2001 Summary of Engineering Research

This pdf file is part of the larger *2001 Summary of Engineering Research,* available on the Web at http://www.engr.uiuc.edu/Publications/engineering_research/ and on CD-ROM. The *Summary of Engineering Research* represents the extensive engineering research program at the University of Illinois at Urbana-Champaign. The efforts of faculty, professional staff, and graduate students working on more than 1,600 projects during the calendar year 2000 are summarized in the larger report.

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.

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 pages to each department or laboratory.

How to obtain publications: Information about technical reports is available from the Engineering Documents Center, 157 Grainger Engineering Library Information Center, 1301 West Springfield Avenue, Urbana, IL 61801, USA; http://www.library.uiuc.edu/grainger/.

Ph.D. theses can be found at the University of Illinois Library, http://www.library.uiuc.edu/. Ph.D. theses may be purchased from University Microfilms, 300 Zeeb Road, Ann Arbor, MI 48106, USA; http://www.umi.com.

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COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Civil and Environmental Engineering

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Civil and environmental engineers carry responsibility for the planning, design, and construction of facilities that provide for the physical well being of people, for the quality of the environment, and for protection from earthquakes, floods, strong winds, and other natural and created hazards. Civil engineering is a broad discipline encompassing activity in many areas:

- transportation facilities and systems (highways, airports, and railroads)
- structures (buildings, bridges, industrial facilities, and space structures with subdisciplines such as dynamics, earthquake engineering, and reliability analysis)
- hydraulics and hydrology (dams, open channel flow, flood control, power projects, groundwater resources, and water resources management)
- construction processes and their management (planning, analysis, automation, and economics)
- geotechnical engineering (foundations, slope stability, tunnels, embankments, waste disposal, and remediation of contaminated ground)
- photogrammetry and geodesy
- environmental engineering (water, sewage, air, waste management, and bioprocessing)
- computer-aided engineering systems
- nondestructive diagnostics

Surrounding these disciplines are a host of other technical areas including numerical analysis techniques; use of modern computational systems in design, analysis, and graphics; engineering materials; and knowledge of the loadings and environments to which a facility may be subjected.

The needs of the State of Illinois and the nation, as well as other countries, continually require development and application of new approaches, concepts, and products to the design and construction of facilities. Research programs in the department add to fundamental knowledge and are directed toward ensuring the early application of new technology. Graduate and undergraduate students participate with faculty in conducting research. A strong integration of research with the educational process has been a decisive factor in the distinguished reputation enjoyed by this department.

The Mid-America Earthquake Center, funded by the National Science Foundation, studies ways to reduce the impact of earthquakes on infrastructures. The Advanced Transportation Research and Engineering Laboratory (ATREL), funded largely by the Illinois Department of Transportation, is located 15 miles north of the main campus. It contains 56,000 square feet of modern classroom, office, and laboratory space on 56 acres and is home to the Center of Excellence for Airport Pavement Research, which is funded by the Federal Aviation Administration. Faculty and graduate students conduct basic research in the mechanics of airport pavement design for the next generation of large commercial aircraft.

Construction Management

A Decision Support System for Estimating the Impact of Weather on Construction Activities

K. El-Rayes,* O. Moselhi*
EPC Consultants, Canada

This project provides the development of a knowledge-based system for quantifying the impact of weather on construction productivity, schedules, and delays. The scope of research includes the development and validation of a knowledge base and a database. The system has been utilized recently in the analysis and resolution of a multimillion-dollar construction claim resulting from adverse weather conditions.

An AI Methodology to Quantify the Impact of Change Orders on Construction Productivity

K. El-Rayes,* O. Moselhi,* I. Assem
Natural Sciences and Engineering Research Council of Canada; Construction Research Institute of Canada

The objective of this project is to develop an AI methodology for estimating the impact of change orders on construction productivity and costs. The research includes data acquisition and analysis as well as development of statistical and Neural Network models to quantify the effects of change orders on productivity losses and construction cost.

* Denotes principal investigator.

An IT-based System for Optimizing Procurement Decisions in Construction

K. El-Rayes,* A. Deshpande
University of Illinois

The objective of this project is to develop an IT-based system for optimizing procurement decisions in construction. The system exploits the power of information technology to optimize procurement decisions in construction. It is being designed to include two main IT-based modules for optimizing supplier selection and material delivery.

Computerized Scheduling and Control of Residential Housing Construction

K. El-Rayes,* O. Moselhi,* R. Ramanathan
Natural Science and Engineering Research Council of Canada

The scope of this project is focused on the development of a computer model for planning and control of housing construction. The model is based on an object-oriented modeling approach and incorporates newly developed algorithms for construction scheduling and control. The model is implemented as a software system using C++ programming language.

CADD Integration and Applications during Construction

L. Y. Liu,* A. Stumpf* (CERL)
U.S. Army Construction Engineering Research

This project explores the application of CADD to construction simulation and animation and the integration with construction specs, schedule, costs, as-built, QA/QC guidelines, and biddability, constructibility, and operability databases.

Construction Object-oriented Process Simulation

L. Y. Liu*
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.

Construction Risk Management

L. Y. Liu,* G. Rao
University of Illinois

This research develops a synthesis approach to manage construction risks for environmental remediation projects. A method is developed to extract information from historical data to assist project managers in identifying risk components that deserve additional attention and analysis. AHP (analytic hierarchy process) techniques are used to aggregate factors and preferences for decision making.

Construction Site Digital Data Collection Devices

L. Y. Liu*
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.

Construction Time–Cost Trade-Off Decision Support

L. Y. Liu,* S. A. Burns* (Gen. Engr.)
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

* Denotes principal investigator.

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.

Environmental Remediation Project Documentation Using Multimedia Technology

L. Y. Liu,* A. Stumpf* (CERL)
U.S. Army Construction Engineering Research Laboratory

This research project applies multimedia technology to store text, photos, sound, and video information with project schedule activities for environmental remediation projects. Construction project progress can be tracked and evaluated visually with computer-integrated site condition photos and videos. The site condition information can be transmitted back to experts at the headquarters through computer networks. This system allows more complete documentation of construction progress, problems, and innovative ideas. The system also may prove useful for presenting facts in legal claims and disputes.

Hierarchical Project Information Documentation

L. Y. Liu,* A. Stumpf* (CERL)
U.S. Army Construction Engineering Research Laboratory

The vast amounts of information generated during construction are a challenge to construction managers. Well-documented project information during construction not only eliminates problems in claims and disputes, it also provides a rich source for lessons learned, improvement, and innovation. This research creates a hierarchical information system that allows users to store project information or knowledge according to CSI Master format or a user-defined information hierarchy. In addition to hierarchical search, keywords can be used to retrieve information. All information, including text, pictures, images, drawings, sound, and video, will be store digitally on CD-ROMs with full indexing and cross-referencing capability. Previous cases, problem-solving ideas, and failures can be quickly retrieved, compared, and cross-referenced.

Impact of Design and Construction Integration on Facility Delivery Process and Performance

L. Y. Liu,* J. Pocock
University of Illinois

This research investigates the impact of design and construction integration on the performance of a constructed facility and the process of delivering a facility. A quantitative model to measure design and construction integration is set up to measure the degree of integration and its impact on construction. In addition, comparisons of traditional construction, partnering, and design-built are made to evaluate the impact of contract relationships on construction time, cost, safety, and quality.

Schedule Evaluation and Reasoning Using 3-D Modeling and Animation

L. Y. Liu*
University of Illinois

A three-dimensional animated display of construction sequences facilitates nonambiguous evaluation of schedules. Potential schedule conflicts and interferences can be easily identified with the visual display. Alternative construction sequences can be simulated and compared as if a facility were being constructed in real life.
The objective of this research is to use 3-D modeling and animation environments for schedule evaluation and reasoning. Information will be extracted directly from components of a design in the 3-D environment and chained with a knowledge base for schedule evaluation and reasoning.

Sensor-based Construction Quality Control and Monitoring

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

A Design Review Checking System with Corporate Lessons Learned

L. Soibelman,* L. Liu, J. G. Kirby, W. East,
C. Caldas, K. Y. Lin
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

* Denotes principal investigator.

for the design review process. DrChecks provides a framework for a standardized review process. With DrChecks and CLL, direct personal experience can be collected into a database while the design review process is ongoing. Lessons learned, success stories and good work practices, easily identified by experienced staff members, can be shared throughout the organization. DrChecks and CLL both take advantage of the Internet and facilitate the management of the design review process and collection and reuse of corporate lessons learned asynchronously and remotely.

Automated Classification and Integration of Text-based Information in Construction Inter-Organizational Systems

L. Soibelman,* C. Caldas
University of Illinois Computer Science & Engineering Fellowship

Current initiatives on interoperability and information integration for the architecture, engineering, construction, and facilities management (AEC/FM) industry focus on structured data types. Considering that a large percentage of construction project information is stored and exchanged in unstructured data type files, there is a need to define methods to integrate unstructured data in AEC/FM information systems. This research objective is to develop an approach to support the integration of text-based data to improve information organization and management in construction inter-organizational systems. In particular, this research explores the use of machine learning algorithms for automated classification and integration of project related text documents based on defined project model objects.

Enhancing Maintainability in Designs through Quantitative Knowledge

L. Soibelman,* H. Ng

This research focuses on development and design of facilities with the goal of increasing the life span by enhancing its maintainability. Maintainability pertains to design and installation, by measuring the ease and economy of maintenance. This research will study maintenance databases to generate quantitative knowledge to help designers make more informed decisions on maintenance issues. A case study will be conducted using University of Illinois maintenance databases to understand the various parameters that increase or decrease maintenance costs. It is important to learn how building systems interact with each other and their existing conditions and to understand the influence of maintenance on deterioration. Generating knowledge in these areas will help designers improve maintainability of facilities, decrease the cost of maintenance, and increase the ease of maintenance. By understanding what knowledge can be generated with existing databases, future databases can be designed to capture the data most beneficial for the user.

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 becomes 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.

Knowledge Generation from Large Construction Databases

L. Soibelman,* H. J. Kim
National Center for Supercomputing Applications

Computerized construction data is proliferating as the construction industry adapts to using new computer hardware and software. The volume of data is overwhelming for traditional methods of data analysis, such as spreadsheets and ad-hoc queries. A promising approach to processing and analyzing the increased amount of data is Knowledge Discovery in Databases (KDD), a process that applies data-mining tools to identify valid, useful, and previously unknown patterns from databases. KDD would be particularly useful to construction managers for analyzing a large volume of construction project data. A prototype of the KDD system is being developed and validated with a

* Denotes principal investigator.

construction management database, Resident Management System, provided by the U.S. Army Corps of Engineers.

Construction Materials

Design of Masonry Mortars for Controlled Curing and Performance

D. A. Lange,* A. Werner
Portland Cement Assn.

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.

Early-Age Cracking of Bonded Overlays for Pavements

D. A. Lange,* B. Bicer, N. Rau
Illinois Department of Transportation

Volumetric instability of concrete at early age is a problem that may lead to cracking. Mechanisms that cause volume changes of young concrete include thermal contraction/expansion, drying shrinkage, autogenous shrinkage, and expansive hydration products. While the isolated mechanisms have been well researched, they continue to be perplexing problems when they occur under structurally restrained conditions. This experimental project explores early-age cracking of bonded overlays to more fully understand difficulties encountered at the University of Illinois Willard Airport in Champaign, Ill., during construction in the summer of 1998.

Fracture Mechanics Testing of Bond in Masonry

D. A. Lange,* C. Park
National Science Foundation; Portland Cement Assn.

The standard test of masonry bond strength is the ASTM C1072 Bond Wrench Test, which measures maximum stress but does not provide insight into deformation and fracture energy. This study will apply fracture mechanics models to masonry to more fully describe the propagation of cracks during failure. The two parameter fracture models, developed initially for concrete, will be adapted for masonry. The benefit of this "energy approach" is that researchers will characterize resistance to deformation and crack propagation in addition to measuring maximum stress. Application of fracture mechanics will provide a rational and more complete foundation for assessing quality of masonry bond.

Fracture Surface Roughness and Fracture Toughness of Cement-based Materials

D. A. Lange,* A. Abell
National Science Foundation, Center for Advanced Cement-Based Materials

Fracture surfaces of concrete and mortar specimens are characterized using confocal microscopy and a video density technique to create 3-D computer-based topographic maps. The texture of the fracture surfaces is quantified using image analysis techniques to compute a roughness parameter and fractal dimension. Previous work has demonstrated a link between fracture surface roughness and fracture toughness. The current effort extends toward computational modeling to explain the toughening increment due to tortuousity of the crack path.

High-Performance Concrete and Thin Bonded Overlays for Airport Pavement Systems

D. A. Lange,* S. Altoubat, H. C. Shin
Federal Aviation Administration; National Science Foundation

Bonded overlays are a relatively fast and inexpensive technique for rehabilitation of concrete pavement surfaces. One difficult aspect of constructing bonded overlays is control of cracking and debonding. The objective of this project is to provide an understanding of early-age stresses that result from thermal and shrinkage mechanisms in bonded overlay systems. Experiments to characterize early-age volumetric instability are under way, and a numerical structural model of a bonded overlay will compute stresses and strains that develop within days of placement. The model will provide guidance on the effect of overlay thickness and joint spacing required to prevent slab cracking.

* Denotes principal investigator.

High-Performance Concrete for Bridge Decks

D. A. Lange,* J. Roesler,* S. Altoubat, C. Park,
M. D. Ambrosia
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.

Microstructural Engineering of Concrete

D. A. Lange*
National Science Foundation, CMS-9623467

The microstructural engineering approach involves control of concrete microstructure through processing to yield specific material properties. The objective of this study is to enhance understanding of the relationship between concrete properties and the physical reality of microstructure and crack geometry. The experimental work addresses three main areas: pore structure, interfaces and bond, and fracture behavior. In addition, performance measures related to microstructure (such as durability) are of interest.

Fatigue of Thermite Welded Rail

F. V. Lawrence, Jr.,* J. Withee
Association of American Railroads

As the railroad industry uses ever higher axle loads, the field-welded thermite welds that connect the rails have proven to be the source of an increasing number of derailments. This study is researching the cause of the poor fracture toughness and fatigue properties of the thermite weldment and searching for ways to improve or replace the thermite welding processes in welding rail in the field.

Cement Paste Rheology

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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.

Concrete Rheometry

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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.

Concrete for Restoration

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It is important to match color and texture when restoring historic concrete structures. This study explores the relationships between the appearance of a concrete structure with parameters such as finishing technique, cement color, concrete composition, and concrete age. The objective is to develop quantitative relationships that can be used in matching the appearance of existing concrete.

* Denotes principal investigator.

Electrokinetic Processes for Reducing Concrete Permeability

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Electrokinetic processes are being explored in hardened concrete as a way of transferring agents into the pores inside hardened concrete and causing the agents to react in a way that leads to blocking of the pores. These electrokinetic processes use an applied electric field to achieve transfer. Reactive agents include sodium silicate solution and silica sol. The goal is use reactive electrokinetic processes to reduce permeability in concrete structures.

Modeling the Rheology of Cement and Concrete

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The flow behavior of both fresh cement paste and concrete is being studied in order to understand the relationships between flow behavior and initial microstructure due to particle packing, flocculation, and early hydration reactions. A major focus throughout this research is to develop a computer simulation model to explore direct mathematical links between microstructure and flow properties. Rheological behavior of concrete is being modeled in terms of the proportions of individual constituents, the gradation of the aggregate, and the rheological behavior of the paste. Relationships are being explored between rheology and more general aspects of concrete workability.

Performance of Cement-Slag Blends in Concrete

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A new product, a blend of portland cement and ground blast furnace slag, is being evaluated for use in concrete. The project encompasses a wide range of performance tests, including workability, strength, and durability. Tests include the cement-slag blend alone and in combination with various chemical and mineral admixtures.

Environmental Engineering and Science in Civil Engineering

Colloidal and Macromolecular Transport in Thin Layers Near Microporous Membrane Surfaces

M. M. Clark,* K. Howe; P. Aimar, P. Bacchin, C. Guigui (CNRS)
University of Illinois; Centre National de la Recherché Scientifique, France

The objective of this University of Illinois–CNRS collaboration is to better understand the dynamics of thin, concentrated, particulate, and macromolecular boundary layers near membrane surfaces and the interaction of colloidal particles and organic molecules with synthetic membranes. This work includes modeling of mechanics of concentrated particle or colloidal suspensions near porous membrane surfaces and incorporation of these models in an overall model of mass transport in membrane separation processes.

Development of Online Integrity Monitoring Systems for Membrane Filtration Systems

M. M. Clark,* R. Sanford, Y. K. Choi, S. M. Lee
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 credit for disinfection of water. However, regulators would like some assurance that membranes are an absolute barrier to pathogens. This project will develop a new method to determine membrane integrity based on positive identification of bacteria intruding into the permeate.

Feasibility Study for the Concentration of TNT and RDX from Pink Water Using Equilibrium Dialysis with Nonionic and Cationic Surfactant Micelles

M. M. Clark,* Y. K. Choi, R. Haye
U.S. Army Construction Engineering Research Laboratory, Champaign, Illinois

TNT and RDX wastes pose a significant disposal problem for the U.S. Army. Researchers have developed a new technique which encapsulates these wastes molecules within a surfactant micelle. The micelle is subsequently filtered from the water using ultrafiltration, resulting in up to 90% removal of wastes.

* Denotes principal investigator.

Role of Coagulation in Microfiltration and Ultrafiltration Fouling and Flux Optimization

M. M. Clark,* K. Howe,* Y. Wang
American Water Works Association Research Foundation

This research seeks to understand the fundamental mechanisms involved in fouling of microfiltration and ultrafiltration membranes by natural organic matter, and the role of metal ion coagulants in minimizing membrane fouling by natural waters. Batch coagulation experiments will be used to evaluate how coagulation affects the organic matter composition, cake layer formation, and membrane fouling. Techniques such as XAD resin fractionation, size exclusion chromatography, and pyrolysis GC-MS will be used to characterize organic matter, while field emission environmental SEM will be used to characterize cake layers formed on membrane surfaces during filtration.

