

## Civil, Construction, and Environmental Engineering Research Projects 2005-06

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The Department of Civil, Construction, and Environmental Engineering encourages active collaboration and cross-disciplinary activities and has a strong commitment to innovative research. The department supports close partnerships with industry and government in an effort to conduct research at the cutting edge of science and technology. Research sponsored and funded by organizations such as the National Science Foundation, the US Environmental Protection Agency, and the North Carolina Department of Transportation is focused primarily in serving public needs and enhancing the ability of industry and government to respond to those needs.

Departmental research and educational activities are strengthened through its centers and laboratories. The Center for Nuclear Power Plant Structures, Equipment and Piping performs research on innovative solutions to problems in nuclear power plants and transfers this technology to the industry. The Constructed Facilities Laboratory (CFL) is located on the University's Centennial Campus and is part of the Larry K. Monteith Engineering Research Center at NC State University. The research and development programs of the CFL support the mission of the Centennial Campus of creating industry, government, and university partnerships. The CFL is a sophisticated structure with specially designed reaction floors and walls to support three-dimensional loading. A \$2.9 million Academic Research Infrastructure grant, co-funded by the National Science Foundation and NC State University, provided extensive state-of-the-art research equipment for constructed infrastructure research. Also on the Centennial Campus is the Institute for Transportation Research and Education (ITRE), which is conducting research, education, and technical assistance projects related to surface transportation issues. ITRE, which is administered at the university level, carries out numerous activities in collaboration with our faculty and graduate students. It is also the administrative home of the Center for Transportation and the Environment, which also involves our faculty and students.

The projects described in this brochure are examples of some of the exciting research taking place in the Department. They are also illustrative of our efforts to create solutions through innovation and multidisciplinary research contributions covering a broad spectrum of basic and applied research. The faculty in Civil, Construction, and Environmental Engineering, their students, and colleagues continue to identify new research opportunities in an effort to find solutions to the problems currently faced by the profession and to predict issues that will challenge the profession in the future.

## PROGRAMS OF GRADUATE STUDY

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The Department of Civil, Construction, and Environmental Engineering offers graduate programs with a major in Civil Engineering leading to the degrees of

- Master of Civil Engineering (MCE) – available both on-campus and by distance education
- Master of Science (MS)
- Doctor of Philosophy (PhD)

Each degree program is available with the following areas of specialization:

- Computer-Aided Engineering
- Construction Engineering and Management
- Geotechnical/Geoenvironmental Engineering
- Structures and Mechanics
- Transportation Systems and Materials
- Water Resources, Coastal, and Environmental Engineering

In addition, interdisciplinary programs, such as Public Works Engineering/Administration, encourage a breadth of background from several specialties. Graduate students are encouraged to take supporting courses in a second area of specialization in civil engineering or the strong supporting programs in other departments of the University, including mathematics, statistics, computer science, operations research, business, economics, public administration, city and regional planning, marine, earth and atmospheric sciences, and others.

The research conducted by graduate students under the direction of the faculty both educates the student in the research process and advances the knowledge available for application in industry. The ability gained by the student in research advances their careers in industry where new methods of design and construction must be frequently discovered, evaluated, and applied. The university research results are published by the students and faculty and conveyed to national societies and industry associations where model codes, specifications, and regulations are promulgated. The faculty are active as members and leaders of such organizations and, as a result, are able to bring this state-of-the-art knowledge to the classroom.

To aid the practicing professional who later discovers the need for advanced study but is not located near a university with appropriate master's programs, the Master of Civil Engineering degree is available by distance education. The requirements for the on-campus and the distance student are the same, and thus the degree awarded is the same. Over 40 of the on-campus courses are now offered in the distance mode.

For more information go to: [www.ce.ncsu.edu](http://www.ce.ncsu.edu)

## COMPUTER-AIDED ENGINEERING

### Application of Municipal Solid Waste Decision Support Tool to Wake County, North Carolina

*M.A. Barlaz and S.R. Ranjithan*

*US EPA*

*\$59,999*

*12/04 to 12/06*

The objective of this project is to develop alternatives for the management of municipal solid waste for Wake County, NC. Alternatives will be developed to examine tradeoffs among cost, environmental burdens, resource consumption and landfill diversion using a solid waste management life-cycle inventory model developed by the investigators.

### Modeling and Optimization of Civil Engineering Infrastructure

*J.W. Baugh and E.D. Brill*

*Blue Ridge Analytics*

*\$341,500*

*12/04 to 12/05*

In this project, computer software was developed to model and optimize civil engineering infrastructure problems using mathematical programming and heuristic search methods. The techniques were designed so that methods could be readily implemented to provide alternative solutions, which would meet given constraints on modeled objectives and which could be provided to users of the software.

### Efficient Computational Methods for Accurate Simulation of Wave Propagation

*M.N. Guddati*

*National Science Foundation*

*\$257,530*

*01/01 to 09/06*

Wave propagation is encountered in countless problems of practical importance such as nondestructive evaluation, earthquake engineering, seismology, and medical imaging. In spite of its immense importance and extensive research performed, the current approaches to modeling of wave phenomenon still suffer from several shortcomings related to computational efficiency and accuracy. This project is aimed at devising new and efficient modeling techniques that would result in highly accurate solutions with relatively low computational cost. Most recent results from this research are related to dispersion reducing finite element methods and absorbing boundaries.

### Strategies for Atomistic-Continuum Coupling in the Simulation of Dynamic Fracture

*M.N. Guddati and P.K. Nukala (ORNL)*

*Un-sponsored*

*02/05 to present*

Detailed simulation of dynamic fracture can be performed by modeling the crack tip region using molecular dynamics, while modeling the rest of the domain as a continuum analyzed by finite element methods. When the two simulation domains are coupled in a conventional manner, there tends to be spurious heat-up (due to energy trapping) at the crack-tip region resulting from the disparity in length scales

combined with the discretization errors. In this project, we are attempting to develop numerical algorithms that minimize the spurious energy trapping, thus resulting in accurate simulation of the physical phenomenon.

### Remote Observation and Control of a Shake Table Experiment

*Abhinav Gupta, V.C. Matzen, and M.A. Gabr*

*NC State University, DELTA/ IDEAS Grant*

*\$9,900 (FY 2003-04), \$9,930 (FY 2004-05)*

This project supports tasks that are needed in addition to those being conducted in the development of a prototype for remote observation and control of a shake table experiment under an NSF-sponsored project. These tasks are needed to integrate the prototype with the University computing network for incorporation in distance education courses. The tasks need to be implemented in a manner that would maintain real-time safety as well as security features built into the prototype. While the tasks being undertaken are specific to the shake table experiment, the outcome of this work can be extended to other experiments either directly or with only minor modifications.

### Development of Multi-axial VEPCD-FEP++ and its Extension to Indirect Tension Test

*Y.R. Kim and M.N. Guddati*

*Federal Highway Administration*

*\$499,907*

*09/05 to 08/07*

Over the past decade, the NCSU research team has been successful in developing HMA models that can accurately capture various critical phenomena such as microcrack induced damage, strain rate – temperature interdependence, and viscoplastic flow that is critical for high temperature modeling; the resulting model is termed the viscoelastoplastic continuum damage (VEPCD) model. The primary objectives of this research are to (1) extend the VEPCD model to multiaxial state of stress; (2) develop a three-dimensional finite element program with the multiaxial VEPCD model; and (3) extend the principles used in the VEPCD modeling to the indirect tension mode.

### Development of the Asphalt Pavement Performance Prediction Methodology Based on the Viscoelastoplastic Continuum Damage Theory

*Y.R. Kim and M.N. Guddati*

*Korea Highway Corporation*

*\$335,021*

*10/04 to 12/06*

The primary objectives of this research are (1) standardization of test and analysis methods for the determination of viscoelastic properties and performance of asphalt mixtures; (2) development of the multiaxial viscoelastoplastic continuum damage (VEPCD) models using the indirect tension test and triaxial permanent deformation test; (3) development of the VEPCD finite element program (VEPCD-FEP++); (4) calibration of the VEPCD-FEP++ using the data measured from the KHC Test Road pavements; (5) development of transfer functions for the 33 asphalt pavements in the Test Road; and (6) development of a user-friendly graphic interface for pre- and post-processing of the VEPCD-FEP++.

### **Tools and Techniques for the Technological Integration of Multi-Hazard Post-Incident Assessment**

*D. Laefer and W.J. Rasdorf*  
*National Science Foundation*  
 \$52,818  
 12/03 to 08/05

Infrastructure management information systems (IMISs) are being created with ever greater rapidity, at all levels of government and private industry. These IMISs are, however, dispersed, stand-alone, in widely disparate formats, not reflective of historical developments, and not easily identified or readily accessed. Thus, they do not promote information exchange between agencies and organizations that would profoundly benefit from shared resources, especially in this time of acute budgetary constraints. The purpose of this project is to identify ways to eliminate these deficiencies and to organize and present a workshop to assist in obtaining solutions for the problems identified.

### **DDDAS-TMRP (Collaborative Research): An Adaptive Cyberinfrastructure for Threat Management in Urban Water Distribution Systems**

*G. Mahinthakumar, E.D. Brill, R. Ranjithan (Co-PI's, NCSU), J. Uber (PI, University of Cincinnati); Gregor Von Laszewski (PI, University of Chicago); and K. Harrison, (PI, University of South Carolina)*  
*National Science Foundation (Dynamic Data Driven Application Systems Program)*  
 \$779,986 (NCSU share is \$264,624)  
 01/06 to 12/08

The goal of this multidisciplinary research is to develop a cyberinfrastructure system for water distribution system threat management that will both adapt to and control changing needs in data, models, computer resources and management choices facilitated by a dynamic workflow design. Using virtual simulation and a field study, this cyberinfrastructure will be tested on illustrative scenarios for adaptive management of contamination events in water distribution systems.

### **PERC: High-end Computer System Performance: Science and Engineering**

*G. Mahinthakumar*  
*UT Battelle LLC*  
 \$189,203  
 10/01 to 06/06

This project is part of a larger scale effort funded by DOE through the SciDAC (Scientific Discovery through Advanced Computing) program. The overall goal of the project is to establish an enabling technology center in the area of high-end computer performance called performance engineering research center (PERC). The NC State University component of this project will focus on performance analysis, performance modeling, and performance tool evaluation.

### **High-end Computing in Environmental Engineering with Application to Subsurface Characterization**

*G. Mahinthakumar*  
*National Science Foundation (Career)*  
 \$400,000  
 07/03 to 06/08

Accurate characterization of the subsurface is an important element in the development of reliable and efficient groundwater management practices. Accurate and reliable estimation of hydraulic conductivity distribution, contaminant distribution, and/or contaminant source release history is necessary for problems such as estimating groundwater yields, design of efficient cleanup strategies, and identifying responsible parties in a contamination incident. This requires solution of an inverse problem because direct measurement of detailed subsurface properties is not feasible. Inverse problems are difficult to solve and are computationally demanding. This multidisciplinary NSF Career project will investigate novel computational strategies for the efficient solution of large-scale inverse problems in subsurface characterization.

### **ITR: A Prototype to Support Near Real-Time Environmental Characterization**

*G. Mahinthakumar, R. Ranjithan, and Nick Karonis*  
*(Northern Illinois University)*  
*National Science Foundation*  
 \$497,418  
 09/03 to 08/06

The overall goal of this project is to investigate formal computational approaches that can readily harness grid computing for the efficient solution of environmental characterization problems. To this end, we will develop a grid-enabled software framework. Two alternative paradigms, one based on the grid-enabled version of MPI (Message Passing Interface), and the other based on Java will be explored. The framework will be applied to groundwater and surface water problems, both of which are of prime societal importance.

### **GRS Supplement to ITR to Increase Minority Participation**

*G. Mahinthakumar and R. Ranjithan*  
*National Science Foundation (Graduate Research Supplement program)*  
 \$33,986  
 09/05 to 08/06

This graduate research supplement supports an African American environmental engineering PhD student to conduct research in parallel simulation-optimization techniques and to carry out teaching activities leading to an academic career.

### **Development of a Design Tool for Planning Aqueous Amendment Injection Systems**

*R.C. Borden (NCSU), G. Mahinthakumar (NCSU), T.J. Simpkin (CH2M HILL), and C. Zawtocki (Solutions-IES)*  
*DOE, Environmental Security Technology Certification Program*  
 \$503,000  
 03/06 to 12/08

The overall objective of this project is to develop a set of tools to assist design engineers in developing effective, reasonably efficient systems for distributing aqueous amend-

ments for *in situ* treatment of groundwater contaminants. At this time, the primary applications for the tools will be for design of *in situ* chemical oxidation systems using permanganate and *in situ* anaerobic bioremediation systems using soluble substrates and emulsified oil. However, as technology evolves, this general approach should be applicable to distribution of other aqueous amendments.

### **Web-Based Observation and Control of an Undergraduate Civil Engineering Laboratory Experiment**

*V.C. Matzen, A. Gupta and J. Nau*  
NCSU LITRE program  
\$8,000  
10/04 to 06/06

A static test of a cantilever beam in CE 324 is being modified so that it can be controlled and observed remotely using web-based tools. In the web-based setup, a controller with a stepper motor will be used to operate the screw actuator, and the strains will be monitored, recorded and displayed using a PC-based data acquisition system. The research will investigate appropriate ways to protect the experiment from overloading and internet/PC malfunctions, as well as procedures for scheduling, access, and security.

### **Internet-Enabled Laboratory Experiences for Undergraduate Civil Engineering Students**

*V.C. Matzen, M.A. Gabr, and A. Gupta*  
National Science Foundation  
\$134,000  
07/03 to 06/06

This study is aimed at adaptation of recent developments in information technology for incorporation of internet-enabled civil engineering laboratory experiments in undergraduate structures and geotechnical courses. Faculty and students will be able to remotely access, run, and control these experiments either independently or in a classroom setting. Such a capability would facilitate the offering of these courses via distance learning program to provide opportunities for “non-traditional” students (e.g., part-time student, working parent, and career-changing adult) seeking careers in civil engineering. Implementation of this work will lead to enhancing the quality of undergraduate civil engineering courses and making laboratory curriculum widely accessible.

### **Traffic Control Design for Portable Concrete Barriers**

*A. Mirmiran and S. Rahman*  
NC Department of Transportation  
\$87,168  
07/04 to 12/05

This project will focus on developing design aids and charts for portable concrete barriers in the State of North Carolina. Safe back distance behind these free standing barriers will be evaluated using finite element and impact analysis software for different boundary conditions and traffic configurations. The findings will be incorporated into the state’s traffic control manual.

### **GIS-Based Research of Natural and Anthropogenic Terrain Change Impacts on Water and Sediment Transport in Different Environments**

*H. Mitsova and M. Overton*  
Army Research Office  
\$118,212  
07/04 to 06/07

The proposed research will focus on the acquisition of new knowledge about the interactions between natural processes and anthropogenic activities that can be used to improve current understanding of terrain change impact on landscape processes. The objectives are to investigate these interactions within three fundamentally different environments affected by different development activity: a coastal barrier island environment, a montane tropical watershed, and a piedmont landscape that includes a military installation. The research will be directed toward the development and analysis of methods for GIS-based modeling of topography, its structure and evolution and innovative numerical landscape erosion and evolution modeling techniques.

