Public Roads

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January/February 2004

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U.S. Department of Transportation

Federal Highway Administration

Public Roads

— featuring developments in Federal highway policies, programs, and research and technology —

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Front cover—The rolling wheel deflectometer (RWD), housed within a semitruck and trailer, is one of the Federal Highway Administration's latest innovations in pavement management. Shown here on a highway in Champaign, IL, the RWD enables pavement managers to measure the load-carrying capacity of paved highways and detect places where weaknesses may exist, while traveling at normal highway speeds.

Back cover—Four lasers like this one mounted on an aluminum bar beneath the trailer measure pavement deflection as the RWD travels down the highway. A personal computer inside the trailer receives and processes the data in real time. The lasers and rapid processing time enable pavement managers to collect a sample every 12.2 millimeters (0.48 inch) at 88 kilometers per hour (55 miles per hour).

U.S. Department of Transportation
Federal Highway Administration

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Public Roads (ISSN 0033-3735; USPS 516-690) is published bimonthly by the Office of Research, Development, and Technology, Federal Highway Administration (FHWA), 400 Seventh Street SW, Washington, DC 20590. Periodicals postage paid at Washington, DC, and additional mailing offices.

POSTMASTER: Send address changes to *Public Roads,* HRTS, FHWA, 6300 Georgetown Pike, McLean, VA 22101-2296.
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Public Roads is sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Requests for subscriptions should be sent directly to New Orders, Superintendent of Documents, P.O. Box 37195, Pittsburgh, PA 15250-7954. Subscriptions are available for one-year periods. Paid subscribers should send change of address notices to the U.S. Government Printing Office, Claims Office, Washington, DC 20402.

The electronic version of *Public Roads* can be accessed through the Turner-Fairbank Highway Research Center home page (www.tfhrc.gov).

Guest Editorial

Yesterday's highway solutions will not necessarily work for today's highway challenges. Our Nation faces a far different and more complex transportation landscape with tighter budgets; environmental, safety, and mobility considerations; and security measures, which will call for a host of new and creative technologies, innovations, and prioritizations. The Federal Highway Administration (FHWA) is in a unique position to look backward at decades of highway progress and advancements and to look forward across surface transportation needs to move the Nation as a whole toward new and exciting breakthroughs.

As FHWA's Deputy Administrator, I have the primary responsibility for overseeing the agency's Research and Technology program. I am proud of our role as *Innovators for a Better Future*. In this role, FHWA creates an environment that proactively identifies, researches, develops, and deploys new highway technologies and innovations (T&I), which will solve the problems of today and the issues of tomorrow. FHWA will accomplish this by setting policies, prioritizing research and development efforts, and developing and deploying new technologies and innovations by involving internal and external stakeholders, including State and local transportation agencies, academia, transportation organizations, and private industry.

During FHWA's Restructuring Assessment and the development of the *FHWA Corporate Master Plan for Research and Deployment of Technology & Innovation* (CMP) over the past year, the FHWA R&T Leadership Team worked with our partners to ensure that we are all moving together in the right direction. Leading by example, the FHWA Leadership Team incorporated stakeholder input and feedback into the development of the preliminary CMP released in April 2003. The CMP includes 26 Agency Commitments framed around 7 Guiding Principles. In addition to involving stakeholders, FHWA leadership is committed to improving communication through multiyear R&T program planning, increasing merit reviews, and measuring performance. FHWA is now moving from planning to taking action on the Agency Commitments with our stakeholders and partners. See "Moving Technologies and Innovations Forward—A Master Plan" on page 2 in this issue of PUBLIC ROADS for more information.

One of the Agency Commitments is a compiled listing of FHWA priority, market-ready technologies and innovations. As part of our stakeholder-driven outreach, FHWA's list also embraces *all* T&I priorities of the American Association of State Highway and Transportation Officials' Technology Implementation Group. The implementation of these priorities supports the FHWA strategic goals, which include increasing safety, reducing congestion, and incorporating environmental stewardship and streamlining into surface transportation. "Championing Innovations" on page 6 highlights the FHWA priority listing.

FHWA plans to stay on top of this innovative technology push to ensure that we deliver the highway innovations that will keep us on the cutting edge. Future phases of the FHWA corporate master plan will involve (1) continuing to improve and incorporate stakeholder involvement and feedback, (2) assessing the human and other resources for achieving the FHWA Agency Commitments, (3) defining and creating performance measurements, and (4) improving communication channels between the R&T Leadership Team and internal and external stakeholders.

In future issues of PUBLIC ROADS, we plan to feature articles that cover other Agency Commitments discussed in the CMP. A Web site will be created for stakeholders to participate in and view the implementation of Agency Commitments and the progress we make as a team at the Federal, State, and local levels to implement technologies and innovations that help solve our transportation problems across the Nation.

J. Richard Capka
Deputy Administrator
Federal Highway Administration

Moving Technologies and Innovations Forward—A Master Plan

The Federal Highway Administration is strengthening its research and technology program.

by Joe Conway

Signals. Tunnels. Bridges. Asphalt. Concrete. Pavement markings. Reflective signage. Without these innovations and thousands more cultivated through research and development, would the Nation be at a standstill?

Research seeks better and more efficient tools to understand, improve, and maintain the transportation system—and the safety and mobility of the Nation. End products include new technologies and innovations (T&I) that range from processes and procedures to management, designs, contracting, and funding; new materials and machinery; software; and other knowledge-based products. To make a difference in transportation, T&Is must be deployed, adopted, and used successfully by transportation organizations and agencies.

With limited budgets and many priorities, however, it becomes necessary to focus on those T&Is that promise the highest payoff on a national level in terms of time, cost, mobility, safety, and the environment. Because stakeholders will implement T&Is, their involvement during the process ensures that new products are on target with their needs, making delivery faster, easier, and less costly.

In 2002, the Federal Highway Administration (FHWA) completed a Restructuring Assessment and discovered an opportunity to significantly improve the performance of its technology research and deployment activities. The assessment and recommendations from two reports provided the guidance for revamping the agency's T&I research and deployment. The reports were the Transportation Research Board's (TRB) Research and Technology Coordinating Committee's (RTCC) *The Federal Role in Highway Research and Technology (Special Report 261)*, and the U.S. General Accounting Office's (GAO) *Report to Congressional Committees: Highway Research: Systematic Selection and Evaluation Processes Needed for Research Program (GAO-02-573)*, published in May 2002.

"We recognized the need to ensure that our research is more visible," says FHWA's Associate Administrator for Research, Development, and Technology Dennis Judycki, "and that on a corporate [agency-wide] basis, we're effectively communicating what our research and technology program is, and ultimately, to ensure that we work more effectively with our partners and stakeholders to deploy technology and innovations based on multiyear program plans."

This article introduces the *Corporate Master Plan* [CMP] *for Research and Deployment of Technology & Innovation*, which incorporates the recommendations from the assessments. This initiative introduces a new vision that emphasizes FHWA's unique role of conducting "advanced research" in the highway community and stresses the agency's responsibilities to stakeholders. The agency adopted the "raise-the-bar" catchphrase for the CMP, which includes 26 Agency Commitments, framed around 7 Guiding Principles. Some key Agency Commitments from the initiative include looking at a project from beginning to end, involving stakeholders throughout the process, and measuring research and technology performance. (See "Guiding Principles and Agency Commitments," page 4.)

Background

The RTCC Special Report 261 made a number of recommendations aimed at achieving more stakeholder involvement, developing multiyear plans or "roadmaps," and using merit reviews. The report also emphasized the importance of the Federal role in

conducting advanced research and filling gaps left by other research and technology (R&T) programs. "For example," says C. Michael Walton, chair of the TRB committee, "the State departments of transportation have very mission-oriented research. It's not likely that they're going to engage in long-term research efforts. The Federal government has that role and responsibility."

In agreement, the May 2002 GAO report also indicates the need for "using a systematic approach to evaluate ongoing and completed research through such techniques as peer review. FHWA acknowledges that its approach for developing research agendas and involving external stakeholders in determining the direction of the program's research lacks a consistent, transparent, and systematic process." In addition, the report mentions that FHWA was in an ideal position to act on an opportunity to provide advanced, long-term research.

The recommendations of the FHWA Restructuring Assessment, the RTCC Special Report 261, and the GAO report are reflected in FHWA's CMP. FHWA considers the plan to be a key step for raising the bar on R&T. It also is a key step to fulfill FHWA's responsibility as "innovators for a better future."

In a speech before the Civil Engineering Research Foundation Executive Program, FHWA Deputy Administrator Richard Capka explained the rationale behind the "innovators" catchphrase. "Today's safe, efficient, and well-built highway infrastructure," he said, "is founded on yesterday's R&T innovators in the private and public sectors, at the local, State, and national levels. These pioneers took calculated risks and were willing to try and try again as they pushed for improvements. We need to provide an effective environment that permits and encourages highway innovation to flourish."

Creating the Corporate Master Plan

In drawing up the CMP, the agency formed a Raise-the-Bar Planning Group chaired by Peter Markle, director for Research, Technology, and Innovation Deployment for FHWA. Development of the plan extended over a 9-month period, with significant input from an array of stakeholders. A key part of the planning group's work was a 2-day workshop in October 2002.

"It was a structured opportunity to engage both external and internal stakeholders to get ideas on what should be included in the Corporate Master Plan," Markle explains.

Workshop participants concluded that FHWA needed to involve stakeholders fully in every stage of the process. Also, outcomes of the process must be linked to the agency's mission and goals, and there has to be continuity from one process stage to another. Agency goals for advanced research, moreover, need to be articulated and the visibility of advanced research increased.

Principles and Commitments

Incorporating the recommendations from the FHWA Restructuring Assessment, RTCC reports, workshop participants, and other internal and external stakeholders, the CMP emphasizes three elements considered essential by other well-established Federal research and technology programs. The CMP stresses involving stakeholders throughout the process, employing merit reviews, and evaluating research and deployment on an ongoing basis.

"The guiding principles identified in the master plan are not really new," says FHWA Associate Administrator for Operations Jeff Paniati. "These principles have helped us historically in our leadership and involvement in national R&T programs. What is new is the agency commitment to make sure that they are applied in a systematic manner across the entire research and technology program." Although the agency already uses many of the techniques mentioned in the assessment, the GAO report indicated the need to make them systematic and consistent. (See "Guiding Principles and Agency Commitments" on page 4.)

Paniati adds, "I'm pleased that the plan doesn't try to provide a cookbook solution. It states the intended results. We're going to let the functional areas and the respective offices determine the specifics of how we get there."

Among other things, the Agency Commitments call for FHWA to identify end users and intended impacts clearly. Information on research and technology should be shared more extensively within the agency and with external stakeholders. Research gaps need to be filled, and stakeholders should be involved in policy decisions. Merit review, agency-level evaluations, and multiyear plans are called for, as is developing a list of priority, market-ready technologies and innovations. (For the market-ready technologies, see "Championing Innovations" on page 6.)

Taking Action and Measuring Success

With the CMP completed, the next step is execution. "Now that we have a plan, our partners and stakeholders should be aware that we are moving to fulfill the agency commitments," says Deputy Administrator Capka.

Actively involved in FHWA's research process, stakeholders meet to coordinate efforts on the Woodrow Wilson Project.

Guiding Principles and Agency Commitments

From research through implementation, the FHWA R&T process is systematic and begins with the end in mind. The agency commits to:

- An R&T process that clearly identifies the end user and an intended impact
- An R&T process that is predictable, repeatable, and well-documented
- An R&T process that is proactive, visible, and accessible to all stakeholders
- Establishment of an internal R&T network for coordinating and sharing R&T information within the agency and with FHWA's stakeholders
- Improvement of FHWA resource (staff and funds) efficiency in the effective deployment of technology and innovation

FHWA engages in advanced and applied research as well as innovation deployment activities where there is an appropriate Federal role. The agency commits to:

- Focusing on long-term, high-cost, high-risk research with high payoff potential, significant research gaps not addressed in other highway research and technology programs, and emerging issues with national implications
- Working with FHWA's stakeholders to increase the agency's advanced research effort
- Developing an advanced research plan with consolidated goals and addressing agency needs

Stakeholders are engaged throughout the R&T process. The agency commits to:

- Expanding the disciplines and diversity of stakeholders engaged in the R&T process
- Engaging stakeholders for FHWA R&T policy decisions
- Engaging stakeholders for FHWA R&T agenda setting and development of multiyear R&T plans
- Engaging stakeholders for merit review during various phases of the R&T process
- Engaging stakeholders in research project, program, and agency-level evaluations and reviews
- Engaging stakeholders in deployment and implementation of technology or innovations

The R&T process is grounded in the agency mission and goals and guided by multiyear plans. The agency commits to:

- Developing multiyear plans that support FHWA goals and guide and direct FHWA's R&T program
- Developing a priority list of market-ready technologies or innovations

The R&T budget allocation is based on and driven by multiyear plans and priorities. The agency commits to:

- Ensuring that national needs and agency goals and priorities are met
- Providing adequate resources for advanced research and unsolicited proposals
- Providing adequate resources for deployment and implementation
- Providing adequate resources for stakeholder involvement

FHWA measures performance of R&T at the agency, program, and project levels. The agency commits to:

- Developing, defining, and adopting a framework for measuring performance
- Using merit review for conducting research evaluation and measuring performance

FHWA effectively communicates its R&T program and projects. The agency commits to:

- Developing a uniform overall FHWA R&T program message
- Working with FHWA's stakeholders to ensure that the R&T program and projects are communicated consistently and in the detail required by each stakeholder
- Publishing an agency-wide R&T performance report
- Including communication, marketing, training, and education in implementation plans

The FHWA R&T Leadership Team, consisting of FHWA associate administrators responsible for R&T, directors of field services, and a representative of the Division Administrators' Council, reflects a unified, corporate approach to R&T and plan implementation. The team met several times to identify measures needed to implement the Agency Commitments and outlined initiatives and activities with target completion dates. In addition, FHWA will ensure internal R&T networking to assist in corporate support functions, including communication, coordination, and collaboration across functional R&T areas and throughout the agency.

An important part of the CMP deals with measuring the success of implementing the Agency Commitments. The Agency Commitments do not lend themselves to the traditional measures of success employed in implementation plans. Rather, they are critical milestones that need to be met as corporate processes are improved. For example, activities such as setting agendas and allocating R&T budgets will apply to the next R&T programming and budgeting cycle.

Among the R&T Leadership Team's priorities are multiyear plans (roadmaps). These roadmaps outline an area's investment challenges and needs over time. A research project, for example, would be added into a roadmap as a future target of opportunity and then be funded as time and resources become available. Multiyear plans for R&T activities include the following:

- Initiatives, budgets, and performance measures tied to R&T goals
- Activities and resources for deployment and implementation
- Roles and responsibilities
- Inputs and outputs
- Stakeholder roles
- Timelines, with a 3-year minimum

"The roadmaps essentially lay out where you are going and give you the ability to measure how you're doing," says FHWA Associate Administrator for Infrastructure King W. Gee. "And if you want to do a better job in communicating the benefits and impact you're having on the transportation business through R&T investments, then you'd better be able to measure the performance of what you're investing in."

