

# CTRE en route

Summer 2005

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*CTRE en route* is published twice a year to inform readers about CTRE's projects and programs.



Intelligent compaction is one way the Partnership for Geotechnical Advancement is helping improve construction processes.



Center for Transportation  
Research and Education

Address: CTRE, 2901 S. Loop Drive,  
Suite 3100, Ames, IA 50010

Phone: 515-294-8103  
FAX: 515-294-0467

Website: [www.ctre.iastate.edu/](http://www.ctre.iastate.edu/)

CTRE Communications:

[Marcia Brink](#)

*CTRE en route* editor:

[Michele Regenold](#)

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### [New concrete handles a heavy, heavy load](#)

Iowa State University researchers break a bridge beam made of ultra-high performance concrete. It only took 595,000 pounds of hydraulic load to do it.

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### [CTRE's new visual identity](#)

CTRE has a new look and feel to its print and web documents.

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Read about projects completed since February 2005. This list includes brief summary and links to project details and related publications.

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Find out about projects begun since February 2005. This list includes links to brief project statements.

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## Partnership for Geotechnical Advancement

Quietly begun in late 2002, the Partnership for Geotechnical Advancement (PGA) is a program that gives CTRE one more piece of the roadway puzzle.

PGA focuses on geotechnical engineering, i.e., soil mechanics, earth structures, foundations, and retaining structures. The main objective of PGA research and outreach is to make highways last longer by improving the quality of the construction process.

### Research on intelligent compaction



Operator display on a CAT compaction monitoring system

Soil is compacted to specific levels in order to give it the structural characteristics to carry the heavy loads of a pavement, a building, or other structure.

Intelligent compaction involves installing an instrument on a roller so the operator knows in real time how well the soil is being compacted. With 100 percent testing information, the quality of the soil compaction is improved. And without having to stop work for manual tests, the specified compaction is also achieved more quickly.

PGA research on intelligent compaction includes the following:

- [Field Evaluation of Compaction Monitoring Technology: Phase I](#) (complete)
- [Field Evaluation of Compaction Monitoring Technology: Phase 2](#) (in progress)

### For more information

For more information about the PGA, view the [program's website](#). (off site)

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Compaction machine



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CTRE Communications:

[Marcia Brink](#)

*CTRE en route* editor:

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## Sharing results: The Mid-Continent Transportation Research Symposium

by Steve Andrie, CTRE Director

Iowa held its fifth biennial Mid-Continent Transportation Research Symposium August 18–19, 2005, in Ames. The symposium is sponsored by the Iowa Department of Transportation and the Center for Transportation Research and Education at Iowa State University. We were pleased to receive 106 papers and presentations from 14 universities in 11 states. Representatives of nine private sector firms presented papers as well as engineers and planners from the Iowa, Minnesota, and Kansas DOTs and the Nebraska Department of Roads.

### Keynote speakers



Sandra Larson, Iowa DOT, and keynote speaker Neil Hawks, TRB, chat during the symposium

Neil Hawks from the Transportation Research Board and Wes Lum from the California Department of Transportation were keynote speakers.

**Mr. Hawks, the TRB director of special programs**, reminded us of our Iowa transportation history and its national importance. Anson Marston, the ISU Dean of the College of Engineering in the early 20th Century, created the Iowa Highway Commission and became the first commissioner. He was instrumental in creating the Highway Research Board (now TRB) in 1920 and was professor and mentor to Tom McDonald, who became the director of the Bureau of Public Roads in 1919, serving until 1953. During his 34-year tenure, Mr. McDonald was instrumental in creating the cooperative research approach among states, the guiding principle for TRB research, and was truly the father of the interstate highway system. Mr. Hawks challenged us to live up to our history.

**Mr. Lum, the national liaison for the California Department of Transportation**, hit some of the highlights of the recently passed SAFETEA-LU such as the Strategic Highway Research Program (SHRP-2), Highways for Life, road weather research, and increased funding for transportation research universities. He talked about the role of universities in conducting transportation research, the importance of partnerships, and how universities can successfully partner with DOTs.

