highway construction.

Optimizing Airport Construction Sites to Maximize Aviation Security and Safety
K. El-Rayes,* A. Khalafallah
University of Illinois

Many major construction projects are either ongoing or being planned for many airports in the United States. These types of projects often require the presence and movement of construction crews in close proximity to aircrafts and the performance of significant portions of the work during off-peak, nighttime hours to minimize disruptions to airport operations. This is not only a management challenge, but also poses significant risks to aviation security and safety and must be considered carefully in the planning and control of airport construction sites. The research objectives of this study are to study and identify the impact of airport construction site layouts on aviation security and safety; establish lighting requirements for nighttime airport construction operations; and formulate a prototype optimization model for site layout planning and control for airport construction.

The proposed developments in this research are expected to maximize aviation security through proactive approaches to prevent unauthorized access to airport operation areas during construction activities; maximize aviation safety by identifying and eliminating various construction-related hazards such as unmarked or uncovered excavation, improper nighttime lighting, and unsafe utilization of construction equipment in the vicinity of aircraft operation areas; and minimize the disruptive effects of construction operations on aviation efficiency and security.

Optimizing Large-Scale Construction Resource Utilization Problems
K. El-Rayes,* A. Kandil
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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.

*Denotes principal investigator.
The findings of this research 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
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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
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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 construction field data are processed and analyzed in the future.

**Construction Object-oriented Process Simulation**

L. Y. Liu*
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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 Site Digital Data Collection Devices**

L. Y. Liu*
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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 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* (Gen. Engr.)
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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.

**Sensor-based Construction Quality Control and Monitoring**  
L. Y. Liu,* C. Erickson, K. Trauth  
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*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.

**Advanced Data Fusion and Modeling for Construction Projects**  
L. Soibelman,* J. Wu  
*University of Illinois*

There are always difficulties for construction researchers and practitioners to get reliable productivity values for various critical missions. On the other hand, data fragmentation problems, such as geometrical, regional, functional, and software barriers, may create problems for collecting objective, long-term, and comprehensive data for construction productivity analysis. The proposed research on advanced data fusion and modeling for construction projects is intended to provide an analysis-oriented integration system by applying various possible data integration techniques, including IFC, XML, and data warehousing. Researchers also will investigate the potential of utilizing multidimensional and multihierarchical data analysis and knowledge discovery. Currently a prototype system for project-level productivity analysis is being developed based on existing project data. Further research will be implemented for company-wide/client-wide and distributed construction productivity data and knowledge management.

**Automatic Recognition and Comparison of Construction Images and Designs through Image Processing and Computer Vision Techniques**  
L. Soibelman,* I. Brilakis  
*University of Illinois*

The inspection of the work in progress, as well as the final inspection of each completed activity, is one of the most important tasks in the construction field. High performance tools in image processing and computer vision can help to achieve the automation of such tasks. The objective of this research is to provide a methodology that can extract valuable information from the visual data and use the existing design and schedule information to compare with and retrieve valuable information regarding the construction progress and accuracy. Specifically, this research explores the use of image processing and computer vision algorithms to identify construction items and activities and to compare them with the existing designs.

**Domain Specific Search Engine for AEC Product Procurement Applications**  
L. Soibelman,* K. Y. Lin  
*University of Illinois*

The goal of this research is to set up a domain-specific search engine that generates fewer but more precise search results for the applications of construction product and material procurements. Search engines nowadays might satisfy the needs for general users but they cannot fulfill the special requirements in AEC practices. Consequently, industry practitioners, such as architectural designers, are not satisfied with these tools when they collect product information and expect performance improvements for a realistic use of the tools. In this research, a combined use of available search engines and add-on components, such as semantic analysis and domain thesaurus, will be coupled for investigation and experiments.

**Knowledge Discovery in Databases and Data Mining as New Tools to Support Research and Educational Advances in Modern Construction Management**  
L. Soibelman*  
*National Science Foundation*

Faster, higher capacity, and cheaper storage devices (such as magnetic disks and CD-ROMS), better database management systems, and data warehousing technology allow transformation of data into a computerized database system. A construction project produces information about labor productivity, materials, equipment, cost estimating, scheduling of activity duration, and so forth. As the
construction industry adapts to new computer technologies, computerized construction data become more and more available. Most project data are used only for communication purposes and stored in a file or database without being analyzed. Objectives of this research are fourfold: develop improved methods to obtain knowledge from large construction databases; improve access to past construction management experience; use active learning techniques to improve education of students at all levels; and teach civil and environmental engineering graduate students the process of knowledge generation through application and development of data mining, machine learning, and artificial intelligence tools.

**Construction Materials**

**Design of Masonry Mortars for Controlled Curing and Performance**
D. A. Lange,* A. Werner
Portland Cement Association

An experimental study of bond between mortar and masonry units is helping researchers establish principles for design of masonry mortar to achieve superior performance. Bond is controlled by the penetration of paste into the masonry pores, the nature of the hydration products at the interface, the enhancement of bond through surface roughness, and the degree of bond across the entire masonry/mortar interface. This research is focused on how mortars retain water, interact with the unit and curing environment, and develop mechanical performance.

The study will help advance the understanding of what parameters of mix design are relevant to superior performance.

**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 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.

**New Sensor Technologies for Measuring Internal Relative Humidity of Concrete**
D. A. Lange,* Z. Grasley
Portland Cement Association

This project investigates new methods for measuring and interpreting internal moisture content of concrete. A new measurement system to analyze the relationship between moisture loss, volume change, and stress arising from drying under restrained conditions is being developed. Shrinkage is typically studied using length change and weight loss measurements, but we want to improve our understanding by using direct measurement of moisture content and relative humidity to understand the origin of stress in the microstructure.

By using appropriate protective membranes and existing data acquisition technology, an attractive, low-cost, and robust system for lab or field applications can be achieved.

**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. Struble,* C. T. Chen
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*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**
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*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. Struble,* 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 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
istruble@uiuc.edu
*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
istruble@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.

*Denotes principal investigator.*
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.

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. 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.

Advanced Seismic Assessment of RC Bridges
A. Elnashai*
Federal Highway Administration

The work entails developing complex models for bridges that are recommended by the Federal Highway Administration. The bridges have complex geometry and their models include 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 deformational response under realistic ground motion. A concerted effort is being allocated to the selection and scaling of the records, which represent scenario earthquakes in the Midwest. Local and global limit states are sought leading to the definition of

*Denotes principal investigator.
the yield and collapse earthquakes, hence to the inherent overstrength of the structure. The effect of deck curvature on the distribution of inelastic demand in the bridge, the effect of soil and foundation characteristics, and the behavior of bearings and abutments are also under investigation. Finally, fragility relationships needed for seismic loss assessment are being derived and plans are under way to implement these relationships in loss assessment and visualization software.

George E. Brown, Jr., Network for Earthquake Engineering Simulation (NEES) Multi-Axial Full-Scale Sub-Structuring Testing and Simulation (MUST-SIM) Facility
National Science Foundation, CMS-0217325

The primary objective of this project is to create a facility in which a full-scale subassembly can be subjected to complex loading and imposed deformation states at multiple connection points on the subassembly, including the connection between the structure and its foundation. The MUST-SIM facility will have the following unique features: six-DOF load and position control at multiple connection points, system modularity to allow for easy expansion and low-cost maintenance/operation, multiple dense arrays of noncontact measurement devices, and advanced visualization and data mining capabilities for integrated teleoperation and teleobservation. The MUST-SIM facility will realize the first two features through the development of modular six-DOF Loading and Boundary Condition Boxes (LBCB) that allow for precise application of complex load and boundary conditions. The LBCBs will be able to impose motions on the test structures that are determined from the results of concurrently running numerical models of the test specimen and the surrounding structure/foundation/soil system employing pseudo-dynamic testing methods. Dense arrays of state-of-the-art, noncontact instrumentation, will allow near real-time model updating for the model-based simulation. In addition, this facility and its telepresence/teleoperation capabilities will be enhanced by development of multifunction data visualization and knowledge interpretation tools in cooperation with the Automated Learning Group of the National Center for Supercomputing Applications. The MUST-SIM NEES facility will stimulate new and unique approaches to experimental research to address earthquake engineering issues through a collaborative shared-use testing environment, ultimately leading to improved seismic performance of our infrastructure, reduced economic losses in natural disasters, and more reliable structures. The MUST-SIM NEES facility will provide a total testing-analysis-visualization-display environment that combines the ability to test portions of structures under complex and continuously changing boundary and loading conditions with the ability to either model or indeed test the SSI feature of response. The MUST-SIM facility will be an NEES asset that has not previously been available.

National Science Foundation, Mid-America Earthquake Center
A. Elnashai*
National Science Foundation, CMS-9701785

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 engineering approaches necessary to minimize consequences of future earthquakes. Correlated interdisciplinary research—synthesizing damage across regions, estimating seismic vulnerability across regional and national networks, and improving current engineering approaches—forms the core research needed to develop such consequence-based approaches and to support stakeholder interests in risk assessment and seismic engineering.

More than 50 faculty researchers and 100 graduate research assistants are included in interdisciplinary research at core institutions that include the University of Memphis, Washington University, St. Louis University, Georgia Institute of Technology, Massachusetts Institute of Technology, Texas A&M University, and the University of Puerto Rico. Research in structural and geotechnical engineering, seismology, urban planning, social science, economics and information technology is supported.