### **Fuzzy Neural Network Models for Geotechnical Problems**

*S. Rahman*  
NC Department of Transportation  
\$97,841  
07/04 to 12/05

The main objective of the proposed research is to (1) develop a general framework and a computational toolbox for development of fuzzy neural network models to geotechnical problems, and (2) develop fuzzy neural network model for a variety of geotechnical problems of interest to the NC Department of Transportation: (a) hammer approval, and (b) settlement prediction.

### **Urban Watershed Management Tools**

*S. Ranji Ranjithan*  
US EPA/MCNC  
\$147,125  
10/01 to 09/04

US EPA’s Multimedia Integrated Modeling System (MIMS) provides a unified computing framework to simulate the cycling of environmental pollutants within and across all media. The simulation models are to be coupled with systems analytic methods (including uncertainty analysis and optimization-based search procedures) to explore and identify efficient strategies to manage urban watershed management problems. In addition, decision-makers require cost/benefit tradeoffs and reliability associated with different strategies. The objective of this project is to integrate urban watershed decisions support tools into MIMS, and demonstrate their use with US EPA’s Storm Water Management Model (version 5).

## Pavement Marking Analysis Plan

*W. Rasdorf*  
*NC Department of Transportation Technical Assistance*  
*Award*  
 \$13,678  
 5/15/06 to 5/30/06

The Work Zone Traffic Control Unit has almost 4 years of pavement marking retroreflectivity data. This data has been collected on all types of materials, surfaces, and regions in the State. The NC Department of Transportation (NCDOT) seeks to learn about the life cycle of pavement markings from this data. However, to be able to analyze all the data, the NCDOT needs to determine what information can be learned from the data and identify the components of a large-scale research project to do so.

## Workshop on Determining Disaster Data Needs in a Multi-Stage, Multi-Disaster Context

*W.J. Rasdorf*  
*National Science Foundation*  
 \$10,000  
 09/04 to 08/05

This project seeks to develop a common data framework for disaster-related data to establish whether or not this data set is both applicable to researchers and to members of the disaster response community. To determine this, a disaster management workshop was developed to establish a paradigm for the creation of the common data set. The objectives of the workshop were as follows: (1) define information needs; (2) establish the quality, format, and location of data; (3) identify data gaps and opportunities to improve data collection and dissemination methods; and (4) define objectives for pre-disaster organized disaster data gathering teams.

## Designing an Efficient Nighttime Sign Inspection Program that Ensures Motorist Safety

*W.J. Rasdorf and J.E. Hummer*  
*NC Department of Transportation*  
 \$132,857  
 07/04 to 06/06

The major objective of the research is to revise and expand out simulation of the effectiveness of sign inspection programs so that the NC Department of Transportation (NCDOT) can optimize its program. The main revisions to allow NCDOT to use the simulation are to (1) model the performance of NCDOT sign inspectors, (2) expand the simulation to include other sign colors besides yellow and red, and (3) include the best sign deterioration functions.

## CONSTRUCTION ENGINEERING AND MANAGEMENT

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### Life Cycle Inventory and Impact Analysis Framework for Nonroad Construction Vehicles and Equipment Based Upon In-Use Measurements

*H.C. Frey and W.J. Rasdorf*  
*National Science Foundation*  
 \$375,000  
 08/03 to 08/06

This project represents the initial step toward development of a probabilistic life cycle inventory and impact analysis framework for nonroad construction vehicles and equipment. The objectives are to (1) characterize second-by-second in-use emissions and energy use of nonroad construction vehicles and equipment, including emissions of NO<sub>x</sub>, CO, hydrocarbons (HC), CO<sub>2</sub>, and particulate matter (PM), including real time sensing and monitoring where needed to fill data gaps; (2) develop a life cycle inventory of conventional nonroad construction vehicles and equipment; and (3) identify and recommend methods for reducing energy use, emissions, and impacts.

### Real World Duty Cycles and Utilization for Construction Equipment in NC

*H.C. Frey and W.J. Rasdorf*  
*NC Department of Transportation*  
 \$164,730  
 07/05 to 06/07

Construction vehicles contribute substantially to statewide emissions. Thirty-two NC counties are partially or fully designated as non attainment under new air quality standards for ozone. Therefore there is a need to more accurately quantify the emissions from construction vehicles and seek opportunities to manage or reduce emissions. The goal of this study is to assess construction equipment types and uses, plan a field study, measure emissions and collect data, analyze the data and develop typical cycles, and demonstrate methods for estimating emissions for construction equipment.

### Instrumentation for Measuring Concrete Lateral Pressures in Formwork

*D.W. Johnston*  
*Institute of Construction*  
 \$4,000  
 07/05 to 06/06

Develop dual instrumentation systems for measurement of fresh concrete lateral pressures in formwork. Evaluate performance of the systems by collection of data of interest on construction sites.

### Value Engineering and Cost Effectiveness of Various FRP Repair Systems

*S. Rizkalla*  
*NC Department of Transportation*  
 \$83,663  
 07/05 to 06/06

This research program is designed to investigate the feasibility of using the most efficient externally bonded FRP repair/strengthening system to rehabilitate prestressed concrete

bridge girders damaged due to accident or collision impact causing loss of prestressing and/or spalling of concrete. The research will investigate the efficiency and cost-effectiveness of externally bonded FRP sheet and strip repair/strengthening systems using prestressed channel beams supplied by the NC Department of Transportation from existing bridges. It will also investigate the use of Near-Surface-Mounted FRP bars and strips to strengthen the same prestressed channel beams along with examining the flexural behavior under the effect of static and fatigue loadings.

### **I/UCRC Center, Repair of Buildings and Bridges with Composites (RB2C)**

*S. Rizkalla*  
National Science Foundation  
\$250,000  
07/02 to 06/07

The NSF Industry/University Cooperative Research Center entitled "Repair of Buildings and Bridges with Composites" (RB2C), is located at the Constructed Facilities Laboratory, North Carolina State University (NCSU). The Center is working in collaboration with the Center located at the University of Missouri-Rolla (UMR). The Center at NCSU focuses on the needs of the construction industry in development of new and innovative structural components as well as strengthening/repair methods for existing structures using advanced composite materials.

### **Evaluation of New Generation of Adhesives for Marine Structures**

*S. Rizkalla*  
IPS Corporation  
\$250,000  
07/02 to 06/07

The project investigates the behavior and material characteristics of two proposed adhesives designed for marine structures. The project is mainly an experimental study at this stage. The experimental program initially consists of lap shear test to determine the bond characteristics of two adhesives between two surfaces; each consists of Carbon Fiber Reinforced Polymer (CFRP) and steel surface. A specially designed insulated room has been constructed at the Constructed Facilities Laboratory to house the instrumentations, which were built to subject the specimens to the specified environment.

### **An Innovative Bridge Deck System**

*S. Rizkalla*  
Martin Marietta Composites  
\$250,000  
07/02 to 06/07

The research includes development of an innovative system for highway bridge decks. The system is also suitable for manufacturing trailer walls using small thicknesses. The innovative concept consists of two layers of 2-D fiber pultruded sheets and styrofoam layers in between to provide the required thickness. At a later stage, bundled fibers are inserted in the third direction to increase the strength through-thickness properties of the panels. The system is a modified process for the Z-technology used for the aerospace industry. The test program consists of different tests to examine the material characteristics as well as the behavior of the panel.

### **Developing a Simplified Method for Predicting Deflection in Steel Plate Girders Under Non-Composite Dead Load for Stage-Constructed Bridges**

*E.A. Sumner and S. Rizkalla*  
NC Department of Transportation  
\$149,000  
07/03 to 12/05

Matching the final bridge deck elevations in stage constructed steel girder bridges has created numerous problems during construction. Misaligned deck elevations between two stages may require grinding of the deck surface or result in reduced concrete cover leading to early deterioration of the bridge deck. The objective of this research is to develop an empirically based method to predict the non-composite deflection of steel plate girders in staged-constructed bridges. The formulation of the simplified method will require a combination of field measured data and extensive three-dimensional analytical simulation.

### **Construction Extension Development and Training**

*E.C. Weaver and R.A. Nuñez*  
Construction Extension Program and Institute of Construction  
\$388,500  
7/05 to 6/06

Develop and implement construction extension activities related to training and applied research on a wide variety of topics of interest to the construction industry. During 2005-06, workshops and seminars were attended by 2,500 participants. Programs developed and delivered included Concrete Testing Technician Certification, Fall Protection Safety, Confined Spaces Safety, Home Inspection, Stormwater Design, Wood Design, Wind Design, Construction Management, Financial Management, Construction Contracts, Estimating and Bidding, and Planning, Scheduling and Control, among others.

### **Implementation of Self-Consolidating Concrete (SCC) for Prestressed Concrete Girders**

*P. Zia and R. Nuñez*  
NC Department of Transportation  
\$55,426  
11/03 to 03/05

The objectives of this research are three-fold: (1) Determine and document the various properties of SCC used in the production of two prestressed SCC girders. (2) Monitor and document the actual production of two prestressed concrete girders using SCC. The girders will be selected from an NC Department of Transportation bridge project under contract. (3) Conduct static load tests of two SCC girders and one non-SCC girder at the production site. The girders will be tested to full service load condition in order to validate their design and performance. Subject to satisfactory performance, the girders may be delivered and installed in the bridge for service as other non-SCC girders.

## Pavement Marking Analysis Plan

*W. Rasdorf*  
*NC Department of Transportation Technical Assistance Award*  
 \$13,678  
 5/15/06 to 5/30/06

The Work Zone Traffic Control Unit has almost 4 years of pavement marking retroreflectivity data. This data has been collected on all types of materials, surfaces, and regions in the State. The NC Department of Transportation (NCDOT) seeks to learn about the life cycle of pavement markings from this data. However, to be able to analyze all the data, the NCDOT needs to determine what information can be learned from the data and identify the components of a large-scale research project to do so.

## GEOTECHNICAL

### Development of Permeable Reactive Barriers (PRBs) using Edible Oils

*R.C. Borden*  
*Department of Defense, SERDP*  
 \$482,500  
 01/01 to 01/07

The overall objective of this proposal is to develop the information needed to reliably design, construct, and evaluate edible oil barriers, including (1) identify factors controlling the loss of permeability during oil injection; (2) identify factors controlling oil biodegradation rate in aquifer sediments; (3) use these results to develop improved procedures for distributing and immobilizing oils that (a) do not cause an excessive decline in permeability, and (b) result in a slow, steady rate of *in situ* oil decay; and (4) use emulsion transport model to identify alternative barrier configurations and injection procedures to improve barrier performance and reduce costs.

### Anaerobic Biotreatment of Acid Mine Drainage at Ore Knob Mine

*R.C. Borden*  
*NC Department of Environment and Natural Resources*  
 \$153,194  
 08/05 to 07/08

Ore Knob Branch and Peak Creek are impaired due to discharge of acid mine drainage (AMD) from an abandoned copper/zinc mine. AMD production from the large tailings impoundment will be controlled by injecting emulsified soybean oil into the sediments to stimulate growth of naturally occurring bacteria. These bacteria will then use the soybean oil as a food source, consuming any dissolved oxygen and stopping further AMD production. Once oxygen is depleted, the sulfate reducing bacteria will reduce sulfuric acid to sulfide and precipitating heavy metals.

### Development of a Design Tool for Planning Aqueous Amendment Injection Systems

*R.C. Borden (NCSU), G. Mahinthakumar (NCSU) T. J. Simpkin (CH2M HILL) and C. Zawtockki (Solutions-IES)*  
*DOE, Environmental Security Technology Certification Program*  
 \$503,000  
 03/06 to 12/08

The overall objective of this project is to develop a set of tools to assist design engineers in developing effective, reasonably efficient systems for distributing aqueous amendments for *in situ* treatment of groundwater contaminants. At this time, the primary applications for the tools will be for design of *in situ* chemical oxidation systems using permanganate and *in situ* anaerobic bioremediation systems using soluble substrates and emulsified oil. However, as technology evolves, this general approach should be applicable to distribution of other aqueous amendments.

### Treatment of Acid Mine Drainage Using Emulsified Soybean Oil

*R.C. Borden*  
*United Soybean Board (through Smith, Bucklin & Associates, LLC)*  
 \$40,000  
 08/05 to 07/07

The United Soybean Board will provide matching support for a NC Department of Environment and Natural Resources (NC DENR) project to evaluate the use of emulsified soybean oil for treatment of acid mine drainage at the Ore Knob Mine in Ashe County, NC.

### NCSU/NCA&T Program for STEM Enrollment Enhancement

*J.J. Ducoste (Co-PI) (Other PIs: John Fountain, MEAS; Carrie Thomas, MEAS, Robert Borden, CCEE; David Haase, Physics; Christine Grant, CBE; Christopher Gould, Physics; Jesus Rodriguez, Math; and William Switzer, Chem)*  
*National Science Foundation*  
 \$399,938 (\$12,006 to CCEE Department)  
 01/03 to 12/05

North Carolina State University and North Carolina Agricultural and Technological State University are collaborating in developing a program designed to increase the number of graduates in science, technology, engineering and mathematics (STEM). Specific program elements include a summer camp at NCSU for graduating high school students who have not selected their majors, summer bridge programs at both NCSU and NCA&T designed to prepare new STEM students for introductory college science and math courses, undergraduate research programs at both schools, tutoring and mentoring of STEM majors, and a faculty exchange program between the two campuses.

## Numerical Study of Loading Conditions with Applications Using a Particulate Approach

*T.M. Evans*

*Un-sponsored (new faculty start-up funds)  
01/06 to present*

Axisymmetric laboratory tests are typically used for the characterization of the mechanical response of granular soils when determining design parameters. However, many of the structures of interest to geotechnical engineers result in plane strain loading conditions in the field (e.g., retaining walls, highway embankments). It is well understood that laboratory tests having plane strain boundary conditions will produce different results than those performed under axisymmetric boundary conditions. However, what is not understood is how these differences manifest themselves in soil microstructure and in field performance. The current study seeks to provide insight into these topics.

## Remote Observation and Control of a Shake Table Experiment

*Abhinav Gupta, V.C. Matzen, and M.A. Gabr  
NC State University, DELTA/ IDEAS Grant  
\$9,900 (FY 2003-04), \$9,930 (FY 2004-05)*

This project supports tasks that are needed in addition to those being conducted in the development of a prototype for remote observation and control of a shake table experiment under an NSF-sponsored project. These tasks are needed to integrate the prototype with the University computing network for incorporation in distance education courses. The tasks need to be implemented in a manner that would maintain real-time safety as well as security features built into the prototype. While the tasks being undertaken are specific to the shake table experiment, the outcome of this work can be extended to other experiments either directly or with only minor modifications.

