A Report of Activities during 2003

This .pdf is part of the larger 2004 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 2003 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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The 2004 Summary of Engineering Research is produced by the Office of Engineering Communications, University of Illinois at Urbana-Champaign.

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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 other natural and man-made hazards. Civil and environmental engineering is a broad discipline encompassing activity in the following areas:

- construction processes and their management (planning, analysis, automation, and economics)
- environmental engineering (water, sewage, air, waste management, bioprocessing)
- geotechnical engineering (foundations, slope stability, tunnels, embankments, waste disposal, and remediation of contaminated ground)
- hydraulics and hydrology (dams, open channel flow, flood control, power projects, groundwater resources, and water resources management)
- materials engineering (understanding and improving the materials used for construction)
- structural engineering (buildings, bridges, industrial facilities, and space structures)
- 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. Faculty and graduate students conduct basic research in the mechanics of airport pavement design for the next generation of large commercial aircraft. The NSF-funded Science and Technology Center on Advanced Materials for Water Purification with systems 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 century’s greatest civil engineering educators were former faculty members—Hardy Cross, Nathan Newmark, Ven Te Chow, Ralph Peck, and Richard Engelbrecht, for instance. Since its founding 132 years ago, this Civil and Environmental Engineering Department has evolved to a large, comprehensive department with approximately 470 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 in the world 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 alumni association.

Faculty and Their Interests

Daniel P. Abrams
Reinforced concrete, masonry, earthquake engineering

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

Scott A. Burns
Engineering design optimization, structural engineering, numerical methods

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

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, optimal lighting design for nighttime construction, impact of weather on construction, object-oriented modeling, artificial intelligence in 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, visualization and virtual reality

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

Clyde E. Kesler, Emeritus
Concrete

Praveen Kumar
Hydroclimatolgy, hydrogeomorphology, hydrologic information systems, knowledge discovery in databases, ecohrology
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

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

W. H. C. Maxwell, Emeritus
Hydromechanics, hydraulic engineering

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, groundwater remediation and monitoring design, interactive and collaborative environmental management using machine learning

Eberhard Morgenroth
Influence of dynamic reactor operation on the performance of biological treatment processes, biofilms

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

Kam W. Wong, Emeritus
Surveying, photogrammetry, computer vision metrology

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
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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 environment.
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.

Evaluation of Operations for Nighttime Highway Construction
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Nighttime construction has been increasingly used in highway maintenance and rehabilitation projects in the United States in the last two decades. Despite the reported advantages of minimal disruption to traffic and improved safety for the traveling public, this practice has many aspects that have not been sufficiently investigated. The goal of this project is to evaluate the impact of nighttime operations on construction cost, quality, safety, and productivity. The objectives of this research are to determine the advantages and disadvantages of nighttime construction, considering safety of the driving public and construction workers; identify construction operations that are most suited for nighttime construction, considering cost, productivity, and quality; and develop analytical models to evaluate the feasibility of nighttime construction.

The findings of this research study will help officials in various Departments of Transportation (DOT) in evaluating the feasibility of nighttime work and identifying operations that are most suited for this type of construction.

Impact of Change Orders on Construction Productivity
K. El-Rayes,* O. Moselhi,* I. Assem
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Natural Sciences and Engineering Research Council of Canada

Change orders occur frequently during the delivery of construction projects, creating disruptions, modifying the orderly sequence of performance, and leading to adverse impact on construction productivity. The quantification of this impact is a major source of dispute, as it is generally underrated and even sometimes goes completely unrecognized by owners. The main goal of this research is to develop a practical model for quantifying the impact of change orders on construction productivity in order to provide an up-front, equitable pricing for change orders. To this end, the research objectives of this study are to investigate and identify the major factors influencing the adverse impact of change orders; analyze real case studies and generate a set of actual cases in order to provide a better understanding of the impact of change orders; conceive, develop, and validate a computer-based model.
for quantifying the impact of change orders on construction productivity, accounting for the timing of these changes and their type of work; and implement and validate the developed model in user-friendly software systems for estimating the impact of change orders on productivity.

The developed model enables construction planners to quantify the impact of change orders on construction productivity. This can lead to speedy and equitable pricing of changes orders in the construction industry, and should contribute to minimizing the disruptive and costly disputes that are often encountered between owners and contractors during the execution and settlement of these changes.

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

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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.

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.

Automated Productivity and Progress Assessments Using Digital Close-Range Photogrammetry

L. Y. Liu,* T. Trupp
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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.

*Denotes principal investigator.
Construction Object-oriented Process Simulation
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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
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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 evaluation is under development.
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.

**A Design Review Checking System with Corporate Lessons Learned**
L. Soibelman,* L. Liu, J. G. Kirby, W. East, C. Caldas, K. Y. Lin
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*U.S. Army Construction Engineering Research Laboratory*

Design reviews are critical to the success of a construction project. They eliminate costly rework and conflicts and promote creative and innovative design and construction. This research evaluates the Design Review Checking System (DrChecks) and the system called Corporate Lessons Learned (CLL), both developed by U.S. Army Construction Engineering Research Laboratory to collect personal experiences and lessons learned on projects and incorporate this data into corporate knowledge, expressly for the design review process. DrChecks and CLL both take advantage of the Internet and facilitate the management of the design review process as well as the collection and reuse of corporate lessons learned asynchronously and remotely.

This research will influence the design and construction integration to minimize construction conflicts.

**Construction Materials**

**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.

*Denotes principal investigator.*
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.

**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.

**High-Performance Concrete for Bridge Decks**
D. A. Lange,* J. Roesler,* M. D. Ambrosia,
C. J. Lee, D. Cowen
Illinois Department of Transportation

High-performance concrete (HPC) offers compelling advantages for transportation structures, such as bridge decks and substructures. HPC has high strength to better resist applied load, low permeability to better protect reinforcing steel from corrosion, improved durability to extend the service life of the surface and structure, and lower life cycle cost for many applications. However, early-age shrinkage or creep and thermal stresses can cause early cracking of HPC. The Illinois Department of Transportation is constructing HPC bridge decks in 2000–2002, and this project provides for University of Illinois participation in laboratory work and field measurements to assess properties and performance.

HPC has high strength to better resist applied load, low permeability to better protect reinforcing steel from corrosion, improved durability to extend the service life of the surface and structure, and lower life cycle cost for many applications.

**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.

**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.

**Performance and Acceptance of Self-Compacting Concrete**
D. Lange,* L. J. Struble, M. D’Ambrosia,
A. Brinks, L. Shen, J. Hildalgo, F. Tejeda
Illinois Department of Transportation

Self-consolidating concrete (SCC) is a high-performance material that is designed to flow into formwork under its own weight. Research and development of SCC materials is widespread and focused mainly on flow behavior. However, the goal of uniformity and acceptance for practical use has not yet been fully realized. In this project, we are investigating stability (segregation), formwork pressure, and hardened properties of SCC.

The results of the study will include recommended test protocol and acceptance criteria to assist Illinois Department of Transportation engineers in the practical use of SCC.
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 Paste Rheology
L. J. Struble,* C. T. Chen  
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*Center for Advanced Cement-Based Materials

The flow behavior of fresh cement paste is being studied to understand how flow is affected by the composition of cement, the addition of mineral admixtures, and the presence of chemical admixtures. By using dynamic rheological techniques, researchers are able to measure changes in rheology as hydration takes place. The objectives are to understand paste microstructure and to explore the setting behavior of admixture combinations.