Visualization of Colloidal Phenomena near Membrane Surfaces

M. M. Clark,* Y. Lee,* K. Kim
U.S. Bureau of Reclamation

Particle deposition on membrane surfaces is an important phenomenon during membrane fouling by colloids. This project develops real-time methods for direct visualization of particle motions and cake layer formation during filtration. One type of visualization uses fluorescence microcopy to monitor particle concentrations and velocities in the concentration boundary layer. A second technique uses confocal microscopy to develop three-dimensional images of cake layers formed along membrane surfaces. These measurements will be supplemented with real-time flux decline data, thus allowing correlation of operational parameters with particle deposition, cake structure, and fouling.

Microbial Characterization for the Anaerobic Aquatic Metabolism Study Required for Herbicide Registration

J. J. Crawford,* L. Raskin,* F. W. Simmons
Waste Management Research Center

Anaerobic herbicide fate is important to cropping practices and herbicide use in soils. The Anaerobic Aquatic Metabolism Study, EPA Protocol N-162-3, is the sole evaluation of anaerobic herbicide fate required for herbicide registration. This study is not representative of environmental conditions; therefore, results do not represent herbicide behavior in anaerobic soils. This research involves characterization of microbial communities in flooded anaerobic soils using molecular biology techniques in herbicide treated and untreated soil microcosms. The EPA protocol is compared with two alternative protocols in order to put forth a protocol that more accurately represents flooded soil conditions.

Development of Risk Assessment Factors and Review of Wildlife Hazard Abatement Systems

E. E. Herricks,* P. Mankin, R. Warner, D. J. Schaeffer, B. Brown
Federal Aviation Administration, Center of Excellence for Airport Pavement Research

This research is conducted in support of a continuing FAA program of research and development directed at airport safety technologies that will decrease aircraft damage and the risk of human fatalities or injuries by reducing bird and wildlife strikes near airports. The objectives of this research are to develop risk assessment factors for airports, review the U.S. Air Force Aerial Hazard Abatement System (AHAS), and evaluate AHAS in relation to FAA needs in wildlife hazard abatement.

Integrated Assessment of Climate Change Impact in the Mackinaw River Watershed, Illinois

E. E. Herricks,* J. W. Eheart,* K. P. Donaghy, B. Orlannd
U.S. Environmental Protection Agency, STAR Research Program

This research will complete an integrated assessment of multiple sector impacts produced by predicted changes in climate using models and innovative analysis tools applied to the Mackinaw River watershed. The consequences of climate change and climate variability on human and natural systems will be developed using site and sector response spectra that support a severity determination for an impact assessment. The research has three phases: identification of climate change phenomena; identification of local impact of climate change with particular emphasis on economic, environmental, and social impact aggregations; and implementation of a Web-based decision-support system.

Real-Time Effect Monitoring for Episodic Event Toxicity

E. E. Herricks*
University of Illinois

The objective of this research is the development of methods to perform *in situ* measurement and analysis of episodic event toxicity associated with stormwater flows.

* Denotes principal investigator.

Specific objectives include the evaluation of the Asiatic clam *Corbicula sp.,* and other mussels and aquatic invertebrates common in Illinois, as test organisms in a commercially available monitoring system (MosselMonitor manufactured by Delta Consult, The Netherlands); laboratory and field evaluations of response spectra of *Corbicula* and other organisms to changing environmental conditions and episodic exposure to contaminants; and development of advanced methods of data analysis from continuous monitoring systems.

Restoration of Duck Creek, Juneau, Alaska, through Control of Iron Floc Associated with Urban Development

E. E. Herricks,* K. V. Koski
National Wildlife Foundation

The proposed project will develop and evaluate BMPs for removing iron floc from streams. Iron floc is the major factor limiting the ecological quality in several streams in Juneau and other southeast Alaska locations. The floc is produced by oxidation of soluble iron in groundwater. Surface disturbance associated with development and urbanization modifies groundwater flow, creating surface discharges that affect downstream habitat and water quality. This project will install and evaluate instream devices to remove iron floc to restore water quality and habitat for *anadromous salmonids*.

Watershed Protection in Agricultural Environments: Integrated Social, Geomorphological, and Ecological Research to Support Ecosystem-based Stream Management

E. E. Herricks,* B. L. Rhoads,* D. L. Wilson
U.S. Environmental Protection Agency

This research advances the proposition that watershed protection, although dependent on science and engineering, is a process that is fundamentally social in nature. The research will focus on how new scientific and engineering knowledge affects how stakeholders value natural resources, specifically habitat and fisheries, and in turn, how they approach stream management.
The research is based on an interdisciplinary approach that combines theoretical perspectives in social theory with a scientific perspective based on geomorphology and ecology. Community-based watershed projects in the Embarras, Salt Fork, and Sangamon river basins will serve as case studies.

The Role of Carbonaceous Aerosols in Climate Forcing

S. M. Larson,* A. Dillner
University of Illinois

Carbonaceous aerosols (elemental and organic carbon) can act to either cool or warm the climate. This project addresses this issue by providing size segregated measurements of the absorption efficiency for laboratory-generated and Midwest ambient EC useful for regional positive forcing determinations. Organic carbon may be a large part of negative forcing. However, accurate determination of the forcing role of organics is limited because of uncertainties of identification, size distribution, refractive indices, and humidity growth. In this project, researchers will investigate these and provide an approach to estimating organic forcing.

Absorption of Light by Organic Aerosols

S. M. Larson*
University of Illinois

In this project, researchers will determine the light absorption efficiency of organic aerosol particles in the ultraviolet range between 250 and 400 nm using a technique involving filtration, extraction, and spectrophotometer analysis. It is hypothesized that nitrated aromatics, PAHs, and benzaldehydes would be efficient UV absorbers, and the extraction procedure is designed to capture these species. The measurement of the ultraviolet light absorption efficiency of organics is important for modeling studies of the formation of ozone and other photochemical components.

Assessing the Feasibility of "Mini Lidar" Technology for an Opacity Instrument

S. M. Larson*
U.S. Army Construction Engineering Research Laboratory

The goal of this project is to evaluate the feasibility of developing and employing new laser diode technology in a rugged, cost-effective, transportable, and easily used system to measure opacity of dust clouds caused by army training maneuvers. The measurement of this cloud's opacity would allow Army personnel to ensure compliance with environmental regulations. While traditional lidars are large, costly, and difficult to operate, new advances in the technology have brought much promise for a "mini lidar," a rugged, easily transported system that can be operated with a minimum of training.

* Denotes principal investigator.

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 currently used for highway projects in Illinois, 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 μm) are selected because they are smaller in size compared to the target pathogens *Cryptosporidium* oocysts (3 to 5 μm) and *Giardia* cysts (10 to 15 μm), 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.

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.

* Denotes principal investigator.

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 through 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.

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.

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

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. 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.

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.

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

* Denotes principal investigator.

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.

Bromate Formation and Control during Ozonation of Low-Bromide Waters

R. A. Minear,* B. Mariñas,* M. Urban
Montgomery-Watson, Inc.; American Water Works Association Research Foundation

An orthogonal matrix of experiments is directed at determining the critical factors in minimizing the formation of bromate in low-bromide-containing waters. Variations in temperature, pH, ammonia content, and a radical scavenger, ethanol, are being studied for a range of ozone doses and contact times that coincide with requirements for the inactivation of *C. parvum* oocysts. The associated disinfection by-products resulting from the treatment and water quality variations are being examined as well.

Development of Undergraduate Laboratory Experience in Civil and Environmental Engineering

R. A. Minear*
National Science Foundation, DUE-9950185

The development of a significant undergraduate laboratory experience in environmental engineering bridges the existing gap between classroom theory and practical measurement techniques. Structured experiments let students participate in common field and laboratory measurements used in environmental engineering to design monitoring programs and treatment systems in air, water, wastewater, hazardous waste, and ecology. Students are involved directly in evaluating data reliability and assessing QA/QC issues as a part of performing the experiments. They will make decisions on the use of their data in classroom projects simulating assessment of the development of design parameters for treatment systems.

Genotoxicity and Occurrence Assessment of Disinfection By-Product Mixtures in Drinking Water

R. A. Minear,* M. J. Plewa,* S. Echigo
U.S. Environmental Protection Agency, R825956-01

Representative drinking water disinfection by-products (DBPs) will be produced from organic matter isolated from a series of representative source waters used for drinking water supplies using both chlorination and ozonation in laboratory reactors under a range of disinfection conditions. Selective conditions will allow differential evaluation of brominated DBPs via ozonation of bromide-containing waters and also provide information on the relationship of toxicity to DBP molecular weight. Bulk DBPs will be analyzed for toxicity and mutation induction in *S. typhimurium* using a suspension test ± S9. The same DBPs will be analyzed with transgenic Chinese hamster lung cells ± S9 using the single cell gel electrophoresis (SCG) method to detect direct genomic DNA damage.

Molecular Weight Separation and HPLC/MS/MS Characterization of Previously Unidentified Drinking Water Disinfection By-Products

R. A. Minear,* S. Barrett,* X. Zhang
U.S. Environmental Protection Agency, R826834-01

A study is proposed in which new approaches are to be developed for better characterizing disinfection by-product molecular weight profiles by using tandem mass spectrometry (MS/MS) techniques. A prerequisite to making such procedures meaningful is the development of preseparation procedures that will simplify the mass spectral data. The MS/MS system has its own separation capabilities. The proposed work is directed at enhancing these capabilities for complex DBP mixtures with preselection by molecular weight separations using ultrafiltration membranes or size exclusion chromatography.

Novel Characterization of Humic Substances and Their Role in the Behavior of Environmental Toxic Substances Using HPLC/MS/MS

R. A. Minear,* M. J. Plewa*
National Science Foundation, INT 97-26617

The underlying hypothesis of the overall proposed cooperative research effort is that NOM and humic substances as a subset affect the environmental toxicology of anthropogenic compounds through complex

* Denotes principal investigator.

interactions that affect membrane transport and mechanisms of toxicological reactions. The three-year project involves a series of composite objectives. These overall objectives complement parallel work in the laboratories of Minear and Plewa. They also provide translation of capabilities in the University of Illinois laboratories to researchers in Kyoto, Japan, while offering the principal investigators an opportunity to explore new research dimensions.

Direct Comparative Genotoxicity Assessment of Disinfection By-Product (DBP) Mixtures in Drinking Water Generated from Different Disinfection Processes

R. Minear,* M. Plewa,* S. Echigo
American Water Works Association Research Foundation

A study is proposed in which a novel assay is coupled with a more traditional assay to evaluate the genotoxicity of disinfection by-products (DBPs) and DBP mixtures. Chlorine (the traditional water treatment disinfectant), ozone (an alternative disinfectant and oxidant), and the sequence of ozone plus chlorine in addition to chloramination and chlorine dioxide treatment methods will be examined. Simple and complex DBP mixtures, produced from chlorination, ozonation, or coupled ozonation/chlorination and chloramination and chlorine dioxide treatments, will be created from an NOM standard (SRFA) containing water. The assays will be augmented by a database created to represent an occurrence assessment of regulated and soon-to-be-regulated DBPs.

Cost-Effective Risk Management Groundwater Contamination

B. S. Minsker,* D. E. Goldberg, J. Lee
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 an NSF 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.

Cost-Effective Risk-based Corrective Action Design for Contaminated Groundwater

B. S. Minsker,* D. E. Goldberg, G. Gopalakrishnan, M. Babbar
National Science Foundation, BES 9903889 (1999-2002)

Given the scope of contamination of U.S. groundwater and the vast amount of money involved in corrective action, improved risk management and remediation design is a critical need. In this project, a risk management model is being developed to investigate relationships between human health risk and corrective action design under conditions of uncertainty. The methodology combines a noisy genetic algorithm, which searches for cost-effective corrective action plans, with a flow and transport model called RT3D and a human health exposure risk assessment module. Theoretical advancements for improving computational efficiency of the model will also be investigated.

Research and Educational Advances in Optimal Groundwater Remediation Design

B. S. Minsker,* D. Goldberg, F. Saied, Y. Liu, F. Espinoza
National Science Foundation, BES 9734076 CAREER (1998-2002)

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.

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

E. Morgenroth*
Illinois Agricultural Experiment Station

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

* Denotes principal investigator.

are developing procedures for physical and chemical characterization of particulate organic matter in swine manure that can serve as a basis for biological denitrification.

Molecular Probe Technology for Studying Biofilms in Drinking Water Distribution Systems

L. Raskin,* V. L. Snoeyink, B. J. Mariñas, S. Meintser, N. Dunahee
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.

Molecular Probes for Anaerobic Wastewater Treatment Process Evaluation

L. Raskin,* D. Zheng
University of Illinois Center for Advanced Study; Campus Critical Research Initiatives Program

This research will focus on anaerobic wastewater treatment systems in which the formation and stability of "granules" or conglomerates of microorganisms are critical for good performance. Methods for studying granule formation and stability will be developed by combining physical methods that determine granule hydrophobicity and liquid surface tension with ribosomal RNA-based identification and quantification techniques. In addition, operating strategies that reduce start-up time and improve performance will be evaluated in laboratory-scale anaerobic bioreactors.

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

L. Raskin,* R. Gaskins, R. Mackie, M. Mau, K. Hristova, D. Zheng, R. Aminov
Campus Critical Research Initiatives Program

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.

Swine Waste Processing Using Anaerobic Sequencing Batch Reactors and Nutrient Recovery Systems

L. Raskin,* L. Angenent
Illinois Council on Food and Agriculture Research

The anaerobic sequencing batch reactor (ASBR) is a new biological process for the conversion of organic wastes to biogas. The technical feasibility of ASBRs to stabilize swine waste has been demonstrated at Iowa State University. This research will evaluate possibilities to further reduce capital and operating costs of ASBR systems and to create an alternative added value to the system. The research will focus on seeding ASBRs with different sludges to reduce start-up periods, recovering nutrients from ASBR effluent, and reusing ASBR effluent as flush water.

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

L. Raskin,* F. L. de los Reyes
National Science Foundation, BES 9733826

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.

* Denotes principal investigator.

Development of an Integrated Scientific and Technological Framework for Stream Naturalization

B. L. Rhoads,* M. García, E. E. Herricks, D. Wilson
U.S. Environmental Protection Agency

The watershed approach to environmental management emphasizes that decision making should occur at the level of local communities. This requires an integrated scientific and community-based framework for decision making—a social and scientific enterprise referred to as naturalization. Naturalization involves a recursive interplay between a community's vision of the stream and the scientific and technical perspective on what the streams can realistically become to achieve the community's vision. This research will explore naturalization programs, integrating both the technical and scientific aspects and the social aspects of community-based watershed management. Three watersheds in Illinois are the focus of a three-year research effort initiated in 1998.

Activated Carbon Fiber Adsorption/Desorption System: Pilot Scale

M. J. Rood,* P. D. Sullivan, C. Lehmann, D. Ramirez, S. Y. Lo
U.S. Army Construction Engineering Research, DACA88-98-D-0005-17

Hazardous air pollutants need to 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.

Adsorption/Desorption Cycling of Carbon Fiber Adsorber-Cryogenic System

M. J. Rood,* P. Sullivan, C. Lehmann, D. Ramirez, K. Dombrowski
U.S. Army Construction Engineering Research Laboratory, DACA88-99-M0155

The ability of air quality control systems to capture and recover gaseous pollutants instead of destroying the pollutants is dependent on costs required to concentrate the pollutant to a sufficient concentration to make it reusable. This project is developing a new sorption-condensation system that captures dilute gaseous pollutants, regenerates the material used to capture the pollutant, and recovers the pollutant in a concentrated form for reuse in the process that generated the pollutant.

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 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 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.

Direct Radiative Forcing of Climate by Anthropogenic Aerosol Particles

M. J. Rood,* C. M. Carrico
National Science Foundation, INT 98-18402 TVL

Quantifying the ability of anthropogenic aerosol particles to perturb the earth's climate is a complex and interdisciplinary task. Such characterization is important so that we can better understand how humans are influencing the earth's climate in ways that could cause changes in heating, precipitation, and cloud formation patterns for the earth's atmosphere. This project will allow collaboration with international researchers having unique capabilities not readily available in the United States. Results from this collaboration can then be used to better quantify the effects of human activity on climate.

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

* Denotes principal investigator.

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.

Measurement of Ambient Aerosol Properties as They Relate to Climate at a Perturbed Mid-Latitude Continental Site

M. J. Rood,* K. E. Winter, 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
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
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.

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.

An Assessment of Anaerobic Dechlorination Activity in Regional River Sediments

R. A. Sanford,* K. Y. Leung, I. Nambi, Q. He, F. Loeffler
University of Illinois; Georgia Institute of Technology

Microbial-mediated reductive dechlorination is a common process in anaerobic ecosystems. A number of anaerobic dehalogenating bacteria have been isolated from pristine river sediment environments leading to the hypothesis that natural chlorinated compounds in the sediments are used as electron acceptors by novel microorganisms.
The objectives of the research are to characterize the microbial halorespiration capacity of chlorinated solvents (such as PCE) in stream sediments in Illinois, Colorado, and Korea as well as in Japanese Rice Paddies. Results will provide evidence of a novel biogeochemical cycle involving natural halogenated compounds and could lead to a better understanding of microbial diversity.

* Denotes principal investigator.

Bioremediation of Perchloroethene (PCE) in a Column System Using Chitin Fermentation as an Electron Donor Source

R. A. Sanford,* C. J. Werth,* R. A. Brennan
University of Illinois; National Science Foundation, Graduate Fellowship; Environmental Protection Agency, STAR 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.