## Design Criteria for Post and Beam Bents with Drilled Shafts and Other Structures

*M.J. Kowalsky and M. Gabr  
NC Department of Transportation  
\$316,941  
07/05 to 06/07*

The research described in this proposal aims to expand upon work currently underway for Pile-Bent bridge structures to all sub-structure systems employed by the NC Department of Transportation, including spread footings and columns supported on drilled shaft foundations. The research tasks encompass identifying issues specific to drilled shaft bent design and selection of a series of sample structures for analysis and design, as well as structural testing of bridge sub-structure to superstructure connections.

## Pile Bent Design Criteria

*M.J. Kowalsky and M.A. Gabr  
NC Department of Transportation  
\$149,307  
07/04 to 07/05*

The objective of this study is to develop improved design criteria for pile bents. Specifically, the work will be focused on (1) evaluating the impact of the pile cap rigidity to loads transferred to the piles within the bent, (2) specifying ap-

propriate k-factors for pile analysis under varying boundary conditions appropriate to the problem geometry and connection scenarios, (3) proposing appropriate point of fixity taking into account the presence of the soil around the pile above the specified point of fixity, and (4) proposing appropriate values for maximum lateral deflection for various boundary conditions and soil properties.

## Pile Bent Design Criteria

*M.J. Kowalsky and M.A. Gabr  
NC Department of Transportation  
\$326,813  
07/05 to 07/07*

Detailed 3D analysis models will be used to provide a better understanding of the actual performance of NC Department of Transportation sub-structure systems (depth to fixity; connection performance, effective length factors). In addition, the proposed work aims at providing a rational basis for identification of key performance limit states (drift and strength limits) as well as design examples comparing LFD and LRFD criteria for bridge sub-structures.

## Geosynthetics Workplan

*M.A. Gabr  
FHWA  
\$60,000  
09/05 to 08/06*

No definitive guidance on the value of systematically including geosynthetics in highway construction projects is currently available for the Federal Land Program of FHWA. It has been identified by engineers that geosynthetics are "under-used in Federal Lands Highway practice." Accordingly, this study aims at developing a geosynthetics work plan to identify, promote, and advance the use of geosynthetics materials across FLH Divisions in the Pavement and Geotechnical areas. The target areas include pavement and geotechnical applications. Geotechnical applications will be focused on slopes, walls, base reinforcement, column supported embankments, capillary barriers to mitigate frost heaving, deep patches for soft shoulders, and geocomposite clay liners to control seepage from ditches.

## Geologic and Environmental Modeling for Implementation of WIDE at Former Lockbourne Air Force Base

*M.A. Gabr  
Department of Defense, through W. Virginia University  
Water Resources Institute  
\$99,998  
07/05 to 12/06*

This project implements Well Injection Depth Extraction (WIDE) technology for removal of JP-4 aviation fuel from the subsurface. Performance evaluation for deployment of WIDE will be performed with continuous monitoring for optimization of contaminant extraction. Baseline comparison of expanded deployment pads to existing field installation will be conducted and results compiled to discern predominant mass transfer mechanisms (vapor, product, or aqueous phases).

## Internet-Enabled Laboratory Experiences for Undergraduate Civil Engineering Students

*V.C. Matzen, M.A. Gabr, and Abhinav Gupta*

*National Science Foundation*

\$134,000

07/03 to 06/06

This study is aimed at adaptation of recent developments in information technology for incorporation of internet-enabled civil engineering laboratory experiments in undergraduate structures and geotechnical courses. Faculty and students will be able to remotely access, run, and control these experiments either independently or in a classroom setting. Such a capability would facilitate the offering of these courses via distance learning program to provide opportunities for “non-traditional” students (e.g., part-time student, working parent, and career-changing adult) seeking careers in civil engineering. Implementation of this work will lead to enhancing the quality of undergraduate civil engineering courses and making laboratory curriculum widely accessible.

## Traffic Control Design for Portable Concrete Barriers

*A. Mirmiran and S. Rahman*

*NC Department of Transportation*

\$87,168

07/04 to 06/05

This project will focus on developing design aids and charts for portable concrete barriers in the State of North Carolina. Safe back distance behind these free standing barriers will be evaluated using finite element and impact analysis software for different boundary conditions and traffic configurations. The findings will be incorporated into the state’s traffic control manual.

## Fuzzy Neural Network Models for Geotechnical Problems Encountered by the NC Department of Transportation

*S. Rahman*

*NC Department of Transportation*

\$97,841

07/04 to 12/05

The main objective of the proposed research is to (1) develop a general framework and a computational toolbox for development of fuzzy neural network models to geotechnical problems, and (2) develop fuzzy neural network model for a variety of geotechnical problems of interest to the NC Department of Transportation: (a) hammer approval, and (b) settlement prediction.

## Analysis of the Characteristics of Seismic Ground Motion and Site Response Using Wavelets

*S. Rahman*

*Un-sponsored*

01/03 to 07/05

In this study, wavelet analysis will be applied to some important aspects of geotechnical earthquake engineering. The main objective of the proposed study to develop an effective method of wavelet representation of earthquake motions, and to study the general characteristics of earthquake motions with a focus on their energy contents in time and frequency domains, and to develop stochastic analysis for nonlinear and nonstationary site response.

## STRUCTURES AND MECHANICS

### Modeling and Optimization of Civil Engineering Infrastructure

*J.W. Baugh and E.D. Brill*

*Blue Ridge Analytics*

\$341,500

12/04 to 12/05

In this project, computer software was developed to model and optimize civil engineering infrastructure problems using mathematical programming and heuristic search methods. The techniques were designed so that methods could be readily implemented to provide alternative solutions, which would meet given constraints on modeled objectives and which could be provided to users of the software.

### Efficient Computational Methods for Accurate Simulation of Wave Propagation

*M.N. Guddati*

*National Science Foundation*

\$257,530

01/01 to 09/06

Wave propagation is encountered in countless problems of practical importance such as nondestructive evaluation, earthquake engineering, seismology and medical imaging. In spite of its immense importance and extensive research performed, the current approaches to modeling of wave phenomenon still suffer from several shortcomings related to computational efficiency and accuracy. This project is aimed at devising new and efficient modeling techniques that would result in highly accurate solutions with relatively low computational cost. Most recent results from this research are related to dispersion reducing finite element methods and absorbing boundaries.

### Remote Observation and Control of a Shake Table Experiment

*Abhinav Gupta, V.C. Matzen, and M.A. Gabr*

*NC State University, DELTA/ IDEAS Grant*

\$9,900 (FY 2003-04), \$9,930 (FY 2004-05)

This project supports tasks that are needed in addition to those being conducted in the development of a prototype for remote observation and control of a shake table experiment under an NSF-sponsored project. These tasks are needed to integrate the prototype with the University computing network for incorporation in distance education courses. The tasks need to be implemented in a manner that would maintain real-time safety as well as security features built into the prototype. While the tasks being undertaken are specific to the shake table experiment, the outcome of this work can be extended to other experiments either directly or with only minor modifications.

### **SST: Polymer Fiber and Waveguide Sensors for Performance-Based Assessment and Health Monitoring of Civil Infrastructure Systems**

*T. Hassan, M.J. Kowalsky, and K. Peters*

*National Science Foundation*

*\$430,000 (\$8,000 supplementary REU grant in 2005-06, and \$8,000 REU grant in 2006-07)*

*08/04 to 07/07*

The goal of the project is to develop polymer sensors for health monitoring of civil infrastructure systems. Of specific interest is to develop a sensor that can measure strains in excess of 6% under high strain rates. Although the sensors to be developed can be utilized under a variety of load conditions and structural materials, this research program will focus on application of the sensors to concrete and steel structures subjected to earthquake loads. The research will develop a data acquisition system that can be utilized in health monitoring and techniques for bonding the polymer sensors to concrete structures.

### **A Multiscale Study of Ratcheting Failure Mechanisms in Austenitic and Ferritic Steel Welded Joints**

*T. Hassan and K.L. Murty*

*National Science Foundation*

*\$319,000 (\$7500 supplementary REU grant in 2006-07)*

*08/04 to 07/07*

The goal of the project is to study multiscale failure mechanisms of austenitic and ferritic steel welded joints subjected to low-cycle fatigue loading. The progressive accumulation of strain with cycle known as ratcheting is believed to result in unexpected failures of defect-free joints. This project will perform low-cycle fatigue tests of welded joints and transmission and scanning electronic microscopy studies of dislocation substructures of the heat affected zone and base metals at various stages of fatigue life. Efforts will be made to develop a model for simulating ratcheting responses of welded joints using both macroscale and multiscale based constitutive models.

### **Calibration of Rutting Models for HMA Structural and Mix Design**

*R. Kim and M.N. Guddati*

*NCHRP 9-30A, Subcontract from Applied Research Associates, Inc.*

*\$70,000*

*11/05 to 10/08*

The objective of this research effort is to recommend revisions to the HMA rut depth prediction model in the mechanistic-empirical pavement design guide and software developed in NCHRP Project 1-37A for consideration by the NCHRP Project 1-40 panel and the AASHTO Joint Task Force on Pavements. The recommended revisions will be based on the calibration and validation of distress models with measured materials properties and performance data from existing field and other full-scale pavement sections that incorporate modified as well as unmodified asphalt binders.

### **Development of Multi-axial VEPCD-FEP++ and its Extension to Indirect Tension Test**

*Y.R. Kim and M.N. Guddati*

*Federal Highway Administration*

*\$499,907*

*09/05 to 08/07*

Over the past decade, the NCSU research team has been successful in developing HMA models that can accurately capture various critical phenomena such as microcrack induced damage, strain rate – temperature interdependence, and viscoplastic flow that is critical for high temperature modeling; the resulting model is termed the viscoelastoplastic continuum damage (VEPCD) model. The primary objectives of this research are to (1) extend the VEPCD model to multiaxial state of stress; (2) develop a three-dimensional finite element program with the multiaxial VEPCD model; and (3) extend the principles used in the VEPCD modeling to the indirect tension mode.

### **Development of the Asphalt Pavement Performance Prediction Methodology Based on the Viscoelastoplastic Continuum Damage Theory**

*Y.R. Kim and M.N. Guddati*

*Korea Highway Corp.*

*\$335,021*

*10/04 to 12/06*

The primary objectives of this research are (1) standardization of test and analysis methods for the determination of viscoelastic properties and performance of asphalt mixtures; (2) development of the multiaxial viscoelastoplastic continuum damage (VEPCD) models using the indirect tension test and triaxial permanent deformation test; (3) development of the VEPCD finite element program (VEPCD-FEP++); (4) calibration of the VEPCD-FEP++ using the data measured from the KHC Test Road pavements; (5) development of transfer functions for the 33 asphalt pavements in the Test Road; and (6) development of a user-friendly graphic interface for pre- and post-processing of the VEPCD-FEP++.

### **Characterization of ALF Mixtures Using the Viscoelastoplastic Continuum Damage Model**

*FHWA*

*Y.R. Kim and M.N. Guddati*

*\$199,795*

*08/03 to 08/05*

The primary objectives of the proposed research are to (1) verify the time-temperature superposition principle in damaged states for various asphalt mixtures used in the current ALF study; (2) characterize the ALF mixtures using the viscoelastoplastic continuum damage model; and (3) predict the performance of various ALF pavements using finite element analysis and the VEPCD model.

### **Behavior of Shear Dominated Reinforced Lightweight Concrete Members under Seismic Conditions**

*M.J. Kowalsky*

*Expanded Shale, Clay, and Slate Institute*

*\$18,170 plus negotiated donations*

*01/04 to 12/06*

The objective of the research described in this proposal is to develop a process by which the characteristic shear resistance under cyclic loading of various lightweight aggregates

concretes can be assessed. The need for this research stems from the following reasons: (1) small dataset of past reversed cyclic shear critical tests, (2) relatively large scatter in experimental data that has been observed for monotonic shear critical tests, (3) lack of consensus among major worldwide concrete codes on lightweight concrete shear performance, and (4) potential economic impact if it is shown that existing shear strength reductions are overly conservative.

### **Design Criteria for Post and Beam Bents with Drilled Shafts and Other Structures**

*M.J. Kowalsky and M. Gabr*  
*NC Department of Transportation*  
 \$316,941  
 07/05 to 06/07

The research described in this proposal aims to expand upon work currently underway for Pile-Bent bridge structures to all sub-structure systems employed by the NC Department of Transportation, including spread footings and columns supported on drilled shaft foundations. The research tasks encompass identifying issues specific to drilled shaft bent design and selection of a series of sample structures for analysis and design, as well as structural testing of bridge sub-structure to superstructure connections.

### **Pile Bent Design Criteria**

*M.J. Kowalsky and M.A. Gabr*  
*NC Department of Transportation*  
 \$326,813  
 07/05 to 07/07

Detailed 3D analysis models will be used to provide a better understanding of the actual performance of NC Department of Transportation sub-structure systems (depth to fixity; connection performance, effective length factors). In addition, the proposed work aims at providing a rational basis for identification of key performance limit states (drift and strength limits) as well as design examples comparing LFD and LRFD criteria for bridge sub-structures.

### **Influence of Low Temperatures on the Ductility of Bridge Structures in High Seismic Regions**

*M. Kowalsky and T. Hassan*  
*Alaska Department of Transportation*  
 \$100,000  
 08/05 to 07/07

Through a series of cyclic experiments on reinforced concrete circular columns at 20°C, 0°C, -20°C, -40°C and -50°C, this research will study the seismic responses of concrete structures at low temperatures. Based on the experimental results at the structural and material levels at various temperatures, ductility and seismic failure mechanisms of reinforced concrete members will be determined and design issues at low temperatures will be addressed.

### **Internet-Enabled Laboratory Experiences for Undergraduate Civil Engineering Students**

*V.C. Matzen, M.A. Gabr, and Abhinav Gupta*  
*National Science Foundation*  
 \$134,000  
 07/03 to 06/06

This study is aimed at adaptation of recent developments in information technology for incorporation of internet-enabled civil engineering laboratory experiments in undergraduate structures and geotechnical courses. Faculty and students

will be able to remotely access, run, and control these experiments either independently or in a classroom setting. Such a capability would facilitate the offering of these courses via distance learning program to provide opportunities for “non-traditional” students (e.g., part-time student, working parent, and career-changing adult) seeking careers in civil engineering. Implementation of this work will lead to enhancing the quality of undergraduate civil engineering courses and making laboratory curriculum widely accessible.

### **Web-Based Observation and Control of an Undergraduate Civil Engineering Laboratory Experiment**

*Vernon Matzen (PI), Abhinav Gupta and Jim Nau*  
*NCSU LITRE program*  
 \$8,000  
 10/04 to 06/06

A static test of a cantilever beam in CE 324 is being modified so that it can be controlled and observed remotely using web-based tools. In the web-based setup, a controller with a stepper motor will be used to operate the screw actuator, and the strains will be monitored, recorded and displayed using a PC-based data acquisition system. The research will investigate appropriate ways to protect the experiment from overloading and internet/PC malfunctions, as well as procedures for scheduling, access, and security.