Cement Sulfate Optimization
L. J. Struble,* N. Mohler  
Holcim USA

The amount of calcium sulfate in portland cement, usually in the form of gypsum, is determined by measuring the strength of hardened mortar. Yet the main role of the gypsum is to control hydration of the calcium aluminate phase such that the concrete does not set (i.e., become hard) too early. Furthermore, too high a gypsum level causes excessive expansion when the concrete has hardened. In this project, we are comparing the gypsum levels determined by measuring strength with the level determined by measuring flow properties of fresh cement paste and the level controlled by limits on expansion. This could lead to development of a more rational protocol for optimizing the amount of gypsum.

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.

Concrete Rheometry
L. J. Struble,* A. R. Robinson*  
lstruble@uiuc.edu  
*University of Illinois

The flow behavior of concrete is important both to the processability of fresh concrete and to the mechanical behavior of hardened concrete. Measurement of concrete flow behavior is difficult because of the broad range in particle size. Rheometers to measure concrete flow behavior are being analyzed, with emphasis on the computation of stress and strain rate from measurements of torque and rotational speed. An existing concrete rheometer was analyzed, a new design was proposed, and this new design is being analyzed.

Rheology of Self-Consolidating Concrete
L. J. Struble,* L. Shen  
University of Illinois Critical Research Initiative

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 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.

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.

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
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.

*Denotes principal investigator.
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 \( \pm 3 \) mm), regardless of surface roughness, base material type and surface condition, surface tining condition, and material internal moisture condition; develop the basis and testing protocol of NDE for determination of \( \text{in situ} \) 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.

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.

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.

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.

*Denotes principal investigator.
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.

**The Effect of Calcium on the Stability of Metal Working Fluid**

M. M. Clark,* K. Rajagopalan, A. Menniti

State of Illinois Waste Management Research Center

Metal working fluid (MWF), an oil-in-water emulsion, is used as a lubricant and coolant in metal machining operations. Since MWF is electrostatically stabilized, hardness-producing ions can cause the emulsion droplets to coagulate and loose functionality. The objective of this research is to examine the effect of calcium on the stability of a commercially available semisynthetic MWF, Castrol 6510. Three methods of stability ratio evaluation are compared: initial slope of absorbance vs. time curve; time change of absorbance; and change in particle number concentration over time using photon correlation spectroscopy. The last two approaches were found to give consistent results.

Disposal of MWF is a problem for Illinois industry, and this project seeks to understand several aspects of the degradation and recycling of MWF.

**Science and Technology Center on Advanced Materials for Water Purification**

J. Economy,* P. Bohn, J. Georgiadis, M. Shannon, E. Mintz, M. Reinhard, V. L. Snoeyink

National Science Foundation

The objectives of this center are to develop new materials that can be used for drinking water purification, and to educate the general public about the issues that are involved in doing this. Researchers from Stanford University, Clark Atlanta University, and the University of Illinois departments of Materials Science and Engineering, Mechanical and Industrial Engineering, Geology, Chemistry, Chemical and Biomolecular Engineering, and Civil and Environmental Engineering are involved. The initial research program is focused on adsorbents and membranes for the removal of organic and inorganic contaminants, catalysts for the conversion of organic and inorganic substances to innocuous substances, and disinfectants.

**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.

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 geomorphic reactions and incorporates adaptive management and other modeling tools to protect and enhance environmental quality. It will develop new methods of integrating ecological protection schemes that are compatible with existing approaches that protect water quality and the public health and safety. Finally, the research will evaluate different policies under high-flow events (e.g. typhoons) and low-flow events (e.g. drought).

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.

**Assessment and Development of Low-Pressure Membrane Integrity Monitoring Tools**

B. J. Mariñas,* B. Mi, J. Curl

*Carollo Engineers; American Water Works Association Research Foundation*

The main objective of this task is to validate current and improved membrane integrity monitoring techniques by performing microbial challenge experiments. The signal from membrane integrity monitoring techniques to be used in the full-scale microfiltration (MF) and ultrafiltration (UF) systems under investigation in this study will be correlated to the actual passage of *Bacillus subtilis* spores. *B. subtilis* spores (1 mm) are selected because they are smaller in size compared to the target pathogens *Cryptosporidium* oocysts (3 to 5 mm) and *Giardia* cysts (10 to 15 mm), thus providing conservative results. Also, they are not pathogens and are thus considered more suitable for full-scale testing.

**Development of an Ozone Contactor Model for Bromate Formation and *C. parvum* Oocyst Disinfection**

B. J. Mariñas,* R. A. Minear,* J. Kim, M. A. Urban

*Montgomery-Watson, Inc.; American Water Works Association Research Foundation*

The objective of this project is to develop a model that will allow the overall optimization of ozone contactor design and operating mode to achieve maximum *C. parvum* oocyst disinfection efficiency and minimum bromate formation with natural waters of various qualities containing low bromide concentrations. Ozone contactors are commonly comprised of one or more transfer chambers, in which ozonated gas is diffused into water, followed by several reactive chambers where additional inactivation and corresponding disinfection by-product (DBP) formation takes place. Modeling the disinfection and DBP formation efficiencies taking place in these contactor chambers requires taking into consideration hydrodynamics, gas transfer, and reaction kinetics.

**Effect of Operating Conditions on the Efficiency of Microbial Contaminant Removal by Low-Pressure Membranes**

B. J. Mariñas,* J. M. Curl

*U.S. Environmental Protection Agency STAR Fellowship*

Low-pressure membranes are used to provide a barrier against microbial contaminants like viruses, bacteria, and protozoan (oo)cysts. However, few studies have been conducted to show the effect of operating parameters on membrane performance with respect to microorganism removal. Further information is needed to determine if operating conditions that minimize membrane fouling or maximize flux also result in maximum microorganism removal. The goal of this study is to investigate the roles that key operating conditions (permeate flux and coagulant dose) and water quality parameters (pH, suspended solids, and natural organic matter) play in the removal efficiency of viruses by UF membranes.

**Impact of Water Quality on the Inactivation of Bacterial and Viral Pathogens**

B. J. Mariñas,* M. A. Larson

*Vivendi Water; American Water Works Association Research Foundation*

The objective of this project is to develop models accounting for the various factors affecting the inactivation kinetics of bacterial and viral pathogens in natural waters. Comprehensive disinfection models require good understanding of the inactivation kinetics of target pathogens with specific disinfectants, including any effects that various water quality parameters can have on inactivation efficiency. Additional information required for modeling is contactor hydrodynamics and disinfectant demand kinetics. Mass transfer must also be characterized if gaseous chemicals such as ozone and chlorine are applied directly to water. Furthermore, water quality parameters, such as natural organic matter, pH, temperature, turbidity, and various inorganic solutes, can have an impact on both disinfectant demand and mass transfer. Nonidealities and disinfectant exposure, as those experienced by *C. parvum* oocysts in full-scale disinfection contactors, can be factors.