He featured the Concrete Pavement Research Road Map, which was prepared for the Federal Highway Administration by a team led by the Center for Portland Cement Concrete Pavement Technology at ISU. Mr. Lum used the roadmap as an illustration of collaborative research and a good model for strategic and tactical thinking. The roadmap defines a “destination” and maps the steps needed to get there. The process is similar to the planning process used by TRB for planning strategic research under the SHRP-2 program. As research is completed he emphasized the importance of implementation to gain the benefits.

### Nationally prominent researchers

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CTRE Communications:

[Marcia Brink](#)

*CTRE en route* editor:

[Michele Regenold](#)

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We were honored by the participation of nationally prominent researchers like William Mahoney from the National Center for Atmospheric Research and Robert Hallowell from MIT's Lincoln Labs, who discussed aspects of road weather research. Stephan Parker from the Transportation Research Board leads TRB's security research. Mr. Parker shared some of the salient findings with the symposium. Joe DeLorenzo from the Federal Motor Carrier Safety Administration discussed the benefits of technology in securing hazardous materials in transport.

## Transportation research in the Midwest

The symposium's theme was "practical solutions to real problems." There was no topical theme. Abstracts were reviewed by a planning committee and the accepted papers grouped into tracks. The response from researchers constitutes an informal survey of the type of transportation research being performed in the Midwest. The symposium's 12 tracks and the number of presentations in each is shown below:

Track	No. of Presentations
Safety	19
Concrete Pavements	14
Bridges and Structures	11
Planning	10
Design and Construction	9
Asphalt Pavements	8
ITS	8
Road Weather	7
Geotechnical engineering	7
Asset Management	5
Security	4
Environment	4

## Symposium proceedings

The [symposium proceedings](#) is available online.

## Next symposium

The Mid-Continent Transportation Research Symposium has been a biennial event since its inception in 1996. The Wisconsin DOT and the Midwest Regional University Transportation Research Center at the University of Wisconsin-Madison would like to make the symposium an annual event. So next year [the symposium will be in Madison with a "research pays off" theme](#). The plan is for the symposium to alternate between Ames and Madison each year.

Welcome, Badgers.

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## CP Road Map

Iowa State University led development of the Long-Term Plan for Concrete Pavement Research and Technology (or [CP Road Map](#) (off site)), and the plan is now being published in two volumes, with a widely distributed executive summary. The CP Road Map is a comprehensive and strategic plan for concrete pavement research that will guide the investment of approximately \$250 million over the next 10 years. It will result in technologies and systems that help the concrete pavement community meet the paving needs of today and the as-yet unimagined paving challenges of tomorrow. In short, the CP Road Map will result in a new generation of concrete pavements for the 21st century. The Federal Highway Administration will be posting an RFP for the administrative support functions of the CP Road Map.

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## Geotechnical Mobile Lab

IOWA STATE UNIVERSITY  
**GEOTECHNICAL MOBILE LAB**  
Advancing Intelligent Construction



This graphic will appear on the side of the mobile lab.

A new Iowa State University mobile lab will soon be ready for use in geotechnical construction quality control/quality assurance (QC/QA). The Geotechnical Mobile Lab will be capable of performing a wide range of new and conventional soil tests. Use of the Geotechnical Mobile Lab is expected to lead to the following benefits: increased productivity and efficiency, reduced construction costs, more responsible use of public investments, greater reliability, and improved performance.

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## Bridge Engineering Center builds latest technology into I-235 bridges



Researchers load test the East 12th Street Bridge over I-235 in Des Moines.

Some very smart bridges are telling engineers just exactly how they're holding up.

They've reported on the stresses and strains of construction. They've quantified the ability of high performance steel to move metro traffic. And they've advanced the state of the art in bridge engineering.