### **Evaluation of a New High Corrosive Resistant Steel Reinforcement for Concrete Structures in the Mediterian Salt Environments**

*T. Hassan and S. Rizkalla*  
*National Science Foundation*  
 \$36,290  
 09/05 to 08/07

MMFX is a high strength, highly corrosion resistant steel, ideal for use in civil engineering applications for salt environments such as the mediterian environment in Egypt and high humidity climate such as in North Carolina and many other ocean exposed states. The research will introduce the MMFX steel as a new material has a high corrosion resistance to the engineering community in Egypt for the first time. The proposed research project consists of three major tasks: (1) experimental work, (2) analytical phase, (3) development of design guidelines.

### **Corrosion Inhibitors for Concrete Bridges**

*A. Mirmiran and S. Rizkalla*  
*NC Department of Transportation*  
 \$170,681  
 07/02 to 12/04

The research project evaluates the effectiveness of commercially available corrosion inhibitors for remediation purposes in delaying, slowing, stopping or reversing the corrosion process in existing concrete under laboratory conditions of wet-dry cycles and salt water spray, simulating severe field conditions. The results will be used to compare the effectiveness of corrosion inhibitors at different levels of chloride contamination and establish the threshold beyond which surface application does not provide any significant improvement. The project will develop guidelines and specifications for surface treatment using corrosion inhibitors and recommend means to incorporate surface treatment scheduling in bridge inspection and maintenance plans for the NC Department of Transportation.

### **Innovative Textile Technology for Modular Bridge Decks**

*S. Rizkalla*  
*National Science Foundation*  
 \$186,290  
 07/03 to 12/05

This research program is designed to, for the first time ever, adapt the 3-D weaving process to develop innovative FRP bridge decks. The work plan has both experimental and analytical components. The experimental work consists of testing scale models of FRP decks as well as coupon testing under static and fatigue loading. The analytical work includes finite element modeling of the FRP decks using micro- and macro-models. Once the models are calibrated using the experimental results of Part I, a parametric study will be carried out to optimize the shape and configuration of the deck.

### **Value Engineering and Cost Effectiveness of Various FRP Repair Systems – Part II**

*S. Rizkalla*  
*NC Department of Transportation*  
 \$83,663  
 07/05 to 06/06

This research program is an extension of NC Department of Transportation Project 2004-15: Value Engineering and Cost-Effectiveness of Various FRP Repair systems, which will be completed in June 2005. Results of Project 2004-15 and the proposed extension will be used to produce complete design guidelines. The project will provide bridge maintenance engineers with a comprehensive document to select the most appropriate repair or strengthening systems along with the cost effectiveness and value engineering for each system.

### **I/UCRC Center, Repair of Buildings and Bridges with Composites (RB2C)**

*S. Rizkalla*  
*National Science Foundation*  
 \$250,000  
 07/02 to 06/07

The NSF Industry/University Cooperative Research Center entitled “Repair of Buildings and Bridges with Composites” (RB2C) is located at the Constructed Facilities Laboratory, North Carolina State University (NCSU). The Center is working in collaboration with the Center located at the University of Missouri-Rolla (UMR). The Center at NCSU focuses on the needs of the construction industry in development of new and innovative structural components as well as strengthening/repair methods for existing structures using advanced composite materials.

### **Evaluation of Bond Characteristics of MMFX Steel**

*S. Rizkalla*  
*MMFX Technologies Corporation*  
 \$83,333  
 07/05 to 06/07

The high-strength steel commercially known as Micro-composite Multi-structural formable (MMFX) steel could lead to potential savings through the use of lower reinforcement ratios due to its higher strength. However, a critical evaluation of the bond characteristics of MMFX steel with concrete is of paramount importance, especially if high

strength is to be utilized. The proposed research will deeply investigate the bond behavior of MMFX steel to concrete. The first phase of the proposed research program will include the parameters believed to significantly affect the bond strength: concrete compressive strength, bar size, concrete clear cover, and confinement level. Three universities are participating in this study, namely, University of Texas at Austin, the University of Kansas, and North Carolina State University. Each university will test twenty-two full-scale splice beams for the first phase of the program.

### **Bond Behavior of SAS High Strength Steel**

*S. Rizkalla*  
*SAS Stressteel, Inc.*  
 \$48,000  
 2004 to 2005

To evaluate the bond characteristics of the SAS high tensile strength steel using end-block and splice beam test specimens according to the ICC specifications.

### **Torsion Behavior of Precast Prestressed Ledger Beams**

*S. Rizkalla and P. Zia*  
*Metromont Corporation*  
 \$65,000  
 09/05 to 12/05

The objective of this project is to evaluate the behavior of precast, prestressed ledger beams under the effect of eccentric loading of precast beams typically used for parking structures. Two full-size beams with spans of 30 and 45 feet will be tested using double T-beams to load the beams up to failure. Four different reinforcement details are considered in this integration.

### **Development of Repair Systems for Steel Structures and Bridges**

*S. Rizkalla*  
*Mitsubishi Chemical America*  
 \$250,000  
 07/02 to 06/07

The project investigates the use of high modulus carbon fiber polymer (CFRP) material for strengthening steel structures and bridges. The material in use now is in the form of sheets and strips bonded to the tension surface of steel structures. The first phase includes selection of the appropriate resin and bond characteristics of the material. The second phase is to test large-scale steel monopoles strengthening with different materials, configurations and subjected to static and fatigue loading conditions. The study will be continued to include the environmental effect on the strengthening system.

### **Evaluation of New Generation of Adhesives for Marine Structures**

*S. Rizkalla*  
*IPS Corporation*  
 \$250,000  
 07/02 to 06/07

The project investigates the behavior and material characteristics of two proposed adhesives designed for marine structures. The project is mainly an experimental study at this stage. The experimental program initially consists of lap shear test to determine the bond characteristics of two adhesives between two surfaces; each consists of Carbon

Fiber Reinforced Polymer (CFRP) and steel surface. A specially designed insulated room has been constructed at the Constructed Facilities Laboratory to house the instrumentations, which were built to subject the specimens to the specified environment.

### **An Innovative Bridge Deck System**

*S. Rizkalla*  
*Martin Marietta Composites*  
 \$250,000  
 07/02 to 06/07

The research includes development of an innovative system for highway bridge decks. The system is also suitable for manufacturing trailer walls using small thicknesses. The innovative concept consists of two layers of 2-D fiber pultruded sheets and styrofoam layers in between to provide the required thickness. At a later stage, bundled fibers are inserted in the third direction to increase the strength through-thickness properties of the panels. The system is a modified process for the Z-technology used for the aerospace industry. The test program consists of different tests to examine the material characteristics as well as the behavior of the panel.

### **Supplement Funding to Support Undergraduate Student**

*S. Rizkalla*  
*National Science Foundation*  
 \$11,625  
 07/03 to 06/06

Efforts at repair of steel bridges with FRP have not been very successful because of low modulus of most FRP materials as compared to steel. The new carbon fibers have high modulus of elasticity that is about three times that of steel in fiber form and twice that of steel in laminate form. The student will be involved in an experimental plan consisting of testing the fibers with a variety of resins to identify the most effective and compatible resin for the repair of steel. Tests will include laminates as well as bond with steel plates.

### **Wireless Sensor Networks for Structural Health Monitoring of Bridges**

*S. Rizkalla*  
*National Science Foundation*  
 \$50,000  
 07/03 to 12/05

The research project deals with structural health monitoring of bridges and civil engineering buildings. The first part addresses sensing/data interpretation, the second part addresses the transfer of data from sensors to the location interpretation occurs. The proposal ties together the expertise of the two NSF-I/UCRC Centers at NC State, RB2C in the Department of Civil Engineering and the Center for Advanced Computing and Communication (CACC) in the Department of Electrical and Computer Engineering. The specific issue is the wireless communication of data for structural health monitoring of civil engineering structures.

### **Macromolecular Science and Infrastructure Engineering**

*S. Rizkalla (Co-PI with Virginia Tech)*  
*National Science Foundation*  
 \$89,215/year (part of IGERT to Virginia Tech)  
 09/01 to 08/05

The Integrated Graduate Education Research and Traineeship (IGERT) Program provides the opportunity for our graduate students to conduct an interdisciplinary research in Macromolecular Science and Infrastructure Engineering, focused on polymeric adhesives and composites in civil engineering structures. The program allows collaboration among the following seven departments: Chemistry, Engineering Science, Civil Engineering, Electrical Engineering, Computer Engineering, Wood Science and Marketing from four universities, including NC State University. It will include exchange of students and faculty members, as well as development of new courses in the field of infrastructures.

### **Application of the LRFD Bridge Design Specifications to High-Strength Structural Concrete Flexure and Compression Provisions**

*S. Rizkalla, A. Mirmiran, and P. Zia*  
*Cooperative Research Programs, Transportation Research Board (NCHRP)*  
 \$600,000  
 05/03 to 08/06

The objective of this research is to develop recommended revisions to the AASHTO LRFD Bridge Design Specifications to extend the applicability of the flexural and compression design provisions to concrete up to 18 ksi. The research results will allow full utilization of the material characteristics and greater use of high-strength concrete, since the current LRFD limits the design strength of the ultimate compressive strength of concrete to 69 MPa (10 ksi). The results will have great economical advantages by allowing bridge design engineers to design AASHTO girders more effectively in terms of the thickness of the web and larger beam spacing.

### **Evaluation of MMFX Steel for NC Department of Transportation Concrete Bridges**

*S. Rizkalla and P. Zia*  
*NC Department of Transportation*  
 \$115,000  
 07/04 to 12/05

This research project investigates the effectiveness of highly corrosive, resistant, high strength steel reinforcements, recently patented as MMFX Steel, for use in highway concrete bridge applications. The experimental program consists of multiple phases to examine the mechanical properties, effect of bend, and corrosion resistance claimed by the manufacturer. The structural performance includes full-scale concrete bridge decks. The analysis will be based on non-linear-finite elements to determine the influence of other parameters, which could affect the design. The research will provide design guidelines for the use of this new tool.

### **Lateral Flange Bending in Heavily Skewed Bridges**

*E.A. Sumner*

*NC Department of Transportation*

*\$109,676*

*07/06 to 12/08*

Today's steel plate girder bridges are more commonly constructed with long spans and a heavy skew. As a result, an increase in problems with lateral flange bending of the steel plate girders during construction has been observed by the NC Department of Transportation. Lateral flange bending induces additional stresses into the flanges of the girders, the end-bent diaphragms, the intermediate cross-frames, and the support bearings. The focus of this research is to quantify the effects of lateral flange bending, establish a method to predict the effects, and develop strategies to mitigate the effects of heavy skew on lateral flange bending. A combination of field monitoring and finite element analysis will be utilized to accomplish these objectives.

### **Digital Recording of Large-Scale Structural Testing for use in Undergraduate and Graduate Civil Engineering Classrooms**

*E.A. Sumner*

*NCSU-LITRE*

*\$5,600*

*01/06 to 06/07*

Laboratory demonstrations are an essential aspect of many engineering classes that improve students' understanding of fundamental concepts by allowing them to associate theoretical concepts and calculations with observed behavior. The objective of this project is to develop a system to record still images, video, sound, and test data into a format that can be played back in real time or at an accelerated rate. The system will be used to document numerous full-scale structural tests conducted at the NCSU Constructed Facilities Laboratory. These recordings will be stored on the web for use in civil engineering courses.

### **Full-Scale Testing of Overhang Falsework Hangers on NC Department of Transportation Modified Bulb Tee (MBT)**

*E.A. Sumner*

*NC Department of Transportation*

*\$72,856*

*07/04 to 12/05*

In the design of the overhang falsework systems, the ultimate strength and safe working load capacity of falsework hangers on modified bulb tee (MBT) prestressed concrete girders is not wholly known. The analysis procedures used by the manufacturers and the NC Department of Transportation to predict the strength of the hangers on MBT girders are not consistent and may have resulted in conservative and more costly falsework designs. The focus of this research is to determine the ultimate strength and safe working load capacity of falsework hangers on MBT girders through full-scale testing and analytical investigation.

### **Developing a Simplified Method for Predicting Deflection in Steel Plate Girders Under Non-Composite Dead Load for Stage-Constructed Bridges**

*E.A. Sumner and S. Rizkalla*

*NC Department of Transportation*

*\$149,000*

*07/03 to 12/05*

Matching the final bridge deck elevations in stage-constructed steel girder bridges has created numerous problems during construction. Misaligned deck elevations between two stages may require grinding of the deck surface or result in reduced concrete cover leading to early deterioration of the bridge deck. The objective of this research is to develop an empirically based method to predict the non-composite deflection of steel plate girders in staged-constructed bridges. The formulation of the simplified method will require a combination of field measured data and extensive three-dimensional analytical simulation.

### **RC Beams Strengthened with Near Surface Mounted FRP**

*Jin-Guang Teng, S. Rizkalla, and B. Taljsten (Sweden)*

*Hong Kong National Research Council*

*HK \$633,695*

*01/05 to 12/07*

The project investigates the use of fiber reinforced polymer (FRP) material to strengthen reinforced concrete (RC) beams to increase their flexural and shear capacity. The project at Hong Kong will focus on installing these materials into the tension zones of the flexural members using the near surface mounted technique. The project complements the research in progress at North Carolina State University sponsored by the NC Department of Transportation using 43-year-old prestressed c-channels and AASHTO girders. The research findings will be greatly enhanced by the collaboration with the University of Technology, Sweden.

### **Debonding Failure in CFRP Strengthened Steel Structures**

*X. Zhao (Monash University), S. Rizkalla,*

*and R. Al-Mahaidi (Monash University)*

*Australian Research Council*

*\$325,000 (Australian)*

*01/05 to 12/07*

The research will make a breakthrough in understanding the bond characteristics between CFRP and steel. It will enhance the capacity of Australian researchers to participate in a new cutting-edge research area, and help create a vibrant new industry for strengthening steel structures. The project will contribute to improved cost efficiency and safety of steel structures, thereby contributing to the socio-economic well-being of Australia and the USA, including road, offshore, building and mining industries.

## An Exploratory Study of a Test Device for Concrete Permeability

*P. Zia*

*National Science Foundation*

\$60,000

03/03 to 08/05

The objectives of this exploratory research are to further develop and refine the test method and a device for measuring air permeability of concrete. More specifically, the research will address four critical issues: (1) determine the effect of the moisture content of concrete on air permeability, (2) explore techniques to dry the concrete surface to a sufficient depth to eliminate the effect of moisture content, (3) improve the test device so as to increase the depth of air flow into the concrete, and (4) establish an appropriate procedure for the concrete surface preparation in the field so that the test device can be applied successfully.

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## TRANSPORTATION SYSTEMS AND MATERIALS

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### In-Vehicle Energy and Emissions Information System (IVEEIS)

*H.C. Frey and N.M. Roupail*

*National Science Foundation*

\$336,928

03/03 to 12/06

The key objectives of this research project are to (1) develop a micro-scale predictor of energy use and emissions that is deployable at the individual vehicle level in real-time; (2) identify, compare, and evaluate alternate energy use and emissions sampling/reporting schemes that are appropriate at the vehicle and network levels; (3) develop and test a prototype In-Vehicle Energy and Emissions Information System (IVEEIS); and (4) formulate and assess the utility of IVEEIS in developing transportation design and control measures aimed at energy and emission management policies.