Self-assessments are a key ingredient of the plan. Staff members in each functional area are conducting self-assessments against the Corporate Master Plan to determine what exactly needs to be done to fulfill the Agency Commitments. These self-assessments are considered a baseline for measuring subsequent progress.

Involving Stakeholders

The R&T Leadership Team also is focusing its attention on enhancing stakeholder engagement, involving transportation agencies and organizations throughout the R&T process. Naturally, the extent of stakeholder involvement will vary from project to project; however, from agenda setting to merit review and performance evaluation, the agency will be

This vehicle is equipped with an automotive collision avoidance system and was displayed at an intelligent vehicle demonstration and workshop at the Turner-Fairbank Highway Research Center.

looking to its external stakeholders for the most direct involvement in technology research and in implementation. This is logical because State and local stakeholders ultimately will be responsible for implementation.

"The two things that I think are most significant in the Corporate Master Plan are the emphasis on stakeholder input throughout the process, and the emphasis on implementation," says FHWA's Associate Administrator for Professional Development Joe Toole. "I think the stakeholder input is particularly critical. My view has always been that we in the highway community only need one research agenda. We need to be a part of that just as our stakeholders need to be as well. Ideally, all of our work should be integrated. And I think the Corporate Master Plan helps create that kind of synergy."

Providing a field perspective is FHWA Georgia Division Administrator Bob Callan. "One of the things I like about the Corporate Master Plan is that it gives those of us in the field not only an opportunity to provide input into the strategic direction we're going, but also gives us a seat at the table so that we can hear what our program officers are thinking and where they want to take research. It's a two-way advantage."

As spelled out in the CMP, stakeholder involvement is critical for the successful implementation of the plan. Stakeholders from State and local agencies, academia, and public sector organizations, along with end users, may be involved in setting R&T policies and developing multiyear plans. In addition, these stakeholders may assist in developing research proposals and reviewing or evaluating R&T results. Different stakeholders may participate in different roles. Finally, as the implementers of technology, some stakeholders will be involved more directly in T&I deployment activities.

Advancing the Master Plan

One of the 26 Agency Commitments is the establishment of a list of priority, market-ready technologies and innovations (T&Is), which the agency and external stakeholders believe will have the highest payoff (the largest impact) on the transportation system, in the shortest amount of time. This list will help foster dramatic changes across the system and will focus efforts inside and outside the agency.

An internal FHWA work group consisting of field and headquarters representatives already compiled the initial list, based on agency priorities and strategic goals, user needs, likelihood of implementation, the extent to which the technologies are market-ready, and availability of expertise to support deployment and implementation. The list of 28 technologies and innovations include the 9 technologies approved by the American Association of State Highway and Transportation Officials' Technology Implementation Group. (For more on the 28 T&Is, see "Championing Innovations" on page 6.)

To enhance communication and awareness, FHWA is developing a Web site that will include updates on the status of the Agency Commitments. Stakeholders will be able to provide input into the Web site. "We plan to put up an externally accessible Web site in order to report on progress," says Associate Administrator Judycki. "We will also make available information on action items being delivered."

A National Payoff

Judycki emphasizes that this CMP initiative is part of a national strategy and effort for research and technology delivery. "It's critically important that we are able to focus resources on those areas where there's a high payoff," he says. "I think you'll find that in the future there will be an increased level of communication on the corporate level. And you'll see a much more visible and accessible program for stakeholders and partners, and multiyear programs for various R&T areas. That will drive the resources dedicated to the agency's goals and objectives."

Glenn Washer (left), program manager for Research, Development, and Technology at the FHWA Nondestructive Evaluation Validation Center, and Nat Jensen, civil engineering technician for the FHWA Eastern Federal Lands Highway Division, perform an ultrasonic inspection of a bridge pin in Colorado.

Joe Conway, P.E., is a transportation specialist at FHWA's Turner-Fairbank Highway Research Center. He directly supports implementation of the CMP for research and deployment of innovative technologies.

For more information, see the Corporate Master Plan at www.fhwa.dot.gov/legsregs/directives/policy/cmp/03077.htm.

Championing Innovations

by Gene K. Fong, Gary Hoffman, and Tony Sussmann

Roundabouts and ITS technologies in work zones are just two of the state-of-the-art technologies that FHWA and AASHTO encourage State and local agencies to adopt.

Developing innovations that can save lives, money, and time on the Nation's highways is a vital research goal, but state-of-the-art technologies benefit the traveling public only when they become everyday practice. Putting prototype into practice is the idea behind the Federal Highway Administration's (FHWA) new list of 28 priority, market-ready technologies and innovations.

The list is one of the outcomes of the FHWA *Corporate Master Plan for Research and Deployment of Technology & Innovation* (T&I), the agency's new vision for fulfilling the Federal government's role in the Nation's highway research and

Use of prefabricated bridge parts like these is one of the many techniques that help accelerate construction projects.

technology efforts (see "Moving Technologies and Innovations Forward—A Master Plan" on page 2).

"It all comes down to assuring that we are investing in those areas that have the highest payoff for achieving agency goals, including the vital few," says FHWA Associate Administrator for Research, Development, and Technology Dennis Judycki, facilitator of the Research and Technology (R&T) Leadership Team.

The 28 technologies on the list may be cutting-edge, he adds, but they are ready for application and have proven benefits. "This list is an important statement of technologies and innovations that agencies should be looking at as they advance their highway programs," Judycki says.

An FHWA working group of field and headquarters representatives distilled the final 28 from nearly 60 technologies and innovations submitted by FHWA offices. The FHWA Research and Technology Leadership Team endorsed the working group's selections, and the list was advanced to the agency at the September FHWA business meeting in Minnesota. The priority list further reinforces one of the agency's key business processes of technology deployment.

The working group evaluated submissions on several criteria, including whether they support FHWA goals of enhancing safety, reducing congestion, and improving the environment. The group also determined if the technologies filled a demonstrated need in the Nation's highway system, whether or not the technologies are ready for the market, and if FHWA or partners have the tools and expertise available to support their implementation.

Advancing the Master Plan

The need for a list of priority technologies and innovations was first identified during the FHWA Restructuring Assessment that led to the corporate master plan. A call for the priority list was reinforced by requests from FHWA field offices—including Resource Center locations, Divisions, and Federal Lands Highway Divisions—looking for a definitive corporate statement of priority technologies and innovations.

FHWA field offices are responsible for deploying the priority technologies and innovations, and marketing them to State and local agencies through special programs and everyday communications.

"The priority list helps FHWA field offices focus on high-payoff items," says Robert Callan, FHWA Georgia Division Administrator and a member of the R&T Leadership Team. "We can gear up and allocate resources appropriately with a finite list. It helps us match agency initiatives and priorities with the tools necessary to achieve results."

FHWA plans to create a fact sheet on each technology or innovation that describes the technology, where the technology was applied, its effect, and the materials and resources available to help agencies implement it. That information will be included on a Web site being developed to track FHWA progress on the corporate master plan.

The priority list will be a living document, one that can be updated as new market-ready, high-payoff technologies are identified.

The FHWA list incorporates all of the focus priorities selected so far by the American Association of State Highway and Transportation Officials (AASHTO) through its Technology Implementation Group (TIG). AASHTO created TIG to identify ready-to-implement technologies with significant potential to benefit the Nation's transportation system and champion their use throughout the country.

Working with State Partners

The nature of the longstanding partnership between FHWA, FHWA's Turner-Fairbank Highway Research Center, and AASHTO; the close match in philosophies; and the common goal of enhancing the Nation's transportation system make it practical and valuable to combine efforts in deploying innovations and technologies. Therefore, part of this Federal initiative also includes the priorities at the State level represented by TIG's approved technologies.

Since the group's launch in 2000, TIG has chosen to support nine focus technologies that are likely to yield significant economic or qualitative benefits, and the group organized teams of lead States to accelerate widespread adoption.

"TIG's vision is to create a culture where rapid advancement and implementation of high-payoff, innovative technologies is the expectation of the transportation community," says Ken Kobetsky, AASHTO's engineering program director and a TIG member.

A key selection factor for a TIG focus technology is that at least one State is willing to take the lead in championing it to others. "What we want to know is that they believe in the technology, they've proven its effectiveness, and they're willing to do the work necessary for others to adopt it," Kobetsky says.

Similar to the manner that FHWA used to identify priority technologies, TIG examines: whether or not a technology meets a need or solves a problem in the transportation system, the effectiveness of the technology, the costs, and the ease of implementation on a widespread basis. "By focusing on the low-hanging fruit [easiest and most cost-effective technologies], TIG is able to increase agencies' return on their investment for the technologies that TIG promotes," says Kobetsky.

The AASHTO group selects three or four technologies per year from submissions it receives from State and local agencies, AASHTO units, and FHWA offices. Information on nominating a technology is available at www.aashtotig.org.

Buy-in [favorable reception] from State departments of transportation (DOTs) is critical to the group's success, Kobetsky says. "Another key element is the composition of TIG members, consisting primarily of senior-level State DOT decision-makers, who can make a difference in implementing best-in-class practices [benchmarking with a specific product, practice, technique, process, or procedure considered to be superior within a certain category] for their agencies." The group also includes representatives of FHWA, local transportation agencies, organizations such as the Transportation Research Board, and other industry entities.

Implementation panels develop strategic plans for delivering each technology to users. Tactics may include sponsoring workshops, developing training materials, and sending experts from lead States to

agencies to advise them on application of the technology.

FHWA and AASHTO held a joint workshop in September 2003 on "Advancing Effective Technology Implementation" to discuss their priority technology lists and develop ways to coordinate their efforts. The workshop explored the roles that State DOTs, TIG, FHWA, and industry organizations play in technology and innovation deployment, along with outreach and communication strategies.

One outcome of the workshop was to identify ways to share good ideas about market-ready technologies and innovations, and how both sides can better manage and operate their processes.

Improving Intersection Safety

Associate Administrator of FHWA's Office of Safety and member of the R&T Leadership Team George Ostensen cited roundabouts as one market-ready technology. "Safety is one of our 'vital few' priorities at FHWA," says Ostensen, "and the bottom line is that roundabouts can be an effective way to improve intersection safety." Every year almost 9,000 Americans lose their lives and 1.5 million Americans are injured in intersection-related crashes, which cost our society more than $90 billion annually.

Roundabouts are circular intersections with two key characteristics: (1) entering traffic yields to circulating traffic, and (2) geometric constraints slow entering vehicles. Improved highway safety and congestion as well as aesthetics and cost savings have made roundabouts an attractive alternative to traditional intersection traffic control. A number of studies have shown that roundabouts can be safe and effective, and as a result they are now widely used internationally. Proper

FHWA Priority, Market-Ready Technologies and Innovations

511 Traveler Information—An easy-to-remember three-digit telephone number available to State and local transportation agencies nationwide so that they can readily provide information and highway and transit conditions to travelers by telephone.
Contact: Bob Rupert, 202–366–2194.

Asset Management Guide—The guide illustrates asset management principles and identifies techniques and methods for adopting the decisionmaking framework in transportation agencies.
Contact: Stephen Gaj, 202–366–1559.

Augered Piles—The technology is characterized by the drilling of a hollow-stem auger into the ground, pumping grout or concrete into the hole, and installing reinforcement in the pile. This eliminates the need for a temporary casing.
Contact: Silas Nichols, 410–962–2460.

Border Wizard—A PC-based software model that accurately simulates all cross-border movements of autos, buses, trucks, and pedestrians, using customs, immigration, and security procedures.
Contact: Mike Onder, 202–366–2639.

Dispute Resolution Guidance for Environmental Streamlining—These procedures present strategies for interagency collaborative problem solving during the transportation development and environmental review process.
Contact: Ruth Rentch, 202–366–2034.

Expanded Polystyrene (EPS) Geofoam—Lightweight material that can be used as fill behind walls and other support structures.
Contact: Peter Osborn, 410–962–0702.

FHWA Traffic Noise Model (TNM), Version 2.1—By improving the ability to predict noise impacts in the vicinity of highways, this model improves the quality of project development decisions.
Contact: Bob Armstrong, 202–366–2073.

Highway Economic Requirements System, State Version—A software model that is designed to evaluate the implications of alternative programs and policies on the conditions, performance, and user cost levels associated with highway systems.
Contact: David Winter, 202–366–4631.

Improved Decisionmaking Using Geographic Information Systems—A software program that allows for manipulation, analysis, and display of geographically referenced data.
Contact: Mark Sarmiento, 202–366–4828.

Interagency Funding Guidance for Environmental Streamlining—Guidance provides transportation and resource agencies with options for using Federal funds to support Federal resource agency coordination for streamlining environmental reviews.
Contact: Ruth Rentch, 202–366–2034.

Intelligent Transportation Systems (ITS) SpecWizard—A software tool that can help transportation agencies write specifications for the National Transportation Communication for ITS Protocol (NTCIP) standards-based ITS equipment.
Contact: Jason Hedley, 202–366–4073.

Load and Resistance Factor Design and Rating of Structures—An AASHTO Load and Resistance Factor Design (LRFD) and Rating (LRFR) bridge specification provides for more uniform levels of safety, which should lead to superior serviceability and long-term maintainability.
Contact: Firas Ibrahim, 202–366–4598.

Pavement Smoothness Methodologies—The new pavement smoothness specification covers smoothness test methods, smoothness equipment specifications, and equipment-certification programs.
Contact: Mark Swanlund, 202–366–1323.

QuickZone—A user-friendly computer software tool for estimating and analyzing length of queues and delays in work zones.
Contact: Scott Battles, 202–366–4372.

site selection and pedestrian channelization are keys to making roundabouts accessible to all users.

According to a status report published on May 13, 2000, a recent study by the Insurance Institute for Highway Safety showed that roundabouts can reduce crashes by 39 percent. Roundabouts also resulted in an 80 percent reduction in injury crashes and a 90 percent reduction in fatal crashes. These findings are consistent with a study conducted by the Maryland State Highway Administration and are summarized in *Maryland Roundabout Safety Experience*, published in October 2001. The overall crash rate was reduced by 60 percent and the injury crash rate was reduced by 82 percent at eight intersections in Maryland where traditional intersections were replaced by roundabouts.

For more information on roundabouts, FHWA published *Roundabouts: An Informational Guide*, which is available on the Web at www.tfhrc.gov/safety/00068.htm.

Reducing Work Zone Congestion

As rehabilitation work on the Nation's aging highway system increases, so does the need to move drivers through work zones safely and with minimum frustration. More than 1,000 people die and more than 40,000 people are injured each year in work zone-related crashes. In addition, work zones account for nearly 24 percent of nonrecurring congestion on roadways, causing 482 million vehicle hours of delay per year.