Response Analysis Tools Mid-American Earthquake (MAE) Center
A. Elnashai, J. Zhang
National Science Foundation, Project DS-3

In this project, advanced concepts and techniques of analysis are developed and tested, with the aim of providing guidance for the derivation of fragility (vulnerability) functions and to increase the accuracy of damage estimates. Measured dynamic test data from laboratory or field experiments or response of instrumented structures during earthquakes shall provide calibration of these tools.

*Denotes principal investigator.
Risk Assessment Modeling
A. Elnashai,* D. Abrams
National Science Foundation, DS-9

This project develops new risk assessment models by establishing the relative merits of existing risk assessment approaches and applications results. This could lead to improved risk and loss modeling procedures that will be used to integrate hazard vulnerability and inventory and also contribute to the development of the visualization tool of DS-1.

Such models will be compared with estimates given by proprietary models used by the insurance industry.

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.

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.

CM-4 Structural Retrofit Strategies
M. B. Hueste,* A. Elnashai
National Science Foundation

This project addresses the issue of level and type of structural intervention for populations of structure to achieve a specified level of consequence minimization. It also deals with new designs where the preliminary design outcome is considered as an existing population of structure. This is addressed by first relating the intervention technique to changes in structural characteristics, and then by deriving intervention-sensitive fragility relationships. For new designs, this intervention may be the addition of extra members. This generic research will be combined with stakeholder-specific appropriate rehabilitation schemes for particular construction types.

*Denotes principal investigator.
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.

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 Univ.), 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.

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 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 tiling 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 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.

**Environmental Engineering and Science in Civil Engineering**

**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.

**Integrating the Thermal Behavior and Optical Properties of Carbonaceous Particles**

T. C. Bond,* J. M. Lee

*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**

T. C. Bond,* L. Qi, P. J. Rasch, D. Bundy

(Natl. Ctr. for Atmosph. Res.)

*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.

*Denotes principal investigator.
Development of a Colloidal Polymer Adsorbent for Selective NOM Removal
M. M. Clark,* X. Li, W. Y. Ahn, N. Sternisha, A. Westbrok, G. Sandhu, R. Riley
National Water Research Institute, WaterCAMPWS;
University of Illinois Board of Higher Education;
Environmental Council; Department of Civil and Environmental Engineering

Research on membrane fouling has shown that natural organic compounds in the feed water can irreversibly adsorb on the membrane surface. Although powdered activated carbon has been used to improve ultrafiltration performance vis-à-vis natural organics removal, it has not been used successfully to limit organic fouling of membranes. Our research suggests that the natural organic matter that fouls membranes is different than that adsorbed by common powdered activated carbon. This project investigates a new polymeric adsorbent that holds significant promise as a tunable adsorbent for removal of specific membrane foulants. The new material can be cast as ~50-nm particles, or long fibers. The material is easily regenerated by contact with a basic solution.

This project investigates a new polymeric adsorbent that holds significant promise as a tunable adsorbent for removal of specific membrane foulants (U.S. patent 6,699,851B2).

Development of Online Integrity Monitoring Systems for Membrane Filtration Systems
M. M. Clark,* B. Lee, D. Ladner, K. Thompson, B. Araya
Korea Institute of Science and Technology, Seoul, Korea

Membrane technologies are very effective at removing particles, bacteria, cysts, and viruses, and engineers and water providers would like membrane technologies to be granted increased federal or state credits for disinfection of water. However, regulators would like some assurance that membranes are absolute barriers to pathogens. In membrane systems that have only small but significant breaches, the contaminants are often so diluted by the contaminant-free product water that they are virtually undetectable by current water quality parameters.

This work focuses on developing an automated instrument that concentrates particulate contaminants in the product stream and preferentially detects microorganism through fluorescence probing.

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

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.

Effects of Discharge Permit Trading on Water Quality Reliability
T. L. Ng and 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.

*Denotes principal investigator.
Uncertainties Associated with Market-based Policies for Pollution Control
J. W. Eheart,* T. Ng
University of Illinois; Universiti Teknologi Petronas, Malaysia

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.

Biodegradation of Nitramine Compounds by Stimulating Humic Substance- and Fe(III)-Reduction
K. Finneran,* S. Drew (GeoSyntec Inc.), J. Davis (U.S. Army Corps of Engineers)
DoD SERDP 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.

Ecologically and Geomorphologically Based Methods for Management and Regulation of Riparian Anthropogenic Activities in Taiwan
E. E. Herricks,* J. W. Eheart*
University of Illinois; Ministry of Education, Taipei, 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 geomorphologic changes in a short period. Because of the diverse and plentiful ecosystems, integrating the hydrological, ecologic, and geomorphologic 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 geomorphologic 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).

**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 Science and Technology 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 for a fixed granular adsorption bed that includes the effect background natural organic matter (NOM) has on trace compound (TC) adsorption. The model includes two key mechanisms observed to reduce an adsorbent’s capacity and uptake rate of TCs: direct competition by a strongly competing fraction of NOM, and pore constriction by a pore blocking fraction of NOM. To test our model, we have completed experiments to determine model input parameters and started longer-term model verification experiments.

**Inactivation Kinetics of Adenovirus with Sequential UV/Monochloramine and Free Chlorine/Monochloramine Disinfection Processes**
B. J. Mariñas,* K. Sirikanchana  
*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 by-products (DBPs) in natural waters treated with ozone and chloramines.

Low and Medium Pressure Ultraviolet Light Technology for Control of Cryptosporidium parvum Oocysts, Viruses, and Bacterial Spores in Seasonal Waters
B. J. Mariñas,* O. Coronell Nieto
Syndicat des eaux d’Ile de France; Compagnie General des Eaux, Paris, France

The overall objective of this study is to assess the adequacy of ultraviolet (UV) light disinfection to provide protection against Cryptosporidium parvum oocysts, viruses, and bacteria in seasonal waters. The scope of work of the project includes: assessment of the kinetics of UV light inactivation for Cryptosporidium parvum oocysts, bacteriophage MS2, and Bacillus subtilis spores; development of recommendations for minimum UV light dose requirements; development of recommendations for minimum ozone and free chlorine dose requirements; and development of final recommendations base on review of field on-line transparency data.

M/DBP Model for the Optimization of Full-Scale Process Design and Operation, Phase I: Ozone Disinfection—Cryptosporidium parvum Oocyst Inactivation and Bromate Formation Control
U.S. Environmental Protection Agency Cooperative Agreement, CX-82918101-0

The main objective of this project is the development of a model for the ozone disinfection process. More specific tasks of the project are the following: determination of kinetic rate constants of reactions representing site-specific seasonal effects of NOM on ozone decomposition and bromate formation for selected source waters by bench-scale ozonation experiments; development of user-friendly windows-based software with graphical user interface (M/DBP model) for optimizing the design and operation of ozone disinfection systems; development of simple experimental protocol for model calibration to specific source water conditions and corresponding seasonal variability in water quality; and demonstration and validation of the model with selected full-scale ozone disinfection systems.

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.

*Denotes principal investigator.
Reverse Osmosis/Nanofiltration (RO/NF) Membrane Systems with Enhanced Water Permeability and Contaminant Rejection Capability
B. J. Mariñas,* J. Moore, P. Braun, B. Mi
National Science Foundation Science and Technology 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 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 Solute and Macromolecules through Reverse Osmosis and Nanofiltration Membranes
B. J. Mariñas,* B. Mi
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 gas adsorption/desorption techniques.

Cost-Effective Risk Management of Groundwater Contamination
B. S. Minsker,* D. E. Goldberg, M. Babbar, F. Espinoza, X. Ren, A. Singh, S. Yan, M. Zavislak, M. Hayes
U.S. Army Young Investigator Award and Presidential Early Career Award for Scientists and Engineers, U.S. Army Research Office, 2000-2006

This project builds on the work begun in a National Science Foundation project to develop a risk management model for groundwater corrective action design. The model will be enhanced to allow tradeoffs to be made among risk, cost, and cleanup time under conditions of uncertainty. Innovative advancements for improving
computational efficiency of the model using advanced stochastic genetic algorithms, hybrid genetic algorithms, and hierarchical multipopulation genetic algorithms are also being investigated.

**Discovering Knowledge in Environmental Data:** An Exploratory Study of BP Service Station Data

B. S. Minsker,* D. Farrell, D. Tcheng, D. Searsmith

*BP Inc., 2003-2004*

Petroleum companies have substantial liabilities for cleaning sites with soil and groundwater contamination, including numerous service stations across the United States. At each site, substantial data exist, including both technical and financial data. While these data are carefully examined at individual sites, the data have rarely been examined across sites to extract knowledge and lessons learned that could be used to improve management of future liabilities. The objective of this study will be to explore how automated knowledge discovery approaches ("data mining") can be used to discover and share such knowledge. More specifically, geological features and management practices documented in service station reports will be mined to identify features and practices that are most likely to lead to high or low future remediation liabilities.

**Research and Educational Advances in Optimal Groundwater Remediation Design**

B. S. Minsker,* D. Goldberg, F. Saied, Y. Liu, F. Espinoza, D. Hill

*National Science Foundation, BES 9734076 CAREER (1998-2004)*

An optimal control model for aerobic in situ bioremediation design has been developed, but the computational effort associated with solving the model prohibits solution of field-scale, heterogeneous problems. Multiscale optimization methods and a hybrid genetic algorithm are being developed to improve performance and capabilities of the model. The research will be integrated with education through development of graphical user interfaces, an educational game, and a new graduate course on coupled optimization and simulation modeling to teach students the complexities associated with developing and applying such models.