### The Human Factors Effects of Nine-Panel Logo Signs

*J.E. Hummer*

*NC Department of Transportation*

\$20,680

01/06 to 06/06

Logo signs provide vital information and minimize the need for billboards. At many interchanges in North Carolina, the number of qualifying businesses providing a service exceeds the maximum of six logo panels allowed per sign. One option in this case is to increase the number of logos allowed per sign to nine. The main concern regarding this option is that drivers will take longer to read the larger signs and may be distracted from more important driving tasks. The objectives of this project are to conduct driver surveys and lab tests to determine whether larger logo signs cause problems or drivers.

## Assessing the Impact of Port Security Measures on Traffic Operation

*J.E. Hummer*

*NC Department of Transportation*

\$20,000

08/05 to 07/06

Truck traffic through the gates of seaports in the US is expected to increase dramatically in the near future. However, tightened security measures at the port gates may mean long delays for trucks, which in turn could lead to other traffic delays, safety problems, air quality issues, and other impacts. During this project, we will construct and exercise a microscopic traffic simulation model of the gates of the Port of Wilmington, NC, to gauge the effects of extra security and to allow the testing of mitigation strategies.

### An Evaluation of the Safety Effects of Speed Enforcement Cameras

*J.E. Hummer*

*NC Governor's Highway Safety Program*

\$110,807

10/03 to 09/05

Speed enforcement cameras that automatically record the license number of a vehicle exceeding a limit are one technologically feasible way to address speed-related safety problems. The North Carolina Legislature has recently given the City of Charlotte approval to use speed enforcement cameras. The purpose of this project is to help evaluate those installations, to see whether other highway agencies could expect collision reductions should they also use speed enforcement cameras. The project will consist of a literature review, an examination of public opinion through focus groups, and before-and-after collision and speed studies at camera sites.

### Railroad Crossing Wayside Horn Evaluation

*J.E. Hummer*

*NC Department of Transportation*

\$95,241

07/02 to 06/06

The noise from train horns is irritating to people living and working along railroad tracks, and causes opposition when new train service is proposed. However, the train horn is also an essential safety device for motorists at grade crossings. A device called a wayside horn has been marketed in the US that promises to reduce that irritation by mounting the horn at the road crossing and directing the sound at motorists. The purpose of this project is to evaluate the device at a crossing in North Carolina by means of driver surveys, resident surveys, and roadway operational measures.

### Tensile Strength – A Design and Evaluation Tool for Superpave Mixtures

*N.P. Khosla*

*NC Department of Transportation/FHWA*

\$189,759

07/04 to 06/06

Tensile strength plays an important role in the performance of asphalt concrete. A minimum tensile strength value can be calculated at a given traffic for fatigue life and an allowable rut depth for rutting and can be used as an additional criterion for evaluating the moisture susceptibility of a mix. Thus, the original values of tensile strength of conditioned

and unconditioned specimens along with TSR values should be employed in assessing the effect of water damage on the performance of pavements. This study will provide a simple, reasonable, and dependable method for mix design and performance evaluation of Superpave mixtures.

### **Development of APA Design Criteria for Surface Mixtures**

*N.P. Khosla*

*NC Department of Transportation/FHWA*

*\$186,159*

*07/04 to 06/06*

The APA test is the most widely used simulative test to assess the rutting potential of a mixture. A comprehensive study will be conducted on all the surface mixtures used in North Carolina to develop the rut depth criteria. The correlations estimated using the data obtained from the APA and Shear tests would be used to develop the rut depth criteria for the APA test. This study will provide a simple and effective methodology and design criteria for using APA for Superpave mixtures. The rut depth criteria could be implemented for all the new surface mix designs and test contractor submitted specimens for compliance.

### **Performance Based Analysis of Polymer-Modified Emulsions in Asphalt Surface Treatments**

*Y.R. Kim*

*NC Department of Transportation*

*\$248,097*

*07/06 to 06/08*

This project focuses on the performance evaluation of polymer-modified emulsions in asphalt surface treatments. Limited research and data exist on quantifying the overall performance of polymer-modified surface treatments and associated cost-effectiveness. This project will test the improvement in surface treatment performance resulting from modifying the emulsion with polymers and its cost-effectiveness, in addition to providing baseline performance information about standard surface treatments which will be most valuable in planning maintenance activities. Recommendations will be made on the selection of a proper surface treatment option based on existing pavement distress, traffic volume, and road functionality.

### **Local Calibration of the MEPDG for Flexible Pavement Design**

*Y.R. Kim*

*NC Department of Transportation*

*\$316,756*

*07/06 to 06/08*

The objective of this study is to calibrate the NCHRP 1-37A Mechanistic-Empirical Pavement Design Guide with local data by developing a material database using typical layer materials (HMA and unbound materials) for flexible pavements in North Carolina. The scope of research includes both fatigue cracking and rutting. The primary products of the proposed research are the flexible pavement layer materials performance database and the MEPDG HMA performance model coefficients for typical North Carolina HMA mixtures. An additional product will be an implementation plan with instructions for modifying the MEPDG to incorporate the local coefficients. This plan will shorten the delay between the research and the implementation of the pavement design.

### **Development of a Virtual Testing Module for an Undergraduate Course on Materials Design**

*Y.R. Kim*

*LITRE Grant, North Carolina State University*

*\$6,000*

*01/06 to 08/07*

The short-term objective of this project is to enhance the students' understanding of the behavior of asphalt concrete through virtual microstructure fabrication and virtual testing. The medium-term goals are to (1) help develop graduate-level asphalt materials courses into distance-learning courses and (2) help enhance student learning in other materials-related course in the department, and elsewhere in the university, state, and country.

### **Evaluation of Geosynthetics and GlasGrid for Rutting Prevention in Asphalt Pavement**

*Y.R. Kim*

*Saint-Gobain Technical Fabrics*

*\$16,014*

*08/05 to 10/05*

The primary objective of this proposed research is to evaluate the performance of geosynthetics and geogrids in retarding the rutting distress in asphalt pavements. The third-scale Model Mobile Loading Simulator will be used to load the laboratory hot-mix asphalt slabs composed of S9.5B mix.

### **Effects of Various Mix Designs on the Performance of Lime-Modified Asphalt Mixtures**

*Y.R. Kim*

*Chemical Lime Company*

*\$16,505*

*10/05 to 02/06*

The primary objective of this proposed research is to evaluate the differences in performance among lime-modified asphalt mixes with different mix designs. The performance characteristics to be evaluated in this study include the time- and temperature-dependent stiffness characteristics, rutting performance, and fatigue cracking performance. The following four mixes will be evaluated in this study: control S9.5C mix; control S9.5C mix plus 1% lime with new mix design; control S9.5C mix with 1% passing #200 materials replaced by 1% lime, and S9.5C mix with adjusted gradation and 1% lime.

### **Top-Down Fatigue Cracking of Hot-Mix Asphalt Layers**

*Y.R. Kim*

*NCHRP 1-42A, Subcontract from University of Florida*

*\$120,000*

*06/06 to 05/08*

In this research, the viscoelastic continuum damage model implemented in the finite element program (VECD-FEP++) will be used to investigate the top-down fatigue cracking mechanism in hot-mix asphalt pavements. The VECD model and the dynamic modulus from the IDT test will serve as the primary experimental tools. The resulting VECD-FEP++ will be used to simulate the behavior of asphalt pavements with varying loading, environmental, and pavement factors. The results from the simulation will be investigated to develop mechanistic procedures to evaluate the top-down cracking propensity of asphalt pavement as a function of various factors and to predict the top-down cracking performance of asphalt pavement.

### Development of Multi-axial VEPCD-FEP++ and its Extension to Indirect Tension Test

*Y.R. Kim and M.N. Guddati*  
*Federal Highway Administration*  
 \$499,907  
 09/05 to 08/07

Over the past decade, the NCSU research team has been successful in developing HMA models that can accurately capture various critical phenomena such as microcrack induced damage, strain rate – temperature interdependence, and viscoplastic flow that is critical for high temperature modeling; the resulting model is termed the viscoelastoplastic continuum damage (VEPCD) model. The primary objectives of this research are to (1) extend the VEPCD model to multiaxial state of stress; (2) develop a three-dimensional finite element program with the multiaxial VEPCD model; and (3) extend the principles used in the VEPCD modeling to the indirect tension mode.

### Calibration of Rutting Models for HMA Structural and Mix Design

*R. Kim and M.N. Guddati*  
*NCHRP 9-30A, Subcontract from Applied Research Associates, Inc.*  
 \$70,000  
 11/05 to 10/08

The objective of this research effort is to recommend revisions to the HMA rut depth prediction model in the mechanistic-empirical pavement design guide and software developed in NCHRP Project 1-37A for consideration by the NCHRP Project 1-40 panel and the AASHTO Joint Task Force on Pavements. The recommended revisions will be based on the calibration and validation of distress models with measured materials properties and performance data from existing field and other full-scale pavement sections that incorporate modified as well as unmodified asphalt binders.

### Implementation Plan for the New Mechanistic-Empirical Pavement Design Guide

*Y.R. Kim*  
*NC Department of Transportation*  
 \$90,422  
 05/05 to 06/06

The goal of the research project is to develop an implementation plan for the Guide. This goal will be attained by accomplishing the following objectives: (1) develop a summary of the design practices outlined in the Guide that differ from the current design practice used by the NC Department of Transportation; (2) perform a sensitivity analysis on the design input parameters using realistic input ranges; (3) develop a local calibration plan; and (4) develop a local training program.

### Quantifying the Benefits of Improved Rolling of Chip Seals

*Y.R. Kim*  
*NC Department of Transportation*  
 \$264,638  
 07/05 to 06/07

This research is aimed at “low hanging fruit,” that is, relatively low cost changes in compaction procedures that could significantly improve the chip seal performance in North

Carolina. The performance measures to be evaluated in this study include aggregate embedment depth, aggregate retention, skid resistance, bleeding, and rutting. The research approach utilizes the chip seal performance test methods that have been used and refined in the ongoing NC Department of Transportation HWY 2003-09 project, Optimizing Gradations for Surface Treatments. The experimental program involves both laboratory and field experiments.

### Viscoelastoplastic Continuum Damage Modeling of Modified and Unmodified Asphalt Mixtures

*Y.R. Kim*  
*Dwight David Eisenhower Transportation Fellowship to Mr. Benjamin Shane Underwood*  
*US Department of Transportation*  
 \$60,800  
 09/04 to 09/06

The primary objectives of this research are to (1) characterize polymer-modified asphalt mixtures being tested under the Accelerated Loading Facility (ALF) at the Federal Highway Administration Turner-Fairbank Highway Research Center in McLean, Virginia, using the viscoelastoplastic continuum damage (VEPCD) model; (2) incorporate the VEPCD model into the finite element code (VEPCD-FEP++); and (3) calibrate the VEPCD-FEP++ using the pavement performance data obtained from the FHWA ALF testing.

### Development of the Asphalt Pavement Performance Prediction Methodology Based on the Viscoelastoplastic Continuum Damage Theory

*Y.R. Kim and M.N. Guddati*  
*Korea Highway Corp.*  
 \$335,021  
 10/04 to 12/06

The primary objectives of this research are (1) standardization of test and analysis methods for the determination of viscoelastic properties and performance of asphalt mixtures; (2) development of the multiaxial viscoelastoplastic continuum damage (VEPCD) models using the indirect tension test and triaxial permanent deformation test; (3) development of the VEPCD finite element program (VEPCD-FEP++); (4) calibration of the VEPCD-FEP++ using the data measured from the KHC Test Road pavements; (5) development of transfer functions for the 33 asphalt pavements in the Test Road; and (6) development of a user-friendly graphic interface for pre- and post-processing of the VEPCD-FEP++.

### Characterization of ALF Mixtures Using the Viscoelastoplastic Continuum Damage Model

*Y.R. Kim and M.N. Guddati*  
*FHWA*  
 \$199,795  
 08/03 to 08/05

The primary objectives of the proposed research are to (1) verify the time-temperature superposition principle in damaged states for various asphalt mixtures used in the current ALF study; (2) characterize the ALF mixtures using the viscoelastoplastic continuum damage model; and (3) predict the performance of various ALF pavements using finite element analysis and the VEPCD model.

### **Designing an Efficient Nighttime Sign Inspection Program that Ensures Motorist Safety**

*W.J. Rasdorf and J.E. Hummer*  
*NC Department of Transportation*  
 \$132,857  
 07/04 to 06/06

The major objective of the research is to revise and expand out simulation of the effectiveness of sign inspection programs so that the NC Department of Transportation (NCDOT) can optimize its program. The main revisions to allow NCDOT to use the simulation are to (1) model the performance of NCDOT sign inspectors; (2) expand the simulation to include other sign colors besides yellow and red; and (3) include the best sign deterioration functions.

### **Blind Pedestrian Crossing at Complex Intersections**

*N. Roupail and Richard Long (WMU)*  
*National Eye Institute through WMU*  
 \$163,707  
 07/05 to 05/06

A pedestrian crossing at roundabouts is initiated by a pedestrian upon detecting a crossable gap, a driver yielding to a pedestrian, or a driver stopping due to an external control mechanism (e.g., signal) that forces gaps to occur in the traffic stream. This program of work is focused on the development and behavioral evaluation of technologies that can detect or create these events and convey the fact that they have occurred to blind pedestrians. The study will extend recent work on induction-loop yield detection by developing and testing improved yield and gap detection systems that rely on video-zone detection technology.

### **Testing the Feasibility of a Video-Image Processing System for Tracking Signalized Arterial Traffic**

*N.M. Roupail*  
*National Institute for Advanced Transportation Technology (NIATT), University of Idaho*  
 \$25,500  
 02/06 to 10/06

A prototype Video Image Processing system has been developed at ITRE. The system is capable of tracking all vehicle, bicyclist, and pedestrian movements in the field of view at high resolutions. Data generated include origin-destination flows, speed profiles, gap and lag acceptance, entry and exit headway distributions, and queue size. From the pedestrian perspective, the system generates micro-scale data on waiting and crossing time distributions, gap and lag acceptance, driver yielding behavior (to pedestrians), and the distribution of the position of yielding vehicles at the crosswalk. This study will duplicate the effort at signalized intersection approaches located in Idaho.

### **Low-Cost Improvements for Recurring Freeway Bottlenecks**

*N. Roupail and Richard Dowling (Dowling and Associates)*  
*NCHRP 3-83, through Dowling and Associates*  
 \$52,568  
 12/05 to 01/07

Low-cost geometric and operational improvements can mitigate the effects of a bottleneck. The benefits may not be as extensive or long-lasting as those of a major reconstruction project, but improved system performance can easily justify its use. Improving a bottleneck may result in the congestion

moving downstream to a new bottleneck that was not apparent previously, greatly reducing the expected benefits. Analysis of the entire network is necessary to accurately estimate the benefits and effects of different improvements. The objective of this project is to develop a technical guide for identifying and treating existing and future recurring freeway bottlenecks.