**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 Aeromonas Hydrophila with Monochloramine**

B. J. Mariñas,* L. Raskin, K. Sirikanchana  
*Royal Thai Government Fellowship; U.S. Environmental Protection Agency Cooperative Agreement, CR-826461010

*A. hydrophila* is a waterborne opportunistic pathogen commonly detected in drinking water, even in the presence of measurable levels of chlorine residual. The persistence of *A. hydrophila* in chlorinated drinking water has been associated with its protection by embedment in biofilms and suspended particles, and with the corresponding exposure to low disinfectant concentration. The main objective of this study is to elucidate some of these effects by characterizing the role of disinfectant concentration, temperature, and pH in the inactivation kinetics of *A. hydrophila* (ATCC 7966) with monochloramine.

**Inactivation of Cryptosporidium parvum Oocysts in Swine Wastewater**

B. J. Mariñas,* J. L. Rennecker  
*MBI International; National Science Foundation STTP

The objective of this study is to investigate the inactivation kinetics of *C. parvum* oocysts with ozone in high oxidant-demand water from pig waste lagoons. Experiments are performed at 20°C with a semi-batch reactor containing 1 liter of filtered wastewater dosed with *C. parvum* oocysts. An additional goal of the study is to investigate the mechanisms responsible for the inactivation of *C. parvum* oocysts under high oxidant-demand conditions.

**Inactivation of Cryptosporidium parvum Oocysts with Ozone**

B. J. Mariñas,* B. Corona-Vasquez  
*Vivendi Water, Paris, France

The overall objective of this study is to assess the efficiency of ozone disinfection processes to inactivate *Cryptosporidium parvum* (*C. parvum*) oocysts under conditions typically encountered at the Neuilly-sur-Marne water treatment plant throughout the various seasons of the year. Representative samples of summer, fall flood, and winter water were taken from the influent to the ozone contactor at the treatment plant and tested in bench-scale reactors in order to investigate the effect that three different initial doses of dissolved ozone would have on the inactivation of *C. parvum* after 15 and 25 minutes of contact time.

**Integral Optimization of Ozone Disinfection Systems with Fluorescent-Dyed Polystyrene Microspheres**

B. J. Mariñas,* G. Tang  
*American Water Works Association Research Foundation

The main objective of this project is the development and demonstration of a novel method for optimizing the performance of full-scale ozone disinfection systems with respect to both disinfection efficiency and disinfection by-product formation control. Fluorescent-dyed polystyrene microspheres are used as nonbiological surrogates for *Cryptosporidium parvum* oocysts. Fluorescent-dyed polystyrene microspheres were selected because the decay in microsphere fluorescence matches closely the loss in *C. parvum* viability when both types of particles are exposed to dissolved ozone under identical conditions. Furthermore, microspheres undergo the same hydrodynamic nonidealities and disinfectant exposure as those experienced by *C. parvum* oocysts in full-scale disinfection contactors.

**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.
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.

Microbial Removal and Integrity Monitoring of High-Pressure Membranes Used for Water Treatment

B. J. Mariñas,* J. H. Kim, B. Mi, C. L. Acker, C. K. Colvin, J. R. Elarde
CH2M Hill; American Water Works Association Research Foundation; U.S. Bureau of Reclamation

The main objective of this project is the bench-scale development of a method for assessing the presence and size distribution of membrane pinholes and other imperfections in reverse osmosis and nanofiltration membrane systems. Membrane imperfections of interest are those that permit the passage of a small fraction of viral, bacterial, and protozoal pathogens without resulting in measurable changes in product water conductivity or total dissolved solids concentration. It is anticipated that the final method for characterizing membrane imperfection size distribution will include the use of fluorescent-dyed polystyrene microspheres of various sizes as nonbiological surrogate indicators of viruses, bacteria, and protozoa cysts and oocysts.

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.

Role of Membrane Pore Size Distribution in the Transport of Solutes and Particles Through Nanofiltration and Ultrafiltration Membranes

B. J. Mariñas,* B. Mi
University of Illinois

Nanofiltration (NF) and ultrafiltration (UF) membranes have the potential capability of removing a broad range of water pollutants, including pathogens and organic contaminants. The objectives of this study are to investigate the pore size distribution (PSD) of NF and UF membranes using gas adsorption and atomic force microscopy (AFM) methods and to elucidate the mechanisms responsible for the passage of organic solutes through NF membranes and biological particles (viruses and spores) through UF membranes. Membranes are
analyzed by a nitrogen adsorption-desorption method and AFM to obtain the PSD information. They are also tested in flat-leaf membrane cells to get water, solute, and particle transport data.

**Sequential Disinfection in Food Processing**

B. J. Mariñas,* C. Toupiol  
*MBI International*

The objective of this study is to investigate inactivation kinetics of bacteria with monochloramine at various temperatures (1, 5, 10 and 20 degrees C) when this disinfectant is applied singly as well as after ozone pretreatment. Monochloramine has been chosen among the existing disinfectants due to its ability to prevent microbial biofilm formation. Bacterial disinfection was evaluated using *E. coli*, which is one of the microbial indicators of the poultry industry. The use of an ozone/monochloramine scheme is studied to determine if the sequential use of these disinfectants at low temperatures provides rates of inactivation greater than those obtained with monochloramine only. Experimental results will be used to develop practical guidelines for the inactivation of *E. coli* in food processing applications.

**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 having probes serve 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.

**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 New Framework for Adaptive Sampling and Analysis During Long-Term Monitoring and Remedial Action Management
B. S. Minsker,* B. Bailey, A. Valocchi, R. Johnson, D. Tcheng, M. Welge

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.

Advanced Materials for Water Purification: Membrane Bioreactors for High Strength Waste
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

*Denotes principal investigator.
same time allow for recovery of clean water, energy, and nutrients for reuse.

**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.

**Characterization of Particulate Organic Matter in Swine Manure: Availability of Organic Substrate for Biological Nutrient Removal Processes**

E. Morgenroth*

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

Land application of residuals from animal production is limited by the regional and seasonal nutrient requirements for soil enrichment. In areas with large animal feeding operations (AFOs), the surrounding farmlands are often not sufficient to allow for a sustainable land application of manure. Consequently, alternative methods for reuse and disposal need to be developed. In this project, researchers are developing procedures for physical and chemical characterization of particulate organic matter in swine manure that can serve as a basis for biological denitrification.

This project will develop tools that are a necessary basis for the design and operation of novel processes for swine manure treatment with the aim of nutrient removal or recovery.

**Influence of Shear in Membrane Bioreactors on Floc Morphology and Overall Process Performance**

E. Morgenroth*

*University of Illinois Research Board*

The purpose is to evaluate the performance of a membrane bioreactor with internal membrane separation. It is expected that increased shear forces and complete particle retention will influence activated sludge floc characteristics, substrate degradation, and membrane performance. An improved understanding of the influence of membrane operation on the overall system operation will help to improve design and operation of this novel treatment technology.

This project will help to evaluate both the benefits and the potential problems for the application of membrane bioreactors for wastewater treatment.

**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.

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

**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.

**Molecular Probe Technology for Studying Biofilms in Drinking Water Distribution Systems**

L. Raskin,* B. J. Mariñas, N. Tong, C. Xi  
*U.S. Environmental Protection Agency, CR-826461010*

Biofilms are complex structures of microorganisms immobilized on a surface and embedded in an extracellular organic polymer matrix. Pathogens may grow or may be entrapped in biofilms that develop in drinking water distribution systems. Molecular techniques are being developed to detect and assess the viability of pathogens and indicator organisms in water samples from distribution systems. In addition, molecular techniques are being developed to visualize these microbes in biofilms and to study the microbial populations that constitute the biofilm. Pipes taken from existing distribution systems are being used to build laboratory-scale systems that simulate distribution systems.