Engineers from Iowa State University's [Bridge Engineering Center](#) (off site) have helped the Iowa Department of Transportation monitor and evaluate three bridges as part of the Interstate 235 reconstruction project in Des Moines.

"This work that we're doing is going to help build more durable bridges," said Terry Wipf, the director of the Bridge Engineering Center and the Pitt-Des Moines Professor in Civil Engineering at Iowa State. "They'll last longer and they'll save the state money."

Here's how Iowa State engineers are helping the state build better bridges over I-235:

### Fiber optic sensors

Engineers have installed fiber optic strain gauges in the East 12th Street bridge and the pedestrian bridges at 40th and 44th streets. The gauges work by transmitting light through glass fibers. Every strain on the fibers changes the light that's reflected back. A black box records the changes and therefore the strains. The system can take up to 250 measurements every second. That strain history is recorded by computers and can tell engineers how a bridge is doing.

It's new technology, said Justin Doornink, a doctoral student from Sioux Center, Iowa, who's specializing in the gauges. Iowa State engineers are researching its uses and applications. And they're helping the transportation department put the technology to work.

### High performance steel

The East 12th Street bridge is the first -- and still the only -- Iowa bridge made with high performance steel. The steel is designed to be stronger and tougher. That means it takes longer for cracks to develop. And once cracks develop, they spread much slower.

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For more information, contact Terry Wipf, Bridge Engineering Center, (515) 294-6979

Brent Phares, Bridge Engineering Center, (515) 294-5879

Mike LaViolette, Bridge Engineering Center, (515) 294-6838

Justin Doornink, Bridge Engineering Center, (515) 294-5642

Ahmad Abu-Hawash, Iowa Department of Transportation, (515) 239-1393



Address: CTRE, 2901 S. Loop Drive, Suite 3100, Ames, IA 50010

Phone: 515-294-8103  
FAX: 515-294-0467

Website: [www.ctre.iastate.edu/](http://www.ctre.iastate.edu/)

CTRE Communications:

[Marcia Brink](#)

*CTRE en route* editor:

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Brent Phares, the associate director of the Bridge Engineering Center and an adjunct assistant professor of civil, construction and environmental engineering at Iowa State, said researchers have built fiber optic strain gauges into the bridge to continuously measure how the bridge and its new steel perform over time.

The Federal Highway Administration supported the monitoring research with a \$155,000 grant from the Innovative Bridge Research and Construction program.

## **Pedestrian bridges**

To overcome difficulties constructing the first pedestrian bridge over I-235 at East Sixth Street, the Iowa Department of Transportation asked Iowa State engineers to install strain gauges on the project's other two pedestrian bridges. Those bridges over 40th and 44th streets are scheduled to be completed this fall.

Mike LaViolette, a bridge research specialist with the Bridge Engineering Center, said the gauges were installed on the hangers supporting the bridges' concrete walking surfaces. The gauges measured the forces on the bridges when crews installed the walking surfaces. Iowa State engineers also installed accelerometers on the bridges as another way to measure the forces during construction. The instruments helped crews prevent cracking by keeping the forces within the bridge's design capabilities.

The Iowa Department of Transportation supported the monitoring project with about \$50,000.

Ahmad Abu-Hawash, the chief structural engineer in the transportation department's Office of Bridges and Structures, said the department called on Iowa State engineers for help with the I-235 bridges because they have specialized expertise.

"Any time you use new design methods or innovative materials, you want to do some research to evaluate performance," Abu-Hawash said. "That's why they're helpful."

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## Bridge Engineering Center protects the bridges of Madison County



Cedar Bridge, Madison County, Iowa

Engineers at Iowa State University's [Bridge Engineering Center](#) (off site) are developing round-the-clock monitoring technology to help protect the bridges of Madison County.

That same technology could be adapted to any bridge where security is an issue, said Terry Wipf, the director of Iowa State's Bridge Engineering Center.