**Technology Transfer of Evolutionary Multiobjective Optimization Software, with Demonstration for Optimizing Long-Term Groundwater Monitoring**

B. S. Minsker,* L. Auvil, D. Clutter, M. Babbar, D. Goldberg

*Office of Naval Research through Technology, Research, Education, and Commercialization Center, 2003-2004*

There are numerous examples of complex problems for which optimal solutions must be found, ranging from engineering design to crisis management. Traditionally, optimization methods have been used to solve only certain types of carefully posed problems. Recently, genetic algorithms have emerged as a promising approach for solving any type of optimization problem. Genetic algorithms are particularly well suited for problems with multiple conflicting objectives, such as minimizing cost versus maximizing reliability of an engineering design.

This technology transfer project will create the first multi-objective genetic algorithm software package with a flexible and powerful user-friendly interface, automated parameter setting, and multidimensional visualization.

**A Collaborative Framework for Integrated Hazard Management**

B. S. Minsker,* W. Dawsey, Y. Liu, D. Goldberg, M. Welge, T. Wentling

*Office of Naval Research through Technology, Research, Education, and Commercialization Center*

To better manage system-wide impacts of environmental hazards, complex multidisciplinary questions must be addressed by physically dispersed teams of experts capable of working together to develop optimum, complete, and effective system solutions. This project will develop an integrated analytical and collaborative framework that can be used to effectively assess and manage hazards. The components of the framework will address issues ranging from collaborative data mining and analysis to knowledge management and modeling to collaborative decision support. Capabilities of the framework will be demonstrated for water distribution system protection.

*Denotes principal investigator.*
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.

**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 different hydrogen based technologies for the treatment of concentrated wastewaters containing perchlorate, including gas-lift biofilm reactors and biomass separating membrane bioreactors. One goal is to develop gas-lift reactors using different types of carrier material that support biofilm growth. Mixing will be achieved in this reactor by introducing gas into a tube that is located in the center of the reactor, generating a recirculating flow pattern. Gas-lift reactors are advantageous as they allow for efficient mass transfer and mixing while they are simpler to operate compared to fluidized bed reactors.

**Pilot and Laboratory Scale Research Using Sequencing Batch Reactors (SBR) to Study Wastewater Treatment at Abbott Laboratories**

E. Morgenroth,* L. Raskin
Abbott Laboratories, CO4400071

A laboratory scale system based on sequencing batch reactors is developed to model processes in an industrial wastewater treatment plant (Abbott, Chicago). The objective is to optimize the overall performance of the treatment plants consisting of an aerobic carbon removal
stage, an anoxic/aerobic nitrogen removal stage, and an anaerobic stage for the treatment of highly organic strength wastewaters.

Novel strategies for process monitoring and process control are being developed to support the reliable treatment of pharmaceutical wastewater.

Räumlich aufgelöste Untersuchung des Schadstoffabbaus in Biofilmen und deren Formation mit Methoden der mathematischen Biologie und des wissenschaftlichen Rechnens
E. Morgenroth, H. J. Eberl*
Volkswagenstiftung (Germany)

The purpose of this research is to develop a three-dimensional biofilm model that comprises full incompressible Navier–Stokes equations and mass transfer with nonlinear reactions in the biofilm and to develop a fully deterministic model for the formation of heterogeneous biofilms based on principles of continuum mechanics and mathematical biology. This biofilm model will then be used to evaluate competition in heterogeneous biofilms.

Advanced mathematical models for growth and mass transport in biofilms will help to understand the microbial interactions in heterogeneous aggregates.

The Influence of Shear on Membrane Fouling and Biological Processes in an Anaerobic Membrane Bioreactor (MBR) for the Treatment of High Strength Wastewater
E. Morgenroth*
National Science Foundation, CTS 01-20978 (3B.2a)

New treatment technologies need to be developed for the treatment of high-strength industrial and animal wastes. The overall goal of this project is to further develop an innovative treatment technology that combines biological treatment (anaerobic digestion) and membrane separation (ultrafiltration and reverse osmosis). A critical issue in these reactors is local shear stress that helps to reduce fouling of membranes but also can reduce the efficiency of anaerobic digestion. Different shear levels and different membrane types (ultrafiltration or microfiltration) are evaluated in this project. Advanced technologies for high-strength waste treatment will help to reduce environmental pollution and at the same time allow for recovery of clean water, energy, and nutrients for reuse.

Biohydrogen Production from Renewable Organic Wastes
L. Raskin,* S. Padmasiri, J. Simmons
Department of Energy (subcontract Iowa State University)

The overall goal of this project is to develop an anaerobic fermentation process that converts negative value organic wastes into hydrogen-rich gas that can significantly enhance the economic viability of many processes either by utilizing hydrogen as a fuel source or as raw material for industries that consume hydrogen. Specifically, we are evaluating different bioreactor configurations and operating conditions to maximize biohydrogen production. We are identifying and quantifying the predominant microbial populations in each bioreactor system. Furthermore, different factors affecting sporulation and spore activation and their correlation with hydrogen production will also be investigated.

Fate of Antibiotics and Antibiotic Resistance Genes in Swine Waste Treatment
L. Raskin,* J. Zilles, Z. Zhou, T. Shimada, M. Robert
Agricultural Research Service, United States Department of Agriculture

The application of antibiotic or antimicrobial 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 will contribute to other research efforts that are investigating whether the suggested link between the use of antimicrobials in farm animal diets and the spread of antibiotic resistance in the environment is real.

Process Optimization, Molecular Microbial Characterization and Biofilm Modeling of a Bioreactor for Perchlorate Removal from Drinking Water
L. Raskin,* E. Morgenroth*
National Science Foundation, BES-0123342

Perchlorate inhibits the production of thyroid hormones, and therefore disrupts normal growth and development. Currently, no widely accepted treatment process exists for the removal of perchlorate from drinking water. The project aims at developing a process based on biological filtration of drinking water for perchlorate removal at microgram/l concentrations. The research will utilize an integrated approach that links the characterization of the microbial community in the
BAC filters and biofilm modeling with developing methods for process optimization and design. Novel processes for biological drinking water treatment are being developed based on a fundamental understanding of mass transport and microbial ecology in biofilms on activated carbon media.

**Solution-based Hybridizations for Rapid Identification and Quantification of Anaerobic Microbial Assemblages**

L. Raskin,* S. Boppart, C. Xi

*National Science Foundation, BES 00-86696*

Current molecular microbial characterization methods are limited because they require immobilization of target nucleic acids on solid supports. This immobilization step precludes automation. This project will develop novel molecular methods that are based on the generation of a fluorescent signal in solution, eliminating the immobilization step required in current molecular techniques. First, researchers will focus on the development of solution-based hybridizations for qualification of anaerobic microbial populations. Then, the research team will evaluate the utility of this technology in separate biological reactor systems inoculated with samples from two distinct environments that share microbial and metabolic features: anaerobic wastewater treatment systems and the mammalian digestive tract.

**Use of Biotechnology to Recover Sulfur in Corn Processing Industries, Integration of Biological Waste Treatment, Pollution Prevention, and Sustainable Technologies**

L. Raskin,* K. Rausch, A. Briones

*Illinois Department of Natural Resources*

The general objective of this research is to use biotechnology to develop a sustainable process for sulfur recovery in the corn processing industry. More specifically, we aim to establish sulfur and nutrient balances for the corn wet milling process and to perform laboratory-scale work to evaluate biological waste treatment strategies to recover and recycle sulfur.

**Use of Molecular Techniques to Evaluate Causes and Control of Foaming in Activated Sludge Systems**

L. Raskin,* D. Frigon, A. Klein

*National Science Foundation, BES 97-33826*

The formation of a viscous, stable foam layer on activated sludge aeration basin and final clarifier surfaces is a common problem for the activated sludge industry and has been linked to the presence of filamentous bacteria. This research will develop oligonucleotide probes targeting the ribosomal RNA of filamentous microorganisms, which can be used as diagnostic tools to evaluate foaming problems without the prior cultivation of bacteria. In addition, the research will test the performance of laboratory-scale activated sludge systems equipped with selectors. Population shifts of foam-causing microorganisms will be followed before, during, and after foaming episodes in these systems using ribosomal RNA-targeted oligonucleotide probes and will be related to operating conditions and system performance.

**Decision-based Environmentally Conscious Design**

M. J. Rood,* D. Thurston,* H. Emamipour, A. Kaldare

*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

*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.

**Optical Sensing Technology Development for the U.S. Army’s Unique Plumes**

M. J. Rood,* K. Du

*U.S. Army Construction Engineering Research Laboratory, W9132T-04-P-0083*

An 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. This digital technique is rapid, simple, and inexpensive.

*Denotes principal investigator.
Optimization of VaPRRS Technology for Commercialization
M. J. Rood,* D. Thurston, D. Ramirez
1-627565-251005-191100

A new 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.