### **Crossing Solutions At Roundabouts and Channelized Turn Lanes for Pedestrians With Vision Disabilities**

*Nagui Roupail*  
*UNC-CH, NCHRP 3-78*  
 \$125,000  
 01/04 to 01/09

The objective of this research is to produce recommendations for geometric designs, traffic control devices, and other treatments that enable pedestrians who are visually impaired to cross roundabouts and channelized turn lanes (CTL's) independently and safely. These recommendations should be suitable for inclusion in transportation-industry practice and policies, including the AASHTO Policy on Geometric Design of Highways and Streets and the FHWA Manual on Uniform Traffic Control Devices. Consideration should be given to the impact of the recommendations on all users of roundabout intersections, including occupants of passenger car and trucks, pedestrians (including pedestrians with vision impairments), and bicycles.

### **Regional Development, Population Trend and Technology Change Impacts on Future Air Pollution Emissions**

*N.M. Roupail and H.C. Frey*  
*UNC-CH, EPA*  
 \$238,690 (including \$73,000 CTE contribution)  
 11/04 to 11/07

The research tests the hypothesis that smart-growth development patterns can significantly influence the quantity and location of direct and indirect emissions from mobile sources. The patterns of interest include the type of development and its location. We will develop a general method for exploring the leverage that smart-growth development patterns have on the spatial pattern and quantity of emissions from mobile sources. We will explore scenarios and chart the envelope of the effectiveness of smart growth as a means for reducing emissions. We will determine whether substantial emissions reductions are feasible with forecasts of the market penetration of smart growth.

### **Evaluation and Application of Pedestrian Modeling Capabilities Using Computer Simulation**

*Nagui M. Roupail*  
*UNC-CH and National Institutes of Health*  
 \$113,000  
 01/03 to 05/06

Modern roundabouts are increasingly being used in the United States in light of their good capacity and safety performances compared to conventional signalized or un-signalized intersections. Many recent applications show that by enhancing priority control and speed enforcement, modern roundabouts can increase vehicle capacity as well as reduce accident rates. Previous research on modern roundabouts was mainly concerned with vehicle performance. Since roundabouts in urban areas have the potential for servicing

large volume of pedestrians, the evaluation of their overall performance should also include analysis of pedestrian crossing capacity, delay, and safety issues.

### Multi-Modal Arterial Level of Service

*N.M. Roupail*  
*NCHRP 3-70 subcontract to ITRE*  
 \$43,387  
 03/03 to 06/07

The objective of this research is to develop and test a framework and enhanced methods for determining levels of service for automobile, transit, bicycle, and pedestrian modes on urban streets, in particular with respect to the interaction among the modes. Two phases of the research have been funded.

### Placement of Detection Loops on High Speed Approaches to Traffic Signals

*G.F. List*  
*NC Department of Transportation*  
 \$134,035  
 07/06 to 06/08

At high-speed, signalized intersections, the placement of detectors is critical for safe and effective operation. Well-placed detectors and carefully chosen signal timing parameters, such as yellow and all-red times, can reduce the likelihood of both right-angle and rear-end collisions as drivers on the main road deal with dilemma zone issues – whether to slow down and stop or continue through the intersection. This project will explore the best placement of detectors on such approaches through a two-pronged effort involving modeling and field testing of alternative configurations. Recommended practices will be developed based on the modeling and field test results and benefit-cost analyses.

### System of Systems Architecture Development Support

*G.F. List*  
 \$25,735  
 10/05 to 09/06

Sandia National Laboratories is involved in projects requiring the implementation of the System of Systems (SoS) architecture. A significant compliment to this approach is in optimizing system components. The project is focused on providing expertise in formulating analytic and descriptive models that can compliment and/or be integrated into the SoS architecture.

### North Carolina Truck Traffic Profiles

*G.F. List, J.R. Stone, and L.F. Huntsinger*  
*NC Department of Transportation*  
 \$128,287  
 07/06 to 12/07

Better trip profiles are needed to understand the extent to which heavy trucks are using the state's various categories of highways, from rural secondary roads to urban interstates. Pavement and bridge engineers need a better sense of truck weights and axle spacings. Investment decision makers and planners need a better picture of truck volumes, trip distances, and weight distributions by highway class and route category. To help meet these needs, this project aims to create better truck trip flow profiles.

### North Carolina Truck Network Model

*J.R. Stone and L.F. Huntsinger*  
*NC Department of Transportation*  
 \$118,932  
 07/05 to 12/06

Truck traffic is a primary determinant of design and maintenance of bridge structures, pavements, and highways. Proximity to good truck routes enhances community development and economic vitality. Therefore, accurate estimates of future truck traffic are vitally important to the NC Department of Transportation and the state economy. This project will develop a statewide truck network model to estimate future truck traffic and the network effects of alternative highway improvement policies.

### Multi-Year Travel Model Research

*J.R. Stone, L.F. Huntsinger, (ITRE), A. Khattak (UNC)*  
*NC Department of Transportation*  
 \$324,222  
 07/04 to 06/07

NC Department of Transportation (NCDOT) staff members develop transportation plans for all NC communities. To simplify, streamline, and standardize the travel demand modeling process, we will develop guidelines for best practices for developing travel demand models and sub-models. In addition, we will develop recommendations for sources of data, and we will undertake various kinds of validations of forecasts. These products and associated tools will help assure that NCDOT staff members efficiently use their time and resources to carry out their statewide transportation planning and modeling mission.

### Benefit-Cost Analysis Software for Transportation Planning

*J.R. Stone and R.S. Foyle (ITRE)*  
*NC Department of Transportation*  
 \$126,732  
 07/04 to 06/06

Evaluating transportation projects for feasibility purposes can be a time-consuming and difficult process. Over time and a variety of projects, the process can also become very inconsistent as different engineers apply various parameters. We will provide the NC Department of Transportation a decision-support tool and software that will provide a consistent methodology for evaluating costs and benefits for NC transportation projects and amendments to programmed projects.

### EPA Truck Anti-Idling Demonstration Project

*Anne Tazewell (NC Solar Center), H. Christopher Frey, and John Stone*  
 \$60,000  
 08/05 to 08/06

The objective is to assess potential environmental benefits of heavy duty diesel freight truck idle reduction technologies installed on trucks in NC. A key goal is to quantify actual grams per gallons emissions with a portable gas analyzer and compare this data with data extrapolated from an on-board data logger and fuel use with and without idle reduction technologies.

### Fatigue Testing for PMI Asphalt Mixtures

A.A. Tayebali  
Petrochem Marketing Inc.  
\$6,210  
09/05 to 03/06S

The objective of this testing program is to characterize the fatigue response of PMI asphalt mixtures using beam fatigue testing device and establish strain versus number of cycles to failure relationship.

### Quantifying Anti-Strip Additive in Asphalt (Binder and Mixes)

A.A. Tayebali and D. Knappe  
NC Department of Transportation  
\$111,914  
07/03 to 12/05

The objective of this research will be to develop a reliable and repeatable laboratory and/or field test procedure to determine the amount of organic anti-strip agent in asphalt binders and asphalt mixtures. In this investigation, two test methodologies will be investigated. These include (1) a colorimetric test, and (2) a litmus test using the StripScan device. Both methodologies utilize a spectrophotometer for the analysis of anti-strip additive concentration in asphalt mixes.

### Effectiveness of Traveler Information Tools

B.M. Williams and N. Rouphail  
NC Department of Transportation  
\$169,994  
07/05 to 06/07

The NC Department of Transportation (NCDOT) has been deploying Intelligent Transportation System (ITS) devices, including Advanced Traveler Information Systems (ATIS), throughout the state over the past decade. However, owing to the limited knowledge about ATIS technology effectiveness and associated benefits and costs, we propose to assess whether they are (1) effective, (2) accessible to a wide range of travelers and (3) accepted/used by travelers. This study will allow the NCDOT to make more informed decisions about ITS deployment. We will also determine if there are other/new ATIS technologies that the NCDOT should consider for deployment.

### Career: System-wide Traffic Condition Monitoring and State Estimation for Intelligent Transportation Systems

B.M. Williams  
National Science Foundation  
\$375,000  
06/02 to 05/07

This five-year research and education program involves the teaching and application of rigorous and robust statistical modeling techniques to the process of assessing and predicting traffic stream states based on remotely sensed traffic data in advanced traffic management systems. Research results will include improved real-time traveler information, more rapid incident detection and response, and enhanced information support for dynamic transportation system management.

### Environmental Implications of Current Domestic Trends in Goods Movement

B.M. Williams and G.F. List  
Center for Transportation and the Environment  
(Prime Sponsor: US Department of Transportation)  
\$200,000  
03/05 to 03/07

This research project will assess the environmental implications of global and domestic freight trends with a primary focus on congested gateways, such as deep water ports and border crossings. The project results will include policy recommendations for addressing freight-related environmental issues in a manner that will “ensure goods move efficiently and effectively through our ports and freight hubs while protecting the environment.”

### I-40 Reversal Operational Traffic Analysis

B.M. Williams (PI) and S.S. Meinhold (Co-PI),  
N.M. Rouphail, Project Advisor, and J.E. Hummer,  
Project Advisor  
NC Department of Transportation  
\$156,580  
07/03 to 06/05

The NC Department of Transportation developed a lane reversal plan for using the eastbound lanes of I-40 for additional hurricane evacuation capacity. Traffic operation under evacuation conditions, especially operation of reversed lanes, are not well understood. This project involved investigational research of reverse lane operation and modeling and analysis of the I-40 lane reversal plan. Results will include recommendations for improving the current plan.

### Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation

B. Williams and H.C. Frey  
US Department of Transportation via Center for  
Transportation and the Environment  
\$75,000  
03/05 to 03/07

This research project involves a comprehensive scan of the freight sector, including public and private sector players, to catalog the practices and programs that are being used to reduce greenhouse gas emissions in the goods movement. All transportation modes will be included. The final research product will be a best practices guidebook to be published and disseminated by the US Department of Transportation.

## WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

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### Predictive Tools for Sustainable Solid Waste Management Using Bioreactor Landfills

*M.A. Barlaz, and C.H. Benson (Univ. Wisconsin)  
National Science Foundation  
\$306,979 (to NCSU)  
02/06 to 08/07*

The objective of this proposal is to develop quantitative, field-validated, engineering methods to improve the design and operation of bioreactor landfills. Three thrust areas have been identified where research can directly contribute to improvements in bioreactor technology by reducing cost and increasing predictability: (1) landfill hydrology, (2) solids decomposition, and (3) settlement prediction. A predictive model will be developed that relates moisture, solids decomposition, and waste settlement that will improve the predictability of airspace utilization, the industry's ultimate metric. In all areas, fundamental laboratory-scale studies are tightly coupled to models and field-scale work at bioreactor landfills operated by industrial partners.

### Application of Municipal Solid Waste Decision Support Tool to Wake County, North Carolina

*M.A. Barlaz and S.R. Ranjithan  
Environmental Protection Agency  
\$59,999  
12/04 to 12/06*

The objective of this project is to develop alternatives for the management of municipal solid waste for Wake County, NC. Alternatives will be developed to examine tradeoffs among cost, environmental burdens, resource consumption and landfill diversion using a solid waste management life-cycle inventory model developed by the investigators.

### Assessment Landfill Gas Pathway – Laboratory Simulation of Partitioning of Chemical and Biological Contaminants under Anaerobic Decomposition in a Landfill

*M.A. Barlaz, D.R.U. Knappe, and F. de los Reyes  
Environmental Protection Agency  
\$700,000  
09/04 to 08/07*

The overall objectives of this research are to (1) develop and validate a model to predict the behavior of chemical contaminants in refuse and (2) measure the survival and transport of biological agents in landfills. Experimental work will be conducted with surrogates for selected chemical warfare agents to quantify physical, chemical, and biological processes affecting their behavior in landfills. Concurrently, a model describing contaminant fate and transport in landfills will be developed. Molecular probes will be developed for suitable surrogates of biological warfare agents and the probes will be used to measure survival and transport in batch and reactor systems.

### Solid Waste Management Life-Cycle Inventory (SWM-LCI) Model Capabilities

*M.A. Barlaz and S.R. Ranjithan  
Delaware Solid Waste Authority  
\$55,000  
09/03 to 06/06*

The objective of this project is to develop alternatives for the management of municipal solid waste for the State of Delaware. Alternatives will be developed to examine tradeoffs among cost, environmental burdens, resource consumption, and landfill diversion using a solid waste management life-cycle inventory model developed by the investigators. After identification of a select group of alternatives, their robustness will be evaluated using the uncertainty component of the life-cycle model.

### Microbial Community Profiling of Anaerobic Refuse Decomposition: Response to Acidic Conditions, Shock Loads and Moisture Addition

*M.A. Barlaz and F. de los Reyes  
Waste Management Inc.  
\$351,407  
04/04 to 03/07*

This research will address the following questions related to landfill bioreactor operation: (1) How do landfills progress from the acid phase of decomposition to a stable methanogenic phase of decomposition, and are acid-tolerant or acidophilic methanogens involved? (2) Is the methanogen community that is active during decomposition stable, and if not, is the variability important? (3) What is the effect of shock loads of rapidly degradable substrate on the methanogen community? (4) What is the effect of leachate recycle on a continuous or pulsed basis on the methanogen community?

### Modeling and Optimization of Civil Engineering Infrastructure

*J.W. Baugh and E.D. Brill  
Blue Ridge Analytics  
\$341,500  
12/04 to 12/05*

In this project, computer software was developed to model and optimize civil engineering infrastructure problems using mathematical programming and heuristic search methods. The techniques were designed so that methods could be readily implemented to provide alternative solutions, which would meet given constraints on modeled objectives and which could be provided to users of the software.

### Evaluating Monitored Natural Attenuation of Perchlorate in Groundwater

*R.C. Borden and M.A. Barlaz  
Solutions-IES  
\$323,000  
02/04 to 12/07*

With support from the Environmental Security Technology Certification Program, Solutions-IES is evaluating the potential for use of Monitored Natural Attenuation (MNA) in managing groundwater contamination by perchlorate. North Carolina State University (NCSU) will support this project by providing laboratory studies to help identify sites where MNA is occurring and to demonstrate its effectiveness. The overall objective of this project is develop tools to (1) identify sites where MNA may be appropriate for management

of perchlorate releases, and (2) demonstrate to regulatory agencies that perchlorate MNA is effective for controlling adverse impacts to the environment.

### Laboratory Evaluation of Aerobic and Anaerobic Biodegradation Processes at the Maryland Sand, Gravel and Stone Site

*R.C. Borden and M.A. Barlaz*  
Solutions-IES  
\$70,000  
01/06 to 12/06

Laboratory microcosm studies will be conducted using sediment and groundwater from the Maryland Sand, Gravel and Stone (MSGs) site to (1) identify factors limiting contaminant biodegradation, and (2) identify treatment(s) that can be evaluated at the pilot scale to increase naturally occurring rates of biodegradation.