Madison County's historic covered bridges—made famous by Robert James Waller's 1992 novel "The Bridges of Madison County" and the 1995 movie directed by Clint Eastwood—have been arson targets in recent years. A September 2002 fire destroyed the 1883 Cedar Bridge. A year later the 1884 Hogback Bridge was damaged by an arson fire.

Engineers from the Bridge Engineering Center are now testing a monitoring system that will cover one of the bridges with three layers of remote monitoring equipment. Brent Phares, the associate director of the Bridge Engineering Center, said the equipment includes:

- Flame detection devices. The devices detect infrared light, ultraviolet light, and the flicker rate as the light frequencies change. Phares said flames emit a light signature the devices will recognize.
- Infrared cameras. The cameras record heat rather than light. They'll photograph people at the bridge—even on the darkest night. And they'll detect the heat flash if a fire is ignited.
- Fiber-optic strain gauges. The gauges will be attached to the bridge and will measure changes in temperature.

Data from the monitoring equipment will be collected and processed by a computer at the bridge, Phares said. If the equipment detects something suspicious, emergency crews will be notified. Dispatchers will also have access to video images from the monitoring equipment so they can determine whether there's an emergency.

The equipment is expected to be installed on one of the covered bridges by September. Engineers and police officials will then stage mock arson and vandalism incidents to test the system's capabilities.

The project is supported by a \$126,000 grant from the U.S. Department of Agriculture Forest Service's Forest Products Laboratory in Madison, Wis. The laboratory and the center have cooperated for more than 20 years on transportation research projects.

"I believe this will help more than anything we've done," said Todd Hagan, the Madison County engineer. "Our other forms of protection are all after-the-fact. This is hopefully something that will get us there before it's too late."

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Bridge Engineering Center researchers are developing a remote monitoring system for deployment on covered bridges in Madison County, Iowa.

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Phone: 515-294-8103  
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CTRE Communications:  
[Marcia Brink](#)  
*CTRE en route* editor:  
[Michele Regenold](#)

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## For more information

View [details of the research project](#).

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## New concrete handles a heavy, heavy load



Researchers examine the cracks along one end of a 71-foot bridge beam made of ultra-high performance concrete. The beam didn't hold up quite as much of a load as researchers expected. But they say a similar beam will still make a mighty strong bridge over Little Soap Creek in southeast Iowa later this summer.

It broke with a loud pop.

And then Iowa State University researchers gathered around to examine the long diagonal crack along one end of a 71-foot bridge beam made of ultra-high performance concrete. The capacity test was part of a \$450,000 project to study the innovative concrete. The project was funded by the Federal Highway Administration and the Iowa Highway Research Board.

The researchers spent the morning of June 10, 2005, applying more and more hydraulic pressure to the top of the beam. They wanted to see how much it could take before breaking. And it took a lot: 595,000 pounds of load. That's more than the weight of seven semi trucks.

Brian Degen, a graduate student in civil engineering, said researchers had predicted the beam would break under 640,000 pounds of load.

It couldn't hold that much. But Brent Phares, the associate director of Iowa State's [Bridge Engineering Center](#) (off site), said a similar beam isn't going to have any problems holding up 100th Avenue over Little Soap Creek in southeast Iowa's Wapello County. When that bridge is built this summer, it will be the first time engineers will use ultra-high performance concrete in an American bridge.

Ultra-high performance concrete is made from sand, cement, water, and small steel fibers. It does not contain the coarse aggregate found in standard concrete. Because the ultra-high performance concrete is engineered to include finer materials and steel fibers, it's denser and stronger than standard concrete.

Phares estimated a beam of ultra-high performance concrete can hold twice the load of a similar beam made of standard concrete.

Did the researchers learn anything else from their cracked beam?

Yes, said Degen, "This bridge is going to be strong."

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## Sign up for CTRE's RSS news feed

RSS, which stands for rich site summary or really simple syndication, is a method for distributing news headlines and links to more information. It's a way for busy people to stay on top of the news they're interested in without having to visit several different websites.