State and local agencies are applying intelligent transportation systems (ITS) technology in work zones to increase safety for both workers and road users and to ensure more efficient traffic flow.

Red Light Cameras—The traditional enforcement of violations for running red lights is automated by using camera systems at light-controlled intersections that detect an offending motorist, capture an image of the license plate, and issue a citation by mail.
Contact: Hari Kalla, 202–366–5915.

Roundabouts—A circular intersection that requires entering vehicles to yield to existing traffic in the circulatory roadway.
Contact: Hari Kalla, 202–366–5915.

Rumble Strips—Shoulder rumble strips are continuous grooved indentations in roadway shoulders that provide both an audible warning and a physical vibration to alert drivers that they are leaving the roadway.
Contact: Dick Powers, 202–366–1320.

Safe Speeds in Work Zones—Two technologies that can improve safety in work zones are portable speed limit signs that automatically display the safe speed based on traffic conditions and the nature of the roadwork, and feedback displays that show the speed of approaching vehicles.
Contact: Davey Warren, 202–366–4668.

Transportation, Economics, and Land Use System (TELUS)—This information-management and decision-support system helps State DOTs and metropolitan planning organizations prepare their annual transportation improvement programs and statewide transportation improvement programs.
Contact: Fred Ducca, 202–366–5843.

AASHTO Technology Implementation Group Approved Technologies

Accelerated Construction—This undertaking promotes creative techniques to reduce construction time and enhance quality and safety.
Contact: Dan Sanayi, FHWA, dan.sanayi@fhwa.dot.gov.

Air Void Analyzer—The air void analyzer can be used to provide real-time evaluation for measuring air content, specific surface, and the spacing factor of fresh portland cement concrete.
Contact: John Wiakowski, Kansas DOT, johnw@ksdot.org.

Fiber-Reinforced Polymer—This material can be used to repair cracks in overhead sign supports by wrapping the support with the fiber-reinforced material.
Contact: Paul Wells, New York State DOT, pwells@gw.dot.state.ny.us.

Global Positioning System (GPS) Surveying—The GPS uses satellites that transmit signals continuously; it has many highway applications, including surveying pavement conditions and inventorying highway assets.
Contact: Charlie Brown, North Carolina DOT, charliebrown@dot.state.nc.us.

Ground-Penetrating Radar—Vehicle-mounted, ground-penetrating radar can be used to collect information about underlying highway pavement layers without incurring the time and labor costs and traffic delays associated with traditional methods of drilling for core samples.
Contact: Mike Murphy, Texas DOT, mmurphy@dot.state.tx.us.

Highway Rail Warning System—A low-cost active warning system used at low-volume, highway-railroad at-grade intersections, most often mounted on standard crossing poles. The technology is solar battery-powered with wireless communications between the device and the locomotive.
Contact: Dave Huft, South Dakota DOT, dave.huft@state.sd.us.

***ITS Technologies in Work Zones—**The use of ITS technologies in work zones, such as ramp-metering systems, intrusion alarms, and queue-detection information (sensors/cameras), is aimed at increasing safety for workers and road users and ensuring a more efficient traffic flow.
Contact: Doug Rose, Maryland State Highway Administration, drose@sha.state.md.us.

Prefabricated Bridge Elements and Systems—These systems minimize traffic impacts of bridge construction projects, improve construction work-zone safety, and make construction less disruptive for the environment by minimizing the need for lane closures, detours, and use of narrow lanes.
Contact: Mary Lou Ralls, Texas DOT, mralls@dot.state.tx.us.

Thermal Imaging Safety Screening System—The system allows an operator at a weigh station to view the relative temperatures of brake drums through the wheel rims of commercial vehicles, using infrared images to detect whether brakes are functioning properly.
Contact: Gary Hoffman, Pennsylvania DOT, ghoffma@dot.state.pa.us.

Signs like this one warn motorists of what to expect in a work zone.

Tracy Scriba

"Congestion mitigation and safety are FHWA priorities, and one way to address these issues in work zones is through the use of ITS technologies," says FHWA Associate Administrator for Operations Jeff Paniati, a member of the R&T Leadership Team.

These technologies include metering systems and cameras that monitor traffic conditions in work zones. Traffic operation centers use the data generated to manage traffic through such techniques as variable speed limits. The data also enables the centers to provide real-time information to motorists through changeable message signs, Web sites, and traveler advisory radio.

"ITS technology can be used to better communicate with motorists on what to expect in a work zone," Paniati says. "It can provide them with information on alternate routes or, if that's not an option, at least give them an idea of how long it's going to take them to get through the work zone."

These technologies were one factor that enabled the Illinois DOT to complete a 64-kilometer (40-mile) bridge reconstruction and pavement resurfacing project on I–55 near Springfield, IL, with no significant traffic backups, a reduced rate of speeding citations, and only two crashes. The ITS technologies helped the Arkansas State Highway and Transportation Department provide delay information at strategic locations during an I–40 reconstruction project in West Memphis, AR, so travelers could choose alternate routes.

FHWA is cooperating with the TIG implementation panel to create an inventory of projects from various States that will serve as the basis for publications, videos, workshops, and presentations.

FHWA also has developed QuickZone, traffic analysis software that agencies can use to reduce congestion and increase safety in work zones. QuickZone compares the traffic effects of work zone mitigation strategies and estimates the costs, traffic delays, and potential backups associated with these impacts.

"Work zones are something that highway agencies create intentionally, and QuickZone is a tool to better understand their impact," says Paniati. "It helps do the 'what if' analysis necessary to evaluate different alternatives."

Using feedback from seven State DOTs that used an early version of the software, FHWA now is working on an updated version. QuickZone is available from the McTrans™ Center for Microcomputers in Transportation, a clearinghouse for highway transportation software, at http://mctrans.ce.ufl.edu/index.htm.

The use of GIS helps to streamline and clarify the environmental review process for ecologically sensitive areas, like this ponded swale in Point Coupee Parish, LA.

Jay Cline, LADOTD

Another resource on the use of ITS in work zones is the Intelligent Transportation Peer-to-Peer Program, an initiative by FHWA, the Federal Transit Administration, and the Federal Motor Carrier Safety Administration to provide technical assistance to public agencies on deploying ITS technologies. Information on the program, which matches agencies in need of short-term technical assistance with experts, is available at www.its.dot.gov/peer/peer.htm.

Streamlining Environmental Reviews

Geographic information systems (GIS)—data collection and communication tools that store, manipulate, and display geographic data—can enhance decisionmaking during transportation planning. Applications range from creating inventories of highway assets to analyzing traffic safety to streamlining the environmental review process.

"FHWA chose GIS as a priority technology because of its potential to advance environmental stewardship and streamlining," says FHWA Associate Administrator for Planning, Environment, and Realty Cynthia Burbank. She adds, "But it is valuable for other reasons as well, such as asset management, safety analysis, planning, and right-of-way."

For environmental stewardship and streamlining, GIS gives Federal and State agencies equal access to information in a common framework, normally over the Internet. "A shared GIS database helps build trust and partnerships," Burbank says. "It also saves time and money by making all data for a project available upfront. This avoids delays and misunderstandings about location of key resources and enables agencies to focus quickly on alternatives that will best serve our common goals of mobility and resource protection."

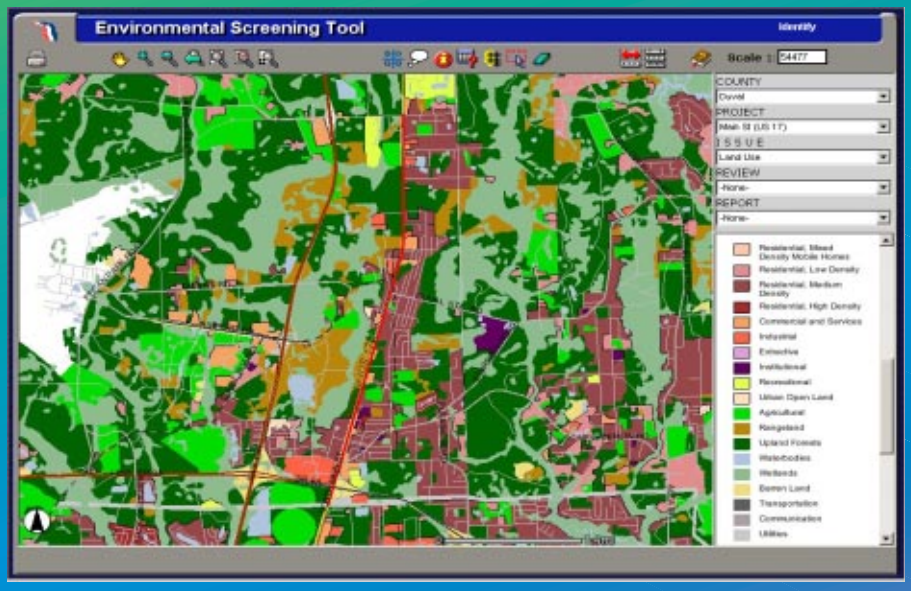
"This database will be valuable across government—EPA [Environmental Protection Agency], Corps of Engineers, Fish and Wildlife Service, Indian tribes, and others—so we are working with these partners and States to build national GIS databases for transportation and environmental resources," Burbank adds.

A GIS application being funded by FHWA will help the agency and States meet a Federal requirement for consultation with federally recognized Indian tribes on federally funded highway projects. FHWA joined with the Advisory Council on Historic Preservation (ACHP) to invest in a GIS database that identifies Indian tribes that have historic and cultural interests in counties in Colorado, Louisiana, and New Mexico. Users can click on State maps, key into a particular county, and bring up information on all the tribes that have a historic or cultural interest in that county. This information currently is available to the public on the ACHP Web site. FHWA and ACHP are seeking funding from other Federal agencies, like EPA, Fish and Wildlife Service, and the National Park Service, to expand this GIS database to all States and counties in the continental United States.

The GIS tool is part of the Florida DOT's process for efficient transportation decisionmaking, helping the agency involve environmental and cultural resources, and permitting agencies earlier and continuously in the process. The screening tool database is an Internet-accessible GIS application that integrates data from multiple sources and analyzes the environmental effects of proposed highway projects. This tool enables planners to perform screening events, or "screens," to document agency and community feedback on projects much earlier in the planning process than in the past. Modifying project plans in response to those early screens enables the Florida DOT to avoid or reduce costly changes later in the process.

"Having a system that eliminates controversy based on lack of information or conflicting data enables agencies to identify other issues earlier and focus on coming to a consensus," Burbank says.

In cooperation with the Bureau of Transportation Statistics, FHWA has developed a course, "Applying Spatial Data Technologies to Transportation," that provides an introduction to GIS and how it can be used in transportation planning applications. Information is available at the FHWA



A computer-based environmental screening tool helps the Florida Department of Transportation analyze the environmental effects of proposed highway projects.

Florida DOT

National Highway Institute Web site at www.nhi.fhwa.dot.gov.

Air Void Analyzer

Many States experience premature deterioration and damage of cement-based concrete pavements and structures from repeated freezing and thawing. Multiple applications of deicing salts accelerate the cracking, deterioration, and surface scaling, which decrease the life of the concrete.

Deterioration also places a tremendous financial burden on many transportation agencies, and adversely affects national economic productivity by increasing repair times, decreasing structural integrity, and placing motorists at risk. Improving the ability of concrete to endure these repeated freeze-thaw cycles and salt applications significantly increases the potential life of the concrete.

Closely spaced air voids in concrete are commonly singled out as the primary factor in improving the freeze-thaw resistance of concrete. The air void analyzer (AVA) offers an efficient, real-time method for assessing the distribution of these air voids in fresh concrete. The device can characterize the air void distribution in less than 30 minutes. With this information, adjustments can be made in the concrete batching process to assure that air voids are spaced properly.

Since 1999, FHWA has used AVA technology on infrastructure projects in nine States. Roughly half of the concrete samples tested had air void spacing factors outside the generally accepted limits for durable concrete, even though air content specifications (using conventional QC tests) were met. These results, albeit from a limited data set, highlight the importance of implementing the use of the AVA, in an effort to prevent appreciable quantities of concrete being placed with inadequate frost resistance.

The Kansas DOT began using the AVA in 2001 because it was experiencing premature pavement joint deterioration. In 2002, the Kansas DOT developed a concrete specification based on the AVA. The agency now uses the AVA for concrete mix qualification, with job site acceptance based on total air content. Kansas estimates cost savings from reduced repairs at $1.1 million.

The air void analyzer in FHWA's Mobile Concrete Laboratory.

Repairing Hazardous Sign Structures

Overhead sign structures support the familiar green interstate signs that make travel safer by providing information on upcoming routes and exits. But these signs—which are exposed to tremendous wind and vibration loads—can become serious hazards if not maintained properly.

When the New York State DOT launched a sign inspection program in 2000, inspectors were startled to find that 10 percent of the State's overhead sign structures were damaged. The most common problem was cracking of the joint between the internal trussing and the main chords of the sign structure, with some joints totally severed.

After a manufacturer suggested a fiber-reinforced polymer (FRP) material to repair the cracked truss joints, the New York State DOT joined forces with the Utah DOT to study the feasibility of using the FRP material.

Samples of cracked joints were salvaged from overhead sign structures that had been taken out of service. The samples were wrapped with FRP and sent to the University

New York highway engineers demonstrate the use of an innovative fiber-reinforced polymer repair to correct distress in a welded joint on an aluminum sign structure truss.

NYSDOT

Ken Sides, City of Clearwater, FL

One priority technology includes single-lane modern roundabouts such as the Acacia Roundabout on North Clearwater Beach in Clearwater, FL.

of Utah for tests. Results showed that the repaired joints were as strong as if they had been fully welded.

A second round of testing is underway to determine the effectiveness of FRP repairs in resisting fatigue loads. If results are positive, the New York State DOT plans to use FRP to rehabilitate overhead sign structures with fatigue stress problems.

The FRP repair method is relatively quick and economical, enhancing its attractiveness as a priority technology for both AASHTO TIG and FHWA. Repairs can be done in place, with only the lanes below the repair area blocked off. A typical repair takes three workers 3 hours to complete at an estimated cost of $3,000 per joint. (See PUBLIC ROADS, November/December 2003, page 25.)

Screening for Faulty Brakes

Safety on the Nation's highways is a priority for transportation agencies, and statistics show that commercial vehicles with defective brakes are likely to have other safety-related problems. That fact sparked TIG's interest in a thermal imaging safety screening system (TISSS) that enables weigh station operators to test the brakes on commercial vehicles quickly and easily to determine which trucks should receive a safety inspection.

The Georgia Tech Research Institute, working with the Georgia DOT, developed the system. An infrared camera and computerized video enable an operator to view, store, and print images that show the relative temperatures of brake drums through a vehicle's wheel rims.

If the brakes are operating correctly, all of the drums look white-hot—that is, about the same temperature. If a brake is defective, the telltale sign is an infrared image in which the drum appears darker and cooler.