Preparation of Pilot-Scale Vapor Recovery System for Field Testing
M. J. Rood,* D. Ramirez, E. Vidal, H. Emamipour, Z. Hashisho
U.S. Army Construction Engineering Research Laboratory, DACA88-98-D-0005-26

A new activated carbon fiber-cloth electrothermal swing adsorption system is under development at the pilot scale to capture and recover hazardous air pollutants and volatile organic compounds in gas streams for reuse.

Steady-State Desorption of ACFC Adsorption/Desorption Systems
M. J. Rood,* D. Cevallos
U.S. Army Construction Engineering Research Laboratory, W9132T-04-2-0005

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.

Strategy Development for Real-TimeOpacity Measurement
M. J. Rood,* D. Ke
U.S. Army Construction Engineering Research Laboratory, DACA88-98-D-0005-21

There are numerous methods that can be used to quantify the opacity of plumes from nonpoint sources. This research describes the methods that can be used to quantify the opacity of plumes generated from nonpoint sources and recommends the most promising technique for future development.

Characterization of Scales in the Chicago Water Distribution System
V. L. Snoeyink,* P. Sarin, M. Raynal, W. J. Liu
City of Chicago, Illinois

The objective of this project is to determine the chemical composition of scales that have been found on cement- and mortar-lined distribution pipes and to determine ways to control the formation of this scale. The approach involves use of energy dispersive spectroscopy to determine elemental composition and nuclear magnetic resonance spectroscopy to determine chemical structure. A pipe-loop system with lead pipe harvested from the Chicago system is being used to show the impact of any changes in aluminum concentration and phosphate dose on lead release.

Development of Red Water Control Strategies
V. L. Snoeyink,* P. Sarin, D. Lytle,
U.S. Environmental Protection Agency; University of Illinois

The objectives of this research are to determine the mechanisms of red water production in drinking water distribution systems and to develop strategies for controlling this problem. This study involves use of small-scale pipe loops in the University of Illinois laboratory to which water with different qualities is applied. Important parameters are pH variation, neutral salt concentration variation, and the concentration of such additives as orthophosphate and polyphosphate. Short-term tests are being developed to show how existing layers of corrosion products on pipes react to produce red water. Research also will include development of procedures for chemically conditioning the scales so that red water does not form and evaluation of using additives to reduce the intensity of the color produced by a fixed amount of iron.

Abiotic Reductive Transformation of Nitroaromatic Contaminants by Iron(II)-Organic Complexes
T. J. Strathmann,* D. Naka, D. Kim
University of Illinois Environmental Council; South Korean Military

Nitroaromatic contaminants (NACs) of concern include pesticides (e.g., trifluralin, parathion) and explosives (e.g., TNT, RDX). Contamination of soil and groundwater by NACs presents a serious environmental problem because many are persistent and toxic. Therefore, it is imperative to understand and predict the processes that control NAC fate in diverse environmental systems. This project examines the abiotic reductive transformation of NACs 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 NACs. 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 NAC structure to identify important mechanistic features of the reactions.

Combined Macro- and Molecular-Scale Characterization of Iron(II) Speciation and Complexation by Naturally Occurring Organic Constituents

T. J. Strathmann,* G. Nano, D. Kim
American Chemical Society's Petroleum Research Fund

Iron(II) is one of the most abundant and important naturally occurring reductants present in suboxic and anoxic subsurface environments. A range of natural organic constituents are also ubiquitous in these settings (e.g., humic acids, microorganisms), and their interactions with iron(II) play a major role in determining the metal’s speciation and reactivity with toxic contaminants of concern. However, existing data are wholly inadequate for predicting either the metal’s speciation or redox reactivity in complex heterogeneous environments (e.g., soil, sediment). The objective of this research is to obtain detailed macro- and molecular-scale data that is necessary to characterize iron(II) speciation and complexion by environmentally relevant organic constituents. Laboratory wet chemical techniques are combined with modern spectroscopic approaches to characterize the fundamental molecular interactions that control the chemistry of iron(II) in natural environments. Information gained from this refines our understanding of the environmental factors that control metal speciation and improves our ability to predict the fate of toxic contaminants in diverse environmental settings.

Photocatalytic Transformation of Organic Micropollutants by Nanophase Titanium Oxide Materials

T. J. Strathmann,* L. Hu, T. Paul, P. Miller
(Rose-Hulman Institute of Technology)
National Science Foundation, Center of Advanced Materials for Water Purification with Systems

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), and quantifying the effects of material doping on catalyst activity.


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.

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 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.

**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.

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

H. Xie,* J. W. Eheart, and B. Bailey

U.S. Environmental Protection Agency; 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.

**Environmental Hydrology and Hydraulic Engineering**

**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 Hydroclimatological 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 hydroclimatological 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 incorporates the hydroclimatological influence; and performing validation studies.

**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.

Metapopulation Dynamics and Control of the Zebra Mussel in Freshwater and Estuarine Systems: The Effects of Hydrodynamics, Larval Supply, and Embayments
D. K. Padilla,* C. R. Rehmann,* D. W. Schneider,* J. A. Stoeckel*
National Sea Grant College Program

Because a patch of mussels cannot sustain itself without a constant supply of larvae, the number of zebra mussels in an entire river can be drastically reduced if the larval supply can be blocked. The success of this and other control measures depends on the details of the river flow and the biology of the zebra mussel. In particular, if zebra mussels can establish local populations in areas with low flow, such as side embayments, the effectiveness of a dispersal barrier could be reduced. The goal of this project is to understand the effect of embayments on zebra mussel populations.

This project seeks to reduce the destructive effects of zebra mussels by determining how they are transported in rivers and estuaries.

Evaluation of a Scheme to Control Invasive Species in the Chicago Sanitary and Ship Canal
C. R. Rehmann,* D. W. Schneider,* J. A. Stoeckel*
Illinois Water Resources Center

The goal of this project was to evaluate a scheme to control zebra mussels in the Illinois River system. The hypothesis that small-scale turbulence can increase the mortality of zebra mussel larvae was tested. Laboratory experiments showed that the mortality increases when the size of the larvae is comparable to the smallest scale of the turbulence. The possibility of using bubble screens as a dispersal barrier in the Chicago Sanitary and Ship Canal was evaluated.

Mixing at a Sheared, Fingering Interface
C. R. Rehmann,* J. H. Hwang
National Science Foundation, Division of Ocean Sciences

In many places in the ocean, the temperature and salinity distributions are conducive for double-diffusive phenomena, such as salt fingers. Understanding vertical mixing in the ocean often requires an understanding of the interaction of double diffusion and mechanical processes, such as shear-driven turbulence. To assess the relative contributions of mechanically generated turbulence and double-diffusive convection to mixing, a laboratory model of a nonrotating gravity current subject to salt fingers was developed. The gravity current can be arrested by releasing cold, fresh water into an opposing flow of warm, salty water. The resulting steady state allows the overall mixing rate, interface properties, and spatial evolution of the temperature and salinity differences to be measured.

Molecular Diffusivity Effects on Mixing in a Diffusively Stable, Turbulent Flow
C. R. Rehmann,* P. R. Jackson
National Science Foundation, Division of Ocean Sciences

In ocean modeling, salt and temperature are usually assumed to mix at equal rates. However, differential transport of heat and salt has been observed in laboratory experiments, simulations, and field measurements. Since even small differences between the mixing rates can produce large changes in the predictions of general circulation models, laboratory experiments are used to study effects of molecular diffusivity on mixing in a turbulent flow stratified with both salt and temperature. The main objectives of the experiments are to quantify the differential transport and determine the conditions under which the mixing rates for salt and temperature differ.

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  
*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.

**Physically-based Three-Dimensional Modeling of Water Flow and Nitrogen Transport in Tile-Drained Agricultural Fields**  
A. J. Valocchi,* R. Hudson (Nat. Res. & Envir. Sci.), F. Yue, E. Han  
*Illinois Council on Food and Agricultural Research (CFAR); U.S. Geological Service, National Competitive Grants Program*

Tile drains have been implicated as a major source of NO₃-N in receiving streams in Illinois and other Midwestern states. Numerous mathematical simulation models have been developed to enhance understanding of processes governing nitrogen fate and transport. These models also serve as management tools to evaluate the impacts of fertilizer application and the effectiveness of various nutrient reduction practices. Most existing models are limited in that they represent a tile-drained field as horizontally homogeneous and having a fixed area. Therefore, they simulate only vertical changes in nitrate concentrations as water percolates into soils and do not account for surface runoff and the variable saturated areas contributing to tile flow.

We hypothesize that nutrient transport and fate are strongly affected by spatial variability in hydrologic factors such as surface ponding, water content, and groundwater flow paths. In order to address these shortcomings, we are developing a hydrologic model that couples two-dimensional surface flow with three-dimensional subsurface flow, including tile drains. The hydrologic model is coupled to a biogeochemical model for nitrogen fate and transport.

The project will help farmers assess the benefits of controlled drainage on reducing nitrate discharge from their fields.

**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 State Water Survey*

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 ≠ 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

*Denotes principal investigator.
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 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.

**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.

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

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

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 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.

Embankment 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 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

*Denotes principal investigator.
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.

**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 $C_{c}/C_{c}$ 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 $C_{c}/C_{c}$ 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
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, A. Michniewicz
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 $C'_v/C_0$ are larger and values of $t_t/t_{pr}$ are smaller for peats than for soft clay and silt deposits. In other words, although surcharging can reduce postconstruction secondary settlement for both clay and peat deposits, surcharging is less effective for peats.