Characterization and Identification of the Microbial Community Colonizing an Anaerobic Fluidized-Bed Bioreactor Treating TNT and RDX Using Molecular Techniques

R. A. Sanford,* S. Oh, K. Moon, N. Adrian
University of Illinois; U.S. Army Construction Engineering Research Laboratory

Two anaerobic fluidized-bed reactors, one with TNT and the other without, have been monitored continuously since January. The objective of this research is to characterize the microbial community in each reactor and identify the responsible organisms that are degrading TNT or RDX. PCR-based terminal restriction fragment length polymorphism (T-RFLP) analysis of 165 rDNA was used to characterize the communities in these reactors. Specific terminal fragments will be targeted for sequencing to identify populations found in the explosives containing reactors. As a result, a method of community analysis will be developed and better anaerobic treatment systems for pink water will be designed.

Determination of Growth Kinetics of Anaerobic Bacteria Growing on Low Concentrations of Limiting Substrate

R. A. Sanford,* Q. He, R. A. Brennan
University of Illinois

Growth kinetic data are difficult to obtain for chlororespiring anaerobic microorganisms. The objectives of this research are to determine the growth kinetics of these cultures using the uptake of ^{14}C-labeled acetate into biomass as a measure of growth. Since the amount of chlorinated compound available to a chlororespiring bacteria is limited by solubility or toxicity, other methods of growth measurement often fail. Radiolabeled biomass is easy to quantify and was shown to correlate well with other tedious methods of measurement. These data will be useful for modeling growth in nature which is needed for designing *in situ* bioremediation.

Fast Dechlorination of Chlorinated Phenols by *Anaeromyxobacter dehalogenans* Strain 2CP-C

R. A. Sanford,* Q. He
University of Illinois

The anaerobic myxobacterium *Anaeromyxobacter dehalogenans* strain 2CP-C grows by coupling the oxidation of acetate to the reductive dechlorination of orth-substituted chlorophenols. Little is known, however, about the physiology or kinetics of dechlorination. The objective of this study was to determine the rates of growth and dechlorination by strain 2CP-C using various halogenated phenolic compounds. Even with cell densities less than 10^7/ml, declorination kinetics are zero-order after induction with a rate of 2l.5 μM/hour for 2-chlorophenol, the highest rate observed for any chlororespiring bacteria. Further investigation will determine if strain 2CP-C is useful for the bioremediation of chlorinated phenols.

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 was 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.

* Denotes principal investigator.

The Use of Micromodels to Study Dissolution and Bioavailability of DNAPLs for Degradation by Microorganisms in Groundwater

R. A. Sanford,* C. J. Werth, I. Nambi
National Science Foundation, Biogeochemistry Program

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 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.

Effects of Redox Conditions on the Bioavailability and Biodegradation of Nonaqueous Phase Chlorinated Ethenes at the Pore Scale

R. Sanford,* A. Valocchi, C. Werth, I. Nambi, C. Chomsurin, C. Knutson
National Science Foundation Biogeochemistry Program

Efforts to predict dechlorination rates in the field using results from batch studies have met with little success. One reason for this lack of agreement is our inability to predict the effects of pore-scale variability on reaction rates. The overall objective of this research is to determine the effects of redox conditions on the bioavailability and biodegradation of nonaqueous phase chlorinated ethenes at the pore scale. Although many geochemical species can affect redox conditions, this study focuses only on the effects of competing electron acceptors. Specifically, the proposed research aims to determine the relationships between PCE DNAPL dissolution and reductive dechlorination at the pore scale, determine the effects of competing electron acceptors on DNAPL dissolution and reductive dechlorination at the pore scale, and determine the effects of pore scale variability on transport and fate at the Darcy scale.

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
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 current processes shorten the life of metal working fluids, and determine the effect of these processes on endotoxin content in MWF.

Adsorption in Hybrid Membrane-Ultrafiltration Processes

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

The objective of this research is to determine the efficiency of the floc blanket reactor (FBR)-PAC-ultrafiltration (UF) process for the removal of both natural organic matter and trace organic contaminants, and to develop new hybrid membrane-adsorption processes. 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% to 50%. Future work will involve testing different surface waters, carbons with a wide range of pore size distributions, new adsorbents and adsorption processes, and model development to describe process performance.

Assessment of the Prevalence and Significance of Aluminum-Containing Scale Deposits

V. L. Snoeyink,* P. Sarin, C. Feld, A. S. C. Chen, L. Wang
Battelle; U.S. Environmental Protection Agency

The objective of this project is to determine the prevalence of aluminum-containing scales in distribution systems of utilities that are using aluminum-based coagulants. Samples of distribution system pipes, especially lead pipes, are being obtained from throughout the United States and Canada and are being analyzed

* Denotes principal investigator.

using x-ray diffraction and energy dispersive spectroscopy to establish the composition of aluminum-containing scales. Common deposits that have been found to date include aluminum silicates, aluminum hydroxides, and aluminum phosphates. After the survey is complete, researchers will focus on establishing the detrimental and beneficial effects of these scales.

Characterization of Scales in the Chicago Water Distribution System

V. L. Snoeyink,* P. Sarin, D. Frommell, W. Kriven
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, W. Kriven
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.

Removal of Perchlorate in Biologically Active GAC Systems

V. L. Snoeyink,* L. Raskin,* J. Brown, R. Lin
University of Illinois

The objective of this project is to show how conventional GAC systems can be modified and operated for removal of microgram-per-liter concentrations of perchlorate that are found in contaminated drinking water supplies. Evaluation of the effects of nitrate concentration, pH, oxygen concentration, and electron donor dose are being investigated at several empty bed contact times. The microbial population is being studied to determine the organisms responsible for perchlorate reduction and their growth requirements. Polishing steps are being investigated to ensure that the product water meets drinking water requirements.

Spatial and Temporal Characterization of Dense Nonaqueous Phase Liquids in Porous Media Using Magnetic Resonance Imaging

C. J. Werth,* C. Zhang
National Science Foundation CAREER Award

Accurate characterization of nonaqueous phase liquid (NAPL) dissolution requires a mechanistic understanding of the complex factors affecting the NAPL-water interfacial area across which mass transfer occurs. Prior experimental techniques have not resolved these factors, resulting in phenomenological mass transfer coefficients that are constrained by experimental conditions. The objectives of this project are to determine the effects of interstitial water velocity on the effective NAPL-water interfacial area, to determine the effects of pore and NAPL characteristics on the effective NAPL-water interfacial area, and to predict time-dependent NAPL dissolution in natural porous media.

Competitive Sorption of Volatile Organics in Model and Natural Solids

C. Werth,* J. Li
National Science Foundation

Laboratory studies have been conducted to characterize the mass transfer limitations in the subsurface. In most cases, mass transfer rates for single sorbates were measured in an attempt to characterize mass transfer limitations in the field. However, mixtures of volatile organic chemicals (VOCs) are often present in the field, both as the source of contamination and as transformation products from biodegradation. The objective of this project is to determine the effects of chemical mixtures on mass transfer in geosorbent (soil and sediment) aggregates.

* Denotes principal investigator.

Evaluation of Polymeric Organic Materials for Stimulating the Reductive Dechlorination of Chlorindated Ethenes

C. Werth,* R. Sanford,* R. Brennan
Student Fellowships from National Science Foundation; U.S. Environmental Protection Agency

This project is focused on developing a new passive bioremediation technology for dense nonaqueous phase liquids (DNAPLs) in groundwater. This technology involves putting polymeric organic materials (POMs) such as chitin and wood chips into boreholes upgradient from and in a DNAPL source. As the POMs degrade, nutrients are released to groundwater, enhancing both DNAL dissolution and biodegradation.

Environmental Hydrology and Hydraulic Engineering

Design of Pool-Riffle Units for River Restoration

M. H. García,* E. Herricks, B. Rhoads, J. Rodriguez, F. Bombardelli, C. García
U.S. Environmental Protection Agency

Researchers are using a three-dimensional hydrodynamics code to design pool-riffle units for streams in urbanized areas. The design will be implemented as part of a river restoration project along the west fork of the North Branch of the Chicago River, in the city of Northbrook, Ill.

Formation of Submarine Gullies and Bedforms

M. H. García,* J. Fedele
U.S. Office of Naval Research

Researchers are testing the hypothesis that oceanic turbidity currents are responsible for the formation of submarine gullies commonly observed in continental slopes. Large-scale laboratory experiments are used in combination with a numerical model for turbidity currents. The research team also is studying the formation of antidunes by turbidity flows, with the help of laboratory experiments and linear stability analysis.

Hydrodynamic Modeling of Density Currents in the Chicago River, Illinois

M. H. García,* F. Bombardelli
Metropolitan Water Reclamation District of Greater Chicago

Density currents are believed to be responsible for the conveyance of water from the North Branch of the Chicago River, consisting mainly of effluent water, toward Lake Michigan through the Chicago River itself. Numerical modeling is being used to assess under what conditions density currents develop and how much strength they have in moving water of lesser quality toward Lake Michigan.

Hydrodynamics of Canoe Chutes

M. H. García,* F. Bombardelli, C. García
Illinois Department of Natural Resources

At many low-head dam sites in Illinois, there is interest in building canoe chutes with the goal of increasing recreational use of streams. Researchers are using a combination of computational fluid dynamics and laboratory experiments to obtain the best design of a canoe chute for low-head dams.

Impact of Coarse-Bubble Diffusers on Combined-Sewer Overflow Sediments

M. H. García,* C. R. Rehmann,* J. P. Spenn
U.S. Army Corps of Engineers

To aid in the design of a reservoir to collect combined-sewer overflows (CSO) near Chicago, researchers are investigating the effect of bubble plumes on sediment suspension in water. A crucial design consideration is whether to keep the sediments suspended in the flow or let them settle on the bottom to be cleaned after a CSO event. Preliminary laboratory experiments with relatively coarse sediment suggest that bubble plumes keep only a small fraction of the sediment suspended. The suspended fraction decreases with time as more particles settle. After approximately one residence time, based on the tank volume and air-flow rate, the suspended fraction reaches an equilibrium value.

Navigation-induced Flow and Bed Shear Stresses

M. H. García,* J. Rodriguez
U.S. Army Waterways Experiment Station, DACW39-96-K-0005

Navigation-induced physical forces in the Upper Mississippi River System have to be quantified with the goal of mitigating associated environmental effects.

* Denotes principal investigator.

A physical model of a navigation river located at the Waterways Experiment Station in Vicksburg, Miss., is being used to measure the flow field generated by the passage of a model vessel. A total of eight acoustic Doppler velocimeters and four flush-mounted, hot-film sensors for measuring bed shear stresses are being used to capture the footprint of barges and their propellers.

Sediment Entrainment Functions for Navigation-induced Resuspension

M. H. García,* J. Rodriguez
U.S. Army Waterways Experiment Station,
DACW39-95-K-0101

The nature of the flow field associated with sediment resuspension caused by the passage of barge tows makes it quite difficult to formulate an appropriate flux boundary condition near the bed and thus to determine how much sediment will be incorporated into the water column. Barges generate turbulence by waves and by changes in the velocity profile due to water displacement. It is clear that the flow field resulting from the passage of vessels is unsteady, nonuniform, and highly turbulent. The main goal is to develop an entrainment function that can be used to estimate sediment resuspension due to barge tow passage, which includes the effect of mean bed shear stress as well as turbulence effects.

Sediment Transport upon Dam Removal

M. H. García,* F. Bombardelli, J. Guzman
Illinois Department of Natural Resources

Many low-head dams in Illinois streams could be removed in the next decade. The fate of sediments accumulated over the years upstream of such dams is an important concern. A 1-D sediment transport model is being developed to estimate sediment erosion, transport, and deposition upon dam removal.

Settling and Oxygen Demand of Suspended Solids from Combined-Sewer-Overflows

M. H. García,* B. Briskin
U.S. Army Corps of Engineers

Laboratory experiments with a carrousel flume are conducted to determine the effect of settling and resuspension on oxygen demand by suspended solids resulting from combined-sewer-overflows.

Wave-Current Induced Mine Burial Due to Sediment Fluidization and Scour

M. H. García,* R. Musalem
Office of Naval Research

The interaction of waves and currents with model mines is being studied with the help of laboratory experiments. The dynamic response of sediments holding an object is analyzed with the goal of establishing conditions for scour and fluidization.

Transient, Low-Pressure-Induced Contaminant Intrusion into Drinking Water Distribution Systems

M. García,* J. Guzman, J. Abad
Battelle

It has been hypothesized that contaminants in a pipe trench can be drawn into drinking water distribution systems. Researchers are performing transient flow analysis to determine under what conditions contaminant intrusions are likely.

Characterizing Multiscale Interaction of Hydrologic Processes Using Multisensor Satellite Data

P. Kumar*
National Aeronautics and Space Administration,
NAG W-5247

To understand large-scale hydrologic processes, it is necessary to characterize the feedback interaction between various systems such as land and atmosphere. Significant advances have been made in this direction through field campaigns to measure parameters from point-to-satellite pixel scale. However, the problem of assimilating measurements at various scales to understand the behavior of processes at small scales and their integrated effect on the larger scale is still elusive. The objectives of this research are to address this problem through the development of stochastic-dynamic multiscale models of key hydrologic processes. Researchers will use the asynchronous multisensor observations from different satellite instruments for the study.

* Denotes principal investigator.

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.

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 objective of this project is 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.

Relative Scales of Hydrodynamic and Geomorphologic Influence on the Hydrologic Response in the Illinois River Basin

P. Kumar,* B. Rhoads (Geog.), B. Yen
Water Resources Center; U.S. Geological Survey, INT-96-GR-02668

The objective of this research is to determine the relative effects of geomorphological dispersion and hydrodynamic dispersion on the hydrological response of the Illinois River system as scale increases. The specific hypothesis to be tested is that as basin size increases, the river network structure, as compared to channel hydrodynamic properties, plays an increasingly dominant role in determining the hydrological response. The research will also explore the effects of two human actions (modification of network structure via land drainage activities and construction of dams) on contemporary hydrological conditions. The results will provide important information and predictive capabilities for assessing the influence of future management scenarios on the hydrology of the Illinois River.

The Land Surface Component of the Climate System: Improved Representation of Subgrid Processes and Analyses of Land Surface Effects on Climate Variability

P. Kumar;* R. Koster,* M. J. Suarez* (NASA-GSFC)
National Aeronautics and Space Administration, NAG 5-3661

The land surface affects precipitation variability partly through evaporation feedback as water that is added to the surface during an anomalously large precipitation event leads to anomalously large evaporation rates. These, in turn, can lead to further rainfall. The amplitude of the original precipitation anomaly is thereby increased. General circulation models are used to perform such studies. One objective of this research is to develop watershed-scale hydrologic parameterizations in GCM for modeling the effects of sub-basin-scale soil moisture variability on surface runoff, baseflow, and evaporation. A second objective is to study temporal and spatial structure of continental-scale hydrological fields using these improved parameterizations.

Mixing and Structure in a Double-Diffusive Gravity Current

C. R. Rehmann,* J. H. Hwang, P. R. Jackson
University of Illinois

In the coastal ocean during the summer, warm, salty water from the continental slope intrudes into colder, fresher water on the continental shelf. To assess the relative contributions of mechanically generated turbulence and double-diffusive convection to the mixing in such a flow, researchers developed a laboratory model of a nonrotating gravity current subject to diffusive layering. The gravity current can be arrested by releasing warm, salty water into an opposing flow of cold, fresh water. The resulting steady state allows the overall mixing rate, interface properties, and spatial evolution of the temperature and salinity differences to be measured.

* Denotes principal investigator.

Modeling Stratified Flows with Rapid Distortion Theory

C. R. Rehmann,* J. H. Hwang
University of Illinois

Much turbulence modeling involves a gradient-transport model or eddy viscosity at some level. Such a model requires time scales of the turbulence to be much smaller than the time scales of the mean flow. In many stratified flows, such as the thermocline of lakes or the ocean, the opposite is true: for strong stratification and weak turbulence, the turbulence time scale is small compared to the time scale of gravitational adjustment. In this case, rapid distortion theory (RDT) should apply. Researchers are using RDT to compute the effect of mixing on turbulence, study the evolution of a localized patch of turbulence, and model turbulence in a field of long internal waves. An eventual objective is to develop a hybrid RDT-eddy viscosity model in which the eddy viscosity is allowed to evolve in space and time.

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.

Predicting Transport of Zebra Mussels in Rivers and Estuaries

C. R. Rehmann,* D. W. Schneider,* D. K. Padilla*
Illinois-Indiana Sea Grant

This companion project to a National Sea Grant project also under way in the department focuses on measuring and modeling the detailed physical processes affecting zebra mussel transport in the Illinois and Hudson rivers. The specific goals are to predict the transport and settlement patterns of zebra mussel larvae in rivers and estuaries and to determine the key parameters affecting the establishment of local zebra mussel populations. Key processes that increase the likelihood of local larval recruitment include trapping in stagnant pools and eddies near locks and dams in the Illinois River and the oscillating tidal flow in the estuarine portion of the Hudson River.

The Role of Larval Growth, Mortality, and Transport in Metapopulation Dynamics and Control of the Zebra Mussel in Freshwater and Estuarine Systems

D. W. Schneider,* J. A. Stoeckel,* R. E. Sparks,* C. R. Rehmann,* D. K. Padilla*
National Sea Grant College Program

After its accidental introduction into North American waterways, the zebra mussel spread rapidly, affected ecosystems, and caused hundreds of millions of dollars of damage. Most measures to control zebra mussels focus on individual sites. However, since mussel populations depend on a maintained larval supply, zebra mussels can be controlled in an entire ecosystem if the larval supply can be blocked. The success of such a control scheme depends on physical and biological processes. Researchers will perform a comparative study of the various processes affecting mussel population dynamics in the Illinois and Hudson rivers.

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.

* Denotes principal investigator.