**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.

*Denotes principal investigator.
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.

Activated Carbon Fiber Adsorption/Desorption System: Pilot Scale
M. J. Rood,* P. D. Sullivan, D. Ramirez
U.S. Army Construction Engineering Research Laboratory, DACA88-98-D-0005-17

Hazardous air pollutants must be removed from gas streams before they are emitted to the ambient environment, according to the 1990 Clean Air Act Amendments. A new activated carbon fiber-cloth adsorber is under development for integration with a condenser to capture, concentrate, and then recover dilute hazardous air pollutants and volatile organic compounds in gas streams for reuse.

Aerosol Properties Related to Direct Aerosol Radiative Forcing at a Perturbed Mid-Latitude Continental Site
M. J. Rood,* P. Kus
National Oceanic and Atmospheric Administration, COM NA06-G00412

Concerns about ambient aerosol particles affecting global warming need to be resolved in order to develop a better understanding about atmospheric changes over time periods of years to decades. Real-time in situ measurements of the ambient aerosol scattering coefficient have been occurring about 15 km. southwest of Champaign, Ill. This site is ideal because it is representative of the region, and it experiences air masses from a wide range of sources. This research project is interpreting the data from that field measurement site. The interpretation of the experimental results can then be used as inputs to global-scale numerical models that predict the influence of global change by atmospheric aerosol particles.

Concept Development for Optical Sensing for Fugitive Plume Opacity
M. J. Rood,* D. Ke
U.S. Army Construction Engineering Research Laboratory, DACA88-98-D-0005-27

An optical sensing technique is under development to quantify the opacity of plumes caused by fugitive emissions. The technique is relatively simple and inexpensive, and it offers rapid response.

Decision-based Environmentally Conscious Design
M. J. Rood,* D. Thurston,* H. Emamipour, A. Kaldate
National Science Foundation, DMI 02-17491 MR

Certain design projects are vulnerable to decision biases that result in irrational and inconsistent decision making. Environmentally conscious design (ECD) falls into this category. This project develops a rational decision-based design framework for ECD that overcomes current difficulties. An adsorption electrothermal-swing air pollution control technology is used as the testbed for this research.

*Denotes principal investigator.
Evaluation of Uncertainties in Satellite Retrievals of Aerosol Forcing Using In Situ Measurements at the Surface
M. J. Rood,* J. A. Ogren,* D. S. Covert,* P. Sheridan,* P. Kus
National Aeronautics and Space Administration, COM 40RANR900971

The accuracy of climate-change predictions is closely linked to the availability of measured aerosol parameters associated with direct radiative forcing. Derivation of results describing aerosol radiative forcing from satellite observations requires assumptions about the properties of the aerosol particles. Tropospheric aerosol properties measured under in situ conditions and at regional aerosol monitoring stations will be used with the NASA aerosol climatology processing facility to test the sensitivity of candidate satellite data retrieval algorithms to observed variations of aerosol properties. Results from this research will allow better quantification of uncertainties associated with satellite retrievals of aerosol properties.

Evaporative VOC Control for Vehicles
M. J. Rood,* Z. Hashisho
General Motors Corp.

A novel technology is under development to capture automobile vapors that would otherwise be emitted into the atmosphere. Trace quantities of these vapors will be captured and then burned in the automobile’s engine.

Measurement of Ambient Aerosol Properties as They Relate to Climate at a Perturbed Mid-Latitude Continental Site
M. J. Rood,* P. Kus
National Oceanic and Atmospheric Administration, COM NA96-GPO342

Concerns about ambient aerosol particles effecting global warming need to be resolved in order to develop a better understanding about atmospheric changes over time periods of years to decades. Real-time, in-situ measurements of the ambient aerosol scattering coefficient have been occurring about 15 km. southwest of Champaign, Illinois. This site is ideal because it is representative of the region, and it experiences air masses from a wide range of sources. This research will provide data for global-scale numerical models that predict the influence of global change by atmospheric aerosol particles.

Methylene Chloride Capture and Recovery during Turbine Blade Preparation
M. J. Rood,* P. Sullivan
Air Force Research Laboratory, Airbase and Environmental Technology Division, AFRL/MLQE Directorate, FO8637-PO389

Environmentally benign coatings for aircraft turbines require specialized surface preparation for proper adherence of the coatings to the turbines. Specialized coatings can be sensitive to the methods used to prepare the turbine’s surfaces, driving the use of chlorine containing volatile organic compounds. Complete capture and recovery of these compounds must occur for the preparation of the turbine parts to be benign. This research project evaluates the effectiveness of novel adsorbents to capture and recover methylene chloride from gas streams.

Optical Aerosol Properties Over the Asian Pacific Ocean
M. J. Rood,* C. Carrico, P. Kus
National Science Foundation, ATM 00-86550

There are numerous aspects of the global environment that need to be better characterized to better understand how our environment is changing. The effect of aerosol particles on the atmospheric radiative-energy balance at clean and polluted marine sites is one area that needs better characterization. This research will allow shipboard measurements of climatically relevant ambient aerosol properties between Hawaii and the coast of China to characterize “clean conditions” and then along the coast of China to characterize “polluted conditions.” Information gained from such research will provide valuable inputs to existing global-climate models, which in turn can provide better insights into how to develop policies related to global climate change.

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.
Strategy Development for Real-Time Opacity 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.

Mercury Vapor Removal from Simulated Flue Gases with Illinois Coal-derived Activated Carbon
M. Rostam-Abadi,* S. G. Chen,* M. J. Rood,* H. C. Hsi
Electric Power Research Institute; Illinois Clean Coal Institute

There is a concern that mercury emissions into the ambient environment from select types of combustion processes may cause health effects. This project is developing methods to produce new materials to separate and remove mercury from flue gas streams generated during the combustion of coal. Select low-cost materials are processed and then characterized with respect to their chemical and physical properties before they are used to remove mercury from flue gas streams. Bench-scale testing and pilot-scale testing of these new materials are important components of this research.

Bioremediation of Perchloroethene (PCE) in a Column System Using Chitin Fermentation as an Electron Donor Source
R. A. Sanford,* C. J. Werth,* G. Barnuevo
Clayton Services, Inc.; Fulbright Fellowship

This research will demonstrate the ability of a new passive remediation technology, Halorespiration Enhancing Redox Transition Zone (HERTZ), to accelerate the bioremediation of a dense nonaqueous phase liquid (DNAPL) source of PCE in groundwater. This technology relies on the fermentation of solid phase polymeric organic materials (POMs), such as chitin, to create electron donors that increase both the bioavailability and biodegradation of DNAPL blobs. Chitin was selected as the POM for this study based on its ability to create favorable reducing conditions for stimulating anaerobic reductive dechlorination of PCE to ethene.

Fate of Nitrate in Groundwater at the Big Ditch Watershed, Illinois
R. A. Sanford,* S. Shiffer
Illinois Council on Food and Agricultural Research

The fate of agricultural nitrate in groundwater is not well defined. The focus of this research is to quantify the denitrification activity in groundwater throughout the Big Ditch Watershed to determine the loss of nitrate that occurs in the groundwater. Two experimental approaches will be used. First, denitrifying organisms in the sediment cores and groundwater will be enumerated using the MPN technique. Second, the intrinsic rate of denitrification for 11 different well sites within the watershed will be determined. Preliminary data show that denitrification activity in the groundwater is dependent on the location of the sample and the availability of carbon.