When researchers tested TISSS at an Interstate 20 weigh station near Atlanta, GA, they found that it was effective in detecting brake problems. They also determined that the training required for operators running the system was minimal. And the system consists of off-the-shelf components, which minimize acquisition and maintenance costs.

The goal of FHWA and AASHTO TIG in promoting a system like TISSS is not only to detect immediate safety hazards, but also to improve compliance with safety systems. During the Georgia test, weigh station personnel noted that once word got out that they were screening brakes, they saw an increase in the percentage of trailer-trucks with operational brakes.

Accelerating Project Delivery

Accelerated construction—an approach that uses an array of innovative techniques and technologies to get the job done faster, more safely, and with better long-term results—is another technology on both the FHWA and AASHTO TIG lists.

Following two successful accelerated construction workshops in Indiana and Pennsylvania in 2002, the TIG implementation panel worked with the California, Connecticut, and Texas DOTs to schedule similar workshops in 2003. The panel plans sessions in other States in 2004.

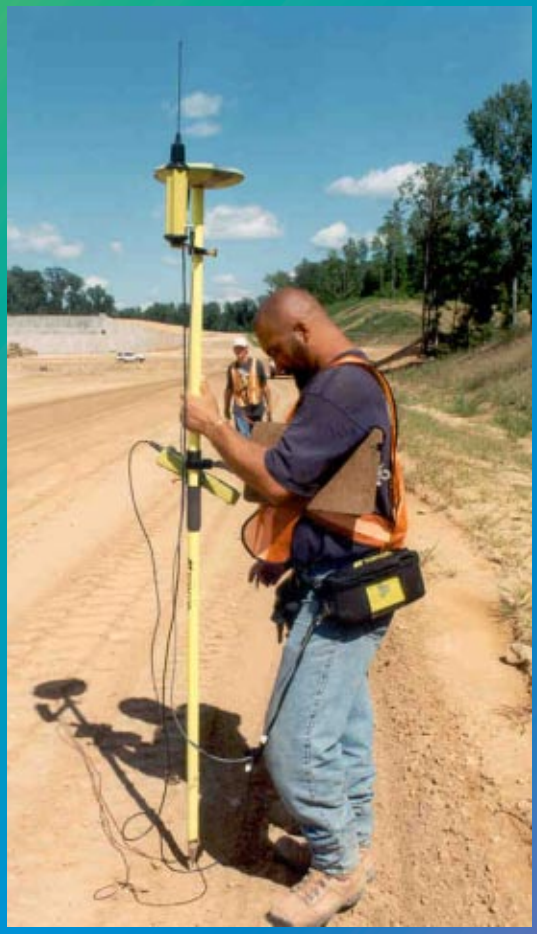
The strategy for major highway projects is to bring together experts from the host DOT and other State agencies, industry, academia, and FHWA to develop an accelerated construction plan. In addition to design and construction, areas of expertise may include right-of-way procurements, prefabricated elements, long-life pavements, safety in work zones, and innovative financing and contracting.

The result of the Indiana workshop was an accelerated plan to rebuild a section of Interstate 465 on the west side of Indianapolis. The plan reduced estimated construction time by 5 years, while maintaining traffic flow and accommodating traffic generators such as the Indianapolis Motor Speedway. Workshop recommendations included using prefabricated highway components, innovative

work zone traffic control, and long-life roadway and bridge designs.

The Pennsylvania workshop focused on accelerating rehabilitation of a section of Route 28 in Pittsburgh. Experts determined that the estimated 4-year construction time could be cut to 2 years. Traffic disruptions could be minimized with such tactics as transporting construction materials by river barge instead of trucks and using multiple construction teams to build retaining walls and travel lanes.

The Connecticut DOT used accelerated construction techniques to minimize disruptions to both traffic and train service while constructing a bridge over rail lines in New Haven, CT. After months of work building the structure alongside the rail lines, the bridge was lifted and set into place during one weekend-night operation. The Connecticut DOT estimates that it saved about 1 year on its overall contract time and more than $1 million by using accelerated construction methods on the project.



This worker is using GPS survey equipment, one of the 28 technologies on the priority list.

Benefiting the Driving Public

Although these are just a few examples of the 28 technologies on the FHWA priority list, they represent an important advancement in the way FHWA encourages the adoption of technologies that can enhance the Nation's highway system and, ultimately, benefit the driving public.

"Technologies and innovations are not an end in themselves," says FHWA Associate Administrator Judycki. "We need to look at each of them in the context of improving our transportation system for our customers and enabling us to meet the important transportation goals we've set."

The concept is the same for AASHTO TIG. Although the group can promote only a small number of technologies, the big picture is that others will adopt the collaborative model and apply it to a broad range of innovations, says AASHTO's Kobetsky.

"Our hope is that through TIG's efforts, the transportation community at large can see that barriers to innovation and implementation can be overcome," Kobetsky says. "Our early feedback is that the model is successful in fostering a problem-solving attitude and that with fairly minimal resources, TIG focus technology teams can promote their product or activity at the national level."

By making technology deployment a key aspect of the FHWA corporate master plan, Judycki concludes, "We are truly taking a corporate, agency-wide view of delivering innovations all the way from the beginning of the research process to the implementation in the field. It's just good business."

Gene K. Fong is the director of FHWA Field Services-East. He assists the executive director in the leadership of 18 FHWA Federal-aid Divisions and the Resource Center, Baltimore, MD, location. Fong's primary responsibility is to assure the accomplishment of the FHWA mission, vision, and the strategic goals, and development of partnerships with modal counterparts and other Federal agencies. He is a member of the FHWA Leadership Team and TIG.

Gary L. Hoffman is the deputy secretary for Highway Administration at PENNDOT. He directs a team of more than 9,600 employees involved in the maintenance, operations, restoration, and expansion of transportation infrastructure. Hoffman has authored or coauthored more than 40 published technical papers and articles focusing on transportation materials, pavement designs, construction practices, and management systems. He is active in strategic planning and innovation implementation at the national level and serves as chairman or as an active member of several National Academy of Science and AASHTO-sponsored boards and committees. He chairs the AASHTO TIG and the AASHTO Subcommittee on Materials.

William ("Tony") Sussmann has worked for FHWA since 1966 and currently serves as FHWA Louisiana Division Administrator. He has held various field positions in the New York, Virginia, and Washington, DC, divisions as well as headquarters positions in the Bridge Division and Construction and Maintenance Divisions. Sussmann has a BSCE from Norwich University and an MSCE from West Virginia University.

For more information, contact the FHWA staff person listed for the specific technology or innovation in "FHWA Priority Market-Ready Technologies and Innovations" (see pages 8–9) or visit www.fhwa.dot.gov/rnt4u. For information on ASSHTO TIG technologies, see www.aashtotig.org.

Seeing Crosswalks in a New Light

by Sheryl Miller, Gabriel K. Rousseau, and Ann H. Do

FHWA is testing in-pavement flashing warning lights at a pedestrian crossing in a Virginia community.

Just about every journey involves walking—to the car, to the bus stop, to shopping, around parking lots, across streets, on paths, or on the sides of roads. However, traveling on foot can be dangerous. According to crash statistics for 2001, a pedestrian in the United States was injured on average every 7 minutes, and one was killed every 108 minutes. The Federal Highway Administration (FHWA) has made improved pedestrian safety part of its "vital few" priorities and seeks to achieve a 10 percent reduction in pedestrian fatalities by 2007.

Research staff members from the FHWA Office of Safety Research and Development at the Turner-Fairbank Highway Research Center are investigating ways to help reach this safety goal. Among the research topics is the evaluation of countermeasures to improve safety in pedestrian crossings that are not controlled by traffic signals.

Transportation agencies are installing in-roadway warning lights (also known as "in-pavement lighting" or "flashing crosswalks") around the United States in an effort to improve pedestrian safety. Each side of a crosswalk is lined with a series of amber lights embedded in the roadway that face oncoming traffic. The lights are visible to approaching drivers as a warning that a pedestrian is in the marked crosswalk or near it.

Lights are actuated in one of two ways. In one system, the pedestrian activates the lights by using a traditional push button. In another, the pedestrian is "sensed" by an automatic detection system that triggers the lights.

Past evaluations found that in-roadway warning lights increase driver yielding at crosswalks and that this effect may be greatest in overcast conditions. Some practitioners are concerned, however, that drivers will become accustomed to the lights over time and that the yield rates will decline.

Further, pedestrians may misunderstand the function of the lights.

This closeup shot shows one of the warning lights in a crosswalk.

(Above) This night photo shows a lighted crosswalk in a northern Virginia suburb.

All photographs: Ted Shafer.

A family crosses the road where the in-pavement lights will be installed in Alexandria, VA.

"[There] may be some confusion over the meaning of the lights," says Bob Garbacz, division chief with the Department of Transportation and Environmental Services in Alexandria, VA. "Many pedestrians may assume that they have the right of way when the lights are flashing. This is not the case. The lights flash yellow, which is not a 'stop' condition. Flashing yellow means that vehicular traffic may proceed only with caution."

The FHWA researchers selected a site in Alexandria to investigate pedestrian and driver behavior at crosswalks during daylight and dark conditions over the course of a year. Evaluations will be conducted immediately before, immediately after, and a year after in-roadway warning lights are installed.

Throwing Light on Illuminated Crosswalks

As early as 1978, researchers began investigating illuminated crosswalks, such as a specialized system that projected light onto the roadway across the length of the crosswalk as a warning sign. Examining almost 200 sites in Israel over a 1- to 2-year period, the researchers found a reduction in nighttime pedestrian incidents compared to sites serving as controls.

Not until the early 1990s did the concept of in-roadway lighting become a reality in the United States. Since then, several companies have been manufacturing in-roadway warning light systems.

Recently, FHWA approved the application of in-roadway warning lights at marked crosswalks at intersections that are not controlled by traffic signals. The new guidance is available in the *Manual on Uniform Traffic Control Devices*, in Chapter 4L, In-Roadway Lights. (See http://mutcd.fhwa.dot .gov/HTM/2003/part4/part4l.htm.)

Seeing the Light

A review of research over the past decade indicates that the installation of in-roadway warning lights has immediate positive effects on driver behavior. According to the research, in-roadway warning lights improve drivers' awareness of crosswalks and pedestrians who are present in them. After the installation of the lights, motorist yield behavior increases; that is, more drivers stop or slow down when pedestrians attempt to cross the road than before the warning lights were present. Researchers, including P.D. Prevedouros, have observed that speed near crosswalks also declined after in-roadway warning lights were activated.

These positive effects make in-roadway warning lights an appealing solution at difficult crossing locations. Researchers P. Boyce and J. Van Derlofske, however, have expressed concern that the meaning of the lights has been unclear to motorists and pedestrians alike. In one case, researchers observed that pedestrians, who could have used the lighted crosswalk, did not and instead crossed elsewhere on the road. Observations from this study also suggested that it was difficult for pedestrians to know whether the lights were on or not, and drivers did not know what to do when the lights were flashing. Some drivers slowed but continued across the intersection in front of a pedestrian, while others stopped and waited for the lights to stop flashing, even when no pedestrian was present.

Some question also exists as to how often and under what conditions pedestrians actually activate the lights when a push button is available. At one study site, Whitlock and Weinberger found that only 33 percent of crossing pedestrians activated the lights by pressing the button. Little is known about the conditions under which pedestrians choose to activate the lights and whether they result in inconsistencies that are confusing to drivers. This problem can be countered by an automatic infrared or microwave device for detecting waiting pedestrians. If automatic detection is used, a button should enable the pedestrian to override the system in case the automatic detection device fails.

Like Day and Night

Statistics from a report by the National Center for Statistics and Analysis indicate that pedestrians are unsafe in a variety of lighting conditions. In 2001, daylight, dark, and "dark but lighted" conditions each accounted for about a third of the total pedestrian fatalities.

Many people expect that in-roadway warning lights will be most effective under dark conditions, such as dusk or dawn, night, or inclement weather. One early research study by Whitlock and Weinberger reported that driver yield behavior was greatest in adverse conditions such as darkness or fog. At several sites, the installation of in-roadway warning lights led to larger increases in yield rates and greater braking distances between drivers and pedestrians at night. But this effect has not received further attention by researchers.

Still Shining?

Most of the research on in-roadway warning lighting has ignored whether positive effects persist over time. Those studies that have examined the persistence of changes over time report mixed results. Whitlock and Weinberger noted that 2 years after installation, drivers at one site

were observed making sweeping motions with their heads approaching a crosswalk with in-roadway warning lights, ostensibly scanning for pedestrians. Additionally, drivers' yielding and braking distances remained higher than the baseline observation.

Boyce and Van Derlofske found that adding in-roadway warning lights to a clearly striped location lead to a reduction in vehicle speed. This effect of lighting on speed tended to diminish over time. Thus, whether the effects of in-roadway warning lights are persistent is unclear at this time.

Answering the Question

To examine the effects of in-roadway lighting on pedestrian safety, the FHWA research team sought the assistance of transportation engineers in Alexandria, VA, to find locations where pedestrians experienced crossing difficulties and where in-roadway lights were planned. Results from a recent National Center for Statistics and Analysis report analyzing 2001 pedestrian fatalities nationwide indicate that (1) 64 percent occurred on urban roadways, (2) 40 percent occurred in areas with a posted speed limit below 64 kilometers per hour (40 miles per hour), and (3) 78 percent occurred at nonintersection locations. The FHWA team therefore sought a midblock crossing with a sizable pedestrian presence during the day and at night in a moderately urban neighborhood where the speed limit was less than 40 mph.

The selected crosswalk is on a four-lane divided road at a subway station. Garbacz says of the crosswalk, "The flashing beacons will improve pedestrian safety by alerting motorists that there may be pedestrians crossing the street. Multilane crossings are particularly dangerous for pedestrians because large vehicles [may] block the view of the pedestrian from other motorists."

Installation of lights using push button actuation will occur in early 2004. The study is structured so that data will be collected immediately before and after the installation of the lights and again a year later. The FHWA researchers will address the following questions:

A pedestrian crosses a lighted crosswalk at night.

- What is the yielding behavior of drivers approaching a crosswalk with in-roadway warning lights?
- Where do pedestrians choose to cross, and do they actuate the system using a push button? Do pedestrians take advantage of in-roadway warning lights if they are present?
- Are the effects of in-roadway warning lights different under nighttime and daytime lighting conditions?
- Are driver and pedestrian behavior changes due to in-roadway warning lights stable over time (for example, 1 year later)?

Investigating the impact of in-roadway warning lights serves the goals of FHWA's "vital few" strategic initiatives. First, the results will add to an understanding of successful countermeasures for pedestrian safety. Second, the study will create the necessary knowledge to guide installation recommendations and justifications. This guidance will assist practitioners in making informed decisions that protect road users in a cost-effective manner.