Investigation of Pore-Scale Processes Affecting Soil Vapor Extraction

A. J. Valocchi,* C. J. Werth;* A. Webb (Elect. & Comput. Engr.); Y. Chu, H. Yoon, J. Stamerjohn
U.S. Department of Energy, Environmental Science Management Program

Research proposed here aims to elucidate the pore-scale processes which limit the removal of dense nonaqueous phase liquid (DNAPL) components from the vadose zone. Specific objectives are to determine the effects 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 which describe the transient distribution of phases inside a column experiment.

Modeling Nutrient Dynamics in Three-Dimensional, Tile-Drained Agricultural Fields

A. J. Valocchi,* R. Hudson (Natural Resources & Envir. Sci.), D. Hill
Illinois Council on Food and Agricultural Research

This is part of a larger modeling effort that couples surface and subsurface hydrology with soil biogeochemical process to better understand the fate of nitrogen on agricultural fields in Illinois. A three-dimensional transport and fate model is being developed and tested. The model will be coupled to the hydrology model. The coupled model will be validated by comparison with data sets collected from ongoing field studies.

Pollutant Fate and Transport in Groundwater: Web-based Interactive Simulation and Instruction

A. J. Valocchi,* C. J. Werth,* J. Decker
University of Illinois, Provost's Initiative on Teaching Advancement; National Science Foundation

Mathematical modeling provides the framework for integrating transport and fate processes that control the behavior of pollutants in groundwater and soil systems. However, available software for solving these models is complex and cumbersome. This project develops simple and flexible java applets that enable students to conduct interactive simulations using a Web browser. Researchers have developed applets for one-dimensional and multidimensional transport that include equilibrium and nonequilibrium sorption, first-order decay, and sequential chain decay processes.

Research and Development of a Reactive Transport Model for the FEHM Computer Code

A. J. Valocchi,* G. Hammond
Los Alamos National Laboratory, C84740016-3Y

FEHM is one of several models being used to determine the viability of the Yucca Mountain site for long-term storage of high-level radioactive waste. The code is very powerful and flexible and can simulate coupled heat and mass transport in three-dimensional multiphase systems. Researchers are making significant enhancements to give FEHM the capability to simulate general equilibrium or kinetic reactions among a subset of significant chemical components. Researchers are then using the enhanced FEHM to simulate the transport of radionuclides at Yucca Mountain and other DOE sites.

Conjunctive Overland, Soil, and Tile Flow Model

B. C. Yen,* Y. Lian
Illinois Council on Food and Agricultural Research

The objective of this project is to develop a field-scale model for simultaneous flows on land surface, in the soil, and in farmland tiles. The flow equations used are the noninertia version of the Saint-Venant equations and the Richards equation. The model is expected to be useful for determining nutrient transport from farmlands.

Conjunctive Surface-Subsurface Flow Modeling

B. C. Yen,* M. Morita*
University of Illinois; Shibaura Institute of Technology, Japan

In this study, overland surface and groundwater flows are simulated simultaneously. Previously, one-dimensional surface flow and two-dimensional subsurface conjunctive numerical models were developed. In the present phase, a conjunctive model of the 2-D overland surface flow and the 3-D subsurface flow in unsaturated and saturated porous media is formulated. Several numerical methods have been evaluated.

* Denotes principal investigator.

Geomorphologic Unit Hydrograph

B. C. Yen,* K. T. Lee*
University of Illinois; National Taiwan Ocean University

The objective of this study is to derive the unit hydrograph of an ungaged watershed using only a topography map without requiring past records of rainfall or runoff. This is accomplished through probabilistic and kinematic wave considerations of the travel time of the water drops of the unit depth into the watershed through which the geomorphological instantaneous unit hydrograph (GIUH) is established. The linearity restriction of the traditional UH theory has been removed. The GIUH can be applied to any effective rainfall through convolution to produce the direct runoff hydrograph.

Hydraulic Performance Graph for Channel Capacity Determination

B. C. Yen,* J. A. Gonzalez-Castro, A. R. Schmidt
University of Illinois

This research develops a new method to determine open channel flow capacity under backwater effects. A hydraulic performance graph is first developed summarizing the subcritical flow backwater profile conditions for all the feasible upstream and downstream water levels and discharges. The channel capacity can be determined accordingly at the marginal condition of the just-at-bankfull stage without spilling over the bank at the most critical point in the channel.

Reliability Analysis in Hydrosystems Engineering

B. C. Yen,* Y. K. Tung, Y. Lian
University of Illinois; Hong Kong University of Science and Technology

This research investigates the possibility of developing, as a complement to the conventional hydraulic structure design and evaluation methods (which consider only the basic hydrologic risk of return period and frequency analysis), alternative approaches for reliability analysis that would account for all the hydrologic as well as nonhydrologic risks and uncertainties. Among the different risk-analysis methods investigated, the first-order methods have been applied to the design of sewers, culverts, levees, dams, and similar structures.

Resistance in Open Channels

B. C. Yen*
University of Illinois

A comprehensive investigation of the hydraulic resistance in open channels has been conducted based on the dimensional analysis and boundary layer theory. Resistance of uniform channels, composite channels, compound channels, and alluvial channels is investigated in view of momentum and energy concepts and point, cross section, and reach coefficients. Currently, this study is focused on resistance for channels with floodplains.

Risk Analysis for Dam Safety Assessment

B. C. Yen,* H. F. Lin
Tjing Ling Industrial Research Institute, Taiwan

Application of risk and uncertainty analyses as an alternative for dam safety assessment in Taiwan is pursued. Various methodologies, such as fault-tree and event-tree analyses and first-order and point-estimation techniques, are evaluated. The concept and techniques permit consideration of all quantifiable contributing factors. In this project, the hydrologic and hydraulic factors are analyzed in detail.

River Floods

B. C. Yen*
University of Illinois

River floods are studied from a risk analysis perspective considering hydrologic, hydraulic, morphological, and other contributing factors. The investigation has revealed the confusion and inconsistency of levels of flood protection in current practice, including the 100-year flood line, x-year design flood, freeboard, and failure level of hydroinfrastructures (for example, levees).

Sediment Fall Velocity in Oscillating Flow

B. C. Yen*
University of Illinois

The fall velocity of a single solid sphere in a vertically oscillating fluid field was investigated in order to provide basic information on sediment behavior in turbulent flows in natural water bodies. A survey of relevant existing information was conducted. The Basset-Boussinesq-Oseen equation was improved for simulations. The terminal fall velocity reduction factor is determined as a function of the particle Reynolds number and oscillation parameters. Particle levitation and hovering against gravity could occur with asymmetric fluid oscillations, whereas for symmetric fluid oscillation, the particle will eventually fall, no matter how slowly.

* Denotes principal investigator.

Shallow-Water Wave Propagation in Open Channels

B. C. Yen,* W. S. Tsai
University of Illinois; National Chao-Tung University, Taiwan

A fundamental study on the unsteady flow equations in open channels is carried out theoretically and numerically. The kinematic wave, noninertia, and Saint-Venant approximations of the exact moment equations are considered. Demarcation of applicability of these approximations is sought. Characteristics of shallow water wave propagation for these approximations are analyzed. The importance of the downstream backwater on the selection of the models is investigated.

Theoretically Derived Channel Flow Rating Curve

B. C. Yen,* A. R. Schmidt
University of Illinois; National Science Foundation, EAR 00-98835

Rating curve describes the stage (water level) discharge relationship of flow in open channels. Presently, rating curves are developed from field measurements of stages and velocities of flows in streams worldwide. Such measurements do not yield single rating curves, instead they show scattered points. This study aims to develop a far less costly and less time-consuming method to derive the rating curve theoretically. The method is based on the application of a new tool, the hydraulic performance graph.

Unsteady Flow Routing in Open Channels

B. C. Yen,* J. A. Gonzalez-Castro
University of Illinois

A new robust and numerically less demanding method to simulate time-varying flow in rivers and artificial channels has been developed. The method couples the continuity equation with the hydraulic performance graph and hydrodynamically is at the level of quasi-steady dynamic wave simulation. Its accuracy has been found to be almost comparable with the full dynamic wave simulation.

Urban Drainage

B. C. Yen,* J. A. Gonzalez-Castro
University of Illinois

This is a comprehensive, long-term research program to investigate the hydraulics, hydrology, sediment transport, and optimization of urban stormwater drainage on the land surface as well as in sewers. Current emphasis is on developing a noninertia hydrodynamic sewer network flow routing model, determining Boneyard Creek drainage capacity, identifying drainage bottlenecks, and determining the hydraulic-hydrologic characteristics of infiltration trenches.

Geotechnical Engineering

Deformation and Stresses in Segmental Tunnel Linings

E. J. Cording,* S. L. Paul,* F. Shalabi
University of Illinois

Stresses and deformation in segmental tunnel linings subjected to static ground loads and earthquake ground motions were investigated using 2-D and 3-D finite element analyses (ABAQUS) with lining rings of four or five elastic segments having convex and planar joints in an elastic soil. Ratios of shear stiffness to normal stress between rings were determined from cyclic testing of full-scale joints. Moments decrease and deformations increase with the increase in flexibility produced by segment joints. In 3-D analyses, as normal forces increase between rings with staggered joints, moments and distortions are closer to those of continuous, non-segmented rings.

Gasketed Concrete Segments for Tunnel Linings under High Water Pressure

E. J. Cording,* S. L. Paul,* F. Shalabi
Jacobs Associates

Gasketed concrete segments have been investigated for use as linings for deep rock tunnels to limit water inflows under high pressure. Load-deformation, relaxation, and water pressure tests were performed on pairs of polymer gaskets at water pressures up to 4MPa. Water pressure at leakage was evaluated in terms of initial contact pressures between gaskets and volumetric changes as contact pressures increased. At high pressures, as the gaskets become confined in their grooves, gasket stiffness increases, the range of displacement over which the gaskets perform without leakage is reduced, and closer tolerances between the segments are required. Guidelines have been prepared for testing and design of gasket assemblies for high pressure applications.

* Denotes principal investigator.

Ground Movements and Pore Pressures Around Tunnels in Soft Clay

E. J. Cording,* T. Srisirirojanakorn
McNaly Tunneling; University of Illinois

Four test sections were installed in the path of a tunnel in a deep deposit of soft-medium Chicago clay. Two were in the vicinity of rail lines where membranes were installed to limit drainage from the clay and the other two were outside the membranes. In two sections, West-bay multiport and pneumatic piezometers revealed low initial pore-pressures in the clay due to bedrock drainage. Tunnel advance caused immediate ground movements and pore-pressure changes typical of undrained clay behavior. Long-term settlements and pore-pressure drops resulting from drainage into the tunnel and consolidation of the clay were successfully reduced by the membranes.

Stability of Tunnels and Rock Ridges Adjacent to Quarries

E. J. Cording,* Y. Hashash,* M. Ajlouni, S. J. Lee, J. M. Oh, J. S. Moon
URS Corporation

Investigation of the stability of haul tunnels beneath an interstate highway as part of the TARP system of the MWSD of Greater Chicago provided an opportunity to investigate the 2-D and 3-D behavior of tunnels and overall stability of the rock ridge beneath the highway. Distinct element analyses, both 2-D and 3-D, were conducted using UDEC and 3-DEC. Two-dimensional evaluations were made of tunnel cross sections and tunnel and ridge cross sections. Three-dimensional analyses were made of the larger ridge and quarry behavior. The analyses distinguished between conditions where stability problems had developed and where problems were not expected. Correlations with field measurements are being conducted.

Subsurface Construction, Resulting Ground Movements, and Protection of the Built Environment

E. J. Cording,* J. H. Long,* Y. M. A. Hashash,* D. Kuchma,* D. Laefer, B. Ghahreman, M. Son, T. Geilen
National Science Foundation, INT 97-22877, 97-13854; Schnabel Foundation Company

Control of building damage due to adjacent excavation is investigated with field case studies, large-scale model tests of braced excavations in soil with adjacent building walls of scaled strength and stiffness, and numerical analyses. Distinct element (UDEC) analyses model each masonry block in bearing walls subjected to ground movement profiles; results correlate closely with the physical models. An advanced soil constitutive model (MIT S1) installed in a three-dimensional finite element code (ABAQUS) provides realistic ground surface displacements due to adjacent braced excavation. Three-dimensional cases are being run for frame structures and foundations adjacent to the excavation.

Direct Field Calibration for Model Simulations of Deep Excavations

Y. M. A. Hashash,* J. Ghaboussi
National Science Foundation

Numerical modeling of geotechnical problems is used routinely in major construction projects. These models and simulations involve nonlinear analysis of staged construction for open-cut excavations, tunnels, slopes, and similar engineered structures. The most important and difficult part of these computer simulations is the representation of the constitutive behavior of the soil strata. In this project, researchers will explore a novel, powerful, and systematic method to calibrate the constitutive model of the soil behavior directly from field measurements. This will be accomplished through the use of autoprogressive method, a neural network based methodology, in the modeling of staged construction for a deep braced excavation.

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

Y. M. A. Hashash,* E. J. Cording*
Federal Highway Administration

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

* Denotes principal investigator.

Non-Linear Seismic Site Response of Deep Soil Deposits

Y. M. A. 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.

Visualization for Constitutive Relations in Engineering

Y. M. A. Hashash*
National Science Foundation

Material constitutive relations or models are mathematical representations of the mechanical response of 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.

Compressibility and Consolidation of Soils

G. Mesri,* T. W. Feng, M. M. Shahien
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
National Science Foundation, CMS 95-30464

Embankment dams or dykes may experience undrained instability during rapid drawdown of the reservoir. Drainage may not occur in compacted clay of a homogeneous embankment or a core upon rapid drawdown. Undrained shear strength at yield of the compacted clay, consolidated under predrawdown shear stress and effective stress conditions, is required for stability analysis. Undrained strength may be expressed in terms of post-drawdown 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

* Denotes principal investigator.

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 post-densification penetration resistance.

Long-Term Stability of Stiff Clay Slopes

G. Mesri,* M. M. Shahien
University of Illinois

The stability of stiff clay slopes is time-dependent because shear strength may deteriorate from the intact value to the residual condition. Because it is not readily possible to specify the dynamics of deterioration in terms of the environmental, hydrologic, and detailed geologic conditions, a precedent-based approach is used to forecast instability. The empirical method is constructed using back-analyses of failures of cut slopes of known age, together with interrelationships for intact and residual strength. For a stiff clay slope, it is possible to predict a stable age that may range from less than a year to more than 200 years.

Residual Shear Strength Mobilized in First-Time Slope Failures

G. Mesri,* M. Shahien
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,* T. D. Stark,* M. A. Ajlouni
University of Illinois

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

Seismic Performance of Waterfront Structures

G. Mesri,* W. J. Hall,* R. M. Ebeling,* M. Shahein, O. Asi, 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 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

* Denotes principal investigator.

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.

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.

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

Surcharging of Soft Ground to Reduce Secondary Settlement

G. Mesri,* M. A. Ajlouni, T. W. Feng, D. O. K. Lo
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''_α / C_α are larger and values of t_ℓ / 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

T. D. Stark,* D. E. Daniel,* K. R. Reddy*
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 objective of this research is 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 is 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

T. D. Stark,* D. E. Daniel,* A. J. Valocchi,* C. J. Werth,* I. G. Krapac*
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 to the variability of the effective diffusion coefficient, hydraulic productivity, and effect of compaction on soil micro- and macrofabric.

PVC Geomembrane Institute Technology Program

T. D. Stark,* D. E. Daniel,* K. R. Reddy*
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.

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.

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

* Denotes principal investigator.

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 man-made 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.

Geothermal Engineering

Lime Stabilization of Clay Slopes

G. Mesri,* D. Rydeen,* N. Schwanz,* M. C. Hallman, V. C. Schifano
U.S. Army Construction Engineering Research, 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 river banks and improve the levee system. One scheme is lime treatment of river bank 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.

Railroad Engineering

Affiliated Laboratory for Railroad Engineering

C. P. L. Barkan, Director
Association of American Railroads

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 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.

In 2000, this program supported 11 different projects in the departments of Civil and Environmental Engineering, Electrical and Computer Engineering, General Engineering, Mechanical and Industrial Engineering, Natural Resources and Environmental Sciences, Theoretical and Applied Mechanics, and the Grainger Engineering Library. A list of AAR Technology Scanning Projects and faculty members follows. More information on these projects may be found by referring to each investigator's individual listings in departmental sections of the *2001 Summary of Engineering Research.*

* Denotes principal investigator.

- 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. Eng.)

- Freight Car Truck Rotational Friction
  T. Conry (Gen. Eng.)
- Environmental Fate of Creosote
  R. Larson (Natural Resources & Environ. Sci.), R. Sanford (Civil & Environ. Engr.)

- Improved Fatigue-Resistant Design of Thermite Rail Welds
  F. Lawrence (Civil & Environ. Engr.)

- Fracture Analysis of Broken Rails
  F. Lawrence (Civil & Environ. Engr.)

- Railroad Engineering Library and Information Retrieval Service
  W. Mischo, M. Schlembach, (Grainger Engr. Library)

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

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

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

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

Other railroad engineering projects include the following:

- Railroad Crosstie Accelerated Wear and Durability Testing, Including Use of Alternative and Recycled Materials
  P. Chow (Natural Resources & Environ. Sci.), various industry sponsors

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

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

RPI-AAR Railroad Tank Car Safety Research and Test Project

C. P. L. Barkan*
Railway Progress Institute; Association of American Railroads

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

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 the hazardous materials releases. Multivariate statistical techniques are being used to understand these relationships and to develop predictive models that use railway engineering data to predict the conditions in which a broken rail is most likely to occur.

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

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

Researchers are investigating the extent to which the rail network, and particularly critical features of the infrastructure, may be affected by a severe mid-America earthquake. GIS and various databases are being used to develop probabilistic estimates of the extent of critical infrastructure exposure to various levels of ground acceleration. This information and knowledge of the response of the infrastructure should enable researchers to

* Denotes principal investigator.