### Development of Permeable Reactive Barriers (PRBs) using Edible Oils

*R.C. Borden*  
Department of Defense, SERDP  
\$482,500  
01/01 to 01/07

The overall objective of this proposal is to develop the information needed to reliably design, construct and evaluate edible oil barriers, including (1) identify factors controlling the loss of permeability during oil injection; (2) identify factors controlling oil biodegradation rate in aquifer sediments; (3) use these results to develop improved procedures for distributing and immobilizing oils that (a) do not cause an excessive decline in permeability, and (b) result in a slow, steady rate of in-situ oil decay; and (4) use emulsion transport model to identify alternative barrier configurations and injection procedures to improve barrier performance and reduce costs.

### Anaerobic Biotreatment of Acid Mine Drainage at Ore Knob Mine

*R.C. Borden*  
NC Department of Environment and Natural Resources  
\$153,194  
08/05 to 07/08

Ore Knob Branch and Peak Creek are impaired due to discharge of acid mine drainage (AMD) from an abandoned copper/zinc mine. AMD production from the large tailings impoundment will be controlled by injecting emulsified soybean oil into the sediments to stimulate growth of naturally occurring bacteria. These bacteria will then use the soybean oil as a food source, consuming any dissolved oxygen and stopping further AMD production. Once oxygen is depleted, the sulfate reducing bacteria will reduce sulfuric acid to sulfide and precipitating heavy metals.

### Development of a Design Tool for Planning Aqueous Amendment Injection Systems

*R.C. Borden (NCSU), G. Mahinthakumar (NCSU), T.J. Simpkin (CH2M HILL) and C. Zawtocki (Solutions-IES)*  
DOE, Environmental Security Technology Certification Program  
\$503,000  
03/06 to 12/08

The overall objective of this project is to develop a set of tools to assist design engineers in developing effective,

reasonably efficient systems for distributing aqueous amendments for *in situ* treatment of groundwater contaminants. At this time, the primary applications for the tools will be for design of *in situ* chemical oxidation systems using permanganate and *in situ* anaerobic bioremediation systems using soluble substrates and emulsified oil. However, as technology evolves, this general approach should be applicable to distribution of other aqueous amendments.

### Treatment of Acid Mine Drainage Using Emulsified Soybean Oil

*R.C. Borden*  
United Soybean Board (through Smith, Bucklin & Associates, LLC)  
\$40,000  
08/05 to 07/07

The United Soybean Board will provide matching support for a NC Department of Environment and Natural Resources (NC DENR) project to evaluate the use of emulsified soybean oil for treatment of acid mine drainage at the Ore Knob Mine in Ashe County, NC.

### Molecular and Engineering Approaches for Analyzing Microbial Selection in Activated Sludge: Competition between Filaments and Floc-formers (NSF Career)

*F.L. de los Reyes III*  
National Science Foundation  
\$375,000  
07/01 to 06/06

This NSF Career project will focus on the most important component of the most widely used wastewater treatment process: the separation of solids from the effluent in activated sludge systems. The research will combine molecular, modeling, and reactor studies to integrate theories of microbial selection of floc-formers over filaments and develop design guidelines for reactor design and operation. The education component involves the training of students in the principles and practices of molecular techniques, the integration of treatment process modeling and full-scale treatment plant exposure experiences in undergraduate and graduate courses, and participation in the College of Engineering Distance Education program at NC State University.

### Ecophysiology of Nitrifying and Denitrifying Microbial Communities and their Interactions in Microbial Flocs

*F.L. de los Reyes III, J.J. Ducoste, and M. Hyman (Microbiology)*  
National Science Foundation  
\$430,000  
07/04 to 07/08

This project will apply a multidisciplinary approach to characterize the factors that control community structure and function in nitrogen-transforming microbial flocs. The specific objectives of the project are to (1) determine the effect of microscopic floc structure on rates and diversity of microbial activities involved in nitrogen removal; (2) determine the impact of bioreactor macro conditions on floc size, shape, and function; (3) characterize the carbon- and nitrogen-based metabolic interactions among ammonia-oxidizing, nitrite-oxidizing, and denitrifying bacteria within a floc; and (4) develop a macroscale model of nitrogen and carbon removal in activated sludge that incorporates microscale processes in flocs.

### Investigating Steam Application for Reducing Foaming in Activated Sludge Systems

*F. L. de los Reyes III  
Hazen and Sawyer  
\$14,260  
07/04 to 12/05*

The objective of this research is to determine the effect of steam addition to foaming. We hypothesize that steam will reduce foaming by lysing the filamentous bacteria that are foam-causing.

### Fundamental Analysis of a Novel Swine Wastewater Treatment Technology

*F.L. de los Reyes III and J. Cheng  
US Department of Agriculture–National Research Initiative Competitive Grants Program (USDA-NRICGP)  
\$320,000  
08/01 to 07/05*

A promising technology that integrates organics destruction, nitrogen removal, and energy recovery has been recently developed at NC State University. This technology utilizes an anaerobic biofilm reactor followed by an intermittently aerated, single-reactor nitrogen removal system. In the second stage, over 90% of the nitrogen is removed through nitrification/denitrification processes. In this project, we will identify, quantify, and monitor the nitrogen-removing populations in a novel single-reactor system using molecular techniques based on 16S rRNA (ribosomal ribonucleic acid) sequence analysis. The microbial community structure will be related to reactor operation in order to optimize the performance of the reactor system.

### Evaluation of Computational Fluid Dynamics (CFD) for Modeling UV-Initiated Advanced Oxidation Processes

*J.J. Ducoste and D. Knappe  
American Water Works Association Research Foundation  
\$150,000  
01/06 to 01/08*

This research will evaluate Computational Fluid Dynamics (CFD) for modeling UV-initiated AOPs that will ultimately help professionals in research, regulatory, consulting, and treatment facilities better analyze, design, and operate UV/AOP systems. Several steps will be taken that include the development of a dynamic UV/H<sub>2</sub>O<sub>2</sub> advanced oxidation CFD model that can be combined with complex kinetic pathways for characterizing the degradation of various water supply contaminants, the evaluation of non-ideal reactor hydraulics on the degradation of contaminants using the UV/H<sub>2</sub>O<sub>2</sub> AOP, and the evaluation of design parameters, including the effects of lamp type, lamp age, and lamp failure on the overall efficiency of the AOP system.

### Fats, Roots, Oils, and Grease (FROG) in Centralized and Decentralized Systems

*J.J. Ducoste and Kevin Keener (Food Science)  
WERF  
\$276,000  
03/05 to 02/07*

The proposed research project will investigate ways to improve grease interceptor performance through novel experimental and numerical techniques. The experimental work includes field measurements of FOG from active grease

interceptors located at different food service establishments (FSE). Tests will be conducted during peak FSE operation as well as under varying conditions. Data from these field tests will be used to develop a synthetic FSE wastewater that will be used to perform pilot scale grease interceptor tests. The pilot scale tests will be performed using a 300-gallon grease interceptor. A numerical simulation of the pilot reactor will be performed.

### A Unified Approach to Understanding, Education, and Design of Disinfection Processes using Computational Fluid Dynamics (NSF Career)

*J.J. Ducoste  
National Science Foundation  
\$375,000  
09/01 to 08/06*

This research program proposes to use CFD to (1) develop and evaluate alternative disinfection models for the prediction of effluent microbial inactivation through continuous flow systems, and (2) assess the impact of disinfectant injection methods and multiple disinfectant injection points on microbial inactivation and DBP formation. The educational plan involves the development of a CFD disinfectant training module. The CFD disinfection-training module will be designed around a graphical user interface (GUI) that will be the primary mode of communication between the user and the CFD model. The training module will be composed of three sections: (1) PowerPoint/video-based disinfection process-lecture series, (2) solved disinfection problems and simulated tracer tests, and (3) team-based disinfection design problems.

### REU Supplement to NSF Career: A Unified Approach to Understanding, Education, and Design of Disinfection Processes using Computational Fluid Dynamics

*J.J. Ducoste  
National Science Foundation  
\$6,000  
09/04 to 09/05*

The proposed REU research program will enable two of my undergraduate students to work alongside MS and PhD students and conduct the following experimentation: (1) bench-scale disinfectant formation studies for chlorine and combined chlorine species to determine the kinetic rate constants in the CFD model, and (2) bench-scale disinfection studies involving the impact of sequential disinfectants on fluorescent microspheres.

### NCSU/NCA&T Program for STEM Enrollment Enhancement

*J.J. Ducoste (Co-PI) (Other PIs: John Fountain, MEAS; Carrie Thomas, MEAS, Robert Borden, CCEE; David Haase, Physics; Christine Grant, CBE; Christopher Gould, Physics; Jesus Rodriguez, Math; and William Switzer, Chem)  
National Science Foundation  
\$399,938 (\$12,006 to CCEE Department)  
01/03 to 12/05*

North Carolina State University and North Carolina Agricultural and Technological State University are collaborating in developing a program designed to increase the number of graduates in science, technology, engineering, and mathematics (STEM). Specific program elements include a summer camp at NCSU for graduating high school

students who have not selected their majors, summer bridge programs at both NCSU and NCA&T designed to prepare new STEM students for introductory college science and math courses, undergraduate research programs at both schools, tutoring and mentoring of STEM majors, and a faculty exchange program between the two campuses.

### NSF Kenan Fellow RET Program

*J.J. Ducoste (Research Participant); Ruben Carbonell, Deborah Mangum (Kenan Institute for Engineering, Technology, and Science)*  
National Science Foundation  
Provides one teacher for project duration  
01/04 to 01/07

The proposed site will provide science and engineering research projects for 20 middle and high school teachers from multiple school districts in order to develop a cohort of teacher leaders who will bring enhanced knowledge of engineering and technological innovation into their classrooms. The program is designed to foster student enthusiasm, interest, and competence both for pursuing careers in the field and for the acquisition of skills and knowledge demanded by an increasingly technological society. As a participant of this research team, I will be providing a research project(s) related to water and wastewater treatment processing and design.

### Development and Application of Optimal Design Capability for Coal Gasification Systems

*H.C. Frey*  
US Department of Energy, Federal Energy Technology Center, via Carnegie Mellon University  
\$205,000  
1997 to 2006

The objective of this project is to develop system analysis tools useful in evaluating energy systems and in addressing the complex problems of environmental management. This project includes the development of a guideline document describing methods for identifying and characterizing key technical and economic uncertainties which are required as inputs for stochastic modeling of energy technologies. This project will include development of new computer simulation models that shall predict the performance, emissions, and cost of advanced fossil fuel power generation and pollution control technologies specified by the US Department of Energy.

### Life Cycle Inventory and Impact Analysis Framework for Nonroad Construction Vehicles and Equipment Based Upon In-Use Measurements

*H.C. Frey and W.J. Rasdorf*  
National Science Foundation  
\$375,000  
08/03 to 08/06

This project represents the initial step toward development of a probabilistic life cycle inventory and impact analysis framework for nonroad construction vehicles and equipment. The objectives are to (1) characterize second-by-second in-use emissions and energy use of nonroad construction vehicles and equipment, including emissions of NO<sub>x</sub>, CO, hydrocarbons (HC), CO<sub>2</sub>, and particulate matter (PM), including real time sensing and monitoring where needed to fill data gaps; (2) develop a life cycle inventory of conventional nonroad construction vehicles and equipment; and (3) identify and recommend methods for reducing energy use, emissions, and impacts.

### Real World Duty Cycles and Utilization for Construction Equipment in NC

*H.C. Frey and W.J. Rasdorf*  
NC Department of Transportation  
\$164,730  
07/05 to 06/07

Construction vehicles contribute substantially to statewide emissions. 32 NC counties are partially or fully designated as non attainment under new air quality standards for ozone. Therefore there is a need to more accurately quantify the emissions from construction vehicles and seek opportunities to manage or reduce emissions. The goal of this study is to assess construction equipment types and uses, plan a field study, measure emissions and collect data, analyze the data and develop typical cycles, and demonstrate methods for estimating emissions for construction equipment.

### In-Vehicle Energy and Emissions Information System (IVEEIS)

*H.C. Frey and N.M. Roupail*  
National Science Foundation  
\$336,928  
03/03 to 12/06

The key objectives of this research project are to (1) develop a micro-scale predictor of energy use and emissions that is deployable at the individual vehicle level in real-time; (2) identify, compare, and evaluate alternate energy use and emissions sampling/reporting schemes that are appropriate at the vehicle and network levels; (3) develop and test a prototype In-Vehicle Energy and Emissions Information System (IVEEIS); and (4) formulate and assess the utility of IVEEIS in developing transportation design and control measures aimed at energy and emission management policies.

### Measurement and Analysis of Gasoline-Fueled Passenger Vehicle Emissions on Dirt versus Paved Roads and During Idling

*H.C. Frey*  
Texas Transportation Institute via Clean Air Technologies International, Inc.  
\$11,500  
06/05 to 07/05

The objectives of the study are to determine the possible increase in vehicular emissions as a result of traveling on a dirt road versus a paved road and to compare emissions during extended idling with emissions for comparable time periods when the vehicle is turned off and later restarted.

### Best Practices Guidebook for Greenhouse Gas Reductions in Freight Transportation

*B. Williams and H.C. Frey*  
US Department of Transportation via Center for Transportation and the Environment  
\$75,000  
03/05 to 03/07

This research project involves a comprehensive scan of the freight sector, including public and private sector players, to catalog the practices and programs that are being used to reduce greenhouse gas emissions in the goods movement. All transportation modes will be included. The final research product will be a best practices guidebook to be published and disseminated by the US Department of Transportation.

### **EPA Truck Anti-Idling Demonstration Project**

*Anne Tazewell (NC Solar Center), H. Christopher Frey, and John Stone*  
\$60,000  
08/05 to 08/06

The objective is to assess potential environmental benefits of heavy-duty diesel freight truck idle reduction technologies installed on trucks in NC. A key goal is to quantify actual grams per gallons emissions with a portable gas analyzer and compare this data with data extrapolated from an on-board data logger and fuel use with and without idle reduction technologies.

### **Geosynthetics Workplan**

*M.A. Gabr*  
FHWA  
\$60,000  
09/05 to 08/06

No definitive guidance on the value of systematically including geosynthetics in highway construction projects is currently available for the Federal Land Program of FHWA. It has been identified by engineers that geosynthetics are “under-used in Federal Lands Highway practice.” Accordingly, this study aims at developing a geosynthetics work plan to identify, promote, and advance the use of geosynthetics materials across FLH Divisions in the Pavement and Geotechnical areas. The target areas include pavement and geotechnical applications. Geotechnical applications will be focused on slopes, walls, base reinforcement, column supported embankments, capillary barriers to mitigate frost heaving, deep patches for soft shoulders, and geocomposite clay liners to control seepage from ditches.

### **Geologic and Environmental Modeling for Implementation of WIDE at Former Lockbourne Air Force Base**

*M.A. Gabr*  
Department of Defense, through W. Virginia University  
Water Resources Institute  
\$99,998  
07/05 to 12/06

This project implements Well Injection Depth Extraction (WIDE) technology for removal of JP-4 aviation fuel from the subsurface. Performance evaluation for deployment of WIDE will be performed with continuous monitoring for optimization of contaminant extraction. Baseline comparison of expanded deployment pads to existing field installation will be conducted and results compiled to discern predominant mass transfer mechanisms (vapor, product, or aqueous phases).