Sheryl Miller received a B.A. in psychology from the State University of New York at Geneseo in 1995 and an M.A. in psychology from George Mason University, Fairfax, VA, in 1997. She expects to receive her Ph.D. from George Mason University in 2003, specializing in human factors and applied cognitive psychology. Miller is employed by Science Applications International Corporation and works at Turner-Fairbank Highway Research Center (TFHRC) on the Human Centered Systems team, specializing in pedestrian and bicycle safety research.

Gabriel K. Rousseau is an engineering research psychologist in FHWA's Office of Safety Research and Development at TFHRC. He leads the Human Centered Systems team's research on speed management and pedestrian and bicyclist safety. He received a Ph.D. in cognitive/experimental psychology from the University of Georgia and completed a postdoctoral fellowship at Georgia Institute of Technology.

Ann H. Do received a B.S. in civil engineering from Virginia Polytechnic Institute and State University, Blacksburg, VA, in 1987. She joined FHWA in 1990 as a highway design engineer. She currently serves as research highway engineer for TFHRC. Do has been the program manager for the FHWA pedestrian and bicycle safety research since 2001. She works in the Office of Safety Research and Development, specializing in research related to safety effectiveness evaluations, pedestrians, bicycles, human factors engineering, and geometric design.

For more information, see http://tfhrc.gov/safety/safety.htm#Bicyclist or contact Ann Do at 202-493-3319 or ann.do@fhwa.dot.gov. For references, see the online version of PUBLIC ROADS.

Measuring Pavement Deflection at 55 MPH

A field test shows that the rolling wheel deflectometer enables engineers to evaluate pavement while keeping pace with traffic.

by Max G. Grogg and Jim W. Hall

Imagine measuring the load-carrying capacity of paved highways and detecting possible pavement weaknesses, while traveling with the traffic flow. No lane closures to collect data. No additional congestion. No traffic backups. No work zone safety issues.

How? The answer is one of today's most significant innovations in pavement management systems—the rolling wheel deflectometer (RWD). The benefit of the RWD is that it helps officials prioritize and target funding and projects to those segments of the highway network that need structural improvement and rehabilitation.

Highway engineers already have valuable and reliable tools for gauging surface conditions and structural capacities. A precursor to the rolling wheel deflectometer, the falling weight deflectometer (FWD) is the workhorse for measuring the stiffness of a designated section of a highway. The FWD is designed and used primarily for project-level analysis. Despite the integrity of its data, the FWD's requirement for stationary operation increases delays caused by closed lanes on busy roads, compromises safety of the traveling public and highway workers, and contains information limits for applications at the network level.

The Federal Highway Administration (FHWA) envisioned a process for gathering pavement deflection data at speeds that match the pace of traffic and that would operate continuously for hundreds of miles in a given day. At the end of a week, highway engineers would have a "structural map" of a major portion of a State's network—and be capable of testing the entire system, quickly and accurately.

"Technology is finally catching up with what our highway engineers need to know about the structural integrity of the whole network," says Associate Administrator King W. Gee, head of FHWA's Office of Infrastructure. "The information we gain from the rolling wheel deflectometer will enable users to determine the remaining life of our highway pavements. It is hoped that it will then translate into proactive programming and strategic management of one of our Nation's greatest investments, our highway transportation infrastructure."

In July 2003, FHWA tested the most recent version of the RWD on a network of highways in Texas.

To the casual observer, the rolling wheel deflectometer (RWD) looks like any semitrailer and truck. The long beam mounted underneath the trailer on the passenger side is the giveaway that this is no ordinary truck.

Moving smoothly with the stream of traffic at a minimum of 88 kilometers per hour (55 miles per hour), the 16-meter (53-foot) semitrailer and truck collected more than 483 kilometers (300 miles) of network data. The Texas test clearly demonstrated that the RWD can do a job in one afternoon that would have taken days using stationary testing devices.

Frank Botelho, team leader in the FHWA Office of Asset Management, began this success story in 1996. "A part of research and development is conceiving better solutions and tools for existing and future problems," Botelho says. "In theory, we knew that one day we would need a faster, more mobile solution. However, FHWA needed to develop the technology and a way to apply the technology before it would be useful for the transportation community." Botelho initiated a research contract under the Small Business Administration's Small Business Innovative Research program.

Research Requirements

The first step in designing the RWD was to investigate whether the technology was already available in the market. Nearly a year's worth of research provided invaluable data that ultimately proved to be the starting point for the engineers. Several other countries—Australia, Denmark, England, and Sweden—and forward-looking States were on the same track, but no agency or company had delivered a fully operational, fast-moving piece of equipment that could collect data without interfering with the traffic flow.

With preliminary research complete, the next step was to design and build an RWD that would meet FHWA's requirements for testing equipment that would be fast, accurate, and safe. The prototype RWD design would need to measure the deflection of asphalt pavement, but not portland cement concrete (PCC) pavements. To measure PCC, additional research would be necessary.

The RWD also needed to supercede the results gained from nondestructive stationary simulations or slow-moving equipment. The RWD would need to measure the overall stiffness (or strength) of a pavement, known as "deflection response," at the moment it receives the impact of a heavy weight, such as a heavy truck rolling over it. The depth and shape of the deflection provides engineers with information about the pavement's structural capacity. Although the FWD can depict the impact of a heavy truck weight, it must remain stationary on the pavement to take the measurement. The body of the RWD *is a moving heavy truck*, therefore, it collects data about heavy weight vehicles during impact in real time.

FHWA set the speed requirement for the RWD at approximately 88 km/h (55 mph). Sensor accuracy had to yield data that would correlate to the FWD and similar proven technologies. Vehicle design and software programming would address the remaining issues such as vehicle dynamics, surface texture, and road curvature and crown. The end product must be a working prototype, not simply a contribution to research data at hand.

Design and Fabrication

Design and fabrication of the working prototype of the RWD did not happen overnight. Guided by early efforts, the engineers finally chose spot lasers to take the deflection measurements. The spot lasers were chosen because of their known accuracy in taking measurements without regard to speed. Using multiple lasers, a spot on the road could be measured before and during its deflection. A semitrailer was to carry a 7.8-meter (25.5-foot) aluminum beam specially designed to house four lasers spaced 2.6 meters (8.5 feet) apart. The beam was mounted on the right side of the semitrailer to follow the wheel path closest to the edge of the roadway, generally the weakest part of the pavement. The semitrailer by itself placed 8,172 kilograms (18,000 pounds) of dead weight over the rear axle, the maximum allowed with the current spacing

A powerful piece of equipment, the falling weight deflectometer (FWD) provides critical data on a project level but must be moved from point to point to take structural capacity readings. Together, the FWD and RWD are a strong duo to help engineers determine structural capacity.

Small Business Innovative Research Funding

Each year the U.S. Department of Transportation (USDOT) sets aside a percentage of its extramural budget to support an annual, highly competitive process for funding new research and technology undertaken by U.S. entrepreneurs in small businesses. The program, Small Business Innovative Research (SBIR), is run by the Small Business Administration. Since the SBIR began in 1982, thousands of small businesses have profited from an opportunity to participate in the investigative and startup phases of commercially viable products. To learn more, see PUBLIC ROADS November/December 2002 or visit www.sba.gov/sbir/indexsbir-sttr.html#sbir.

Data Comparison, Second RWD Road Test

Device	RWD	Accelerometer	FWD
Dates tested	July 25–26, 2002	July 25–26, 2002	July 12, 2002
Thick pavement mean deflection, mils	11.1	10.3	8.7
Thin pavement mean deflection, mils	12.8	13.3	14.0

between the dual tires. A computer system for receiving the data was located inside the trailer.

Information from the lasers downloads, in real time, into the computer. Spot lasers and rapid processing time allowed for a sample every 12.2 millimeters (0.48 inch) at 88 km/h (55 mph).

Proof of Concept

The most critical step that followed the design and build phase of the RWD was the "proof of concept." West of Champaign, IL, Staley Road was selected as the test site for the proof of concept. The road's pavement consisted of both thick and thin asphalt concrete sections. In the summer of 2002, the pavement was in fair condition; the surface had small amounts of cracking, rutting, and the weathering typical of a Midwestern road.

Best results are gained when a road is dry and warm, and the subgrade soil is not frozen—hence the summertime testing. The team prepared by first taking deflection data using the FWD. From those measurements, accelerometers were placed in the pavement at six locations, three in the thick asphalt concrete sections and three in the thin sections.

The proof-of-concept test was designed to correlate the RWD measurements with the corresponding FWD and accelerometers' measurements. An improved computer system allowed for complete data intake. For 3 days, the RWD made multiple passes at 48 to 88 km/h (30 to 55 mph), each time testing two 153-meter (500-foot) sections of the thick and thin pavement. In the end, the RWD data compared favorably with data retrieved from both the FWD and accelerometers.

Calibrating the Lasers

All four lasers must be "adjusted" to a perfectly level reference. In the calibration process used, the reference is obtained using a 7-meter (24-foot)-long water level.

The process is simple in design and effective in results. The researchers cut four short sections of 203-millimeter (8-inch) polyvinyl chloride (PVC) pipe, closed them on one end, and set them up vertically with the open end beneath the laser. These containers are connected by sections of water hose, and each container is filled with water to the same level. A very thin reflective float is placed on top of the water in each container. Each laser is tested to gauge the length of its beam to the reflective tile. Water is added or taken from the containers to ensure that the lasers are providing comparative readings as the depth of the water changes. Remarkably, the differences generally are only slight and are compensated for by using mathematical adjustments in the data processing software.

The laser is calibrated by aiming the beam at a reflective disk floating on water. The remaining three lasers are tested simultaneously to identify any differences in the sensors' measurements.

Ground Truthing

One factor became clear after the analysis of the 2002 data: The rearmost laser would yield better information if it were placed between the dual wheels so it would read the point of maximum deflection. The team had custom-designed rims built with aluminum spacers to provide 25.4 millimeters (1 inch) of clearance between the laser box and the dual wheels. With this enhancement and the continual upgrading of the software, the RWD was ready to hit the road once again in July 2003, this time in Texas.

The Texas Department of Transportation (TXDOT) arranged the field test to include comparisons between the RWD and three other independent data points—the FWD, a multidepth deflectometer (MDD), and a rolling dynamic deflectometer (RDD). The RDD, which was developed by the University of Texas, accurately measures deflection while moving at 2.4 km/h (1.5 mph).

The MDD was used for what engineers call "ground truthing." Because an MDD sensor is deeply rooted 3.05 meters (10 feet) in the ground, it reads the absolute deflection at the point in the pavement where it is placed. To ensure an accurate comparison between the data from the MDD and the RWD, the lane where the MDD was placed was blocked off for the test. The pavement was visibly marked to assist the truck driver in positioning the lasers directly over the MDD sensors. Cameras were stationed on the roadside to capture the transverse location of the truck (RWD) as it drove over the MDD.

After several passes over the MDD sensors, the Texas RWD test continued on three other types of pavement: weak, intermediate, and strong, such as found on farm-to-market roads and State highways. The Texas team was on the road with the RWD for nearly 7 days to capture quality information in multiple situations.

Initial analyses of the test data are promising and have generated excitement in State DOTs and in transportation agencies in other Nations. "Texas DOT has always been active in equipment development," says Dr. Michael Murphy, manager of TXDOT's Pavements and Materials System Branch. "After the Texas test, we see the potential for the RWD to be a tool in our inventory that we don't have right now. We'll use it where it works best and expand on it as improvements are made." Indeed, the team continues to envision future enhancements to the equipment and process, but the prototype has gone the distance and returned results that meet the goal set out in 1996.

Next Steps

The next step for the RWD technology is to move from research and conceptual testing into real-life deployment. FHWA is seeking State DOTs for further developments in this technology.

Facts and Figures

Lasers: four lasers mounted 2.6 meters (8.5 feet) apart with rearmost laser placed 152 millimeters (6 inches) behind the axle centerline

Trailer: 16 meters (53 feet) to control for pitch and accommodate the long beam

Aluminum beam: 51 millimeters (2 inches) wide x 216 millimeters (8.5 inches) high x 7.8 meters (25.5 feet) long

Surfaces tested: various types of asphalt concrete and asphalt surface treatment during summer months

Data collection: every 12.2 millimeters (0.48 inch) at 88 km/h (55 mph), averaged every 30.5 meters (100 feet)

Max G. Grogg, P.E., has been FHWA's lead engineer on the RWD project from its inception in 1996 to the present. He is a pavement and materials engineer and team leader for FHWA's Technical Programs Team in the Iowa Division. He has 18 years of service with FHWA in division, region, and headquarters offices, and previously worked for the Illinois DOT and a pavement consulting firm. He has been actively involved in the development of FHWA's RWD, implementation of products developed during the Long-Term Pavement Performance study (such as calibration of falling weight deflectometers and resilient modulus testing), implementing and improving pavement management systems, and measuring and improving ride on highways. He graduated from the University of Missouri-Rolla and holds a master's degree in pavement engineering from the University of Illinois. He is a licensed professional engineer in Virginia and has served on committees and task forces for the American Association of State Highway and Transportation Officials and Transportation Research Board.