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.

Structural Engineering and Structural Dynamics

Mid-America Earthquake Center

D. P. Abrams*
National Science Foundation, CMS-9701785

The headquarters of one of three national earthquake engineering research centers is at the University of Illinois at Urbana-Champaign. The Mid-America Earthquake Center concentrates on reducing potential earthquake losses in the central and eastern United States by focusing on identifying local seismic hazards and developing strategies for retrofit of essential facilities and transportation systems. The center includes partners at the University of Memphis, Washington University, St. Louis University, Georgia Institute of Technology, Massachusetts Institute of Technology, and Texas A&M University. Numerous research projects will be funded through the center over a five-year period in the areas of structural and geotechnical engineering, seismology, social science, urban planning, and economics.

Performance of Rehabilitated URM Components

D. P. Abrams*
National Science Foundation, Mid-America Earthquake Center

The project investigates strength, stiffness, and deformation capacities of unreinforced masonry walls retrofitted with different rehabilitation techniques. Static load reversal tests on large-scale wall specimens are being done to define nonlinear force-deflection behavior and to relate lateral story drifts with specific performance limit states. The effectiveness of rehabilitation techniques applicable to masonry construction in the eastern and central United States will be explored, including reinforcing, posttensioning, surface coatings, and shotcrete. Computational models will be developed to simulate measured behavior and to help extrapolate test results to a wider range of wall types and configurations.

Earthquake Performance of Unreinforced Masonry Buildings

D. Abrams,* S. Orton
National Science Foundation, Mid-America Earthquake Center; U.S. Army Construction Engineering Research

Dynamic response of unreinforced brick masonry buildings is being investigated through analysis and experimentation on a typical two-story building system consisting of clay-unit masonry shear and bearing walls and flexible floor and roof diaphragms. A half-scale test structure is being subjected to a progression of multi-axial, simulated earthquake motions on the CERL shaking table to investigate dynamic response patterns as well as the effectiveness of selective retrofit techniques. Corresponding computational simulations are done to help discern tendencies in measured dynamic response and to develop new analysis tools for seismic assessment and rehabilitation of existing masonry buildings.

Advancing the Performance-based Seismic Design of Buildings

M. Aschheim,* I. Cuesta
National Science Foundation CAREER Award

This work will develop and validate simple techniques for the performance-based seismic design and rehabilitation of multistory buildings. Design techniques will utilize Yield Point Spectra, a variant of the Capacity Spectrum Method. Simple graphical techniques for determining combinations of strength and stiffness to achieve arbitrary performance objectives will be validated. Various strategies for addressing higher modes in design will be investigated to determine those for which response amplitudes are predicted well using a single mode analogy. Advanced multivariate statistical techniques will be applied to identify mode shapes in the results obtained from nonlinear dynamic analyses. Improved techniques for estimating peak interstory drifts will be evaluated. A laboratory module will be developed for use by the 22 undergraduate institutions nationwide that are acquiring bench-top shaking tables through the NSF CCLI program. Groups of students will design, build, instrument, and test small multistory frames. Data acquired will be postprocessed to identify fundamental response characteristics. The performance of the system as well as the utility of the design methodology will be assessed.

* Denotes principal investigator.

Analytical Assessment of Seismic Demands in Untopped Diaphragm Shear Connectors

M. Aschheim,* N. Hawkins, D. Kuchma, J. Baldwin, H. J. Lee
Precast/Prestressed Concrete Institute

The performance of parking garages in recent earthquakes has raised questions about the design of the floor diaphragms. This project assesses the demands placed on the connectors that are used to interconnect precast, prestressed concrete double-tee girders when subjected to simulated earthquake excitation. Techniques for estimating the demands using simple, design-oriented procedures will be developed.

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 using reduced-scale idealized structures subjected to simulated earthquake motions using 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.

Evaluation of Elastomeric Bearings

M. Aschheim,* N. Hawkins,* W. Gamble,* J. Schwartz, C. Ash
Illinois Transportation Research Council

The seismic hazard in the central U.S. was recognized only recently by the engineering profession. As a result, most of the bridges in Illinois were not designed for seismic actions. Elastomeric bearings provided to accommodate thermal movements of the bridge deck may have a beneficial role in mitigating the hazard. However, the mechanical properties of the bearings are known to be sensitive to temperature, age, and the chemical formulation of the elastomer. This project characterizes the mechanical behavior of bearings obtained from existing bridges throughout the state under various temperatures and loading conditions. Simulations of the dynamic response of representative bridges will assess the potential benefits of the bearings for improving the behavior of bridges.

Response Modification of Bridges

M. Aschheim,* C. Ash
National Science Foundation, Mid-America Earthquake Center

This project determines the effects of low temperature on the mechanical characteristics of elastomeric bearings used in the 10 states that border the seismic zones of New Madrid, Missouri, and Charleston, South Carolina. The degree to which the bearings stiffen at low temperatures has a significant effect on the damage expected in future earthquakes. New details to improve the seismic performance of existing bridges will be developed, including a low-profile fuse-type bearing suitable for replacement of existing fixed bearings.

Strategies for Displacement-based Design of Reinforced Concrete Bridges

M. Aschheim,* M. Inel
University of Illinois

Traditional seismic design practice has been concerned with providing ductility to members deforming inelastically. Often, this has resulted in columns having relatively large diameters and an increased vulnerability to shear failure. Ductility capacity, however, is only important in its relation to ductility demand, and this can be expressed equivalently in terms of displacement capacity and demand. This project explores design strategies having the objective of achieving sufficient displacement capacity relative to the corresponding displacement demands.

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.

* Denotes principal investigator.

Fracture Mechanics in the Ductile-to-Brittle Transition Region

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

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

Fracture of Welded Steel Joints

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

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

Models for Ductile Crack Growth in Thin Aluminum Structures

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

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

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

R. H. Dodds, Jr.,* G. H. Paulino
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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 H_2 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

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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.

* Denotes principal investigator.

A Rational Procedure for Determining R Factors for Seismic Design of Buildings

D. A. Foutch*
U.S. Army Construction Engineering Research

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. The goal of this project is to develop a method for assigning R values based on analytical and experimental studies. Analysis procedures developed for the FEMA-sponsored SAC program will be used.

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.

Torsional Seismic Response of Structures

D. A. Foutch
U.S. Army Construction Engineering Research Laboratory; 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.

Analysis of Seismic Retrofit Measures for Major Bridges

J. Ghaboussi,* S. Nam
National Science Foundation, Mid-America Earthquake Center; University of Illinois

Methods of analysis 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.

Detection of Hidden Faults in Rails

J. Ghaboussi,* S. Jung
Association of American Railroads; Sperry Rail Service

Undetected hidden cracks in rails can grow and lead to track failure and possibly to costly derailments. The conventional method of rail inspection is to periodically run detector cars which may use ultrasonic detection techniques. The objective of this project is to use neural networks to aid in the process of detection. Using field measurements, neural networks are trained to identify possible hidden flaws from the traces generated by the ultrasonic detectors.

Smart Fiber Optics System for Condition Monitoring of Railway Bridges

J. Ghaboussi,* D. A. Foutch;* S. L. Chuang,* (Elect. & Comput. Engr.); J. H. Chou, N. Limsamphancharon
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.

* Denotes principal investigator.

High-Explosive Shock Transmission and Shock Spectra

W. J. Hall,* G. W. McMahon
U.S. Army Waterways Experiment Station; University of Illinois

The objective of this research is to investigate the ground motion effects associated with accidental detonation of munitions stored in underground rock cavities, with emphasis on defining source and wave transmission parameters. In addition, the response of simple systems (shock spectra studies) will be undertaken and will include consideration of nonlinear effects. The goal is to arrive at techniques for estimating "effects" of explosives on civilian and military systems and for improving design and analysis techniques.

Assessment of Remaining Capacity of Deteriorated Pretensioned Deck Beam Bridges

N. M. Hawkins,* D. A. Lange,* J. Fuentes
Illinois Department of Transportation

There are more than 1,200 pretensioned deck beam bridges on the Illinois Department of Transportation inventory of Illinois state highways and an additional 6,000 such bridges on county inventories. Several of these bridges in the northern part of the state have shown unacceptable levels of corrosion deterioration after only about 20 years of service. Procedures that can be used to determine the degree of corrosion in existing bridges, the rate at which that corrosion is proceeding, and the likely remaining service life of those bridges are being explored.

Precast Concrete Slabs for Airfield Pavements

N. M. Hawkins,* E. J. Barenberg,* S. Wattar
Precast/Prestressed Concrete Institute

Concrete is the preferred material for most airfield pavements. However, rehabilitation of existing concrete pavements at busy airports causes schedule disruptions felt nationwide. In this project, the feasibility of using precast concrete slabs for pavement replacement is being examined through the development of a design for a typical precast slab and examination of optimum construction procedures for supporting and post-tensioning such slabs. Researchers also will characterize appropriate details for joints between construction segments.

Seismic Strengthening of Bridge Columns

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Many of the bridge columns built in mid-America in the 1960s have inadequate strength lap splices at connections between those columns and their foundation beams. During an earthquake, those lap splices are likely to be the first, or one of the first, elements of the bridge to fail. This project is exploring cost-effective methods for assessing the vulnerability of such bridge columns and for seismically strengthening their lap splices in order to reduce the economic losses likely due to disruption of mid-American transportation networks during a future earthquake.

Shear Strength of Precast Concrete Inverted Tee Beams

N. M. Hawkins,* S. L. Wood,* R. A. Victor
Precast/Prestressed Concrete Institute

After the January 17, 1994, Northridge (Calif.) earthquake, it was observed that the ends of several inverted tee and double tee beams were cracked in shear at locations in which shear cracking was not anticipated. The partial collapse of some of the precast garages in the earthquake has been attributed to the propagation of those cracks. The implications of such failures for the precast concrete industry are being explored through a survey of producer practices, a detailed finite-element analysis of conditions in the end of inverted tee beams, and laboratory testing of such beams.

Use of Carbon Composites and Robotic Winding Technology to Upgrade Weather-Damaged Bridge Columns

N. M. Hawkins,* W. L. Gamble
Federal Highway Administration; Illinois Department of Transportation; XXsys Technologies

A combined field and laboratory examination is being made of the use of carbon composites and robotic winding technology to upgrade corrosion-damaged bridge columns in regions where subsequent freeze-thaw resistance and enhanced seismic performance are simultaneous considerations. Corrosion-damaged columns, simulating columns as repaired in the field, are being reproduced in the laboratory. The corrosion-damaged areas of those columns will be removed, the concrete repaired, the columns wrapped with carbon fiber jackets of varying forms, the wrapped columns subjected to multiple freeze-thaw cycles, and the seismic

* Denotes principal investigator.

performance of the inadequate length lap splices at the column bases examined. The performance of the laboratory columns will be correlated with that of the field columns at the end of the two-year study period.

Web-based Bibliography for Structural Identification

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University of Illinois

Every novice researcher faces the monumental task of getting a grip on the existing literature. Staying abreast of the literature in a field is difficult and time consuming. An ordinary committee assignment to assemble a state-of-the-art report on structural identification led researchers to seek a more effective model of such a report that makes use of current Web-based tools. This pilot project aims to develop an online database of articles on structural identification. The database will include self-reporting of contributions by authors and online reviews by experts in the field. The database will help to classify and characterize contributions (as is done in a traditional state-of-the-art report or literature survey).

Analytical Assessment of Seismic Demands in Untopped Diagram Shear Connectors

D. Kuchma, M. Aschheim*
Prestressed Concrete Institute

There are several issues regarding the design and behavior of precast parking structures that 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.

Earthquake Engineering Experimental Research: Development of Standards for Data Collection and Data Sharing

D. Kuchma*
National Science Foundation, Mid-America Earthquake Center

Existing models for predicting the strength and behavior of structures subjected to seismic action are less accurate than desired. Improved models can and are being developed from extensive experimental research programs. Unfortunately, the impact of the experimental work is often limited by the common practice of reporting only a summary of the research results in paper form. The Internet now provides a medium for publishing the complete experimental results (including images). A host site is being developed for dissemination of this information. This site will properly deal with issues of authorship and standardization.

Effect of Superstructure Flexibility on Bridge Deck Deterioration

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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 will address 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.

Examination of Strut-and-Tie Design Methodologies: Implications on Practice Through the Use of a Computer-based Design and Analysis Tool

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Portland Cement Association

There is a complex variation of strain in the portions of a concrete structure that are near a discontinuity, such as an abrupt change in cross-section dimension or a concentrated force. These D-discontinuity regions are currently designed using empirical relationships that have been shown to poorly predict capacity. One emerging and rational procedure for the design of D-regions is to imagine that an internal truss (strut-and-tie model) supports the applied load and to provide reinforcing steel to act as the tension members of the truss. A Windows-based computer program is being developed to help designers use this method.

Improved Shear Design Provisions for Structural Concrete

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The current building code for structural concrete requires the designer to consider dozens of empirical and

* Denotes principal investigator.

impenetrable relationships in order to determine the required shear reinforcement to use in a beam. This is an unsatisfactory situation. In addition, recent research has revealed that these relationships are not conservative, particularly for large or lightly reinforced concrete members. A review of experimental test data is being conducted to identify shortcomings in the test data bank and to facilitate the development of improved, more transparent design criteria.

Seismic Performance of Light-Frame Construction

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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.

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 of Functionally Graded Materials: Modeling, Synthesis, and Experiments

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National Science Foundation, CMS 9996378

This project involves an investigation of functionally graded materials (FGMs) within a framework that integrates modeling, materials processing, and mechanical properties experiments. Special emphasis is given to the influence of compositional distribution functions on the structural behavior and the mechanics of crack initiation and propagation in FGMs under mechanical and/or thermal loads. The FGM system $MOSi_2$/SiC and Nb/Nb_5Si_3 are investigated. A novel technique, developed at UC-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 are 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 their suitability for the problem at hand.

Fracture Mechanics of Viscoelastic Functionally Graded Materials

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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

* Denotes principal investigator.

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.

Functionally Graded Material Applications to Advanced Thermal Protection Systems

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

Generalized Isoparametric Finite Elements for Fracture of Functionally Graded Materials

G. H. Paulino,* J. H. Kim
University of Illinois

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

High Order Gradient Theory for Fracture of Functionally Graded Materials

G. H. Paulino,* Z. Dong
Campus Research Board, University of Illinois

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

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Computational Science and Engineering Program, University of Illinois

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

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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.

Estimation of Tank Car Inspection Interval

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Union Tank Car, T99-101

Railway tank cars with stub sills are subject to fatigue cracking in weldments in the area where the tank is supported on the sill, which may eventually lead to component failure. In this project, a damage tolerance analysis (DTA) methodology is being developed, in cooperation with other tank car builders and owners and Southwest Research Institute, with the objective of establishing required inspection intervals for stub sill-type tank cars. The DTA involves the use of finite-element stress analyses of the tank cars in conjunction with fracture mechanics-based fatigue crack growth calculations.

Strength of Simple Joints

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Design formulas for the ultimate static strength of steel tubular joints in offshore structures have, since the early 1970s, been based primarily on data from large-scale testing programs. Over the last decade, 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 this phase of the project is to establish appropriate guidelines for modeling and numerical analysis of tubular joints and to carry out a parametric study on the strength of simple uniplanar K-joints under balanced in-plane brace loading.

Where Has All the Creosote Gone? An Exploration of PAH Degradation by Microbes and Sunlight

R. A. Sanford,* J. Holt, H. Howerton, R. Larson
University of Illinois Environmental Council; Railroad Industry

Creosote is an undefined, commonly used wood preservative. Its main components are polycyclic aromatic hydrocarbons (PAHs), many of which are known toxins with carcinogenic and mutagenic properties. It is known that some PAHs can be degraded by microorganisms, and some PAHs can also be degraded photolytically. The combined effects of photodegradation and biodegradation, however, have not been determined. The objectives of this research are to investigate these processes individually and in concert and to show how they impact the fate of PAHs in the environment.

System Safety, Reliability, and Design

Development of Minimum Life Cycle Cost Design Criteria

Y. K. Wen,* Y. J. Kang
National Science Foundation, CMS 95-10243; Campus Research Board

As a large number of the civil constructed facilities in this country were built in the first half of this century and many are too expensive to replace, the repair-and-retrofit problem will become more acute. The objective of this study is to develop design criteria for new and existing systems based on consideration of life-cycle costs. The emphasis is on proper modeling of the uncertainty in resistance of and loadings on the facilities, costs of failure consequences, and discounting of cost and loss over time. The problem is formulated as that of a constrained minimization problem. The results show that current design against winds and earthquake loads are suboptimal. The design is dominated by the hazard of the largest uncertainty and the hazard causing highest consequence. The lesser hazards, however, still contribute. Also, uniform reliability against different hazards is not required.

* Denotes principal investigator.

Fragility Analysis of Essential Facilities in Mid-America

Y. K. Wen,* S. H. Song, K. W. Liao
National Science Foundation, CMS 97-01785 COOP

Essential facilities (EF) such as hospitals and fire stations are crucial in postearthquake disaster relief. Based on inventories carried out in Memphis, Tenn., St. Louis, Mo., and Carbondale, Ill., representative EF structural types have been identified. Structural modeling and response analysis of these structures with or without retrofit can be carried out under uniform hazard ground motions in the form of response spectra or ground motion time histories. The results are used to obtain the probabilistic performance curves of the facilities, which allow evaluation of the adequacy of the current facilities and the effectiveness of retrofit by comparing reduction in expected loss versus retrofit cost.