It's also a way to avoid spammers because you select the news sources you're interested in. Once the news sites you want are programmed into your news reader (see below), you'll just have to open your news reader and all the news you've requested will be there.

CTRE's news feed provides information about recently completed research, upcoming events, and other transportation-related news.

Link to CTRE's news feed: <http://www.ctre.iastate.edu/rss/ctre.xml>

## Using a news reader/ aggregator

To collect news from websites that use RSS, you'll need special software called a news reader or news aggregator. This software is often free or inexpensive and available for download. [See this list of news readers at Google.](#)

Once you have a news reader, you're ready to find sources of news ("feeds"):

1. Go to your favorite websites to see if they offer news feeds. Look for the "RSS" or "XML" symbol.
2. Click on the symbol to get the URL of the feed.
3. Enter the URL into your news reader. You only need to do this once for each site.

Your news reader will automatically and periodically check all the sites you enter for the latest

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## CTRE's new visual identity

The Center for Transportation Research and Education (CTRE) has developed a new look and a new logo. With the diversity and growth of CTRE programs, we needed an identity that helped explain the relationship of CTRE to its various programs.



CTRE's old logo clashed with program logos rather than unifying them.

The new text-based logo (see left) is also more flexible. The "C" changes color to match the primary color of our individual program logos.

When CTRE adopted its previous logo in 1995 (see right), the center consisted of two programs: the Iowa Local Technical Assistance Program and the Midwest Transportation Center (the University Transportation Center for Iowa, Kansas, Missouri, and Nebraska from 1988 to 1996).

Since 1995, several more programs have sprouted or been transplanted beneath the CTRE umbrella:

- The [Iowa Pavement Management Program \(IPMP\)](#) provides Iowa agencies with automated distress data collection services, IPMP database software and support, and training workshops. This program is being folded into a broader asset management program called Roadway Infrastructure Management Systems. Program Manager: Omar Smadi, 515-294-7110, [smadi@iastate.edu](mailto:smadi@iastate.edu)
- The [Center for Portland Cement Concrete Pavement Technology \(PCC Center\)](#) is vigorously supported by Iowa's PCC paving industry, which recognizes the critical need for longer lasting, better performing pavements. Center Manager: Tom Cackler, 515-294-3230, [tcackler@iastate.edu](mailto:tcackler@iastate.edu)
- The [Bridge Engineering Center](#) research addresses the improvement and maintenance of bridge infrastructure, particularly with non-destructive testing. Center Manager: Terry Wipf, 515-294-9501, [tjwipf@iastate.edu](mailto:tjwipf@iastate.edu)
- The [Partnership for Geotechnical Advancement](#), begun in 2002, is a partnership between Iowa's grading industry, the Iowa Department of Transportation, and CTRE. Program Manager: Tom Cackler, 515-294-3230, [tcackler@iastate.edu](mailto:tcackler@iastate.edu)
- The [Construction Management & Technology \(CM&T\)](#) program researches innovative construction technologies and processes for the transportation industry. Program Manager: Ed Jaselskis, 515-294-0250, [ejaselsk@iastate.edu](mailto:ejaselsk@iastate.edu)
- The [Iowa Traffic Safety Data Service \(ITSDS\)](#) serves transportation professionals in Iowa who need quick access to recent crash facts and who want to present that information in meaningful, graphical formats to councils, supervisors, or the public. Program Manager: Reg Souleyrette, 515-294-5453, [reg@iastate.edu](mailto:reg@iastate.edu)
- The [Iowa Statewide Urban Designs and Specifications manuals](#) for public improvements are being developed by CTRE. The manuals include design and construction details that are unique to specific jurisdictions across the state. Program Manager: Larry Stevens, 515-294-0419, [lstevens@iastate.edu](mailto:lstevens@iastate.edu)
- The [Midwest Transportation Consortium \(MTC\)](#) is building a community of expertise around an important emerging issue—transportation asset management—in its role as the U.S. DOT's University Transportation Center Program (from 1999 to the present) for Iowa, Missouri, Kansas, and Nebraska. Program Manager: Tom Maze, 515-294-9459, [tmaze@iastate.edu](mailto:tmaze@iastate.edu)

CTRE's new logo also coordinates better with the Iowa State University logo and identity system. The redesign of the *CTRE en route* and CTRE websites in particular reflect the Iowa State look.