Metal Working Fluid (MWF) Recycling by Centrifugation, Filtration, and Pasteurization: Assessing Environmental Benefits and Implications for Health and Safety
R. Sanford,* M. Clark,* K. S. Kim, E. Moosbrugger, K. Moon, J. Holt, K. Rajagopalan
State of Illinois Waste Management and Research Center

Large volumes of MWF are being used and disposed of on an annual basis. This waste stream has the potential to be a significant burden on the environment and a threat to the health of industrial plant workers. Microbial growth in metal working fluids is a common problem and because some of the bacteria produce endotoxins, a health hazard is created for machine operators. The objectives of this work are to determine the effectiveness of centrifugation, filtration, and pasteurization in removing bacteria and reducing waste volume; determine if these processes shorten the life of metal working fluids; and determine the effect of these processes on endotoxin content in MWF.

The Use of Micromodels to Study Dissolution and Bioavailability of DNAPLs for Degradation by Microorganisms in Groundwater
R. A. Sanford,* C. J. Werth, R. Suarez-Soto
National Science Foundation, SURGE Fellowship

The objective of this study is to improve fundamental understanding of key biogeochemical processes affecting dense nonaqueous phase liquid (DNAPL) dissolution in natural porous matrices. To accomplish this objective, researchers will use micromodels to measure DNAPL entrapment and dissolution as a function of geochemistry. Micromodels are a two-dimensional representation of a porous matrix etched into a silicon wafer and

*Denotes principal investigator.
geochemically modified by the addition of different oxide surfaces and aqueous phase ionic substituents. Through the use of microscopy, the behavior of microorganisms in the micromodel relative to the DNAPL can be directly observed.

**Adsorption in Hybrid Membrane-Ultrafiltration Processes**

V. L. Snoeyink,* Q. Li, L. Schideman, B. J. Mariñas

*ONDEO, Paris, France; National Science Foundation*

The objective of this research is to determine the efficiency of the upflow adsorption-ultrafiltration (UA-UF) process for the removal of both natural organic matter and trace organic contaminants and to develop new hybrid membrane-adsorption processes. The research involves evaluation of many different adsorbents and the development of a mathematical model of the process.

By recycling the PAC from the PAC UF part of the process to the floc blanket reactor, researchers can reduce the dosage of carbon required to achieve a certain effluent concentration by 30-50%.

**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.

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

T. J. Strathmann,* S. Feng, G. Nano

*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 complexation 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.

**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.

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

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

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

Finding Principles of Large-Scale Hydrologic Response: Linking Hydroclimatology and River Basin Dynamics
P. Kumar*
National Science Foundation, EAR 97-06121

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

*Denotes principal investigator.
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,

*Denotes principal investigator.
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.

**Computational Methods for Multicomponent Geotechnical Transport**

A. J. Valocchi,* G. Hammond

*U.S. Department of Energy, Computational Science Graduate Fellowship Program; Los Alamos National Laboratory*

In reactive transport, accuracy can be improved by increasing the complexity (number of chemical components and reactions simulated), heterogeneity (nature is never homogeneous), and size (mesh refinement) of the numerical problem. Parallel computing provides this capability because problem size is not restrained by the physical limitations of a single computer. Hundreds of processors with their distributed memories can tackle these larger and more complex problems simultaneously. This project is a collaboration with the Geoanalysis Group at Los Alamos National Laboratory. The goal is to develop new computational tools for massively parallel simulation of multicomponent transport.

By developing new computational tools that take advantage of powerful supercomputer technology, scientists can develop improved understanding of complex groundwater contamination scenarios. Applications include radioactive waste management, uranium mine tailings problems, and enhanced *in situ* bioremediation.

**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.

*Denotes principal investigator.
Investigation of Pore-Scale Processes that Affect Soil Vapor Extraction
A. J. Valocchi,* C. J. Werth;* A. Webb
(Elect. & Comput. Engr.), H. Yoon
U.S. Department of Energy, Environmental Science Management Program

Research proposed here aims to elucidate the pore-scale processes that limit the removal of dense nonaqueous phase liquid (DNAPL) components from the vadose zone. Specific objectives are to determine the effect of unswept zones, retarded vapor phase transport, and interphase mass transfer, all as a function of changing moisture and DNAPL content. Researchers propose to use magnetic resonance imaging (MRI) to observe and quantify the location and size of individual pores containing DNAPL, water, and vapor in flow-through columns filled with model and natural sediments. Imaging results will be used in conjunction with innovative modeling techniques to develop spatially and temporally dependent constitutive relations that describe the transient distribution of phases inside a column experiment.

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.

Positive Solution of Reactive Transport in Multidimensional Heterogeneous Aquifers
A. J. Valocchi,* P. Herrera
Los Alamos National Laboratory; InterAmerican Development Bank Scholarship, Government of Chile

The transport of contaminants through a porous medium is usually represented by a convection-dispersion equation. There are several well-known problems associated with numerical solutions of this equation. Numerical dispersion, oscillatory solutions, poor mass conservation, and nonpositive concentrations are among the main obstacles to the application of these techniques. Specifically, negative values of concentration are unphysical and produce several problems for the implementation of coupled reactive-transport models. We are investigating two classes of methods to address these problems. One approach is to solve the standard form of the convection-dispersion equation, but to use alternate finite difference and finite volume discretization of the cross-dispersion terms. The other approach is based upon a streamline solution technique.

The project addresses a source of numerical error in models that are commonly applied in government and consulting. New improved methods will be developed.

Knowledge Discovery from Remote Sensing Data
A. White,* P. Kumar
National Aeronautical and Space Administration, Graduate Student Fellowship, NASA NGT 5-30433

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

*Denotes principal investigator.
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.

**Geotech/Information Technology**

**Visualization for Constitutive Relations in Geomechanics and Engineering**

Y. Hashash*  
*National Science Foundation; National Center for Supercomputing Applications*

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

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

**Geotechnical Engineering**

**Simulation of Machine-Medium Interaction in a Real-Time Virtual Reality Environment**

J. Ghaboussi,* Y. Hashash  
*National Science Foundation; Caterpillar, Inc.*

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

**Collaborative Research: A Joint Northwestern University–University of Illinois Project for the Development of New Integrated Tools for Predicting, Monitoring, and Controlling Ground Movements due to Excavations**

Y. Hashash,* R. Finno, J. Ghaboussi  
*National Science Foundation*

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

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

**Measured Performance of Excavations and Jacked Tunnels for the Boston Central Artery/Tunnel Project**

Y. Hashash*  
*University of Illinois; Federal Highway Administration*

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

*Denotes principal investigator.*
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,* V. Schifano
*University of Illinois*

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

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

**Geotechnical Properties of Peat**
G. Mesri,* M. A. Ajlouni
*University of Illinois*

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

**Granular Soils Improved by Dynamic Methods**
G. Mesri,* B. Vardhanabhuti
*National Science Foundation, CMS 95-30464*

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

*Denotes principal investigator.
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 Cc, display the highest values of Cc/Cu 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 Cc/Cu 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.