Multihazard Approach to Force-Protection Design

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A scoping study is being carried out on current state-of-the-art design against blast loads and research necessary for a risk-based multihazard approach to this problem. The current largely deterministic approach based on mechanical analysis and test results for force-protection design is reviewed. The need for a comprehensive risk-based multihazard approach to this problem is identified. Several salient features of future required research include evaluation of reliability implied in current load combination against blast loads; development of statistical and probabilistic models for quantification of the large uncertainty of blast loads; and development of necessary simple design format to include such loads in current design procedure.

Multivariate Regression Analysis of Tank Car Lading Loss

Y. K. Wen,* D. G. Simpson,* Y. J. Kang, L. Fu
Association of American Railway; Sims Engineers

A multivariate regression analysis is being carried out to establish the relationship between probabilities of railway tank car lading loss and sources of loss as a function of tank car attributes and track type. The results will provide a basis for car manufacturers, railway regulators, and commercial shippers to make better evaluation of future tank car performance and quantitative risk assessment. A database of accident records in the last 30 years of 6,000 tank cars is used. Results obtained so far indicate the importance of insulation, shelf coupler, head shield, and shell thickness. Effectiveness of these features in reducing lading loss probability is also quantified.

Redundancy Factor For Structures Under Seismic Forces

Y. K. Wen,* C. S. Wang, K. W. Liao
National Science Foundation, CMS 95-10243, CMS 97-01785 COOP

The emphasis of this study is on investigation of a proper redundancy factor for design under seismic load. In addition to structural configuration, the randomness of ground excitation, inelastic structural response behavior, uncertainty in structural resistance, and torsional effect are all considered. The results are compared with NHERP redundancy factor ρ, which is a function of the structural configuration only. The results obtained thus far indicated that the ρ factor generally produces inconsistent results. It overestimates the effect of configuration and underestimates those of nonlinear dynamic response, 3-D dynamic motion, and structural ductility capacity.

Redundancy of Dual Systems under Random Dynamic Loads

Y. K. Wen,* S. H. Song
National Science Foundation, CMS 95-10243, CMS 97-01785 COOP

The redundancy concept in structural engineering has been used often, but there is also misunderstanding of the concept and interpretation when there is uncertainty in both loading and structural resistance. The redundancy under static loads in terms of reliability has been investigated extensively by researchers in the past. Redundancy under random dynamic loads, such as seismic forces, has not been fully understood. This study concentrates on reliability and redundancy of dual systems under stochastic loadings. The results show that, contrary to common belief, the structural configuration (for example, the number of shear walls) is not the most important contributing factor to structural redundancy. The nonlinear, 3-D response and ductility capacity play a more important role.

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Transportation Facilities and Systems

Center for Excellence for Airport Technology

B. J. Dempsey,* Director; E. J. Barenberg,* Assoc. Director; M. R. Thompson,* Assoc. Director
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 is a cooperative partner 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. An experienced research team has been assembled for conducting basic research in airport technology, including modeling of airport pavement structures, constitutive behavior of pavement materials, material characterizations, and wildlife hazard abatement and systems.

The COE has completed research in 13 project areas (11 projects at the U of I and 2 at NU) relating to pavement structural modeling, materials, subgrades and base courses, nondestructive evaluation, design, and management.

Eight COE projects are presently in progress and include *Analysis of Pavement Responses at Denver International Airport, Analysis of NAPTF Pavement Response Data, Materials Testing and Evaluation for the NAPTF, Modifications to NIKE3D for Pavement Analysis, Fatigue Resistance of Airport Concrete Pavements, Reflective Crack Mitigation for Bituminous Overlays on Airfield Pavements, Wildlife Hazard Abatement Systems,* and *Graduate COE Minority Summer Research Program with NC A&T.* 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/refining its recently developed 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/or new) and layer configurations/arrangements; will include new design features (such as improved load transfer devices in concrete pavements); and will accommodate a broad range of aircraft loadings. Numerous publications 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://uiairpave.ce.uiuc.edu.

Analysis of Data from the Denver International Airport

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Federal Aviation Administration, Center of Excellence for Airport Pavements

Instruments installed in pavement sections at the Denver International Airport (DIA) have been collecting data since 1995. Currently several gigabits of data have been collected on the behavior of these pavements under climatic and aircraft loading. The objective of this study is to organize these data into usable formats, to compare the pavement responses indicated by these instruments with theoretical predictions, and to evaluate the changes in pavement behavior over time. Information obtained from these studies is critical to the development of improved and more economical pavement design procedures for the new generation aircraft such as the Boeing 777 and Airbus 380.

Development of Signal Coordination Models for Congested Networks

R. F. Benekohal,* G. Abu-Lebdeh
Federal Highway Administration (Eisenhower Fellowship)

This study investigates the current signal coordination procedures and develops a methodology for handling coordination of congested intersections. The current signal coordination models rely primarily on delay as the measure of effectiveness. However, the delay model used in these procedures is not developed for congested conditions, thus the coordination plans are not very accurate or effective. Other measures of effectiveness are examined to optimize traffic flow through a congested network of intersections.

* Denotes principal investigator.

Enhancements to IDOT Traffic Management Algorithms

R. F. Benekohal,* A. Butzek, M. Girianni
Illinois Department of Transportation

The IDOT maintains travel time information obtained from its traffic sensors for freeway segments in the northeast Illinois region. These are used to inform motorists of expected travel times by way of radio and television station traffic reports, World Wide Web traffic maps, and changeable message signs. This research is to incorporate travel time information taken from electronic toll collection records to give the IDOT complete travel time information for all tollways in addition to freeways in northeast Illinois. Algorithms are being designed, calibrated, and validated to provide estimates of tollway segment travel times based on real-time toll transaction information.

Evaluation of Automatic Vehicle Identification in a Weigh-in-Motion System for CVO

R. F. Benekohal,* J. Barnett, Y. El-Zohairy, C. Tirums
Illinois Department of Transportation

This study evaluates the performance of an automatic vehicle identification (AVI) and a high-speed weigh-in-motion (WIM) system to preclear trucks around the weigh stations. This project includes the following studies: travel time and flow interruption, overall performance of the system, an opinion survey, comparison of WIM and static scales data, and traffic safety and accidents around weigh stations. The AVI system will be installed on commercial vehicles, and the WIM will be at the mainline speed of vehicles.

Evaluation of Pilot Study of Advisory On-Board Vehicle Warning Systems at Railroad Grade Crossings

R. F. Benekohal,* E. Forrler, M. Aycin
Illinois Department of Transportation

This study will evaluate the effectiveness of advisory on-board vehicle warning systems at five railroad grade crossings. Approximately 300 commercial vehicles will be outfitted with the on-board system. The vehicles will be provided with supplementary on-board warning messages to advise them of a train approaching or occupying the crossings. Four opinion surveys will be conducted with drivers before the modality is switched. Emphasis will be placed on the reaction/perception of drivers to the information provided and how well drivers understood the information. The system reliability and effectiveness will also be determined.

Interconnected Rail–Highway Intersection Signal System Simulator

R. F. Benekohal,* R. Morocoima
Partnership Illinois Funds; University of Illinois

This project will provide hands-on education and training opportunities on the use of complex railroad-highway interconnect signal systems. A simulation model for an interconnected rail-highway intersection signal system simulator (IRISSS) will be developed. It will be used to educate and train municipal and state officials on safe and effective use of these systems. IRISSS not only will be an educational tool, but also will be used to showcase the potential for future partnerships with private and public agencies.

Modeling Platooning and Headway Characteristics of Vehicles

R. F. Benekohal,* S. Sadeghhosseini
University of Illinois

This study examines the platooning and headway characteristics of vehicles at different traffic volumes. Models for platoon size distributions are developed, and the relationships between platoon size and platoon headway are studied. Spacing, speed, and safe following distances are determined, and potential safety impact of each is examined. A significant portion of vehicles platoon even at relatively low-volume conditions. Understanding the platooning characteristics of vehicles would help to utilize the ITS technologies that would increase the traffic throughput and improve traffic safety.

Multilevel Analysis of Highway Accidents

R. F. Benekohal,* E. Shim
University of Illinois

The objectives of this study are to conduct multilevel analyses of highway traffic accidents. The relationships between accident frequency and geometry, traffic composition, and capacity of highways are examined. Accident data are grouped into different levels, and correlations among different levels and variables are examined. Furthermore, longitudinal and cross-sectional analyses are made to determine the temporal and spatial effects of variables on accidents.

Platooning Effects on Delay at Signalized Intersections

R. F. Benekohal,* Y. El-Zohairy
University of Illinois

This study is developing delay models that directly consider the platooning characteristics of vehicles at

* Denotes principal investigator.

signalized intersections. The Highway Capacity Manual (HCM) delay models use an adjustment factor to account for the platooning effects. The 94 HCM uses a delay adjustment factor, DF, that can increase the uniform delay by 256% or reduce it by more than 70%. The new models eliminate the need for applying delay adjustment factors. Delay models are developed that consider the platooning characteristics as a part of the model derivation. The effects of platoon size and platoon density are formulated on the intersection delay.

Technology Transfer Models for FAA Center of Excellence

R. F. Benekohal,* F. Colemen III,* E. Shim
Federal Aviation Administration, Center of Excellence for Airport Pavement Research

The project will develop a framework for airport pavement technology transfer. The primary objectives of this study are identifying, reviewing, and evaluating the most current, emerging, and new technology transfer techniques appropriate for the Center of Excellence, recommending viable options to the FAA for accomplishing the technology transfer, and preparing at least one demonstration package to illustrate the most viable option(s). A website is being developed and is expected to become an integral component of an ongoing technology transfer mechanism for the center.

Traffic Flow Simulation Models for Unsignalized Intersections

R. F. Benekohal,* M. F. Aycin
University of Illinois

Traffic flow characteristics at unsignalized intersections influenced by the adjacent signalized intersections are modeled. The flow behavior at the microscopic level is studied and mathematical models are developed to describe it. Car-following models are developed for the signalized and unsignalized intersections. A computer program has been written and debugged. Calibration and model validation are in progress. Effects of platooning on delay at unsignalized intersections will be studied using this model.

Analysis of Flexible Overlay Systems for Airport Pavements

W. G. Buttlar,* J. Bauer, 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,* J. M. Bauer
Test Quip, Inc.; Pine Instrument Company

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.

Rehabilitation Alternatives for Runway 18-36 at Rantoul, Ill.

W. G. Buttlar,* S. H. Carpenter, B. J. Dempsey, M. R. Thompson, S. M. Smith
Illinois Division of Aeronautics

The National Aviation Center (NAC) at Rantoul, Ill., was originally constructed as part of the Chanute Air Force

* Denotes principal investigator.

Base during the World War II era. The condition of the 60-year-old concrete runways and taxiways is generally very poor. Under these conditions, maintenance costs are high (sweeping of FOD and other activities) and serviceability levels are low (smoothness, safety, and so forth). A demonstration project is under way to evaluate several strategies for the mitigation of reflective cracking at GAA pavements, including rubblization, the use of an Interlayer Stress Absorbing Composite (ISAC), and saw and seal. Sensors were installed in the pavement during construction to monitor deflections, strains, and temperature as a function of traffic and environmental loads.

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
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.

Compaction Characteristics of Hot Mix Asphalt Concrete

S. H. Carpenter,* W. R. Vavrik
Caterpillar Inc.

The characterization of deformation properties of hot mix asphalt concrete at temperatures and void levels representative of those encountered during paving have not been identified in a manner that would provide for optimization of construction equipment. With the new Superpave mixtures, the operation of pavers and rollers is even more crucial to attaining proper density prior to opening to traffic. This project will conduct specific stress path testing at air void levels up to 15% and temperature regimes up to 136 degrees C to characterize the deformation properties of one typical hot mix asphalt concrete mixture and to demonstrate equipment capabilities and data quality.

Developmental Work on Cold Patching Mixtures

S. H. Carpenter,* L. Diaz
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 which can indicate the required quality in the laboratory and in the field, allowing construction crews to test their finished patch before leaving the construction site.

Highway Problems: Illinois Cooperative Highway and Transportation Research Program

S. H. Carpenter*
Illinois Department of Transportation

Four separate projects were included in the Illinois Cooperative Highway Research Program in 2000. They range in subject from the development of an aggregate image analyzer to concrete column rehabilitation.

Materials Characterization for the National Airport Pavement Testing Facility

S. H. Carpenter,* E. Tutumluer,* K. Ghuzlan, U. Seyhan
Federal Aviation Administration Center of Excellence for Airport Pavement Research

Provide testing for materials utilized in the construction of the pavements undergoing full-scale testing at the Federal Aviation Administration's full-scale testing facility. The testing for response variables and performance characteristics will be used to interpret observed

* Denotes principal investigator.

performance of test sections under full-scale aircraft loadings to improve existing pavement design procedures.

SHRP Asphalt Testing for Performance-related Specifications

S. H. Carpenter,* W. Vavrik, N. Mannel, S. Behrman
Illinois Department of Transportation

The Strategic Highway Research Program (SHRP) has developed a new sequence of tests and specifications for asphalt cements and mixes to enhance the ability of specifications to provide a level of service in the constructed pavement. These new procedures require the use of new equipment and methods not normally used in the transportation industry. The objectives of this study are to install the new equipment, perform shakedown testing to establish operational characteristics, and then perform characterization testing of typical Illinois materials. This will include evaluating the suitability of asphalt cements and mixtures currently available to determine if modification will be required to satisfy the new Superpave specifications for Illinois climate, traffic, and materials.

Airport/Airline Simulation Integration in Wildlife Hazard Abatement System

P. Chen,* H. Hsing, D. Sun
Federal Aviation Administration

The objective of this research is to facilitate a virtual airport environment for the development and deployment of FAA's Wildlife Hazard Abatement System (WHAS). A special-purpose simulation-assignment model, AirLiniSim, will be used for the integration of the various sub-models in WHAS. This research is conducted in support of a continuing FAA program of research and development directed to airport safety technologies.

Earthquake Vulnerability of Air Transport System

P. Chen,* N. Guo, H. Hsing, D. Sun
National Science Foundation, Mid-America Earthquake Center

The goal of this project is to assess the impact of a major earthquake in the mid-America region on the nation's air transport system. This includes analyses of potential damage to airport infrastructure, impact on airport airside operations, the network effect on airlines' flight schedules as well as the resulting trip delays and cancellations. Both direct damage losses and indirect economic impacts will be estimated. A case study of the impact of the Nisqually earthquake on Seattle-Tacoma and Boeing Field airports will be conducted.

Wildlife Strike Risk to Airframes and Engines

P. Chen,* H. Hsing
Federal Aviation Administration

The objective of this research is to provide analysis support to the development of a risk-based assessment model for wildlife hazards at airports. This includes the construction of 3-D spatial airspace fragility, simulation of the impact on flight operations and safety, and forecast of various aspects of the aviation industry. The product of this project will be used to support Federal Aviation Administration ANM rule-making requirements.

Four-Quadrant Gate Safety Analysis

F. Coleman, III,* M. Chitturi
Federal Railroad Administration; U.S. Department of Transportation

A stochastic simulation model incorporating human factors, vehicle kinematics, vehicular volumes, and train operations has been formulated to determine four-quadrant gate operation values. This model will be modified to incorporate adverse weather conditions and driver decision-making into the four-quadrant gate simulation model.

Performance and Design of Separated (Unbonded) Overlays

M. Darter (ERES), J. Roesler,* L. Khazanovich (ERES), E. Kohler
Innovative Pavement Research Foundation

The majority of highway work over the next decade will be rehabilitating the existing pavement infrastructure. One viable option for rehabilitation of both existing concrete and asphalt pavements are separated or unbonded concrete overlays. A mechanistic-empirical design procedure for separated concrete overlays will be developed during this project along with recommended construction guidelines. Laboratory testing will also be conducted to obtain material properties for separated concrete overlays for input into finite element analysis.

Accelerated Pavement Loading System

B. J. Dempsey*
Illinois Department of Transportation

This research program is funded at $1.72 million and includes the design-build of a unique Accelerated Pavement Loading System (APLS) and development of a full-scale pavement testing site at the Advanced Transportation Research and Engineering Laboratory (ATREL). The APLS is unique in that it can be used to study accelerated loading effects on highway pavements,

* Denotes principal investigator.

airport pavements, and railroad tracks. The APLS can apply rolling loads ranging up to 80,000 pounds and at a speed up to 10 miles per hour. Site development at ATREL is nearing completion and the APLS is expected to be delivered in October 2001.

Performance Evaluation of Longitudinal Pipe Underdrains

B. J. Dempsey,* J. S. Stein
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. Progress to date has 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.

Cyclic Plasticity Models for Low-cycle Fatigue Analysis

K. D. Hjelmstad,* R. H. Dodds,* K. Bergeron
National Aeronautics and Space Administration, NAG 8-1751

High performance structures (such as space shuttle main engines) are often vulnerable to low-cycle fatigue (on the order of 10^4 cycles at intensities higher than would be typically associated with high-cycle fatigue). In this project researchers intend to model low-cycle fatigue using computational fracture mechanics tools. One of the key features required to solve this problem is a model that accurately captures the cyclic plasticity of the background material. This project aims to develop and implement better cyclic metal plasticity models in the context of continuum inelasticity.

Mixed Methods and Nonlinear Flexibility Methods for Structural Analysis

K. D. Hjelmstad,* E. Taciroglu
Department of Energy, Center for Simulations of Advanced Rockets

Displacement-based finite element formulations can perform poorly on certain types of problems. Mixed (variational) methods have been used to improve the performance of low-order finite elements. For example, mixed methods have been used to cure locking in bending-dominated problems in three dimension solids. Nonlinear flexibility methods have been recently proposed to accurately capture inelastic response of beam-type structures (such as found in plastic hinge regions). This project aims to find a consistent variational structure for nonlinear flexibility methods and to assess the relative merits of mixed versus displacement-based finite elements.