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## Recently completed research

Below is a list of projects that were completed between February 2005 and July 2005. All links will take you off site.

### CTRE projects

- [Safety Impacts of Street Lighting at Isolated Rural Intersections](#)

This study was initiated to evaluate the effectiveness of rural street lighting in reducing nighttime crashes at isolated rural intersections so that Minnesota agencies have more information to make lighting decisions.

- [Cost Comparison of Treatments Used to Maintain or Upgrade Aggregate Roads](#)

This report describes a research project that provides Minnesota counties, and townships with information and procedures to make informed decisions on when it may be advantageous to upgrade and pave gravel roads.

- [Identification of the Best Practices for the Design, Construction, and Repair of Bridge Approach Sections](#)

Bridge approach settlement and the formation of the bump is a common problem in Iowa that draws upon considerable resources for maintenance and creates a negative perception in the minds of transportation users. This research study was undertaken to investigate bridge approach problems and develop new concepts for design, construction, and maintenance that will reduce this costly problem.

- [Iowa Drainage Law Manual](#)

To assist property owners, public agencies, and others with interest in better understanding drainage maintenance responsibilities, a reference manual was developed to describe Iowa's drainage laws and offer interpretations in a clear and concise manner.

- [Development of a Method to Determine Pavement Damage Due to Detours](#)

The research presented in this report provides the basis for the development of a new procedure to be used by the Iowa DOT and cities and counties in the state to deal with

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detours.

- [Review of Stability Berm Alternatives for Environmentally Sensitive Areas](#)

The purpose of this project was to review existing stability berm alternatives for potential use in environmentally sensitive areas. The project also evaluates how stabilization technologies are made feasible, desirable, and cost-effective for transportation projects and determines which alternatives afford practical solutions for avoiding and minimizing impacts to environmentally sensitive areas.

- [Implementing the Mechanistic-Empirical Pavement Design Guide \(MEPDG\)](#)

This project includes an implementation plan to help state DOTs effectively and efficiently transition to the M-E Pavement Design Guide and a report that outlines the technical aspects of the new MEPDG.

## Construction Management & Technology projects

- [Synthesis of Non-destructive Testing Technologies for Geomaterial Applications](#)

This research resulted in a synthesis of potential technologies for compaction monitoring with a strong emphasis on moisture sensing.

## Bridge Engineering Center projects

- [Impacts of Overweight Implements of Husbandry on Minnesota Roads and Bridges](#)

The objective of the work presented in this report was to perform a synthesis study related to the impacts of heavy agriculture vehicles on Minnesota pavements and bridges and to identify those impacts. The synthesis and associated analyses were completed using metrics that are consistent with engineering design and evaluation concepts.

- [Health Monitoring of Bridge Structures and Components Using Smart-Structure Technology](#)

The objective of this research was to synthesize information on structural health monitoring technologies with a specific interest in those having smart-structure attributes.

## Midwest Transportation Consortium projects

- [Evaluation of Different Methods to Calculate Heavy-Truck VMT](#)

This research evaluated three different methods for calculating heavy-truck annual average daily traffic (AADT), which can subsequently be used to estimate vehicle miles traveled (VMT).

- [An Investigation of User Costs and Benefits of Winter Road Closures](#)

This project investigated the costs and benefits of road closures and found that evaluating the benefits and costs is not as simple as it appears.