Seismic Performance of Waterfront Structures
G. Mesri,* W. J. Hall,* R. M. Ebeling,* M. Shahein, B. Vardhanabhuti

National Science Foundation, Mid-America Earthquake Center

This project investigates the seismic design of river and port facilities in the mid-American transportation network. The objectives of the research for mid-American waterfront structures are to examine performance during previous earthquakes, identify the typical design conditions, develop a simplified design procedure, and develop a fragility relationship for typical mid-American waterfront structures. Researchers also will prepare a brief nontechnical document for port owners and operators to alert them to the potential consequences of an earthquake in the region.

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 text (DSPT), and the second method uses push cone penetration test (PCPT) measurements. Settlements taking place during static or dynamic external loading and those that follow with time are being evaluated. Variables other than the condition of granular soil and nature of loading include depth of foundation and adjacent structures.

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

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

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

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

**Surcharging of Soft Ground to Reduce Secondary Settlement**
G. Mesri,* M. A. Ajlouni, 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 $C'_{v}/C'_{n}$ are larger and values of $t_{1} / t_{pr}$ 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.

*Denotes principal investigator.
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.

**Long Term Performance of Compacted Soil Liners**
Illinois Office of Solid Waste Research, OSWR-11-002

Although compacted soil liners are widely used for waste-containment facilities, there is little information on their long-term performance. A heavily instrumented soil liner (plan dimensions 8 m by 15 m and 0.9 m thick) has been monitored for approximately 8 years. Evaluation of the resulting data provides a unique opportunity to quantify the long-term advection and diffusion of compacted soil liners. In addition, excavation and dissection of the soil liner will provide insight on the variability of the effective diffusion coefficient, hydraulic productivity, and effect of compaction on soil micro- and macrofabric.

**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 Liquified 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.

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

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

Railroad Engineering

Affiliated Laboratory for Railroad Engineering
C. P. L. Barkan, Director
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 2003 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.)

*Denotes principal investigator.
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.

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.

Tank Car Reliability Design and Analysis
D. A. Pecknold,* H. Sehitoglu,* C. Barkan,* O.-C. Lee, S. Kibey
Federal Railroad Administration, DFTRDV-00-G-60019

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

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

*Denotes principal investigator.
**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.

**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*

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, and fragility curves for damage limit states are developed.

**Seismic Performance of Reinforced Concrete (R/C) Eccentric Beam-Column Connections**  
J. M. LaFave,* M. Shin  
*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 r, which is a function of the structural configuration only. The results obtained thus far indicate that the r factor generally produces inconsistent results. It overestimates the effect of configuration and underestimates those of nonlinear

*Denotes principal investigator.
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.

**Structural Engineering and Structural Dynamics**

**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 interaction 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.

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.

∗Denotes principal investigator.
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.

*Denotes principal investigator.
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 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 $J^{\text{int}}$ 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.

*Denotes principal investigator.
**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).

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**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, $J_c$, 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.

**Fracture Behavior of Full-Scale Fiber Reinforced Concrete Slabs**
D. Lange,* J. Roesler,* S. A. Altoubat
W. R. Grace, Inc.

A testing program was initiated to determine the fracture behavior of concrete slabs reinforced with steel and synthetic, discrete fibers, wire mesh, and plain concrete under monotonic loading. Full-scale slabs were cast and tested at the University of Illinois Advanced Transportation Research and Engineering Laboratory (ATREL). The research is exploring the effects of various fiber types and volume fractions on the full-scale monotonic behavior of concrete slabs-on-grade. Furthermore, the testing of slabs includes comparison of the full-scale test results with comparative test results of simply-supported beams in terms of tensile strength, flexural strength, ultimate strength, and fracture toughness.

**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 features required to solve this problem is a model that accurately captures the cyclic plasticity of the background material.

*Denotes principal investigator.
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.

Development of a Hollow-Cylinder Tensile Tester for Asphalt Mixtures

W. G. Buttlar,* M. P. Wagoner
Test Quip, Inc.

The Strategic Highway Research Program (SHRP) was a $50-million research effort that led to the development of performance-based tests and prediction models for the design of asphaltic paving mixtures. However, there are many obstacles standing in the path of full implementation of the new methodologies, particularly the cost and complexity of the new test devices. A hollow-cylinder tensile test device is being developed to serve as a low-cost, easy-to-operate device for the control of low-temperature cracking of asphalt pavements. Viscoelastic and fracture-related properties of standard laboratory cylinders will be determined at low and intermediate temperatures using the new device.

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.

The Greater Peoria Regional Airport Demonstration Project

W. G. Buttlar,* S. Carpenter, J. Bauer, D. Sherman, J. Kim
Illinois Division of Aeronautics; Federal Aviation Administration, Center of Excellence for Airport Technology

The Illinois Department of Transportation/Division of Aeronautics, FAA Center of Excellence for Airport Pavement Research, Crawford, Murphy, and Tilly, Inc. (CM&T), and representatives from the Greater Peoria Regional Airport have developed a partnership to design, build, and monitor innovative pavement design and rehabilitation strategies for Taxiway E at PIA. The project will showcase innovative materials, such as high-strength geotextile interlayers, polymer-modified asphalt binders, and gyratory compactor-based mixture designs for the purpose of extending the service life of bituminous pavements used by heavy aircraft.

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.

Evaluation of Coal Tar Emulsion Seals

S. H. Carpenter,* B. Xie
Federal Aviation Administration, Center of Excellence for Airport Pavement Research

The purpose of this project is to conduct an evaluation of coal tar emulsion seals and recommend a performance based specification to be used to modify the current Engineering Brief.

*Denotes principal investigator.
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.

Center for Excellence for Airport Technology
B. J. Dempsey*
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Federal Aviation Administration, DOT 95-C-001

The Federal Aviation Administration established an Air Transportation Center of Excellence (COE) for Airport Pavement Research in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign on April 12, 1995. Northwestern University and North Carolina A&T are cooperative partners in the research program. In March 2001, the COE was given a new title of Center of Excellence for Airport Technology.

The universities have developed a strong working partnership with the FAA in providing new technologies for airport facilities. Eight COE projects are presently in progress and include Analysis of NAPTF Pavement Response Data, Materials Testing and Evaluating for the NAPTF, Fatigue Resistance of Airport Concrete Pavements, Reflective Crack Mitigation for Bituminous Overlays on Airfield Pavements, Fatigue in Airport AC Pavements, Moisture Curling of Concrete Slabs in Airfield Applications, Wildlife Hazard Abatement Systems, and Graduate COE Minority Summer Research Program. Most of the COE project summaries can be found within this report.

New technology from the studies is being coupled with existing Best Demonstrated Available Technology (BDAT) to support the development of pavement designs adequate for accommodating the new generation of larger aircraft, such as the Boeing 777-300 and Airbus 380. The new COE technology and BDAT are being provided to the FAA for supporting, enhancing, and refining its LEDFAA pavement design procedure. As activities progress, the center is providing information to (and cooperating with) FAA staff to support the development of alternative mechanistic-based design systems for the economical and reliable design of new pavements and overlay design for existing pavements. These pavements will be constructed with a wide variety of paving materials (traditional and new) and layer configurations or arrangements will include new design features (such as improved load transfer devices in concrete pavements). The pavements will accommodate a broad range of aircraft loadings.

Twenty five Ph.D. theses and approximately 190 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 COE website at http://cee.uiuc.edu/research/coeairporttech.