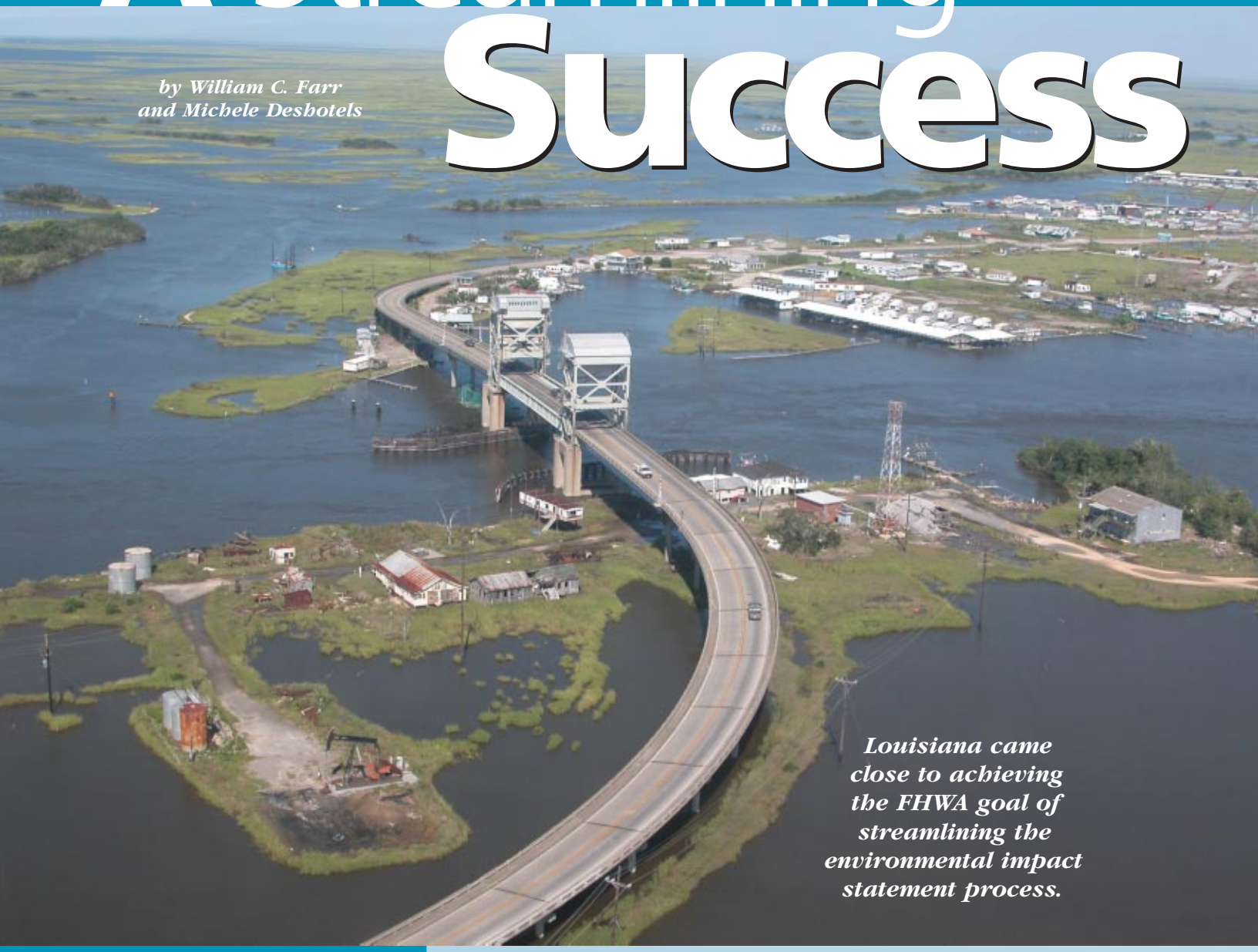
Jim W. Hall, Ph.D., is the director of pavement engineering at Applied Research Associates, Inc. He is the principal investigator on the contract to build the RWD for FHWA and has more than 38 years of experience managing large research programs pertaining to highway and airfield pavements. He was a pioneer developer of nondestructive testing and developed early methodologies based on correlations of deflection response measurements to conventional methods for structural assessment for both flexible and rigid pavements. He has directed field, laboratory, and office projects to perform structural and functional evaluations of airfield and roadway pavements. His doctoral dissertation was based on pavement deflection response under moving wheel loads. He holds three degrees in civil engineering: a B.S. from Mississippi State University, an M.S. from Texas A&M University, and a Ph.D. from Auburn University.

Interested States should contact Max Grogg at 515-233-7306 or e-mail him at max.grogg@fhwa.dot.gov. The complete report on the RWD's Texas test, due January 2004, will be available to those who want to learn more. For more information on the Texas field test, contact Dr. Mike Murphy at 512-465-3586.

Here the truck wheels sit on a painted grid that indicates the location of the multidepth deflector (MDD) under the laser.

A Streamlining Success

by William C. Farr and Michele Deshotels



Louisiana came close to achieving the FHWA goal of streamlining the environmental impact statement process.

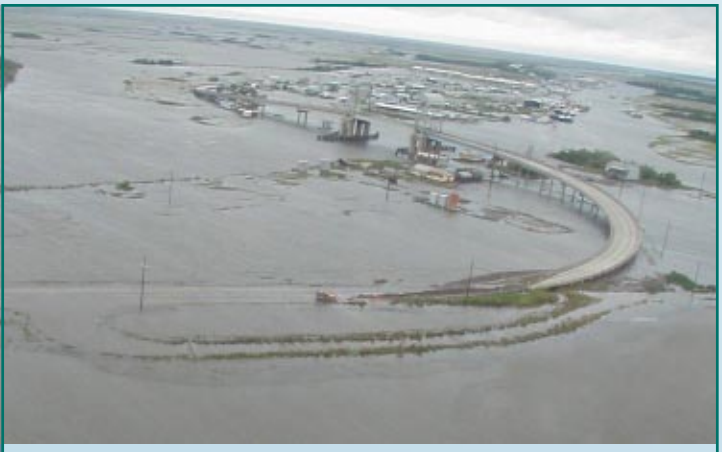
(Above) LA 1 bridge over Bayou Lafourche at Leeville, LA, looking southeast towards Grand Isle and the Gulf of Mexico. *Photo: David Miller, LADOTD.*

When the environmental study for a new Louisiana highway took only 44 months from start to finish (including the Record of Decision), the speedy turnaround proved that the Federal Highway Administration's (FHWA) goal of streamlining the review process is definitely achievable. The time span was very close to the FHWA 2007 goal of a median of 36 months for completing the environmental impact statement (EIS) process from the Notice of Intent to the approval of the final EIS.

On January 29, 2003, Louisiana Division Administrator William A. Sussmann signed the Record of Decision for the EIS for the new highway, which will link Port Fourchon, LA, to Golden Meadow, LA, and connect the port with the rest of the country. The $540 million project includes a new four-lane roadway for LA 1 and a new fixed span over Bayou Lafourche at Leeville to replace the existing lift bridge.

"To have a study of this magnitude completed in such a relatively short period of time is a credit to our local, State, and Federal leaders, as well as our members who provided the private financial support," says Roy Francis, executive director

of the LA 1 Coalition, an advocacy group for the project. "We are now excited to move into the preliminary construction phase of a highway



Tropical Storm Isidore made landfall in September 2002, washing over LA 1, as shown in this aerial photo.

Greater Lafourche Port Commission

that has [played] and will continue to play such an important role in America's energy supply."

A Vital Highway

The present LA 1 is a two-lane roadway following the natural levee of Bayou Lafourche. The highway is subject to periodic tidal inundation, which necessitates maintenance beyond the normal requirements, including removing debris washed up by high water and repairing shoulders washed out during major storms. The highway serves as the lone land access to Port Fourchon and Grand Isle in southern Louisiana.

LA 1 traverses two of the Nation's most productive estuaries, the Barataria and Terrebonne. "This marshland . . . is a national treasure," says Dr. Kam Movassaghi, secretary of the Louisiana Department of Transportation and Development (LADOTD).

Louisiana, home to the seventh largest delta on the planet, is rich in natural resources. Forty percent of the Nation's wetlands are located in the State, and more than 30 percent of the U.S. fisheries catch comes from offshore Louisiana. The Port Fourchon/Grand Isle area is considered one of the top fishing spots in the world. In addition, half of the bird species in North America make their home in Louisiana or travel through it while migrating.

"No less important is that LA 1 is the access to another national treasure—the oil and gas reserves in the Gulf," says LADOTD Secretary Movassaghi. According to statistics compiled by the LA 1 Coalition and Port Fourchon, 75 percent of the deepwater oil and gas production from the Gulf of Mexico goes through the port. In addition, Port Fourchon is the land base for the Louisiana Offshore Oil Port, which handles 13 percent of the Nation's foreign oil and is connected by pipeline to 30 percent of the U.S. refining capacity.

This aerial shot is looking south toward Port Fourchon and the Gulf. The existing LA 1 sits on the natural levee of Bayou Lafourche.

Greater Lafourche Port Commission

All of this is threatened by coastal loss. In the past 50 years, more than 3,885 square kilometers (1,500 square miles) of coastal Louisiana have been lost to erosion and subsidence. Louisiana's wetlands are a buffer from hurricanes and Gulf storms, protecting the coastal cities, including New Orleans. The wetlands also protect the wells, pipelines, roads, and levees that service the oil and gas industry, assuring delivery of this vital fuel supply to the eastern United States. Louisiana's wetlands are working wetlands, and transportation is the key to accessing these resources.

What the ongoing coastal loss will mean not only to Louisiana but also to the Nation is only now becoming fully understood. "The LA 1 improvements recognize the important role that transportation has in our daily lives and in our future, as well as acknowledging the important role that Louisiana plays as gatekeeper for the Nation's natural resources wealth," says Secretary Movassaghi. "We are grateful for the time and hard work that all of our sister agencies—Federal, State, and local—invested to enable us to reach a decision on this project that provides an essential link across such an environmentally sensitive, fragile marsh."

The Need for the Road

In addition to serving the residents, petroleum industry, commercial fishermen, and recreational

The EIS Chronology

- Notice of Intent published in the *Federal Register*: May 5, 1999
- EIS consultant work ordered: September 20, 1999
- Approval of the Draft EIS for distribution: October 25, 2001
- Public Hearing: December 18, 2001
- Approval of Final EIS: September 9, 2002
- Record of Decision: January 29, 2003

sportsmen, LA 1 must serve as a hurricane evacuation route. "With continued coastal erosion and subsidence, it has become increasingly susceptible to flooding early in any weather event," says Marcus N. Redford, a branch chief with the U.S. Coast Guard in New Orleans.

The need for an all-weather road for port access and emergency evacuation, plus the current and projected heavy truck volumes, helped shape the proposed project. To replace the two-lane highway, a four-lane elevated facility with full control of access would be required, with fixed bridges spanning the navigable waterways. The project would be approximately 27 kilometers (17 miles) in length, extending from LA 3235 at the town of Golden Meadow south to the intersection of LA 1 with LA 3090, the entrance to Port Fourchon.

LA 1 from U.S. 90 (future I–49) to Port Fourchon is part of the National Highway System (NHS) because of its intermodal link to the Nation's energy supply. The proposed facility would complete the southernmost portion of this NHS route. When completed, a four-lane divided highway will be available from LA 3090, north of Port Fourchon, to north of Galliano.

For some time, the need for guaranteed continuous access to Port Fourchon had been recognized by the State of Louisiana, the Greater Lafourche Port Commission (which operates Port Fourchon), and Lafourche Parish. The overall importance of LA 1 is stated in the Governor's Executive Order No. MJF 98-46: "LA 1, a two-lane highway with sections [that] are impassable during inclement weather, is vital to the citizens who work and live in the region, for hurricane and tropical storm evacuation, work-related and shopping commutes, shipping of shellfish and finfish harvested in the region's waters, and support services to the offshore drilling facilities."

William Huffstetler, Wilbur Smith Associates

Shrimp boat on Bayou Lafourche. The fishing industry will benefit from improved access to markets.

The EIS Partnership

National recognition resulted in identification of funding in the Transportation Equity Act for the 21st Century (TEA-21) for construction of a bridge at Leeville and reconstruction of LA 1 from the Gulf of Mexico north. The growing realization of the importance of Gulf resources, both fisheries and oil and gas production, and the dependence on a single land access route, LA 1, for utilization of these resources resulted in the formation of a unique partnership that includes LADOTD, the LA 1 Task Force, Port Fourchon, and the LA 1 Coalition. The Port, partnering with interested stakeholders, provided the local share to match the TEA-21 funds used to fund the National Environmental Policy Act (NEPA) process.

Due to the broad range of issues and the potential for significant impacts, the transportation agencies recognized that they would be able to reach a decision on an EIS only if all interested partners were identified at an early stage and provided the opportunity to participate fully. Because of the importance of this roadway and the surrounding marsh to Louisiana and the Nation, LADOTD and FHWA approached Federal, State, and local agencies prior to the *Federal Register* notice and finalizing the scope of work to assure that agency concerns were made a priority even before a consultant was hired.

"Through an orchestrated streamlining effort by FHWA and in cooperation with the stakeholders, a team was brought together to address requirements, routes, alternatives, and impacts in an open forum," says the Coast Guard's Redford. "FHWA served as the lead Federal agency for the NEPA process to produce a product in a timely manner that met the objectives for the project and [will have] the least impact on the environment."

From the beginning, all of the agencies involved realized that a timely decision could be reached only if everyone committed to open communication and sharing of

information throughout the process. Active agency partners included the Eighth District, U.S. Coast Guard; New Orleans Office, U.S. Army Corps of Engineers; National Marine Fisheries Service; U.S. Environmental Protection Agency; U.S. Fish and Wildlife Service; Louisiana Department of Natural Resources (Coastal Zone Management); Louisiana Department of Culture, Recreation and Tourism; and the Barataria-Terrebonne National Estuary Program.

"The Coast Guard Bridge Administration participated in that process as a cooperating agency to the NEPA process to ensure that the current and future needs of navigation were met and preserved while protecting the environment," says Redford. "From the initial purpose and need, to scoping and through the final EIS document, close coordination has ensured that all objectives have been met.

"The product we have is the result of that cooperative effort, a plan that promises to protect the environment while providing for the intermodal needs of transportation in this economically important region of the State and Nation."

The Secrets of Success

Each agency committed to putting its concerns on the table. "The process worked so well because all the major agencies were in attendance and committed," says Richard Hartman, chief of the Habitat Conservation Division, Baton Rouge Office of the National Marine Fisheries Service. "All involved knew there was a basic need for the project in terms of both public safety and economics. The consultants utilized by LADOTD actually listened to the agencies and did quite a good job of addressing our concerns and comments early in the process."

In addition, there was considerable involvement and input from numerous other agencies, communities, elected officials, and citizens throughout the process. LADOTD and FHWA, through the consultant, Michael Baker, Jr., Inc., addressed each concern with the best data available. Each agency continued its responsibility by actively assisting in reviewing data and providing comments and direction.

"For years, local residents and the thousands of energy workers who travel through Port Fourchon have recognized the immense importance of LA 1," says Rep. Loulan Pitre of Cut Off, LA. "Today, our message is being heard in Baton Rouge and in Washington, DC. Now more than ever, improvements to this significant highway are not only a local need but a national necessity."

FHWA Louisiana Division Administrator William Sussmann signs the Record of Decision on January 29, 2003, for LA 1 Improvements from Golden Meadow to Port Fourchon. Looking on, left to right: Marcus Redford, U.S. Coast Guard; Commissioner Chuckie Cheramie, Greater Lafourche Port Commission (GLPC); Ted Falgout, Johnny Melancon, and Larry Griffin, GLPC; Louisiana Representative Loulan Pitre; Ron Ventola, U.S. Army Corps of Engineers; Roy Francis, LA 1 Coalition; Deputy Secretary Blaise Carriere, DOTD; and Tom Eubanks, LA Department of Culture, Recreation, and Tourism.

Michele Desbotels, LADOTD

At the same time, LADOTD and FHWA announced they had made a joint decision that end-on construction would be given full consideration everywhere it could be done. End-on construction is a "top-down" technique. Instead of being placed on the ground or in the water, the heavy construction equipment is placed on top of a work platform mounted on concrete piles. From these platforms, a crane drives piles and pushes the bridge viaducts forward, one span at a time. Once a span is completed, the crane crawls forward onto the next work platform to repeat the cycle.

The decision to use end-on construction let the other agencies know from the beginning that the transportation agencies realized and valued the importance of both road and marsh. Ultimately the final decision was for end-on construction for the entire project with the exception of the fixed high-rise bridge at Leeville, where the vertical grade rise made end-on construction impractical. In fact, conventional construction techniques to be used at this bridge site may well provide exceptional opportunities for marsh restoration in this rapidly subsiding area.