Effects of Traffic Signal Coordination on Accident Rates

F. Coleman III,* K. Venkataraman, A. Chong
Illinois Department of Transportation; Illinois Transportation Research Center

Signal coordination on higher volume roadways is a practice instituted to allow more efficient traffic movement on major streets. This has led to changes in driver behavior on the major and minor streets and affects the ability of pedestrians to cross streets safely. Preliminary analysis of accidents suggests a change in number and types of accidents related to driver and/or pedestrian behavior on roadways with signal coordination. This research will explore and identify if there is a correlation between signal coordination and a change in accident patterns along major corridors.

Human Factors and Hardware Reliability Analysis of a Vehicle-arresting Barrier (VAB) at Proposed High-Speed Passenger Train At-Grade Crossings

F. Coleman III,* M. Chitturi, D. D. Moses, K. Venkataraman
Illinois Department of Transportation; Federal Railroad Administration; U.S. Department of Transportation

Guidelines prepared by the Federal Railroad Administration (FRA) for high-speed passenger trains that are expected to travel at speeds between 110 mph and 125 mph require that at-grade crossings be blocked from vehicle entry. The FRA has accepted a proposal from the Illinois Department of Transportation to test a vehicle-arresting barrier at three sites along the proposed high-speed passenger train corridor. The objective is to fully document the demonstration of this new technology and to determine the operating requirements necessary for successful implementation.

* Denotes principal investigator.

High Performance Concrete for Transportation Structures

D. Lange,* J. Roesler,* M. D'ambrosia, C. Park
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. Laboratory material characterization of the early-age creep and shrinkage properties of HPC is being conducted for several mixes used by IDOT. HPC field projects are being instrumented and monitored for their performance. Data analysis is being completed to interpret the behavior of field HPC relative to the material properties measured in the laboratory.

Accelerated Pavement Testing of Continuously Reinforced Concrete Pavement Sections

J. Roesler*
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 pavement loading system (APLS), which can simulate 40 years of traffic in several months, will load and fail the test sections. The full-scale testing data will allow for better understanding of the failure of CRCP sections and for extrapolation to new extended-life CRCP sections on highway systems in Illinois.

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

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

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

Characterization and Design of Aggregate Interlock Joints in Concrete Pavements Using Surface Roughness Measurements

J. Roesler,* P. Chupanit
University of Illinois at Urbana-Champaign, 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.

Fatigue Resistance of Airport Concrete Pavements

J. Roesler,* P. Littleton
Federal Aviation Administration

With the introduction of the Boeing 777 aircraft for commercial service, the FAA 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, present 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.

* Denotes principal investigator.

Longitudinal Cracking Investigation on Continuously Reinforced Concrete Pavements

J. Roesler,* G. Ulreich
Illinois Department of Transportation

Over the past five years, IDOT 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.

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 guide, which predicts fatigue cracking at transverse joints. 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.

Fatigue Resistance of Airport Concrete Pavements

J. R. Roesler,* P. Littleton
Center of Excellence for Airport Technology

This research will address resistance of concrete slabs to fatigue cracking. The major areas that will be addressed in this research project are the effects of different load pulses (tridem versus single wheel gears) and slab thickness on the fatigue behavior of concrete slabs and the initial moisture and temperature curling strains and deflections in the concrete, prior to loading. The main objective of the fatigue testing is to determine how to count the number of fatigue cycle contributions for a tridem gear pass. The project consists of repetitively loading of full-scale concrete slabs in a specially constructed loading frame.

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

M. R. Thompson,* E. J. Barenberg,* B. J. Dempsey, C. Rao, F. Gomez, H. Ceylan, 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/mixture design and construction control (materials, soils, compaction, and such) data are available. Additional soils/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.

Mechanistic Design Implementation and Monitoring

M. R. Thompson,* E. J. Barenberg,* I. Kim
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 IDOT-sponsored projects. 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 and/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.

* Denotes principal investigator.

Upgrade Subgrade Stability Manual

M. R. Thompson,* E. Tutumluer*
Illinois Department of Transportation

The current IDOT 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).

Evaluation of Granular Material Quality for Pavement use

E. Tutumluer,* I. T. Kim
U.S. Army Corps of Engineers, Applied Research Associates; Indiana Department of Transportation

This research is primarily aimed at evaluating unbound and stabilized pavement granular materials for quality and potential performance in highway and airport pavement use obtained from laboratory testing using an innovative test device called University of Illinois FastCell. A new test procedure enables determination of the vertical and horizontal deformation behavior of laboratory samples under extreme compression and extension field stress conditions and establishes anisotropic modular (horizontal to vertical) ratios. These ratios are then conveniently related to performance indicators, such as shear strength and rutting potential of the materials in the field, and used to develop material specifications.

Laboratory Determination of Anisotropic Properties of Granular Materials

E. Tutumluer,* U. Seyhan
University of Illinois

Unbound aggregates essentially of a particulate nature are extensively used in the unstabilized bases and subbases of flexible highway and airport pavements. These granular layers loaded under anisotropic conditions typically exhibit a directional dependency of material properties. As the material stiffens, the deformability decreases with a higher modulus attained in the vertical loading direction. A new repeated load triaxial testing device, named FastCell, has been custom-designed to independently pulse either vertical or radial loading/confining pressures. Anisotropic properties of aggregates are determined in the laboratory from the measured vertical and radial specimen deformations. Significant improvements are achieved in material characterization of aggregates.

Structural Evaluation of Unbound Aggregate Bases to Support the 2002 AASHTO Design Guide Development

E. Tutumluer,* F. J. Chou
Aggregates Foundation for Technology, Research, and Education

With increasing demands being placed on highways through the heavier and increasing number of loads, it is critical that researchers better characterize the unbound aggregates component of the highway by incorporating recent advances in characterization. This research is primarily aimed at enhancing the understanding of actual anisotropic, stress-path dependent behavior of unbound aggregate bases and developing better characterization of the excellent compressive characteristics of the high-quality aggregates for proper representation in the newly developed AASHTO 2002 Design Guide. The research activities will be conducted in collaboration with project investigators at the International Center for Aggregates Research (ICAR).

Video Analysis of Aggregates

E. Tutumluer,* C. Rao, J. Stefanski
Federal Highway Administration

Aggregate particle shape, size, and gradation can impact the performance of asphalt concrete (AC) pavements. The Strategic Highway Research Program (SHRP) has developed a set of consensus properties to identify proper aggregates for AC mix designs. The efforts in this project are mainly focused on comparing results of different video imaging systems for flat and elongated particles, coarse aggregate angularity, and gradation. Both the precision and accuracy of results for each property are studied. The project has also facilitated the development of a new image analysis system, the University of Illinois Aggregate Image Analyzer, for automating the determination of the aforementioned high-priority aggregate properties.

Laboratory Evaluation of Anisotropic Properties of Fiber-stabilized Sands

E. Tutumuluer,* U. Seyhan, I. T. Kim
U.S. Army Corps of Engineers, Waterways Experiment Station

This research aims at evaluating anisotropic properties of fiber-stabilized sands as obtained from University of Illinois FastCell triaxial testing. The strength and modulus characteristics of just sand, fiber-stabilized sand, and fiber-stabilized sand and soil mixtures will be evaluated. Reinforcement mechanisms will be identified by investigating the effects of different types of fibers on horizontal and vertical moduli. Because the material is

* Denotes principal investigator.

better confined when fibers are present, horizontal modulus is expected to become higher, thus resulting in an increase in the anisotropic horizontal-to-vertical modular ratios. The results will be used to better characterize and model fiber-stabilized layers in flexible pavement systems.

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Hawkins, N. M., W. L. Gamble, F. P. Shkurti, and Y. Lin. **Seismic strengthening of inadequate length lap splices.** Proc. 12th World Conf. on Earthquake Engineering (Auckland, New Zealand, Jan. 2000) (2000).

Jin, Z. H., and G. H. Paulino. **Transient thermal stress analysis of an interior crack in a functionally graded material.** 2000 ASME Int. Mechanical Engineering Cong. and Expo. (Orlando, Fla., Nov. 2000) (2000).

Jin, Z. H. and G. H. Paulino. **Transient thermal stress analysis of cracked functionally graded materials.** 6th Int. Symp. on Functionally Graded Materials (Estes Park, Colo., Sep. 2000) (2000).

Mukherjee, S., M. K. Chati, and G. H. Paulino. **Adaptive meshless boundary node methods for three-dimensional problems.** 20th Int. Cong. of TAM (Chicago, Ill., Aug. 2000) 206 (2000).

Paulino, G. H. and Z. H. Jin. **Fracture mechanics of viscoelastic functionally graded materials.** 6th Int. Symp. on Functionally Graded Materials (Estes Park, Colo., Sep. 2000) (2000).

Paulino, G. H. and Z. H. Jin. **Fracture of viscoelastic functionally graded materials.** 2000 ASME Int. Mechanical Engineering Cong. and Expo. (Orlando, Fla., Nov. 2000) (2000).

Paulino, G. H. and Z. H. Jin. **Viscoelasticity theory of functionally graded materials.** 20th Int. Congr. of TAM (Chicago, Ill., Aug. 2000) (2000).

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Paulino, G. H., Y. S. Chan, and A. C. Fannjiang. **Strain gradient elasticity theory for mode I crack in functionally graded materials.** 6th Int. Symp. on Functionally Graded Materials (Estes Park, Colo., Sep. 2000) (2000).

Pothisiri, T. and K. D. Hjelmstad. **The effect of non-uniqueness of parameter estimation schemes on damage detection.** EM2000, 14th Engineering Mechanics Conf., ASCE (Austin, Tex., May 21-24, 2000) (2000).

System Safety, Reliability, and Design

Kang, Y. J. and Y. K. Wen. **Minimum lifecycle cost design criteria under multiple loads.** Proc. 8th ASCE Joint Specialty Conf. on Probabilistic Mechanics and Structural Reliability (Notre Dame, Ind., Jul. 24-26, 2000) (2000).

Song, S. H. and Y. K. Wen. **Redundancy of dual systems under earthquake loads.** Proc. 8th ASCE Joint Specialty Conf. on Probabilistic Mechanics and Structural Reliability (Notre Dame, Ind., Jul. 24-26, 2000) (2000).

Wen, Y. K. **Reliability and performance-based design (keynote lecture).** Proc. 8th ASCE Specialty Conf. on Probabilistic Mechanics and Structural Reliability (Notre Dame, Ind., Jul. 24-28, 2000) (2000).

Wen, Y. K. and Y. J. Kang. **Design against multiple hazard based on optimization (keynote lecture).** Proc. 9th Int. Federation of Information Processing (IFIP) WG 7.5 Conference on Reliability and Optimization of Structural Systems (Ann Arbor, Mich., Sep. 25-27, 2000) (2000).

Wu, C. L. and Y. K. Wen. **Generation of uniform hazard response ground motions for mid-America cities.** Proc. Int. Conf. on Monte-Carlo Simulation (Monte Carlo, Monaco, Jun. 18-21, 2000) (2000).

Wu, C. L. and Y. K. Wen. **Uniform hazard response spectra and ground motions for mid-America cities.** Proc. 8th ASCE Joint Specialty Conf. on Probabilistic Mechanics and Structural Reliability (Notre Dame, Ind., Jul. 24-26, 2000) (2000).

Transportation Facilities and Systems

Abu-Lebdeh, G. and R. F. Benekohal. **Micro-genetic algorithms for adaptive signal coordination.** Proc. 6th Int. Conf. on Application of Advanced Technologies in Transportation Engineering, ASCE (Singapore, Jun. 2000, accepted for publication) (2000).

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Al-Khateeb, G. G., and W. G. Buttlar. **Hollow cylinder tensile tester for asphaltic paving mixtures.** Proc. Mid-Continent Transportation Symp. (Ames, Iowa, May 2000) pp. 14-19 (2000).

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Yen, J. R. and P. S. Chen. **Measuring the level of service at airports using a fuzzy algorithm.** Conf. on Integrating Theory and Application, Institute of Operations Research and the Management Sciences Mtg., WB15 (San Antonio, Tex., Nov. 2000) (2000).

Theses

Construction Management

Assem, I. **An AI methodology to quantify the impact of change orders on construction productivity.** M.S. thesis, Department. of Building, Civil and Environmental Engineering, Concordia University, Montreal, Que., K. El-Rayes, adviser (2000).

Ramanathan, R. **Computerized scheduling and control of residential housing projects.** M.S. thesis, Department. of Building, Civil and Environmental Engineering, Concordia University, Montreal, Que., K. El-Rayes, adviser (2000).

Construction Materials

Abell, A. **Microstructure and its relationship to fracture in Portland cement mortar and concrete.** Ph.D. thesis, D. A. Lange, adviser (2000).

Altoubat, S. **Early age stresses and creep-shrinkage interaction of restrained concrete.** Ph.D. thesis, D. A. Lange, adviser (2000).

Bicer, B. **Thermal stresses in bonded concrete overlays at early ages.** M.S. thesis, D. A. Lange, adviser (2000).

Park, C. **Fracture behavior of masonry bond.** Ph.D. thesis, D. A. Lange, adviser (2000).

Rau, N. **Stress distribution in early age bonded concrete overlays.** M.S. thesis, D. A. Lange, adviser (2000).

Shin, H. C. **Early age behavior of bonded concrete overlays due to shrinkage and thermal changes.** Ph.D. thesis, D. A. Lange, adviser (2000).

Environmental Engineering and Science in Civil Engineering

Aragon, A. **Characterization of non-aqueous phase liquid dissolution in porous media using nuclear magnetic resonance imaging.** M.S. thesis, C. Werth, adviser (2000).

Arnaiz, E. **Foaming potential of *Gordonia amarae* grown under different conditions. Is foaming linked to cell wall hydrophobicity?** M.S. thesis, L. Raskin, adviser (2000).

Bebee, J. **Interactions between aluminum and phosphate in treated drinking water.** M.S. thesis, V. L. Snoeyink, adviser (2000).

Bleisteiner, S. **Hydrolysis of particulate organic matter in biofilm reactors.** M.S. thesis, Technical University of Denmark and the Technical University of Munich (Germany), E. Morgenroth, P. Harremoes, and P. Wilderer, advisers (2000).

Carrico, C. **Direct aerosol radiative forcing based on optical measurements at contrasting, climatically important sites.** Ph.D. thesis, M. J. Rood, adviser (2000).

Chu, H. H. **The use of wavelet analysis to assess the valve-movement response data of *Corbicula fluminea* and *Dreissena polymorpha* to environmental change.** M.S. thesis, E. E. Herricks, adviser (2000).

Corona-Vasquez, B. **Sequential inactivation of *Cryptosporidium parvum* with chlorine dioxide followed by free chlorine or monochloramine.** M.S. thesis, B. J. Marinas, adviser (2000).

de los Reyes, F. **Filamentous foaming in activated sludge systems: a study combining molecular and engineering approaches.** Ph.D. thesis, L. Raskin, adviser (2000).

Dillner, A. M. **Speciated local aerosol characteristics and radiative forcing at a rural midwestern site.** Ph.D. thesis, S. M. Larson, adviser (2000).

Driedger, A. M. **Inactivation of *Cryptosporidium parvum* oocysts with ozone, free chlorine and monochloramine.** M.S.E.E. thesis, B. J. Marinas, adviser (2000).

Eppich, J. D. **Sodium fate and transport in an urban stormwater wetland treatment system.** Ph.D. thesis, E. E. Herricks, adviser (2000).

Kiristis, M. J. **The abiotic and biotic reductions of bromate.** Ph.D. thesis, V. L. Snoeyink, adviser (2000).

Loor-Vela, S. **Anaerobic dissipation of 14C-acetochlor in flooded soil microcosms.** M.S. thesis, L. Raskin, adviser (2000).

Medrano Gener, A. **Biodegradation of methyhl tert-butyl ether by a mixed bacterial culture.** M.S. thesis, Technical University of Denmark, E. Morgenroth and E. Arvin, advisers (2000).

Ramirez, D. **Adsorption of organic vapors on tire, coal and phenol derived activated carbons.** M.S. thesis, M. J. Rood, adviser (2000).

Urban, M. A. **Ozonation of low-bromide waters in a flow-through ozone contactor: bromate formation and minimization.** M.S. thesis, R. A. Minear, adviser (2000).

Vera, S. **Evaluation of different polymeric organic materials (POMs) to stimulate reductive dechlorination.** M.S. thesis, C. Werth, adviser (2000).

Environmental Hydrology and Hydraulic Engineering

Caisely, M. E. **Hydraulic model study of a canoe chute for Illinois streams.** M.S. thesis, M.H. Garcia, adviser (2000).

Gonzalez-Castro, J. **Applicability of hydraulic performance graph for unsteady flow routing.** Ph.D. thesis, B. C. Yen, adviser (2000).

Hwang, J. H. **Flow structure and mixing rate in double diffusive gravity currents.** M.S. thesis, C. R. Rehmann, adviser (2000).

Peabody, A. M. **Hydraulic model study of the Boneyard Creek at Lincoln Avenue, Urbana, Illinois.** M.S. thesis, M. H. Garcia, adviser (2000).

Schuster, J. M. **Hydraulic model study for the optimization of the spillway at Batavia Dam, Fox River, Illinois.** M.S. thesis, M. H. Garcia, adviser (2000).

Geotechnical Engineering

Ajlouni, M. A. **Geotechnical properties of peat and related engineering problems.** Ph.D. thesis, G. Mesri, adviser (2000).

Al-Zoubi, M. S. **Stability of embankment dams following reservoir drawdown.** Ph.D. thesis, G. Mesri, adviser (2000).

Structural Engineering and Structural Dynamics

Black, E. **Seismic design and evaluation of multistory buildings with yield point spectra 2000.** Ph.D. thesis, M. Aschheim, adviser (2000).

Chou, J. H. **Study of condition monitoring of bridges using genetic algorithm.** Ph.D. thesis, J. Ghaboussi, adviser (2000).

Cuesta, I. **Using pulse R-factors to estimate structural response to earthquake ground motions.** Ph.D. thesis, M. Aschheim, adviser (2000).