Performance Evaluation of Longitudinal Pipe Underdrains
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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.
Summer College of Engineering Internship Program for Minority Graduate Students
B. J. Dempsey*

Federal Aviation Administration, Center of Excellence for Airport Technology, DOT 95-C-001

During the Summer of 2003 the Center of Excellence (COE) for Airport Technology conducted a Graduate Research and Study Internship Program for minority students from Historically Black Colleges and Universities. A similar program was conducted during the summers of 2001 and 2002. The objective of this program is to increase the number of underrepresented minorities obtaining advanced degrees in civil engineering with an emphasis on expertise directly relevant to improving airport technology. Six students were involved in the program conducted during the summer of 2003. Three graduate students from the 2001 and 2002 programs are presently enrolled in civil engineering at the University of Illinois. A summer 2004 program is planned.

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.

Development of a Tent Staking Test Program and Interpretation of Results
J. Long,* E. Tutumluer,* G. Menezes

Industrial Fabrics Association, International

This project aims at testing and interpreting results of pullout tests on tent anchorage. A pullout test device is designed to determine pullout capacities of single and multiple anchors, long cylindrical steel rods, used in tent staking. A testing program is undertaken to quantify the effects of several anchor properties, anchor embedment and inclination, loading characteristics, and different subsurface soil types and profiles. A dynamic cone penetrometer is used to characterize the soil strength. Results from the testing program will provide the industry with more consistent methods for determining anchor capacity and an improved understanding of important variables.

This applied research provides improvement in stake design and tent staking practices by advancing the understanding of stake anchor capacities and pull-out performances.

*Denotes principal investigator.
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 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.

*Denotes principal investigator.
Characterization and Design of Aggregate Interlock Joints in Concrete Pavements Using Surface Roughness Measurements
J. Roesler,* P. Chupanit
University of Illinois, Paul Kent Fellowship

The behavior of aggregate interlock joint systems in PCC pavements is being studied. The monotonic and cyclic shear behavior of the joint is being quantified through the use of the joint’s surface roughness characteristic. The surface roughness of the concrete joint is being characterized by a 2-D laser profilometer, which represents the 3-D contours of the joint surface. Scale invariant parameters are being developed to relate surface roughness to the joint performance and concrete mix design variables such as the compressive strength, aggregate type, hardness, and gradation.

This research will help to characterize and improve the joint design in concrete pavements.

Fatigue Resistance of Airport Concrete Pavements
J. R. Roesler,* P. Littleton
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.

Longitudinal Cracking Investigation on Continuously Reinforced Concrete Pavements
J. Roesler,* G. Ulreich, J. Popovics, J. Ranchero
Illinois Department of Transportation

Over the past five years, the Illinois Department of Transportation has been experiencing significant longitudinal cracking on several continuously reinforced concrete pavements (CRCP). The cause of the cracking has not been determined, and it is becoming severe enough that rehabilitation of the affected sections needs to be programmed. Field investigations are under way to determine the cause and extent of the longitudinal cracking. Once the cause of the problem is identified, proposed solutions will be developed to rehabilitate these affected sections and to eliminate this distress from occurring on newly constructed CRCP sections.

The goal of this research is to determine the mechanism of the observed cracking so that it may be mitigated in future CRCP designs completed by IDOT.

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 have been constructed at the NAPTF (FAA William J. Hughes Technical Center, Atlantic City, N.J.). Extensive instrumentation has been 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 will be developed. Full-scale aircraft gear (duals, dual-tandem, and dual-tridems) and heavy-weight-deflectometer load-induced pavement responses (stresses, strains, and deflections) will be analyzed using several pavement structural analysis programs.
The study will serve 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.

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.

Upgrade Subgrade Stability Manual
M. R. Thompson,* E. Tutumluer*
Illinois Department of Transportation

The current Illinois Department of Transportation Subgrade Stability Manual was implemented in 1982. Some new and improved technologies in the areas of subgrade strength evaluation, soil and materials testing, pavement structural evaluation and design, and subgrade remedial procedures (particularly in the use of geotextiles and geocomposites) have been developed since that time. The sponsor has requested that the manual be reviewed and upgraded to incorporate the Best Demonstrated Available Technology (BDAT).

This upgrade will provide the Best Demonstrated Available Technology (BDAT).

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.

Permanent Deformation Behavior of Airport Pavement Base and Subbase Courses
E. Tutumluer,* I. T. Kim
University of Illinois; 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/subbase aggregates, identification of the most damaging field stress states affecting aggregate performance, and development of material characterization and laboratory performance-based models. Finally, using laboratory performance-based evaluation, researchers will develop specifications for field construction and compaction of unbound granular layers.

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.

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

**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.

**Journal Articles**

**Construction Management**


**Construction Materials**


**Earthquake Engineering**


**Engineering Mechanics and Materials**


*Denotes principal investigator.
Environmental Engineering and Science in Civil Engineering


Environmental Hydrology and Hydraulic Engineering


**Geotechnical Engineering**


**Structural Engineering and Design**


**Geotech/Information Technology**

Structural Engineering and Structural Dynamics


Structural Engineering and Structural Mechanics


Structural Mechanics and Dynamics


Transportation Facilities and Systems


Book Chapters

Environmental Engineering and Science in Civil Engineering


Papers Presented at Conferences and Symposia

Construction Management


Earthquake Engineering


Engineering Mechanics and Materials


Raskin, L. Microbial ecology of waste and drinking water treatment systems. Presentation at Wageningen Agricultural University (Wageningen, The Netherlands, Jul. 2003).


Environmental Hydrology and Hydraulic Engineering


**Geotech/Information Technology**


**Structural Engineering and Design**


**Structural Engineering and Structural Dynamics**


Zuo, D. and Jones, N. P. Interpretation of observed damper performance in mitigating wind and rain-wind induced stay cable vibrations. 11th International Conference on Wind Engineering (Lubbock, TX, Jun. 2003).

Structural Engineering and Structural Mechanics


Structural Mechanics and Dynamics


Transportation Facilities and Systems


Environmental Engineering and Science in Civil Engineering


Ren, X. Which groundwater remediation objective is better, a realistic one or a simple one? M.S. thesis, B. S. Minsker, advisor (2003).

Theses

Earthquake Engineering


**Environmental Hydrology and Hydraulic Engineering**


**Geotechnical Engineering**


**Transportation Facilities and Systems**


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**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

**Alfred H. S. Ang, Emeritus**

Member, National Academy of Engineering
Fellow, American Society of Civil Engineers
Associate Fellow, American Institute of Aeronautics and Astronautics
Past President, International Association for Structural Safety and Reliability

**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 Bond**

NOAA Climate and Global Change Postdoctoral Fellowship 2000-2002
Fannie and John Hertz Foundation Award for outstanding doctoral dissertation 2000
LeRoy T. Boyer, Emeritus
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1989

Scott A. Burns
Presidential Young Investigator Award, National Science Foundation, 1989
Everitt Award for Teaching Excellence, College of Engineering, 1990
Beckman Associate, Center for Advanced Study, University of Illinois, 1992
Advisors List for Advising Excellence, College of Engineering, 1996
State-of-the-Art in Civil Engineering Award, American Society of Civil Engineers, 1998

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

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 Sao Paulo, 1998
Distinguished Visiting Professor, Imperial College of Science 7 Technology, 1999
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