Context-Sensitive Solutions

On all levels, the project serves as a textbook example of fulfilling the goals of environmental stewardship and streamlining. At one level, for example, the partnership used geographic information system (GIS) technology in the alignment selection, thereby reaching decisions efficiently. At a broader level, a major reason for success was that the process embodied the principles of context-sensitive solutions.

Each of the following principles were given full credence: (1) develop projects through a collaborative process that actively engages communities and other stakeholders early and often; (2) balance safety, mobility, and economic goals with the preservation of environmental, scenic, aesthetic, historic, and

William Huffstetler, Wilbur Smith Associates

Offshore oil rigs are visible from the shoreline at Fourchon, LA. The breakwaters in the foreground were installed to attenuate wave action and protect the shoreline.

cultural values; (3) build projects that add lasting value to communities and involve minimal disruption; (4) implement a flexible design process that is sensitive to project goals, timelines, and the environment; and (5) exceed the expectations of designers and stakeholders.

Marsh Dieback

In the summer of 2000, during the development of the EIS, a massive dieback of salt marsh grass severely affected 42,525 hectares (105,000 acres), or about 425 square kilometers (164 square miles), with an additional 55,890 hectares (138,000 acres) stressed. The dieback made the LA 1 project team only more determined to assess potential impacts to marsh grass from the proposed elevated structure.

The result was a study to evaluate the possible effects that shading from the elevated structure would have on smooth cord grass. The agencies agreed that the required mitigation acreage would be determined by adding to the direct wetland impacts (the marsh area directly affected by pile driving) the amount of marsh that would be shaded for 4 hours or more each day. The agencies agreed that this proactive approach would enable mitigation to be in place prior to construction and impacts on vegetated wetlands.

Giving Credit Where Credit Is Due

The U.S. Army Corps of Engineers (USACE) gives primary credit to the Federal and State transportation agencies for the successful environmental review. "Two factors contributed to the timely preparation of the EIS for the proposed relocation of LA 1 between Fourchon and Golden Meadow," says Ronald Ventola, chief of the Regulatory Branch, New Orleans District, USACE. "First, the Federal Highway Administration and the Louisiana Department of Transportation and Development understood the sensitivity of the habitat traversed by the proposed project and were willing to incorporate design features that significantly reduced the overall impacts of traversing over 16 miles [26 kilometers] of brackish and saline marshes.

"Second, the Federal Highway Administration and the Louisiana Department of Transportation and Development were able to relay to the resource and regulatory agencies the importance of the proposed project and the lack of viable alternatives. The only remaining item was to hammer out a document that addressed all public interest concerns and satisfied the Corps' regulatory requirements under NEPA. In the course of preparing the EIS, I believe there was mutual respect between all agencies and a willingness by the transportation agencies to consider and incorporate into the document suggestions made by the resource and regulatory agencies."

Only because the two transportation agencies assumed responsibility for being good environmental stewards could the Record of Decision for a project of this magnitude in such a fragile area be issued in 44 months from the time of the Notice of Intent. This project required intense coordination, cooperation, and commitment on the part of all involved: LADOTD, FHWA, the consultant, and the regulatory and resource Federal, State, and local agencies. This Louisiana success story is a prime example of how diverse interests can respond in a timely manner without seriously compromising their views.

The project is now in the design stage and will be phased to accommodate funding.

William C. Farr, program operations manager for FHWA's Louisiana Division, is a graduate of the University of South Carolina (B.S. in civil engineering) and began his career with FHWA in 1979. He has been working in Louisiana for the past 10 years, where he also has held the position of technical operations manager. Before that, Farr held engineering positions in the Virginia and Nevada divisions. Prior to FHWA, he worked for the South Carolina DOT.

Michele Deshotels, environmental impact manager, has worked for LADOTD since 1980. A graduate of Louisiana State University (B.A. in anthropology), she leads a team of environmental scientists who conduct environmental analyses and write NEPA documents. Deshotels served as LADOTD's project manager for the EIS on the LA 1 improvements project.

For more information, contact William C. Farr at william.farr @fhwa.dot.gov or Michele Deshotels at micheledeshotels@dotd.louisiana.gov.

An Environmental Frontrunner

by James B. Struzzi II

A Pennsylvania engineering district is the first in the Nation to achieve ISO 14001 registration.

In December 2002, a highway engineering district in Pennsylvania became the first State transportation agency in the United States to be 14001 registered by the International Organization for Standardization (ISO). Serving as the Pennsylvania Department of Transportation's (PENNDOT) pilot organization for the ISO process, Engineering District 10 earned this distinction for its Maintenance Unit's implementation of a Strategic Environmental Management Program (SEMP) for winter materials, stockpile management, and erosion and sedimentation controls.

(Above) Erosion and sedimentation controls like these implemented on Falls Creek in Jefferson County, PA, are standard practice under ISO 14001 registration.

An organization achieves ISO 14001 registration by minimizing any harmful effects of its activities on the environment and continually improving its environmental performance. Since ISO registration requires evaluation by an independent third-party auditor, achieving 14001 was no easy task for a transportation district that is responsible for 5,117 kilometers (3,178 miles) of State highways, including two interstates and 1,617 bridges, in five Pennsylvania counties.

The achievement of most goals usually begins with a challenge. For PENNDOT's Engineering District 10, achieving the goal of ISO 14001 registration began with a challenge from the governor.

All photographs: PENNDOT.

The Governor's Green Plan

In 1998 former Pennsylvania Gov. Tom Ridge issued the Governor's Green Plan, an executive order that called for State agencies to improve their environmental performance. PENNDOT's leadership further reinforced this order when they committed the organization to developing and implementing a program to improve environmental performance. This emphasis on environmental stewardship continues under Gov. Edward G. Rendell.

In the spring of 2001, District 10 began its journey to becoming the

A PENNDOT employee conducts a quality assurance check on a winter materials stockpile.

first U.S. transportation agency to receive the ISO 14001 registration. Through a cooperative effort with the American Federation of State, County, and Municipal Employees (AFSCME), District 10 set a goal to achieve registration by December 2002.

Located in western Pennsylvania, District 10 covers Armstrong, Butler, Clarion, Indiana, and Jefferson counties. Residents of the area value their breathtaking landscapes and outdoor activities like hunting and fishing. Many State roads in the district are near trout streams, game lands, and other environmentally sensitive areas.

"We are proud of our district staff under the leadership of District Executive Richard H. Hogg for leading the way toward ISO registration," says PENNDOT Secretary Allen D. Biehler. "Our ultimate goal is to build environmental sensitivity into everything we do and win the trust of our partners in the resource agencies. The benefit for our customers will be expedited and environmentally sound projects."

Developing a Strategic Environmental Management Program was the direct result of PENNDOT listening to the voices of its customers. "Quality of life and environmental stewardship are important to our customers," District Engineer Hogg explains, "and we must strive diligently to preserve and protect those aspects of the region we hold dear."

The district's journey to ISO registration began with the creation of a leadership team to drive the effort. Once the district team was formed, each maintenance office in District 10's five counties formed its own implementation team to ensure that a consistent message was conveyed at all levels throughout the organization.

"ISO 14001 registration confirms that an organization has developed and implemented an environmental management system that supports environmental protection and the prevention of pollution in balance with socioeconomic needs and is fully interwoven within the fabric of the organization's core business activities," says Richard T. Pavic, an environmental planner who became the SEMP process owner and coordinator of District 10's ISO effort.

Process Creates Quality

"In order to obtain and maintain ISO 14001 registration, an organization must develop and implement detailed processes related to the performance and management of activities that have the potential of negatively impacting the environment," Pavic says. "Secondly, to ensure that the processes are implemented consistently, the organization must commit to conducting audits in the form of internal quality assurance/quality control evaluations and internal surveillance audits that focus on whether the environmental management system is functioning accordingly or requires the implementation of corrective and preventative action plans to correct deficiencies within the system."

Although the official process to earn registration began in 2001, the actual work had started many years before. During the 1990s, recognizing its responsibility as an environmental steward, the district systematically incorporated environmental controls into its maintenance operations. The district created formal processes to monitor materials usage and established strict guidelines for erosion and sedimentation controls.

According to Pavic, ISO registration requires documented, visible evidence that all employees adhere to policies, procedures, and processes in their everyday work in all aspects of operations. In short, every employee in the organization must believe in a shared environmental vision. In District 10's case, this shared vision is manifested in adherence to policies and procedures pertaining to winter materials, stockpile management, and erosion and sedimentation controls.

The district began its effort by forming several committees under the direction of the SEMP leadership team and TLI Systems Inc., a consulting firm that assisted in the effort to earn ISO registration. Recognizing the need to communicate the organization's goal to employees at all levels, the team implemented the following measures to create awareness and shared responsibility: (1) developed a SEMP manual, (2) included specific SEMP goals and roles

Technology like this GL400 computer mounted in each PENNDOT truck helps operators apply the correct amount of winter materials for the desired result.

on employee performance reviews, and (3) formed a subcommittee designated to communicate SEMP throughout the organization, including every maintenance facility in the 9,244 square-kilometer (3,569 square-mile) district. The leadership team conducted systematic SEMP training, and the subcommittee created posters that were displayed in facilities around the district.

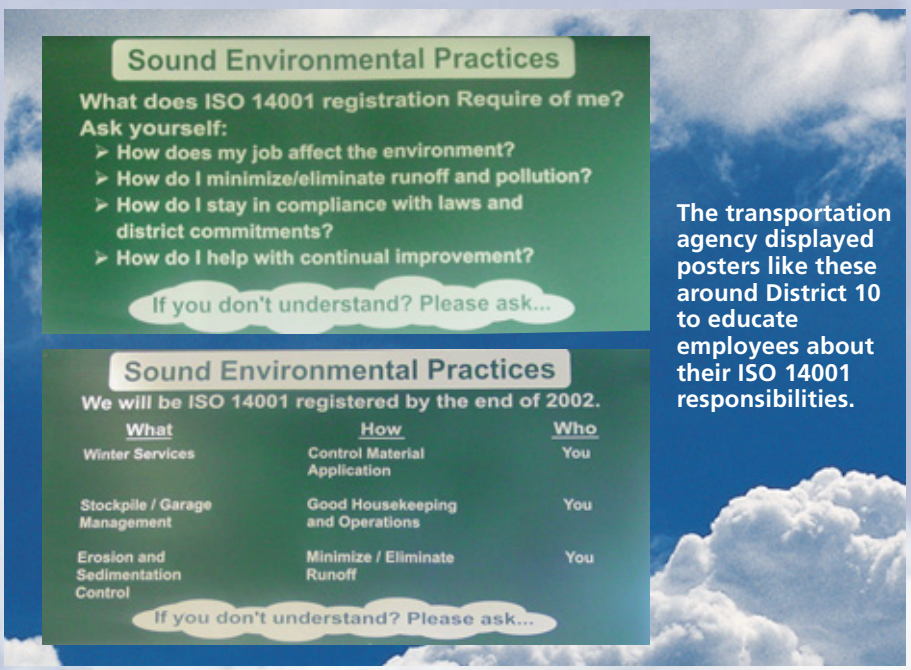
This unified message helped to create SEMP ownership with employees and instilled the basic principles of ISO registration. The district also created a system to police itself by selecting internal auditors to monitor SEMP processes.

A Goal Is Achieved

In the fall of 2002, the third-party review of District 10's SEMP effort to obtain ISO registration began. The organization's environmental processes underwent extensive scrutiny to verify validity, consistency, and full implementation across the district. Then, on December 31, 2002, PENNDOT Engineering District 10 met its goal by becoming the first transportation agency in the United States to receive the ISO 14001 registration.

Pavic says, "ISO 14001 registration represents confirmation that PENNDOT District 10's Maintenance Unit has developed and implemented an environmental management system within its core business plan that strives to minimize unavoidable environmental impacts associated with maintaining a safe and efficient transportation system."

Although the district was successful in its effort to achieve registration, the work to maintain environmental compliance has just begun. Registration represents a commitment to PENNDOT's customers to continual improvement and requires frequent audits with an emphasis on continual improvement.



The transportation agency displayed posters like these around District 10 to educate employees about their ISO 14001 responsibilities.

"We, as a transportation agency serving our customers, the people of Pennsylvania, are committed to being sound environmental stewards," District Engineer Hogg says. "We will continue to improve our environmental efforts and preserve the quality of life in District 10."

Expedited Permitting

One of the goals associated with implementing an ISO 14001 registered environmental management system is acknowledgement on the part of Federal and State agencies, such as the U.S. Environmental Protection Agency and the Pennsylvania Department of Environmental Protection, in the form of an expedited permitting process.

"By demonstrating environmental stewardship through better management of our environmental responsibilities and demonstrated compliance with applicable Federal and State laws and regulations, District 10 is hoping for the development of environmental interagency agreements related to environmental clearance activities," Pavic says. "The interagency agreements would grant PENNDOT authority to approve specific environmental permits in-house related to the performance of maintenance activities associated with maintaining our existing roadway system."

This streamlined permitting process could save Pennsylvania taxpayer dollars by reducing the time needed by the regulatory agencies to review and approve environmental permits.

Following District 10's lead, other PENNDOT engineering districts across the Commonwealth have begun the process to become ISO 14001 registered. The race is on for Pennsylvania to continue and expand its environmental leadership.

This zero-velocity spreader, along with the GL400 computer, helps ensure that materials are not wasted or overused.