- [A Web-based Implementation of Winter Maintenance Decision Support System \(WMDSS\) Using GIS and Remote Sensing](#)

A major goal of the project was to implement a web-based Winter Maintenance Decision Support System (WMDSS) for planning snow removal operations that enhances the capacity of stakeholders (city/county planners, resource managers,

transportation personnel, citizens, and policy makers) to evaluate different procedures to manage snow removal assets optimally.

## Center for Portland Cement Concrete Pavement Technology projects

- [Long Term Plan for Concrete Pavement Research and Technology \(Task 15\)](#)

A new long term plan for concrete pavement research to chart the path from the current state-of-the-practice to a new generation of concrete pavements that are affordable, constructible, safe, reliable, durable, and renewable.

- [Soil Stabilization of Non-uniform Subgrade Soils](#)

This project report is in two volumes: (Volume I) Engineering Properties and Construction Guidelines and (Volume II) Influence of Subgrade Non-Uniformity on PCC Pavement Performance.

- [Measuring Pavement Profile at the Slip-form Paver](#)

In an attempt to correct the inconsistency between measuring techniques, lightweight profilers intended to produce values to be used for construction acceptance are being made that measure the same profile as high-speed inertial profilers. Currently, two profiler systems have been identified that can measure pavement profile during construction. This research has produced a field evaluation of the two systems.

- [Field Evaluation of Elliptical Fiber Reinforced Polymer Dowel Performance](#)

Iowa State University has completed a large amount of laboratory research to determine the diameter, spacing, and durability of FRP dowels. This report documents the performance of elliptical FRP dowels installed in a field situation.

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# CTRE en route

Summer 2005

## Recently started research

Below is a list of projects that were started between February 2005 and July 2005. All links will take you off site.

### CTRE projects

- [Linking Five- and Seven-a-Day Fresh Produce Serving Equivalents for Iowa Consumers with Economic Benefits for Farmers](#)
- [Four-Lane to Three-Lane Analysis](#)
- [Empirical Bayes Analysis of High Speed Signalized Expressway Safety](#)
- [Planning, Development, and Implementation of the Iowa Pavement Marking Management Program](#)
- [Sign Management System for the Iowa DOT](#)
- [Best Practices and Recommended Strategies for Shared Left Turn Lanes at Signal Control Approaches](#)

### Construction Management & Technology projects

- [Using Scanning Lasers for Real-Time Pavement Thickness Measurement](#)

### Bridge Engineering Center projects

- [Development of an Improved Integral Abutment-to-Approach Slab Connection](#)

### Center for Portland Cement Concrete Pavement Technology projects

*CTRE en route* is published twice a year to inform readers about CTRE's projects and programs.



Center for Transportation  
Research and Education

Address: CTRE, 2901 S. Loop Drive,  
Suite 3100, Ames, IA 50010

Phone: 515-294-8103

FAX: 515-294-0467

Website: [www.ctre.iastate.edu/](http://www.ctre.iastate.edu/)

CTRE Communications:

[Marcia Brink](#)

*CTRE en route* editor:

[Michele Regenold](#)

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center.

- [De-icer Scaling Resistance of Concrete Pavements, Bridge Decks, and Other Structures Containing Slag Cement](#)
- [Iowa Data Collection and Analysis for the 2005–2006 National Surface Characteristics Field Experiment Plan](#)

## Midwest Transportation Consortium projects

- [Asset Management Strategies to Mitigate Freeway Work Zone Congestion](#)
- [Development of Fatigue Design Procedures for Slender, Tapered Support Structures for Highway Signs, Luminaries, and Traffic Signals Subjected to Wind-Induced Excitation from Vortex Shedding and Buffeting](#)
- [An Integrated Systems Approach to the Development of Winter Maintenance / Management Systems](#)
- [Secondary Accident Data Fusion for Assessing Long Term Performance of Transportation Systems](#)
- [Determining the Costs of Truck Transit Delays for Shippers of Freight: An Exploratory Study](#)

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