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 études de cycles supérieurs, de perfectionnement et de reinsertion a la recherche, 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

Marcelo H. García
Hokkaido River Institute Lectureship, Japan, 1990
MUCIA International Development Travel Grant, 1992
Invited Professor, Institute di Idrulia, 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

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William J. Hall, Emeritus
Member, National Academy of Engineering
Honorary Member, American Society of Civil Engineers
Fellow, American Association for the Advancement of Science
Howard Award, American Society of Civil Engineers, 1984
Nathan M. Newmark Medal, American Society of Civil Engineers, 1984
Distinguished Engineering Service Award, University of Kansas School of Engineering, 1986
Senior University Scholar, University of Illinois, 1986
C. Martin Duke Lifetime Earthquake Engineering Award, American Society of Civil Engineers, 1990
John Parmer Award, Structural Engineers Association of Illinois, 1990
Norman Medal, American Society of Civil Engineers, 1992
Daniel C. Drucker Tau Beta Pi Eminent Faculty Award, University of Illinois College of Engineering, 1993
Houser Medal, Earthquake Engineering Research Institute, 1998
National Honor Member, Chi Epsilon, 1998

Yousef Hashash
James Croes Medal, American Society of Civil Engineers, 1994
Thomas Middlebrooks Award, American Society of Civil Engineers, 1997
Faculty Fellow, National Center for Supercomputing Applications, University of Illinois, 1999
Arthur Cassagrande Professional Development Award, Geo-Institute, American Society of Civil Engineers, 2000
Representative at 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, 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

Moreland Herrin, Emeritus
Past President, Association of Asphalt Paving Technologists
Man-of-the-Year Award, Illinois Asphalt Paving Association, 1985

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

**Clyde E. Kesler, Emeritus**
Fellow, American Society of Civil Engineers
Member, National Academy of Engineering
Honorary Member and Past President, American Concrete Institute
Honorary Member, Wire Reinforcement Institute

**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 Khachatryan Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1998
Faculty-Student Fellowship Award (with student, Anne Werner), Portland Cement Association, 1998
Faculty-Student Fellowship Award (with student, Zach Grasley), Portland Cement Association, 2002
Wason Medal for 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**
Incomplete List of Teachers Ranked as Excellent by their Students, University of Illinois 1999, 2000, 2001, 2002
Advisory Award, University of Illinois College of Engineering, 2002
W. E. O’Neil Construction Faculty Research Fellowship, 2002
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
Arthur and Virginia Nauman Faculty Scholar, University of Illinois Department of Civil and Environmental Engineering, 1999-2000
Association of Environmental Engineering and Science Professors (AEESP) Parsons Engineering Science Doctoral Thesis Award (doctoral student: Qilin Li co-advised with V. L. Snoeyink), 2003
W. H. C. Maxwell, Emeritus
Fellow, American Society of Civil Engineers
Fellow, International Water Resources Association
Editorial Award, International Water Resources Association, 1994

Gholamreza Mesri
Fellowship, Royal Norwegian Council for Scientific and Industrial Research, 1970
Norman Medal, American Society of Civil Engineers, 1988
Visiting 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

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 Research Prize, American Society of Civil Engineers, 2003

Eberhard Morgenroth
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

William H. Munse, Emeritus
Honorary Member, American Society of Civil Engineers
Honor Member, Chi Epsilon, University of Illinois
Special Citation Award (with E. H. Gaylord), American Institute for Steel Construction, 1988

Joseph P. Murtha, Emeritus
Andersen Consulting Award for Excellence in Advising, University of Illinois College of Engineering, 1989
Commander’s Award for Distinguished Public Service, U.S. Army Construction Engineering Research Laboratory, 1989

Glaucio H. Paulino
Collins Scholar, University of Illinois, 2000
2003 Xerox Award for Faculty Research

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

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
Narbay 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 Roessler
ACPA Marlin J. Knutson Award for Technical Achievement (shared with University of California-Berkeley, WSCACPA, Caltrans), 2001

Incomplete List of Teachers Ranked as Excellent, University of Illinois, 2003

Mark J. Rood


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

Montgomery-Watson-Harza Association of Environmental Engineering Professors Master Thesis Award for advisee Katherine Dombrowski, 2002

Associate Editor, Journal of Air and Waste Management Association, 1994-

Associate Editor, Journal of Environmental Engineering, 1998-2002

Editor-in Chief, Journal of Environmental Engineering, 2002-

Richard A. Glenn Best Paper Award, 214th ACS National Meeting Fuel Chemistry Division, 1997

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

Vernon L. Snoeyink
Member, National Academy of Engineering

Past President, Association of Environmental Engineering Professors

Nalco-AEEP Award for 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

American Water Works Association, adviser of student (I. Najm) receiving the Best Ph.D. Thesis Award, 1992

American Water Works Association, adviser of student (F. Cannon) receiving second prize in the Ph.D. Thesis Competition, 1994
Distinguished Monsanto Lecturer, Purdue University, 1994
Samuel Arnold Greeley Award, American Society of Civil Engineers, 1995
Tau Beta Pi Daniel C. Drucker Eminent Faculty Award, University of Illinois College of Engineering, 1996
Chi Epsilon Honor Member, 1998
Ambassador Award, American Water Works Association, 1999
Best Paper Award, Research Division, American Water Works Association (with F. Courson), 1999
Founders Award, Association of Environmental Engineering and Science Professors, 1999
Life Member, American Water Works Association, 1999
Excellence in Advising Award, University of Illinois College of Engineering, 2000
Excellence in Advising Award, University of Illinois College of Engineering 2001, 2002
Best Paper Award, Water Science and Research Division, American Water Works Assoc. (with D. Knappe, P. Roche, M. J. Prados, and M. M. Bourbigot), 2001
Simon W. Freese Environmental Engineering Award and Lecture, ASCE, 2002
Multiyear Faculty Achievement Award, University of Illinois, 2002
Association of Environmental Engineering and Science Professors (AEESP) Parsons Engineering Science Doctoral Thesis Award (doctoral student: Qilin Li co-advised with B. J. Mariñas), 2003
Best Paper Award, Water Science and Research Division, American Water Works Assoc. (with J. Brown and M. J. Kirisits) 2003
Honorary Knight of St. Patrick, 2003

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, Vicksburg, Miss. 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, 1991
Arthur Casagrande Professional Development Award, American Society of Civil Engineers, 1992
Xerox Award for Faculty Research, University of Illinois College of Engineering, 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

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 CO1, 2001
Sanford E. Thompson Award for Outstanding Paper, ASTM CO9, 2003

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
Certificate of Recognition, Engineering Education Scholars Program, 1997
General Electric Scholar, University of Illinois, 1997
General Electric Fellow, University of Illinois Academy for Excellence in Engineering Education, 1999
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

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

Y. K. Wen
Fellowship, Japan Society for the Promotion of Science, 1986, 1996
Moisseeff Award, 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

Kam W. Wong, Emeritus
Talbert Abrams Award, American Society for Photogrammetry and Remote Sensing, 1971
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1971
Outstanding Teacher Award, University of Illinois Student Chapter, American Society of Civil Engineers, 1985
Meritorious Service Award, American Society of Photogrammetry and Remote Sensing, 1994
Talbert Abrams Award, Honorable Mention, American Society for Photogrammetry and Remote Sensing, 1996

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