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.

Guidelines for Geofoam Applications in 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.

Importance of Three-dimensional Slope Stability Methods
T. D. Stark,* 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 Response of Soils in Mid-America
T. D. Stark,* S. M. Olson
National Science Foundation, Mid-America
Earthquake Center

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. This integrated experimental and analytical study seeks to improve the procedures by which liquefaction potential of sandy soils in the MAE region is assessed by considering the influence of region-dependent factors, such as the earthquake frequency content and the magnitude scaling factors.

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.

Paleoliquefaction and Paleoseismology in Mid-America
T. D. Stark,* S. M. Olson
National Science Foundation, Mid-America
Earthquake Center

Sites that experienced liquefaction and/or lateral spreading during the 1811–1812 New Madrid earthquakes and possibly during prehistoric earthquakes in the New Madrid seismic zone are being studied to improve the paleoearthquake chronology of the region. Geotechnical investigations are being performed at these sites to enhance understanding of the formation of the liquefaction features and to back-calculate the levels of ground shaking required to form these features. In addition, levels of ground motion inferred from this study will be used to improve ground motion estimates, earthquake magnitude estimates, and liquefaction hazard maps throughout mid-America.

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.

Soil Strength of Liquefied Soils
T. D. Stark,* S. M. Olson
National Science Foundation, CMS 95-31678

A method for estimating the shear strength ratio of liquefied soil using cone penetration test (CPT) results is being developed. The strength ratio from 30 field case histories of liquefaction flow failure and lateral spreading is being used to develop a relationship between equivalent clean sand corrected CPT tip resistance and mobilized strength ratio. This project also involves convening an international workshop to evaluate the state-of-the-art and state-of-the-practice of determining the shear strength of liquefied soil for use in stability and deformation analyses and to identify and prioritize research needs.

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.
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**

**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, General Engineering, Mechanical and Industrial Engineering, Natural Resources and Environmental Sciences, and Theoretical and Applied Mechanics, 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.*

- High Performance Machine Vision System and Algorithm for Monitoring Railcar Health
  N. Ahuja (Elect. & Comput. Engr., Beckman Inst.)

- Railroad Applications of Fiber-Optical Force Sensors with Optical Time Domain Reflectometry (OTDR) Technologies
  S. L. Chuang (Elect. & Comput. Engr.)

- Freight Car Truck Rotational Friction
  T. Conry (Gen. 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)

- Advanced GPS Algorithms for High-precision Monitoring of Rail Position
  D. C. Munson (Elect. & Comput. Engr., Beckman Inst.)

- Broken Rail Monitoring/Detection System Using Acoustic Sensors
  H. L. M. dos Reis (Gen. Engr.)

- Wheel/Rail Contact Force Analysis for High Adhesion Locomotives
  H. Sehitoglu (Mech. & Indus. Engr.)

- Vibration Measurement of Rail Stress
  R. Weaver (Theoret. & Appl. Mech.)

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

- Scheduling, Communications and Control of Traffic Flow with Heterogeneous Vehicle Characteristics
  J. Medanic (Gen. Engr.); C. Barkan, T. Basar (Elect. & Comput. Engr.); R. Benekohal (NSF)

- Tank Car Design Reliability
  D. Pecknold, H. Sehitoglu (Mech. & Indus. Engr.), C. Barkan (USDOT FRA)

**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.

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.

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.

Structural Engineering and Design

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.

*Denotes principal investigator.
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. Renetskis, 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.

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 ρ, which is a function of the structural configuration only. The results obtained thus far indicate that the ρ 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**

**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.

**Advanced Simulation Tools**
A. Elnashai,* J. Zhang

*National Science Foundation, Mid-America Earthquake Center (DS-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 interactin effects and a detailed environment for seismic capacity estimation are provided.

**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 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.

**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.

*Denotes principal investigator.
Integrated Computational and Experimental Simulation (ICES)
J. Ghaboussi,* Y. M. Hashash,* A. Elnashai,* G. J. Yun, S. Jung
National Science Foundation (NSF), NEES Grant

The ICES system is being developed to control the NEES (National Earthquake Engineering Simulators) facility being developed at the Civil and Environmental Engineering Department under an NSF grant. It will allow the integration of the computational simulation of the structural response of major structures with experiments where components of the same structure are being tested. The information being generated by the experiment will be incorporated in the computational simulation, and the results of the computational simulation will be used to continue the experiment. Future expansions are envisioned with smart control systems that will involve online modification of the structural modes.

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.

Hurricane Loss Reduction—Wind and Structural Engineering Initiative: University of Illinois and Johns Hopkins University Contributions
N. P. Jones*
Clemson University; National Institute of Standards and Technology

Each year devastating windstorms cause considerable losses to property in the United States and other nations worldwide. Low-rise construction, in particular residential and light industrial construction, tends to be the hardest hit in these severe storms. Building codes often dictate the design of many of these “nonengineered” or “marginally-engineered” low-rise structures.

The goal of the project is to use data collected at a full-scale facility in natural wind to assess the suitability of meteorological, structural load, and performance aspects of wind load provisions; identify areas of concern, make recommendations for modification; and identify areas where additional investigation is necessary.

Measurement of Stay Cable Vibration: Houston Ship Channel Bridge
N. P. Jones*
State of Texas Department of Transportation

In order to better understand the vibration of stays at the Fred Hartman and Veterans’ Memorial cable-stayed bridges in Texas, a full-scale instrumentation program was developed, implemented, and analyzed. The goals of the monitoring program were to establish a baseline set of data taken under varying atmospheric conditions with the stays unrestrained; to record a set of data taken under varying atmospheric conditions with the stays restrained with various mitigation devices including dampers (two types), crossties, and aerodynamic treatments; and to compare these data sets to evaluate the performance of these systems.

Modeling and Mitigation of Stay Cable Vibration
N. P. Jones*
National Science Foundation

Cable-stayed bridges are commonly exhibiting large-amplitude vibrations of the main stays, frequently associated with the simultaneous occurrence of wind and rain. These vibrations are of concern because they potentially induce fatigue in the cables and anchorages. Prediction of field behavior based on a set of supplied parameters is still not possible, nor does a plausible, accepted model exist. This research effort is building upon these findings and full-scale data collected in past projects. The purpose of this effort is to improve the understanding of the mechanics of stay-cable vibration at a more fundamental level to enable the development of more effective and economical mitigation strategies.

Wind-Induced Vibration of Stay-Cables
N. P. Jones*
Federal Highway Administration
Award to Johns Hopkins Univ. This research is conducted in collaboration with HNTB Corp. and RWDI and Buckland & Taylor Ltd. of Canada.

Cable-stayed bridges have become the form of choice over the past several decades for long-span bridges. In some cases, serviceability problems involving large amplitude vibrations of stay cables under certain wind and rain
conditions have been observed. This study was conducted in order to develop a set of consistent design guidelines for mitigation of excessive cable vibrations on cable-stayed bridges. Analytical and experimental research was performed to study mitigation methods, covering a range of linear and nonlinear dampers and crossties. Based on the above, design guidelines for mitigation of wind-induced vibrations of stay cables were developed.

**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.

**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.

**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.

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

*Denotes principal investigator.
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.

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.

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 MOSi2/SiC and Nb/Nb5Si3 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 \( J^* \) 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).

**Structural Engineering and Structural Mechanics**

**Fracture Mechanics in the Ductile-to-Brittle Transition Region**

R. H. Dodds, Jr.,* J. Petti
U.S. Nuclear Regulatory Commission, N00167-97-K-0029

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 midregion 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.

**Fracture of Welded Steel Joints**

R. H. Dodds, Jr.,* C. Matos
National Aeronautics and Space Administration, Ames and Langley Research Centers, NAG 2-1126; University of Illinois

Welded steel joints in moment-resisting frames have exhibited unexpected brittle fractures during recent earthquakes in California and Japan. This study applies micromechanical models for cleavage fracture to assess the significance of residual stresses, material properties, and geometric details of the design on the fracture behavior under both static and dynamic loading. Comparisons with small-scale experiments performed on welded plates validate the fracture mechanics models.

**Models for Ductile Crack Growth in Thin Aluminum Structures**

R. H. Dodds, Jr.,* S. RoyChowdhury
National Aeronautics and Space Administration, Ames and Langley Research Centers, NAG 2-1126

Models to predict extensive amounts of ductile crack growth in thin, 2024-T3 aluminum sheets are being developed. Multisite damage at rivet holes in aging aircraft represents a key application of this work, where predictions of remaining strength play a major role in repair decisions. The 3-D numerical models employ a cohesive-volumetric finite element model including large displacement and rotation effects to simulate crack extension. Emphasis is on calibration of model parameters and validation against full-scale tests.

**Next Generation Modeling of Damage Tolerance for Risk Assessment and Mitigation in High-Performance Spaceflight Structures**

R. H. Dodds, Jr.,* G. H. Paulino
National Aeronautics and Space Administration, Ames Research Center, MS 2313-3

Verified computational models and simulation software for high-performance spaceflight structures will be developed. Advanced theoretical and computational models, verified by material and component testing and implemented in
modern software for parallel computers, provide the
needed tools to develop quantitative characterization
of damage tolerance. While the new models and
computational software will have a broad range of
applicability, this program adopts two specific applications
to motivate and focus development efforts. The first is
external thermal protection systems. The second is critical
engine components that show strong sensitivity to
low-cycle fatigue while operating in highly demanding
environments, such as H2 steam. Both of these systems
have ongoing maintenance and key safety concerns for the
current space shuttle and future aerospace structures.