### **Remote Observation and Control of a Shake Table Experiment**

*Abhinav Gupta, V.C. Matzen, and M.A. Gabr*  
NC State University, DELTA/ IDEAS Grant  
\$9,900 (FY 2003-04), \$9,930 (FY 2004-05)

This project supports tasks that are needed in addition to those being conducted in the development of a prototype for remote observation and control of a shake table experiment under an NSF-sponsored project. These tasks are needed to integrate the prototype with the University computing network for incorporation in distance education courses. The tasks need to be implemented in a manner that would maintain real-time safety as well as security features built into the prototype. While the tasks being undertaken are specific to the shake table experiment, the outcome of this

work can be extended to other experiments either directly or with only minor modifications.

### **Internet-Enabled Laboratory Experiences for Undergraduate Civil Engineering Students**

*V.C. Matzen, M.A. Gabr, and Abhinav Gupta*  
National Science Foundation  
\$134,000  
07/03 to 06/06

This study is aimed at adaptation of recent developments in information technology for incorporation of internet-enabled civil engineering laboratory experiments in undergraduate structures and geotechnical courses. Faculty and students will be able to remotely access, run, and control these experiments either independently or in a classroom setting. Such a capability would facilitate the offering of these courses via distance learning program to provide opportunities for “non-traditional” students (e.g., part-time student, working parent, and career-changing adult) seeking careers in civil engineering. Implementation of this work will lead to enhancing the quality of undergraduate civil engineering courses and making laboratory curriculum widely accessible.

### **High-Silica Zeolites for the Removal of Polar Organic Contaminants from Drinking Water - Development of a “Green” Adsorption/Regeneration System**

*D.R.U. Knappe*  
American Water Works Association Research Foundation  
\$150,000  
02/03 to 02/06

The principal objective of this research is to develop an effective and environmentally friendly adsorption/regeneration system for removal of polar organic contaminants (POCs) from drinking water. The fuel oxygenate methyl tertiary butyl ether (MTBE) and antimicrobial compounds sulfamethoxazole and trimethoprim will serve as model POCs. The hypotheses that will be tested are (1) high-silica zeolites are more effective adsorbents for POCs than activated carbon and carbonaceous resins, (2) high-silica zeolites are resistant to fouling by natural organic matter (NOM), (3) adsorption capacity of spent high-silica zeolites can be recovered by low-temperature steam regeneration, and (4) regeneration waste stream can be effectively treated by photocatalytic oxidation.

### **Predicting Single-Solute Adsorption Isotherms for Non-Regulated Contaminants from Fundamental Adsorbent and Adsorbate Properties**

*D.R.U. Knappe*  
US Environmental Protection Agency  
\$65,000  
08/03 to 09/06

The objective of the proposed research is to predict single-solute adsorption isotherms for currently regulated organic contaminants, organic compounds on the EPA Contaminant Candidate List (CCL), emerging contaminants (endocrine disruptors, pharmaceutically active compounds, personal care products), and chemical agents (nerve agents, blister agents, blood agents, selected biological toxins, and toxic industrial chemicals). The Polanyi-Dubinin-Manes approach will serve as the basis for the model that will, for the first time, combine fundamental properties of the adsorbent and the adsorbate for isotherm prediction. Using Quantitative

Structure Property Relationships (QSPRs), molecular descriptors will be identified from which affinity coefficients for individual target molecules can be predicted.

### Evaluation of High-Silica Zeolites for MTBE Removal from Santa Monica Groundwater

*D.R.U. Knappe*  
University of Colorado, Boulder (subcontract for NCSU)  
\$5,000  
04/06 to 08/06

The principal objective of this research is to assess the effectiveness of a high-silica zeolite for MTBE removal from Santa Monica groundwater. Rapid small-scale column tests will be conducted to compare the useful life of an adsorption system containing high silica-zeolite to adsorption systems containing activated carbons with a range of physicochemical properties.

### Removal of 2-Methylisoborneol and Geosmin with High-Silica Zeolites and Zeolite-Enhanced Ozonation

*D.R.U. Knappe*  
American Water Works Association Research Foundation  
\$150,000  
02/06 to 01/08

The principal objective of this research is to assess the effectiveness of two innovative treatment methods for the control of earthy/musty odors associated with the presence of 2-methylisoborneol (MIB) and geosmin in drinking water. Treatment method 1 is an adsorption/reaction process based on the use of high-silica zeolites, a class of catalytic adsorbents that has not been studied extensively for water treatment applications. Treatment method 2 is an adsorption/oxidation process based on the combined use of high-silica zeolites and ozone (zeolite-enhanced ozonation).

### Design Criteria for Post and Beam Bents with Drilled Shafts and Other Structures

*M.J. Kowalsky and M. Gabr*  
NC Department of Transportation  
\$316,941  
07/05 to 06/07

The research described in this proposal aims to expand upon work currently underway for Pile-Bent bridge structures to all sub-structure systems employed by the NC Department of Transportation, including spread footings and columns supported on drilled shaft foundations. The research tasks encompass identifying issues specific to drilled shaft bent design and selection of a series of sample structures for analysis and design, as well as structural testing of bridge sub-structure to superstructure connections.

### Pile Bent Design Criteria

*M.J. Kowalsky and M.A. Gabr*  
NC Department of Transportation  
\$149,307  
07/04 to 07/06

The objective of this study is to develop improved design criteria for pile bents. Specifically, the work will be focused on (1) evaluating the impact of the pile cap rigidity to loads transferred to the piles within the bent, (2) specifying appropriate k-factors for pile analysis under varying boundary conditions appropriate to the problem geometry and connection scenarios, (3) proposing appropriate point of fixity taking into account the presence of the soil around the pile

above the specified point of fixity, and (4) proposing appropriate values for maximum lateral deflection for various boundary conditions and soil properties.

### Pile Bent Design Criteria

*M.J. Kowalsky and M.A. Gabr*  
NC Department of Transportation  
\$326,813  
07/05 to 07/07

Detailed 3D analysis models will be used to provide a better understanding of the actual performance of NC Department of Transportation sub-structure systems (depth to fixity; connection performance, effective length factors). In addition, the proposed work aims at providing a rational basis for identification of key performance limit states (drift and strength limits) as well as design examples comparing LFD and LRFD criteria for bridge sub-structures.

### DDDAS-TMRP (Collaborative Research): An Adaptive Cyberinfrastructure for Threat Management in Urban Water Distribution Systems

*G. Mahinthakumar, E.D. Brill, R. Ranjithan (Co-PI's, NCSU), J. Uber (Univ. of Cincinnati); Gregor Von Laszewski (Univ. of Chicago); and K. Harrison, (Univ. of South Carolina)*  
National Science Foundation (Dynamic Data Driven Application Systems Program)  
\$779,986 (NCSU share is \$264,624)  
01/06 to 12/08

The goal of this multidisciplinary research is to develop a cyberinfrastructure system for water distribution system threat management that will both adapt to and control changing needs in data, models, computer resources and management choices facilitated by a dynamic workflow design. Using virtual simulation and a field study, this cyberinfrastructure will be tested on illustrative scenarios for adaptive management of contamination events in water distribution systems.

### PERC: High-end Computer System Performance: Science and Engineering

*G. Mahinthakumar*  
UT Battelle LLC  
\$189,203  
10/01 to 06/06

This project is part of a larger scale effort funded by DOE through the SciDAC (Scientific Discovery through Advanced Computing) program. The overall goal of the project is to establish an enabling technology center in the area of high-end computer performance called performance engineering research center (PERC). The NC State University component of this project will focus on performance analysis, performance modeling, and performance tool evaluation.

### High-end Computing in Environmental Engineering with Application to Subsurface Characterization

*G. Mahinthakumar*  
National Science Foundation (Career)  
\$400,000  
07/03 to 06/08

Accurate characterization of the subsurface is an important element in the development of reliable and efficient groundwater management practices. Accurate and reliable

estimation of hydraulic conductivity distribution, contaminant distribution, and/or contaminant source release history is necessary for problems such as estimating groundwater yields, design of efficient cleanup strategies, and identifying responsible parties in a contamination incident. This requires solution of an inverse problem because direct measurement of detailed subsurface properties is not feasible. Inverse problems are difficult to solve and are computationally demanding. This multidisciplinary NSF Career project will investigate novel computational strategies for the efficient solution of large-scale inverse problems in subsurface characterization.

### **ITR: A Prototype to Support Near Real-Time Environmental Characterization**

*G. Mahinthakumar, R. Ranjithan, and Nick Karonis  
(Northern Illinois University)  
National Science Foundation  
\$497,418  
09/03 to 08/06*

The overall goal of this project is to investigate formal computational approaches that can readily harness grid computing for the efficient solution of environmental characterization problems. To this end, we will develop a grid-enabled software framework. Two alternative paradigms, one based on the grid-enabled version of MPI (Message Passing Interface), and the other based on Java will be explored. The framework will be applied to groundwater and surface water problems, both of which are of prime societal importance.

### **GRS Supplement to ITR to Increase Minority Participation**

*G. Mahinthakumar and R. Ranjithan  
National Science Foundation (Graduate Research Supplement program)  
\$33,986  
09/05 to 08/06*

This graduate research supplement supports an African American environmental engineering PhD student to conduct research in parallel simulation-optimization techniques and to carry out teaching activities leading to an academic career.

### **GIS-Based Research of Natural and Anthropogenic Terrain Change Impacts on Water and Sediment Transport in Different Environments**

*H. Mitsova and M. Overton  
Army Research Office  
\$118,212  
07/04 to 06/07*

The proposed research will focus on the acquisition of new knowledge about the interactions between natural processes and anthropogenic activities that can be used to improve current understanding of terrain change impact on landscape processes. The objectives are to investigate these interactions within three fundamentally different environments affected by different development activity: a coastal barrier island environment, a montane tropical watershed, and a piedmont landscape that includes a military installation. The research will be directed toward the development and analysis of methods for GIS-based modeling of topography, its structure and evolution and innovative numerical landscape erosion and evolution modeling techniques.

### **Shoreline Monitoring at Oregon Inlet**

*M.F. Overton and J. S. Fisher  
NC Department of Transportation  
\$84,440  
07/05 to 06/06*

The purpose of this ongoing project (1989 to present) is to monitor and evaluate the response of a six-mile stretch of shoreline just south of the terminal groin constructed to protect the bridge at the north end of Pea Island. The purpose of phase one was to establish the “historical erosion rates” for the study area since the change in dredging operations in the inlet in 1984 and before the March 1989 storm. The continuing phases of the project consist of determining position of the shoreline from air photography every two months and evaluating the response of the shoreline in the context of the historical erosion rates.

### **Urban Watershed Management Tools**

*S. Ranji Ranjithan  
US EPA/MCNC  
\$147,125  
10/01 to 09/04*

US EPA’s Multimedia Integrated Modeling System (MIMS) provides a unified computing framework to simulate the cycling of environmental pollutants within and across all media. The simulation models are to be coupled with systems analytic methods (including uncertainty analysis and optimization-based search procedures) to explore and identify efficient strategies to manage urban watershed management problems. In addition, decision-makers require cost/benefit tradeoffs and reliability associated with different strategies. The objective of this project is to integrate urban watershed decisions support tools into MIMS, and demonstrate their use with US EPA’s Storm Water Management Model (version 5).

### **Regional Development, Population Trend and Technology Change Impacts on Future Air Pollution Emissions**

*N.M. Rophail and H.C. Frey  
UNC-CH, EPA  
\$238,690 (including \$73,000 CTE contribution)  
11/04 to 11/07*

The research tests the hypothesis that smart-growth development patterns can significantly influence the quantity and location of direct and indirect emissions from mobile sources. The patterns of interest include the type of development and its location. We will develop a general method for exploring the leverage that smart-growth development patterns have on the spatial pattern and quantity of emissions from mobile sources. We will explore scenarios and chart the envelope of the effectiveness of smart growth as a means for reducing emissions. We will determine whether substantial emissions reductions are feasible with forecasts of the market penetration of smart growth.

## **CIVIL, CONSTRUCTION, AND ENVIRONMENTAL ENGINEERING FACULTY**

Sankar Arumugam, Assistant Professor (919-515-7700); PhD Tufts University; Understanding, modeling and forecasting hydrological fluxes at large spatial scales based on land surface and climatic indices; water resources planning and analysis; integrated water management and environmental assessment in developing countries. [sankar\_arumugam@ncsu.edu]

Morton A. Barlaz, Associate Head and Professor (919/515-7676); PhD University of Wisconsin-Madison; Environmental, solid waste management, decomposition in landfills, anaerobic microbiology, biological processes. [barlaz@unity.ncsu.edu] [http://people.engr.ncsu.edu/barlaz]

John W. Baugh, Professor (919/515-7697); PhD Carnegie Mellon University; Computer-aided engineering, mathematical modeling, optimization, support for engineering design. [jwb@eos.ncsu.edu]

Leonhard E. Bernold, Director of the Center for Construction Technology and Integration and Associate Professor (919/515-3677); PhD Georgia Institute of Technology; Advanced construction technologies, project-wide integration, space construction, automated processing planning and control. [bernold@eos.ncsu.edu] [http://CARL.ce.ncsu.edu]

Robert C. Borden, Professor (919/515-1625); PhD Rice University; Groundwater contamination and remediation, stormwater quality management. [rcborden@eos.ncsu.edu]

Roy H. Borden, Professor (919/515-7630); PhD Northwestern University; Geotechnics, geoenvironmental engineering, *in situ* and laboratory evaluation of soil properties, grouting and soil improvement techniques, excavation support and foundation engineering. [borden@eos.ncsu.edu]

E. Downey Brill Jr., Professor (919/515-2331); PhD The Johns Hopkins University; Environmental systems analysis, modeling, optimization. [brill@eos.ncsu.edu]

Allen C. Chao, Associate Professor (919/515-7702); PhD Clemson University; Unit operations and processes of water and waste treatment. [chao@eos.ncsu.edu]

Francis L. de los Reyes III, Assistant Professor (919/515-7416); PhD University of Illinois at Urbana-Champaign; Biological wastewater treatment, environmental microbiology, molecular techniques in microbial ecology, biological process engineering. [fldelosr@eos.ncsu.edu] [http://www4.ncsu.edu/~fldelosr]

Joel J. Ducoste, Associate Professor (919/515-8150); PhD University of Illinois at Urbana-Champaign; Water/wastewater treatment, solid/liquid separation, chemical mixing, disinfection, computational fluid dynamics (CFD) modeling. [jducoste@eos.ncsu.edu]

T. Matthew Evans, Assistant Professor (919/515-7631); PhD Georgia Institute of Technology; Geotechnical engineering, soil micromechanics, granular materials, unsaturated soil mechanics, discrete element methods, complex earth structures and geotechnical processes, soil-continuum interfaces, computer applications, image analysis. [matt\_evans@ncsu.edu]

John S. Fisher, Director of the Center for Transportation and the Environment and Professor (919/515-7627); PhD Massachusetts Institute of Technology; Coastal engineering and sediment transport, natural hazard mitigation. [john\_fisher@ncsu.edu] [http://itre.ncsu.edu/cte/]

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