Kim, Y. J. **Active control of structures using genetic algorithm.** Ph.D. thesis, J. Ghaboussi, adviser (2000).

Lee, K. **Performance prediction and evaluation of steel special moment frames for seismic loads.** Ph.D. thesis, D. A. Foutch, adviser (2000).

McMahon, G. W. **Development of an engineering model for prediction of ground shock from decoupled detonations.** Ph.D. thesis, W. J. Hall, adviser (2000).

Yun, S. Y. **Performance prediction and evaluation of low ductility steel moment frames for seismic loads.** Ph.D. thesis, D. A. Foutch, adviser (2000).

Structural Engineering and Structural Mechanics

Sidarta, D. E. **Neural network based constitutive modeling of granular materials.** Ph.D. thesis, J. Ghaboussi, adviser (2000).

System Safety, Reliability and Design

Song, S. H. **Structural redundancy of dual and steel moment frame systems under seismic excitation.** Ph.D. thesis, Y. K. Wen, adviser (2000).

Wu, C. L. **Earthquake motion simulation and reliability implications.** Ph.D. thesis, Y. K. Wen, adviser (2000).

Transportation Facilities and Systems

Al-Khateeb, G. G. **Development of a hollow-cylinder tensile tester to obtain fundamental mechanical properties of asphalt paving mixtures.** Ph.D. thesis, W. G. Buttlar, adviser (2000).

Habboub, A. K. **Evaluation/characterization of airport pavements using the impact-echo and spectral analysis of surface waves.** Ph.D. thesis, H. L. M. dos Reis, adviser (2000).

Hongschaovalit, P. **Development and evaluation of a modified VFR lighted flyway marker.** Ph.D. thesis, B. Dempsey, adviser (2000).

Shin, H. C. **Early age behavior of bonded concrete overlays due to shrinkage and thermal changes.** Ph.D. thesis, D. A. Lange, adviser (2000).

Vavrik, W. R. **Asphalt mixture design concepts to develop aggregate interlock.** Ph.D. thesis, S. Carpenter, adviser (2000).

Waldhoff, A. S. **Investigation of thermal cracking at Mn/ROAD using the superpave IDT.** M.S. thesis, W. G. Buttlar, adviser (2000).

Awards and Honors

Daniel P. Abrams
William and Flora Hewlett Fellowship, 1989
Xerox Award for Faculty Research, U of I College of Engineering, 1992
Hanson Engineers Professorship in Civil Engineering, U of I, 1997
President's Award, The Masonry Society, 1997
Scalzi Research Award, The Masonry Society, 1997

Alfredo 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

Mark A. Aschheim
General Electric Scholar Award, U of I College of Engineering, 1997

R. F. 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, U of I, 1989
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1991, 1993
IBM Innovations Award for Teaching, U of I Educational Technologies Board, 1991
Arthur M. Wellington Prize, American Society of Civil Engineers, 1993
Advisor's List for Excellence in Advising, U of I College of Engineering, 1994
Faculty Honor Member, Phi Kappa Phi, 1994
Certificate of Recognition for Outstanding Mentoring of Graduate Students (finalist), U of I Graduate College, 1997
Past President's Award, Institute of Transportation Engineers, 1998

LeRoy T. Boyer
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1989

William G. Buttlar
Walter J. Emmons Award, Runner-up, Best Technical Paper and Presentation, *Journal of the Association of Asphalt Paving Technologies,* 1996
General Electric Scholar Award, U of I 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, U of I College of Engineering, 1999
Fred Burggraf Award, National Academy of Sciences, Transportation Research Board, 2000

Samuel H. Carpenter
D. Grant Mickle Award, Transportation Research Board, 1989
Andersen Consulting Award for Excellence in Advising, College of Engineering, U of I, 1992
Everitt Award for Teaching Excellence, U of I College of Engineering, 1994
Advisor's Lists for Excellence in Advising, U of I College of Engineering, 1997

Peter S. Chen
Fellow, Advanced Institute for Transportation Infrastructure Engineering and Management, University of Texas, 1998
American Society of Civil Engineers Outstanding Instructor Award, U of I, 2000
Collins Scholar, College of Engineering, U of I, 2000

Mark M. Clark
Research Initiation Award, National Science Foundation, 1988
Xerox Award for Faculty Research, U of I College of Engineering 1994
Advisor's Lists for Excellence in Advising, U of I, College of Engineering 1997

Edward J. Cording
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, 1985-92

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.
Burlington Northern Foundation Faculty Achievement Award, U of I, 1990
Walter L. Huber Research Prize, American Society of Civil Engineers, 1991
Nathan and Anne M. Newmark Professor of Civil Engineering, U of I, 1997-2000
Munro Prize, International Journal of Engineering Structures, 2000
M. T. Geoffrey Yeh Chair in Civil Engineering, U of I, 2000-

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

K. El-Rayes
American Association of Cost Engineers Competitive Scholarship Award, 1992
Project Management Institute Excellence Award, 1993
Concordia University External Grant Holder Doctoral Scholarship, 1993-1996
FCAR-Bourse d'excellence pour des etudes de cycles superieurs, de perfectionnement et de reintegration a la recherché, Quebec, Canada, 1993-1996
American Association of Cost Engineers Scholastic Scholarship Award, 1994
School of Graduate Studies Teaching Assistantship Award, Concordia University, Canada, 1996
Doctoral Prize in Engineering and Computer Science, most deserving graduate of the Doctor of Philosophy Programme, Concordia University, Canada, 1999

Ben B. Ewing, Emeritus
Diplomate, American Academy of Environmental Engineers
Fellow, American Society of Civil Engineers
Past President, American Association of Professional Sanitary Engineers

Douglas A. Foutch
Arthur M. Wellington Prize, American Society of Civil Engineers, 1990
Haliburton Award for Engineering Education Leadership, U of I College of Engineering, 1992
Norman Medal, American Society of Civil Engineers, 1992
Arthur M. Wellington Prize, American Society of Civil Engineers, 1998

Marcelo H. García
Hokkaido River Institute Lectureship, Japan, 1990
MUCIA International Development Travel Grant, 1992
Invited Professor, Institute di Idraulica, University of Genoa, Italy, 1993
Invited Professor, Universidad Nacional del Litoral, Argentina, 1995
Guest Lecturer, University of Essen, Germany, 1995
MUCIA International Program Development Award, Argentina, 1995
Karl Emil Hilgard Hydraulic Prize, American Society of Civil Engineers, 1996
Advisor's List for Excellence in Advising, U of I 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, U of I, 2000-2001

Jamshid Ghaboussi
Research Fellowship, Royal Norwegian Council for Scientific and Industrial Research (SINTEF), 1972-1973
Best Theoretical Paper Award, International Conference on Intelligent Engineering Systems through Artificial Neural Networks in Engineering, November 1997
Short Term Invitation Fellowship, Japanese Society for Promotion of Science, Spring 2000
Guest Chair Professorship, National Research Council of Taiwan, National Taiwan University, Taipei, Taiwan, Fall 2000

German R. Gurfinkel, Emeritus
Fellow, American Society of Civil Engineers
First Prize, Bridge Design Competition, Commission for National Development of Cuba, 1959
Danforth Teacher Award, Danforth Foundation, 1964

James F. Lincoln Arc Welding Foundation, nine awards, 1973, 1977-1983, 1988
Three Awards for Innovative Design, Structural Engineers Association of Illinois, 1981, 1984, 1989
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, U of I Student Chapter, 1991, 1995, 1999
Harriet and Charles Lucian Undergraduate Distinguished Teaching Award, U of I, 1992
Most Outstanding Paper Award, *ASCE Journal of Performance of Constructed Facilities,* 1997

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, U of I, 1986
C. Martin Duke Lifeline 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, U of I College of Engineering, 1993
Houser Medal, Earthquake Engineering Research Institute, 1998
National Honor Member, Chi Epsilon, 1998

John D. Haltiwanger, Emeritus
Distinguished Visiting Professor, U.S. Air Force Academy, 1977-1978
Bliss Medal, Society of American Military Engineers, 1981
Meritorious Public Service Award, U.S. Coast Guard, 1984
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1989
Stanley H. Pierce Award, U of I College of Engineering, 1990
Public Service Commendation, U.S. Coast Guard, 1994

Yousef Hashash
Arthur Casagrande Professional Development Award, Geo-Institute, ASCE, 2000
Presidential Early Career Award for Scientists and Engineers, President of the United States, William J. Clinton, 2000

Neil M. Hawkins
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

Alfred J. Hendron, Jr., Emeritus
Member, National Academy of Engineering

Edwin E. Herricks
Guest Professor, University of Essen, Germany
Fulbright Distinguished Professor, Yugoslavia
Education and Public Services Award in Water Resources, Universities Council on Water Research, 1992
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1992, 1993, 1998

Moreland Herrin, Emeritus
Past President, Association of Asphalt Paving Technologies
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, U of I College of Engineering, 1993
University Scholar, U of I, 1993
Advisor's List for Excellence in Advising, U of I College of Engineering, 1995

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

Praveen Kumar
New Young Investigator Award, National Aeronautics and Space Administration, 1996

David A. Lange
CAREER Award, National Science Foundation, 1996
Narbey Khachaturian Faculty Scholar, U of I Department of Civil and Environmental Engineering, 1998

Susan M. Larson
Lilly Endowment Teaching Fellowship, 1989
Everitt Award for Teaching Excellence, U of I College of Engineering, 1991
Presidential Young Investigator Award, National Science Foundation, 1991
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1993
Finalist, Harriet and Charles Luckman Undergraduate Distinguished Teaching Award, 1993
Xerox Award for Faculty Research, U of I College of Engineering, 1994
Advisor's List for Excellence in Advising, U of I College of Engineering, 1995

Jon C. Liebman, Emeritus
Fellow, American Association for the Advancement of Science
Outstanding Civil Engineering Teacher Award, U of I 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, U of I College of Engineering, 1989
Rose Award for Teaching Excellence, U of I College of Engineering, 1997

James H. Long
Shell Faculty Award, 1987
Newmark Scholar Award, U of I, 1991-1992

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, U of I Department of Civil and Environmental Engineering, 1999-2000

W. Hall 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
Visiting NTNF Senior Scientist, Norwegian Geotechnical Institute, 1981
Norman Medal, American Society of Civil Engineers, 1988
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

Roger A. Minear
Faculty Achievement Award, University of Tennessee College of Engineering, 1977
American Water Works Association, adviser of student (J. C. Bird) receiving Academic Achievement Award for Best Master's Thesis, 1980
Past President, Association of Environmental Engineering Professors, 1980
Tennessee Tomorrow Professor Award, University of Tennessee College of Engineering, 1980
Armour T. Granger Professorship in Engineering, University of Tennessee, 1983
American Water Works Association, adviser of student (C. M. Morrow) receiving Academic Achievement Award for Best Master's Thesis, 1984
First Distinguished Service Award, Association of Environmental Engineering Professors, 1984
Distinguished Service Award, American Chemical Society, Division of Environmental Chemistry, 1985
Certificate of Merit for co-authorship of paper, American Chemical Society, Division of Environmental Chemistry, 1991, 1992, 1993

Commander's Award for Distinguished Public Service, U.S. Army Construction Engineering Research Laboratories, 1993
Universities Council on Water Resources, adviser of student (M. A. Nanny) receiving first place award for outstanding water resources dissertation, 1995
Guest Professorship, Nankai University Department of Environmental Science, China, 1996
Visiting Research Scholar, Kyoto University Laboratory for the Control of Environmental Micropollutants, Japan, 1996

Barbara S. Minsker
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

Eberhard Morgenroth
Ulrich-Finsterwalder-Award for an outstanding Ph.D. thesis, sponsored by Dykerhoff & Widmann, presented by the Technical University of Munich Department of Civil Engineering, 1998
Collins Scholar in the Academy for Excellence in Engineering Education, U of I, 2001

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

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

I. Dennis Parsons
Presidential Young Investigator Award, National Science Foundation, 1991

Glaucio H. Paulino
Collins Scholar, U of I, 2000

David A. Pecknold
Outstanding Civil Engineering Undergraduate Teaching Award, U of I Student Chapter, American Society of Civil Engineers, 1978, 1992
Outstanding Paper Award, *ASCE Journal of Performance of Constructed Facilities,* 1997

John T. Pfeffer, Emeritus
Illinois Association of Sanitary Districts Trustee Service Award, 1989
J. J. James R. Croes Medal, American Society of Civil Engineers, 1993
Clarence W. Klassen Award, Illinois Association of Water Pollution Control Operators, 1991

Lutgarde Raskin
Research Initiation Award, National Science Foundation, 1994
Fellow, U of I 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, U of I College of Engineering, 1997
CAREER Award, National Science Foundation, 1998
Narbey Khachaturian Faculty Scholar, U of I 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

Chris R. Rehmann
Post-Doctoral Scholarship, Woods Hole Oceanographic Institution, 1996
Incomplete List of Teachers Ranked as Excellent by Their Students, U of I, 1998-2000

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

Mark J. Rood
Past Treasurer and Executive Board Member, Association of Environmental Engineering Professors

Adviser to graduate student advisees who have won national paper-writing and presentation awards from the Air and Waste Management Association, American Chemical Society and Biennial Conference on Carbon, 1989, 1990, 1991, 1992, 1993, 1995, 1997, 1999
Incomplete List of Teachers Ranked as Excellent by Their Students, U of I, 1990, 1992, 1998, 1999
Andersen Consulting Advisor Award, U of I College of Engineering, 1991, 1993, 1994, 1999
James M. Montgomery Master's Thesis Advisor Award, Association of Environmental Engineering Professors, 1992
Associate Editor, *Journal of Air and Waste Management Association,* 1994-
Associate Editor, *Journal of Environmental Engineering,* 1998-
Richard A. Glenn Best Paper Award, 214th ACS National Meeting Fuel Chemistry Division, 1997

William C. Schnobrich, Emeritus
Fellow, American Concrete Institute
Senior U.S. Scientist Award, Alexander Von Humboldt Foundation, Germany

Chester P. Siess, Emeritus
Engineering Hall of Distinction, Louisiana State University
Member, National Academy of Engineering
Honorary Member and Past President, American Concrete Institute
Honorary Member, American Society of Civil Engineers
National Honor Member, Chi Epsilon

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
William L. Everitt Undergraduate Teaching Excellence Award, U of I College of Engineering, 1982, 1998
Outstanding Civil Engineering Teacher Award, U of I ASCE Student Chapter, 1982
Best Paper Award, Research Division, American Water Works Association, 1983
Campus Award for Excellence in Undergraduate Teaching, U of I, 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, U of I 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, U of I 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, U of I College of Engineering, 2000
Warren A. Hall Medal, The Universities Council on Water Resources, 2000

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 Cassagrande Professional Development Award, American Society of Civil Engineers, 1992
Xerox Award for Faculty Research, U of I College of Engineering, 1993
DOW Outstanding New Faculty Award, American Society for Engineering Education, 1994
William J. and Elaine F. Hall Scholar Award, U of I 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, U of I, 1998-2001
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1999

Leslie J. Struble
Fellow, American Ceramic Society
Young Investigator Award, National Science Foundation, 1992

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
Certificate of Recognition, Engineering Education Scholars Program, 1997
General Electric Scholar, U of I, 1997
General Electric Fellow, U of I Academy for Excellence in Engineering Education, 1999
Collins Fellow, U of I, 2000
Fred Burggraf Award for Excellence in Transportation Research, Transportation Research Board, National Academy of Sciences, 2000

Valocchi, Albert J.
NATO Fellowship, Visiting Lecturer, Summer School on Environmental Dynamics, Venice, Italy, 1990
Invited Lecturer, NATO Advanced Study Institute on Migration and Fate of Pollutants in Soils and Subsoils, 1992
Danish Research Academy Fellowship to support a visiting professorship at the Technical University of Denmark, 1993

William H. Walker, Emeritus
Andersen Consulting Award for Excellence in Advising, U of I College of Engineering, 1989

Y. K. Wen
Fellowship, Japan Society for the Promotion of Science, 1986, 1996
Moisseiff Award, American Society of Civil Engineers, 1986
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1986
Research Prize, International Association of Structural Safety and Reliability, 1997

Kam W. Wong, Emeritus
Walter L. Huber Civil Engineering Research Prize, American Society of Civil Engineers, 1971
Talbert Abrams Award, American Society for Photogrammetry and Remote Sensing, 1971
Outstanding Teacher Award, U of I 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

Ben C. Yen
Fellow, American Society of Civil Engineers
Fellow, International Water Resources Association
Fellow, Japan Society for the Promotion of Science
Fulbright Distinguished Senior Lecture Award, 1988
Member, Center for Advanced Studies, University of Virginia, 1988-1991
National Science Council (Taiwan) Distinguished Lectureship, 1989
National Science Council (Taiwan) Distinguished Professorship, 1992
Best Technical Note Award, American Society of Civil Engineers Hydraulic Division, 1994
Honorary Distinguished Professor, Hohai University, China, 1994
Ven Te Chow Memorial Lecture Award, International Water Resources Association, 1996
Best Discussion Award, ASCE Journal of Irrigation and Drainage Engineering, 1999
Hunter Rouse Hydraulic Engineering Lecture Award, American Society of Civil Engineers, 1999
Sino Tech Science and Technology Distinguished Lecture Award, Taiwan, 2000
Hong Kong Environmental Hydraulics Fellowship, 2001

J. Francis Young, Emeritus
Fellow, American Ceramic Society
Fellow, American Concrete Institute
Bruanauer Award, Cements Division, American Ceramic Society, 1988
Copeland Award, American Ceramic Society, 1992

Patents

Rood, M. J., P. Sullivan, and K. J. Hay. Selective Sorption, Desorption, and Liquification of Vapors for Gas Streams. Invention Disclosure Statement to RTMO, TF00018 (2000).