Software for Large-Scale, Nonlinear 3-D Analysis
of Solids
R. H. Dodds, Jr.,* S. RoyChowdhury, N. Rau, M. Walters
National Aeronautics and Space Administration, Ames
and Langley Research Centers, NAG 2-1126

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, 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.

Extraction of Stress Intensity Factors from
Generalized Finite Element Solutions
C. A. Duarte,* J. P. Pereira
University of Illinois

This project investigates the performance of several
superconvergent techniques to extract stress intensity
factors (SIFs). The contour integral, the cutoff function
and the $J$ integral methods are considered. The
formulations of these methods are extended to the case of
cracks with tractions applied to their faces. The path
independence of the extraction methods is also analyzed.
Numerical solutions of elasticity equations are computed
with the generalized finite element method. The following
are considered: use of polynomial enrichment functions on
geometric meshes and use of enrichment with singular
functions on uniform meshes.

A Generalized Finite Element Method for
Polycrystalline Aggregates
C. A. Duarte,* A. Simone, E. van der Giessen
University of Illinois; Netherlands Institute for
Metals Research

In many polycrystalline materials, grain-boundary sliding
is considered to be one of the main mechanisms behind
superplastic flow. In this project, we consider novel
developments in the field of generalized finite element
methods and develop a model for the analysis of
polycrystals in which grain boundaries are represented
by means of elements with embedded displacement
discontinuities. Grain boundary sliding is described
by using a cohesive surface model with a nonlinear
constitutive law that is applied across the two faces of
every element crossed by a discontinuity line, i.e. a grain
boundary. We also investigate an extension of the method
for the description of grain refinement, a phenomenon that
is believed to be a key ingredient in the development of
superplastic flow in some coarse-grained polycrystals.

Structural Mechanics and
Dynamics

Analysis of the Response of Structures to Fire
K. D. Hjelmstad,* S. Ball
University of Illinois

Traditionally, the design of the fire protection system
for building structures has been done by the architect.
The collapse of the World Trade Center towers was a
poignant reminder of how important it is to understand
the response of structures in elevated temperature
environments.

This project is focused on surveying and summarizing
current capabilities for including elevated temperature
response in structural analysis software and current
design practice.

Cyclic Plasticity Models for Low-cycle Fatigue Analysis
K. D. Hjelmstad,* R. H. Dodds,* K. Cochran
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

*Denotes principal investigator.
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.

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.

**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.

**Innovative GFRP Joints for Pultruded Frames**

K. D. Hjelmstad,* J. LaFave,* S. White, J. Carrion, D. Turner  
*National Science Foundation, CMS-9978588*

Pultruded glass-fiber reinforced plastic (GFRP) structural members are now routinely manufactured and provide an important alternative construction material in environments where corrosion or electromagnetic interference are concerns. The main problem with using this material in practice is the lack of available technology for connecting GFRP members together.

This project is focused on the manufacturing and testing of a novel monolithic GFRP cuff joint that is designed to take advantage of the particular strengths of composite materials.

**Transportation Facilities and Systems**

**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.
Performance Evaluation of Longitudinal Pipe Underdrains
B. J. Dempsey,* J. S. Stein
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Illinois Department of Transportation

This project relates to the evaluation of the design procedures presently being used by the Illinois Department of Transportation for longitudinal pipe underdrains. The program objectives are focused on the development of guidelines and recommendations for improved pavement underdrain performance and cost savings. The research included the study of three different subdrainage systems that were proposed for design consideration. These subdrainage systems were tested in the laboratory at full scale. Based on these tests, recommendations for improved subdrainage design and construction are being made to the Illinois Department of Transportation. A draft final report has been submitted to the Illinois Department of Transportation 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
D. A. Lange*
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Federal Aviation Administration, DOT 95-C-001; 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 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.

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 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, J. Stein,
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

*Denotes principal investigator.
California and the performance of several design options, such as widened lanes, tied concrete shoulders, and dowelled 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 dowelled 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.) P. Littleton, 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.

**Analyses of National Airport Pavement Test Facility (NAPTF) Response Data**

M. R. Thompson,* K. Gopalakrishnan

*Federal Aviation Administration, Center of Excellence for Airport Pavement Research*

Flexible and rigid pavement test sections were constructed at the NAPTF (FAA William J. Hughes Technical Center, Atlantic City, N.J.). Extensive instrumentation was installed in the pavement sections. Materials, soils, and mixture design and construction control (including materials, soils, and compaction) data are available. Additional soils and materials testing and characterization data have been developed. Full-scale aircraft gear (duals, dual-tandem, and dual-tridems) and heavy-weight-deflectometer load-induced pavement responses (stresses, strains, and deflections) were analyzed using several pavement structural analysis programs.

The study served to evaluate the veracity of the analysis programs and provide insight concerning their modification and improvement.

**Concepts for Developing a Mechanistic-Empirical Based ACN Procedure for New Generation Aircraft**

M. R. Thompson*

*Boeing Aircraft Company*

The current Aircraft Classification Number (ACN) procedure is based on the Federal Aviation Administration’s CBR approach to flexible pavement design. A recent paper (2002) by Thompson and Gomez-Ramirez of the University of Illinois outlined a mechanistic-empirical approach for developing a new approach for new generation aircraft (NGA) ACN calculations. The suggested procedure utilizes calculated “structural responses” (stresses, strains, deflections, stress ratios, etc.) to characterize the “damage potential(s)” of a candidate NGA gear configuration.

The Boeing Company is sponsoring this study to further develop and evaluate the procedure as an alternative for the current ACN procedure.

*Denotes principal investigator.
Mechanistic Design Implementation and Monitoring
M. R. Thompson,* E. J. Barenberg*
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.

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.

Industry Survey and Review of Performance and Remediation Methods for Track Substructure
E. Tutumluer,* T. Bond
Association of American Railroad; BNSF Railroad Company

The focus in this project has been to conduct a survey or review of poor track substructure (ballast, subballast, and subgrade) performances encountered by the railroad industry in an effort to provide guidelines to maintenance engineers on the effectiveness of various track remediation methods. Both known and new or emerging remedial procedures are reviewed for the various substructure problems identified and applied by the industry. Next, a decision-making guidance system is developed for the railroad engineers first to identify the substructure problem affecting track deterioration and then to apply the most effective remedial procedure applicable for the specific track maintenance and design.

This research is aimed at compiling a knowledge database of the current best practices in dealing with various track substructure problems to improve the safety, network reliability, and productivity of the AAR member railroads.

Investigation of Aggregate Shape Effects on Hot Mix Performance Using an Image Analysis Approach
E. Tutumluer,* S. H. Carpenter,* T. Pan
Federal Highway Administration

An aggregate image analysis device, the University of Illinois Aggregate Image Analyzer is used to automate determination of coarse aggregate size and shape properties, such as the gradation, angularity, flatness and elongation, surface texture, and the surface area. The impact of these imaging based shape and size indices on the performances of asphalt concrete mixes is investigated in this pooled fund study. The field rutting performances of the National Center for Asphalt Technology test track mixes are studied together with the laboratory rutting performances of asphalt mixes received from eight participating states and the Federal Lands and Highways Division.

This research utilizes advanced imaging technology in the selection of proper shaped and textured aggregates to build more durable and longer lasting asphalt concrete pavements.

Materials Testing and Permanent Deformation Behavior of NAPTF Base, Subbase, and Subgrade Layers
E. Tutumluer,* I. T. Kim
Federal Aviation Administration Center of Excellence for Airport Technology

This research focuses on studying the deterioration behavior of airport pavement granular layers through improved testing and modeling. The measured performances of full-scale flexible pavement test sections provide the field database. The work areas consist of sampling and advanced laboratory testing of granular base or subbase aggregates, determining the most damaging field stress states affecting aggregate performance, development of material characterization and laboratory performance based models, and finally, based on laboratory performance based evaluation, development of
specifications for field construction and compaction of unbound granular layers.

This experimental and analytical research advances science and technology for making rut resistant airport pavement structures that can withstand heavy aircraft loading.

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 4-30: Test Methods for Characterizing Aggregate Shape, Texture, and Angularity
E. Tutumluer,* T. Pan
National Cooperative Highway Research Program

This study aims at identifying or developing a test method for measuring shape, angularity, and texture characteristics of aggregates. The research approach includes collecting information on both aggregate characteristics and methods used to measure them. A methodology has been developed to evaluate potential tests and conclude that the final recommended test is based on sound scientific concepts; able to characterize the different aspects of aggregate characteristics; give results that are easy to interpret; and be practical in terms of labor requirements, ease of use, field applicability, and cost.

This nationwide research is aimed at identifying or developing the best methodology 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.

*Denotes principal investigator.
Transportation Systems

Development of Performance-Based Guidelines for Hot-Poured Crack Sealants
I. L. Al-Qadi,* S. Yang, E. Fini, M. Elseifi, S. Dessouky
Federal Highway Administration; 12 DOT's in the U.S. (NRC is the Canadian Counterpart along with 13 agencies)

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, M. Elseifi
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 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. To achieve that, in this study, 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.

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.
Field Assessment of I-90/94 (Dan Ryan Expressway) by Ground Penetrating Radar
I. L. Al-Qadi,* K. Jinag
Illinois Department of Transportation

The Dan Ryan Expressway (I-90/94) bridge in Chicago, Illinois, has a 7.5-in. reinforced concrete bridge deck with no overlay. In this study, six lanes (four southbound and two northbound) of the bridge were evaluated using a nondestructive investigation tool, ground penetrating radar (GPR). An image processing technique was developed to detect the reinforcing rebars and estimate the cover depth. The analysis approach allows for detecting the rebar’s classic parabolic signature using a high-frequency ground-coupled antenna. An air-coupled antenna is used to determine the dielectric constant of the bridge deck. The outcome of the study will be used to optimize the rehabilitation technique of the bridge deck.

Arrival Based Uniform Delay Model for Oversaturated Signalized Intersections
R. F. Benekohal,* S.-O. Kim
University of Illinois

For oversaturated traffic conditions, Highway Capacity Manual (HCM) does not apply a progression adjustment factor (PF) to the delay for signalized intersections when there is an initial queue. This research introduces a new approach for computing uniform delay for oversaturated traffic conditions. This approach directly considers the platooning effects in delay, thus eliminating the needs for applying PF. The approach is validated by comparing the control delays obtained from CORSIM simulation to delays from the proposed model. Validation procedures are conducted based on zero and nonzero initial queue conditions. The proposed approach results in more accurate delay values than the HCM model.

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, D. Sun, 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, M. Maestranzi
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

*Denotes principal investigator.
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.

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.

Comparison of QUEWZ, FRESIM and QuickZone with Field Data for Work Zones
M. Chitturi, R. F. Benekohal*
Illinois Department of Transportation; Federal Highway Administration

The objective of this study is to use the field data to evaluate QUEWZ, FRESIM, and QuickZone, and to identify which of them represents real-world queue conditions better. Detailed data were collected at eleven work zones, eight with and three without queues, on interstate highways. Relevant field data were used as input to the software packages, and their results were compared with the field data using statistical tests, where appropriate. The measures of effectiveness (MOEs) used in this study included work zone capacity, speed, queue length, and user delay. The results of this study indicate that none of these three software packages gave estimates that were reasonably and consistently close to the observed field data.

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 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.

**GIS-Based Integrated Intersection Inventory System**

D. Sun, R. F. Benekohal,* M. Girianna  
*Illinois Department of Transportation*

Information about intersections resides in different databases and is not easily accessible. This study developed a GIS-based Intersection Inventory System (GIS-IIS) for the signalized intersections on the state-maintained highway system. Data for IDOT District 6 were used in developing the system. Procedures were developed for field data collection and processing as well as integrating multimedia and other traffic signal information into the GIS framework. It was recommended to expand GIS-IIS to create a comprehensive information system that incorporates information such as traffic, geometric, construction, maintenance, and intersection accident data.

**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 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**

Garrett, J. H., Flood, I., Smith, I. F. C., and Soibelman, L.  

Ho, S. P. and Liu, L. Y.  
Analytical model for analyzing construction claims and opportunistic bidding. *Journal of Construction Engineering and Management, 130*:1, 94-104 (Jan.-Feb. 2004).

Ho, S. P. and Liu, L. Y.  

Khalafallah, A. and El-Rayes, K.  

Park, M. and Peña-Mora, F.  
Construction Materials


Earthquake Engineering


Environmental Engineering and Science in Civil Engineering


Environmental Hydrology and Hydraulic Engineering


Geotech/Information Technology


Geotechnical Engineering


Railroad Engineering


Structural Engineering and Design


Structural Engineering and Structural Dynamics


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**Structural Engineering and Structural Mechanics**


Structural Mechanics and Dynamics


Transportation Facilities and Systems


Transportation Systems


**Book Chapters**

**Construction Materials**


**Papers Presented at Conferences and Symposia**

**Construction Management**


Kandil, A. and El-Rayes, K. *Distributed computing for optimal planning of large-scale construction projects*. 10th International Conference on Computing in Civil and Building Engineering (Weimar, Germany, Jun. 2004).


**Construction Materials**


Grasley, Z. and Lange, D. A. *Early-age concrete stresses induced by drying shrinkage and thermal dilation*. 5th International Ph.D. Symposium in Civil Engineering (Delft, the Netherlands, Jun. 2004).


Environmental Engineering and Science in Civil Engineering


Bond, T. C. and Bergstrom, R. W. Toward resolution on the optics of light-absorbing carbon. 8th International Conference on Carbonaceous Particles in the Atmosphere (Vienna, Austria, Sep. 2004).


Choi, Y.-C., Xi, C., Li, X., Raskin, L., and Morgenroth, E. Interrelationship between dissolved oxygen levels and growth patterns of biofilms and their effects on perchlorate removal from drinking water using biofilm reactors [poster]. 10th International Symposium on Microbial Ecology (Cancun, Mexico, Aug. 2004).


Coronell, O. and Mariñas, B. J. Water quality effects on the inactivation kinetics of MS2 phage with free chlorine. 2004 American Water Works Association Water Quality Technology Conference (San Antonio, TX, Nov. 2004).


Lopez, C., Pons, M. N., and Morgenroth, E. From optical to two-photon-excitation microscopy for sludge characterization. 1st Workshop on Recent Advances in Activated Sludge Flocculation (Ghent, Belgium, Sep. 2004).

Mi, B. and Mariñas, B. J. Role of pore size distribution in the transport of water contaminants. 2004 American Water Works Association Water Quality Technology Conference (San Antonio, TX, Nov. 2004).


Sun, H. and Bond, T. C. Primary carbonaceous aerosols and climate modeling: Classifications, global emission inventories, and observations [poster]. American Geophysical Union 2004 Fall Meeting (San Francisco, CA, Dec. 2004).


Environmental Hydrology and Hydraulic Engineering


Geotechnical Engineering


Erbay, O. O. and Abrams, D. P. *A methodology to assess seismic risk for populations of unreinforced masonry buildings*. 13th International Brick-Block Masonry Conference (Amsterdam, the Netherlands, Jul. 2004).


**Structural Engineering and Structural Mechanics**


**Structural Mechanics and Dynamics**


Elnashai, A. S., Spencer, B. F., Kuchma, D., Ghaboussi, J., Hashash, Y., and Quan, G. *Multi-axial full-scale substructured testing and simulation (MUST-SIM) facility at the University of Illinois at Urbana-Champaign*. 13th World Conference on Earthquake Engineering (Vancouver, BC, Aug. 2004).


Transportation Facilities and Systems

Al-Qadi, I. L. and Elseifi, M. **Field installation and design considerations of the steel reinforcing nettings to reduce reflection of cracks.** 5th RILEM International Conference on Cracking in Pavements (Limoges, France, May 2004).


Altoubat, S., Roesler, J., and Rieder, K.-A. **Effects of synthetic fibers on structural behavior of concrete slabs supported on ground.** 1st International Conference on Application of Traditional and High Performance Materials in Harsh Environments (Sharjah, United Arab Emirates, Jan. 2004).


Elseifi, M. and Al-Qadi, I. L. **Effect of thermal and vehicular loading on rehabilitated jointed concrete pavement with and without steel reinforcing netting.** 5th RILEM International Conference on Cracking in Pavements (Limoges, France, May 2004).


Kim, I. T. and Tutumluer, E. Predicting rutting performances of pavement granular layers at the FAA’s national airport pavement test facility. Federal Aviation Administration Worldwide Airport Technology Transfer Conference and Exposition (Atlantic City, NJ, Apr. 2004).


Tutumluer, E. and Kim, I. T. Stress rotations due to moving wheel loads and their effects on pavement materials characterization. 57th Canadian Geotechnical Conference (Québec City, QC, Oct. 2004).


Transportation Systems


Aycin, M. F. and Benekohal, R. F. Performance of generalized car-following model obtained from macroscopic flow relationships in simulating field data. 83rd Transportation Research Board Annual Meetings (Washington, DC, Jan. 2004).


Chitturi, M. and Benekohal, R. F. Comparison of QUEWZ, FRESIM and QuickZone with field data for work zones. 83rd Transportation Research Board Annual Meetings (Washington, DC, Jan. 2004).


Sun, D. and Benekohal, R. F. Analysis of car-following characteristics for estimating work zone safety. 83rd Transportation Research Board Annual Meetings (Washington, DC, Jan. 2004).

**Theses**

**Construction Management**


**Construction Materials**


**Environmental Engineering and Science in Civil Engineering**


Environmental Hydrology and Hydraulic Engineering


Geotechnical Engineering


Railroad Engineering


Structural Engineering and Structural Dynamics


Structural Engineering and Structural Mechanics


Transportation Facilities and Systems


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

**Rahim Benekohal**
Honorary Professorship in Transportation Engineering, Harbin University of Civil Engineering and Architecture, China
Certificate of Appreciation, Illinois Institute of Transportation Engineers, 1989
Chi Epsilon Faculty Honor Member, 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
Faculty Honor Member, Phi Kappa Phi, 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

**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

**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

**Samuel H. Carpenter**
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

**Edward J. Cording, Emeritus**
Member, National Academy of Engineering
Hogentogler Award, American Society for Testing and Materials, 1976
Thomas Middlebrooks Award, American Society of Civil Engineers, 1985
Martin S. Kapp Award, American Society of Civil Engineers, 1993

**David E. Daniel**
Member, National Academy of Engineering
Croes Medal, American Society of Civil Engineers, 1984
William J. Murray Fellowship in Engineering, 1985-1992
Faculty Excellence Award, College of Engineering, 1989
Standards Development Award, American Society for Testing and Materials, 1991
L. B. (Preach) Meaders Professorship in Engineering, University of Texas at Austin, 1992-1996
Special Service Award, American Society for Testing and Materials, 1994
Middlebrooks Award, American Society of Civil Engineers, 1995
Richard R. Torrens Award, American Society of Civil Engineers, 1995

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 São Paulo, 1998
Distinguished Visiting Professor, Imperial College of Science 7 Technology, 1999
Chi Epsilon Chapter Honor Member, University of Illinois, 2000
M. T. Geoffrey Yeh 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

C. Armando 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

J. Wayland Eheart
Distinguished Professor Award, Council for International Exchange Scholars, 1988

Amr Elnashai
Fellow, Royal Academy of Engineering, U.K., Armstrong Medal for the best paper in the Institution of Structural Engineers
Donald Biggar Willett Professor in Engineering, University of Illinois College of Engineering, 2003-2008

Khaled El-Rayes
Competitive Scholarship Award, American Association of Cost Engineers, 1992
Excellence Award, Project Management Institute, 1993
External Grant Holder Doctoral Scholarship, Concordia University, 1993-1996
FCAR Bourse d’excellence pour des etudes de cycles superieurs, de perfectionnement et de reintegration a la recherché, 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), National Science Foundation, 2003

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, Institute 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
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
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, University of Illinois Student Chapter, 1991, 1995, 1999
Harriet and Charles Luckman Undergraduate Distinguished Teaching Award, University of Illinois, 1992

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, 1999
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

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

**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
Presidential 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

**Nicholas P. Jones**
George Owen Teaching Award, Johns Hopkins University, 1987
Maryland Young Engineer of the Year, 1988
Presidential Young Investigator Award, National Science Foundation, 1989
Robert Pond Teaching Award, Johns Hopkins University, 1991
Huber Research Prize, American Society of Civil Engineers, 1997
Erskine Fellow, University of Canterbury, New Zealand, 1999

International Editor, *Journal of Wind Engineering and Industrial Aerodynamics*, 1999-
Inducted as Faculty Initiate, University of Illinois Chi Epsilon Chapter, 2002

**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

**David A. Lange**
Sigma Xi, 1994
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 1996
Narbay Khachaturian 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

**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
Advisory Award, University of Illinois College of Engineering, 2002, 2003, 2004
W. E. O’Neil Construction Faculty Research Fellowship, 2002-2004
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
Abraham Rosenberg Research Fellowship, University of California, Berkeley, 1984
University of California Regents Fellowship, 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
Incomplete List of Outstanding Instructors, University of Illinois, Fall 1996, Fall 1997, Spring 2002, Fall 2003, Fall 2004
Arthur and Virginia Nauman Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1998-2004
Association of Environmental Engineering and Science Professors (AEESP) Parsons Engineering Science Doctoral Thesis Award (advisor to doctoral student: Qilin Li, co-advised with V. L. Snoeyink), 2003

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

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, 2000
Fellow, Center for Advanced Study, 2001
Nauman Faculty Scholar, 2001-
Fellow, Japan Society for the Promotion of Science, 2003
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 2003

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
Incomplete List of Teachers Ranked as Excellent by Their Students, 2003
C-FAR Donald A. Holt Achievement Award, Livestock & Urban Waste Recycling Team, 2003
Beckman Fellow, Center for Advanced Studies, University of Illinois, 2003

Scott M. Olson
Arthur Casagrande Professional Development Award, American Society of Civil Engineers, 2004

Glaucio H. Paulino
Collins Scholar, University of Illinois, 2000
Xerox Award for Faculty Research, University of Illinois, College of Engineering, 2003
David A. Pecknold, Emeritus
Outstanding Civil Engineering Undergraduate Teaching Award, University of Illinois Student Chapter, American Society of Civil Engineers, 1978, 1992
Special Paper Award, ASME Ocean, Offshore and Arctic Engineering Division, 2000

John S. Popovics
University of Illinois American Society of Civil Engineers Outstanding Teacher Award, 2004
Accenture Outstanding Advisor Award, 2004

Shaoying (Shawn) Qi
Recipient, 2003 Editor’s Award, Journal of Environmental Engineering, ASCE 129(12), 1076, 2003

Lutgarde Raskin
Research Initiation Award, National Science Foundation, 1994
Fellow, University of Illinois Center for Advanced Study, 1996
Montgomery Watson and Association for Environmental Engineering Professors, adviser of student (M. Griffin) receiving second prize in the M.S. Thesis Competition, 1997
Xerox Award for Faculty Research, University of Illinois College of Engineering, 1997
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 1998
Nar bey Khachaturian Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1998
Illinois Water Environment Association, adviser of student (F. de los Reyes) receiving Best Student Paper Award, 1998
Incomplete List of Teachers Ranked as Excellent by Their Students, 1998-2000
Montgomery Watson and Association for Environmental Engineering and Science Professors, adviser of student (D. B. Oerther) receiving first prize in the M.S. Thesis Competition, 1999
Water Environment Federation, adviser of student (F. de los Reyes) receiving first place in Student Paper Competition Ph.D. Category, 1999
Distinguished Service Award, Association of Environmental Engineering and Science Professors, 2002
Paul L. Busch Award, Water Environment Research Foundation Endowment for Innovation in Applied Water Quality Research, 2002
Xerox Award for Faculty Research, University of Illinois College of Engineering, 2002

Chris R. Rehmann
Post-Doctoral Scholarship, Woods Hole Oceanographic Institution, 1996
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 1998-2000
Robert E. Miller Award for Teaching of Mechanics, 2003
Best Paper Award, Center of Aquatic Ecology, Illinois Natural History Survey, 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

Mark J. Rood
Valle Scandinavian Exchange Program Scholarship, 1985
Plenary Lecture, Universiti Teknologi Malaysia, Partec’91, Kuala Lumpur, Malaysia, 1991
James M. Montgomery Master’s Thesis Advisor Award, Association of Environmental Engineering Professors, 1992
Distinguished Service Recognition as Treasurer and Executive Board Member, Association of Environmental Engineering Professors, 1993-1995
Plenary Lecture, Chinese Association of Aerosol Research Conference, Taiwan, 1997
Associate Editor, Journal of Air and Waste Management Association, 1994-2004
Associate Editor, Journal of Environmental Engineering, 1998-2002
Montgomery-Watson-Harza Association of Environmental Engineering Professors Master Thesis Award for advisee Katherine Dombrowski, 2002
Editor-in-Chief, Journal of Environmental Engineering, 2002-2004
Keynote Lecture, Carbon 2003 Conference, Spain, 2003
Richard A. Glenn Best Paper Award, 214th American Chemical Society National Meeting Fuel Chemistry Division, 1997
Environmental Engineering Committee Member, U.S. Environmental Protection Agency, Science Advisory Board, 2003-

A. R. Schmidt
University Council on Water Resources Ph.D. Dissertation Award in the field of Natural Science and Engineering, 2003

Vernon L. Snoeyink, Emeritus
Member, National Academy of Engineering
Past President, Association of Environmental Engineering Professors
Nalco Agricultural Environmental Enhancement Program 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
Boston Society of Civil Engineers, Thomas R. Camp Lecture, 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

Lucio Soibelman
Master’s Fellowship, CAPES, Brasilia, Brazil, 1985-1986
Doctoral Fellowship, CNPq, Brasilia, Brazil, 1993-1997
Outstanding Student Contribution, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 1996
Teacher Assistant Fellowship, Massachusetts Institute of Technology, 1997
Incomplete List of Teachers Ranked as Excellent by Their Students, 2001-2002
Teacher Assistant Fellowship, Massachusetts Institute of Technology, 1997
Faculty Early Career Development Program (CAREER) Award, National Science Foundation, 2001

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, ASCE, 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
Thomas A. Middlebrooks Award, American Society of Civil Engineers, 1998
University Scholar, University of Illinois, 1998-2001
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1999
Outstanding Paper Nomination, one of eight papers nominated for ASCE Journal of Performance of Constructed Facilities annual outstanding paper award, Editors Note, 2001
Standards Development Award, American Society for Testing and Materials, 2002
R. M. Quigley Award, Best Paper, Canadian Geotechnical Journal, 2002,
Paper Award, Canadian Geotechnical Society, 2003
Incomplete List of Teachers Ranked as Excellent by Their Students, University of Illinois, 1995, 1996, 2004

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

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 C09 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

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, Civil Engineering, Georgia Institute of Technology, 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
Albert J. Valocchi
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 to support a visiting professorship at the Technical University of Denmark, 1993
Collins Award for Innovative Teaching, University of Illinois, College of Engineering, 2002
Center for Advanced Study Associate, University of Illinois, 2003-2004

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 (CAREER) Development Award, National Science Foundation, 1988-2002
Environmental Engineering and Science Faculty Scholar, 2001-2004

Jian Zhang
JSPS Short-Term Invitation Fellowship, Japan Society for the Promotion of Science, 2003