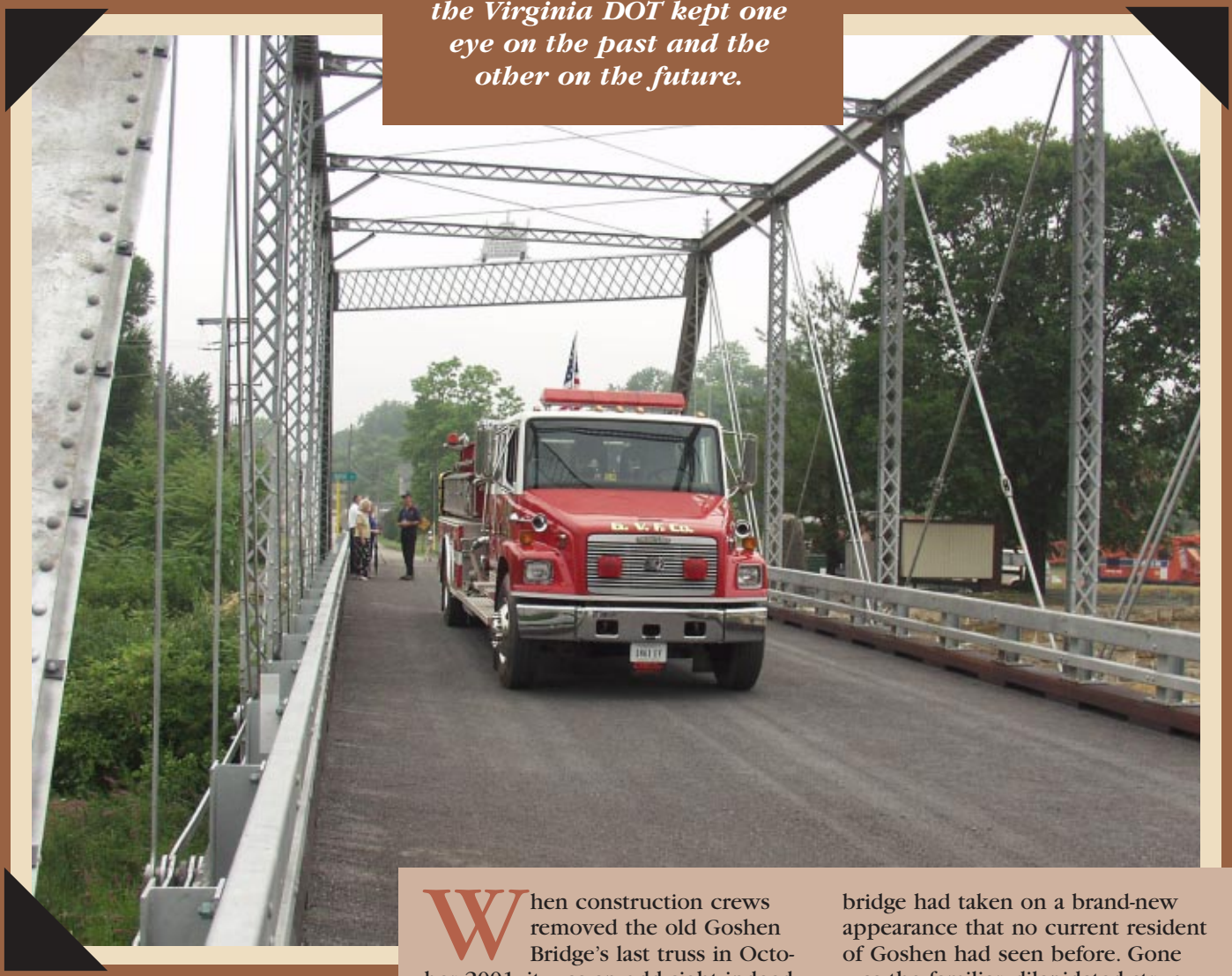
Jim Struzzi is the community relations coordinator for PENNDOT Engineering District 10. He joined PENNDOT in 1999 after working for several years as a transportation reporter for a daily newspaper in Butler County, PA. Struzzi is a graduate of the University of Pittsburgh and is currently pursuing a master's degree in public administration from Indiana University of Pennsylvania.

Visit www.iso.ch for more information on ISO registration, or contact PENNDOT Engineering District 10 at 724-357-3061.

Building a Bridge from Yesteryear

by Eric Gorton

In this historic restoration, the Virginia DOT kept one eye on the past and the other on the future.



When construction crews removed the old Goshen Bridge's last truss in October 2001, it was an odd sight indeed. The historic bridge had carried State Route 746 over the Calfpasture River in Goshen, VA, for as long as any resident of this picturesque western Virginia town could remember.

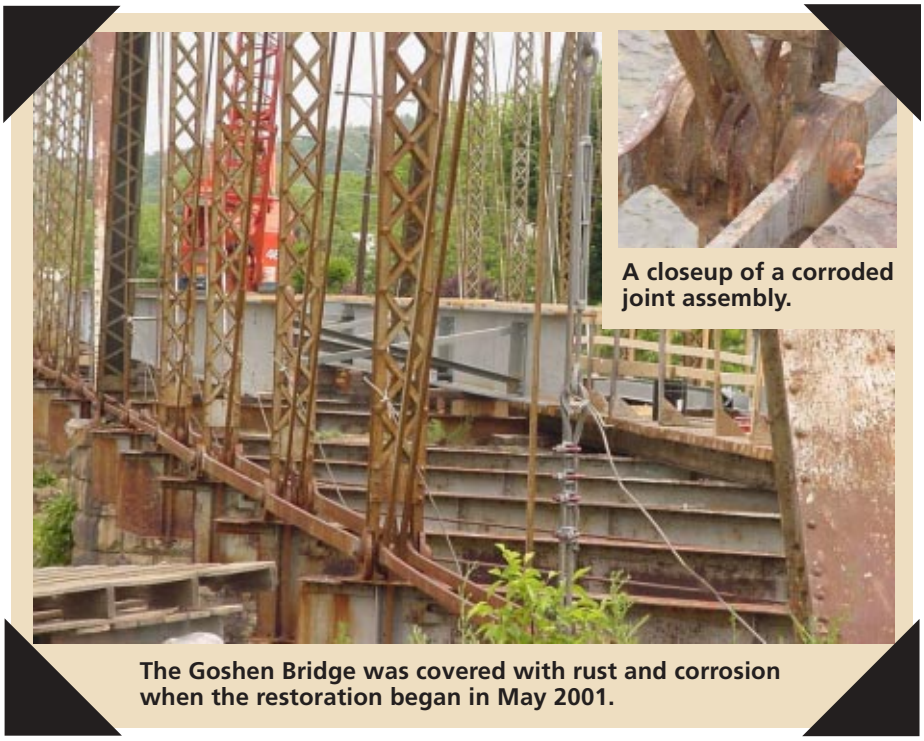
The bridge's absence was only temporary—by July 2002, the truss bridge was back in place. With a galvanized finish, the two-span bridge had taken on a brand-new appearance that no current resident of Goshen had seen before. Gone was the familiar, dilapidated structure spotted with rust and peeling paint, with half of its timber deck restricted due to weight limitations.

The mission for the Virginia Department of Transportation (VDOT): Restore the bridge to the original appearance it had when it was built in 1891, using as many of the original parts as possible.

(Above) After the restoration, a fire truck crosses the Goshen Bridge during the dedication ceremony. Previously, fire trucks were too heavy for the bridge.

All photographs: VDOT.

"It's a shining example of what can be done when all parties are committed to the preservation of historic structures," says Claude Napier, a bridge engineer responsible for the Federal Highway Administration's (FHWA) bridge program in Virginia and a member of VDOT's Historic Structures Task Group. Restoration of the bridge was done with "an eye for the past and an eye for the future," says VDOT senior structural engineer Robert ("Robbie") Saufley.



A closeup of a corroded joint assembly.

The Goshen Bridge was covered with rust and corrosion when the restoration began in May 2001.

Restoring a Treasure

VDOT personnel measured and photographed every inch of the old bridge, which is listed on the National Register of Historic Places and the Virginia Landmarks Register. They had to create new blueprints because the original drawings were no longer in existence.

The restored bridge retained the appearance of the original, including round-headed bolts that look like rivets. But stronger steel and other improvements increased its capacity from 5.4 metric tons (6 tons) to more than 18 metric tons (20 tons), strong enough for fire trucks, schoolbuses, and other heavy vehicles that could not use it before. The makeover also involved restoring the bridge's stone abutments and pier, and replacing the timber deck with a new glue-laminated deck.

"They've done a spectacular job being true to the original structure," says Al Hodson, who researched the history of the bridge and rehabilitation options in the mid-1990s while working on a master's degree in civil engineering at the University of Virginia.

During the reopening ceremony, Goshen Mayor Darell V. Sprouse said that the bridge "can again be looked at with pride and satisfaction . . . knowing that yet another great Virginia treasure of the past has been [restored]."

Building a 19th Century Bridge with 21st Century Technology

The Goshen Bridge was state-of-the-art for its day, carrying two lanes of traffic and designed to handle the weight of electric streetcars. Built by the Groton Bridge & Mfg. Co. of Groton, NY, the bridge measured 79 meters (260 feet) in length, with a pair of trusses about 6 meters (20 feet) above the water.

Pins and rivets held the bridge together. Back in 1891, the builders used die forging and loop welding to shape pinholes at the ends of the steel members. VDOT looked into creating replacement members using the same fabrication processes that produced the originals. But according to VDOT designer Saufley, the original processes, such as die forging and loop welding, were limited, expensive, and undesirable from a structural standpoint. Instead, VDOT elected to fabricate new steel, using computer-controlled machines.

"It's unique because we've never worked on a 100-year-old bridge before," says Mike Cumber, head of engineering at Structural Steel Products Corporation of Clayton, NC. "Just trying to use our new technology to match up to 100-year-old steel is a challenge."

The first step for Cumber and his coworkers was putting all the measurements into AutoCAD® and making sure that the components would go back together the way they were originally. Using Saufley's measurements, Cumber entered dimensions for all the elements—from bolt heads to the largest steel members—into the program to create a complete scale diagram. Although the computer simplified some things, Cumber notes that "a lot of brain work went into it," adding that the original basic drafting principles still applied.

Using contemporary methods brings out an appreciation for those used more than 100 years ago, he adds. "When you go back and look at some of the calculations that people had to do by hand, it's almost like artwork."

Once the measurements were accurate and the designs completed, specifications for the replacement parts were stored on computer disks. The disks were taken to the shop floor and fed into computers that controlled plasma cutters and other machines. As many as six of the largest members could be cut out of a single sheet of steel, already in the necessary shape without any of the muscle required a century ago. The new and salvaged parts were galvanized to reduce maintenance and provide longer protection against rust and corrosion than is possible with paint.

Grandest Boulevard Of the South

A century ago, the Goshen Land and Improvement Company commissioned the bridge to connect the east and west sides of its booming company town. Goshen was to become the "Iron Centre of America," according to the research by graduate research assistant Hodson.

In late May 1890, the company issued shares of stock totaling $175,000. The group quickly purchased land on both sides of the Calfpasture River and platted thousands of commercial and residential lots for its new steel-manufacturing town. Industrial sites were built near the river at the southern end of town, and large home sites were planned for a hillside between Mill Creek and the Calfpasture River. Surveyors plotted about 9,000 lots on about 324 hectares (800 acres).

The company built an electric rail-car manufacturing facility on the east side of the Calfpasture River. That factory was to employ 300 to 500 workers. By June 1891, the lumberyard for the facility covered 5.7 hectares (14 acres).

Another investing group purchased the Victoria Furnace, which was capable of producing up to 181 metric tons (200 tons) of iron per day from ore that was mined at nearby Bratton's Run, south of Goshen. Investors quickly planned a rolling mill, pipe factory, nail works, and other steel-related production facilities. They also planned a box factory, door factory, and three brickworks capable of producing 30,000 bricks a day. By late June, construction began on a rolling mill whose 400 workers manufactured steel tubing.

Goshen was like many villages in western Virginia experiencing the land boom of the 1890s. Opportunities seemed limitless for those willing to invest capital with speculators. Enthralled by the combination of mineral resources and railroad access to the larger markets of the northeast, investors contributed heavily to the Goshen Land and Improvement Company.

The boom in Goshen was at full throttle. By mid-June, the town's population reached several hundred. Speculators expected it to reach 6,000 during the following year. The Goshen Land and Improvement Company remodeled existing hotels to address the town's housing crunch and to provide hospitable accommodations for potential investors. The company created several spin-off firms to provide other housing and infrastructure in the new town. The only thing limiting the pace of housing construction, and, in turn, full production from the mills, was the shortage of laborers available to wield hammers and drive nails.

The Goshen Land and Improvement Company laid out Maury Avenue, the town's new Main Street, along the line of the existing county road to Lexington, VA. The developers planned for Maury Avenue to be one of the "grandest boulevards in the South," a road 24 meters (80 feet) wide and lit by gas street lights. According to Hodson's report, "*Goshen Bridge Rehabilitation Options: Balancing Structural*

The stone pier after cleaning and repointing.

The stone abutments and piers needed to be cleaned and repointed.

The Goshen Bridge before (left) and after (right) rehabilitation.

Requirements with Historic Preservation Concerns, the road was to cross the river ". . . on a large iron bridge built with width and strength sufficient for the passage of electric railway cars. On one side will be a foot way." The previous year, the Goshen Land and Improvement Company had offered to combine funds with Rockbridge County to relocate a bridge already under construction. The bridge relocation plan would serve both parties well. The Land and Improvement Company would assume the majority of the construction and maintenance costs of a bigger, grander bridge, and any traffic heading from Goshen to Lexington would have to pass through the company town. Rockbridge County was to receive a much larger, stronger bridge at no cost to the county. Additionally, Maury Avenue passed the site of the electric car manufacturing facility, which supporters thought would become one of Goshen's largest industries.

Crews completed the bridge in June 1891, about 6 months behind schedule and at a cost exceeding $16,000, more than double the estimated cost of $7,000. No known description details the reason for the cost overrun.

Goshen's boom times ended abruptly in 1893, largely due to economic troubles in Europe. A London-based international banker had failed that year, and the failure affected the U.S. Treasury. The Panic of 1893 set in, also fueled by the Treasury's own gold shortages. Goshen, like many other Virginia boomtowns, never recovered. The town dwindled in size as laborers sought employment elsewhere.

In the early 20th century, Andrew Carnegie's United States Steel Corporation monopolized the steel industry and crippled many small southern steel producers. Goshen's population fell to several hundred, where it essentially remains today. During the first half of the 20th century, many prominent vestiges of Goshen's boom disappeared, leaving the Goshen Bridge as the most visible symbol of the speculators' hopes that the town would become "The Iron Centre of America."

Bridge to the Past

Although the bridge is once again a useful structure, its importance goes far beyond its utilitarian purpose, says Kathleen Kilpatrick, director of the Virginia Department of Historic Resources. Historic preservation "is not so much about old buildings and old structures," she says, "but about people and communities and serving communities by rebuilding on the assets that we have through our historic resources. They are cultural, economic, and educational assets that we have a responsibility to invest in for the future.

"What we do today and the efforts that we make to preserve our resources are about ensuring a strong and vital future for the citizens of the future. It's no secret that the strongest communities are not the cookie-cutter communities and subdivisions, but places like Goshen that have a sense of character and identity and connectedness to their past . . . And what better symbol of that important connectedness [is there] than a bridge?"

George M. Clendenin, P.E., State structure and bridge engineer at VDOT, adds: "The extent of our efforts demonstrates our commitment to carrying out the recommendations of our historic bridge management plan . . . By doing the design of the rehabilitation in-house, VDOT has had the opportunity to relearn historic technology and develop new approaches to rehabilitation work."

Summing it up, FHWA's Napier says: "The Goshen Bridge is an excellent example of how to preserve a historic structure where practical and still maintain the mobility, safety, and economic opportunities that the existing highway and the bridge provide."

Eric Gorton is a public relations assistant for VDOT and works out of the Staunton District Office. He joined VDOT in September 2000 after spending 12 years as a newspaper reporter and editor. He has a bachelor's degree in communications from James Madison University.

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Update on Intelligent Vehicles and Intersections

by Keri A. Funderburg

Take a look at the latest automotive innovations and intersection technologies for improving driver performance.

Cited in more than 90 percent of police crash reports, driver error remains the leading cause of crashes on America's roads. To help improve driver performance and safety, the U.S. Department of Transportation (USDOT) and the Intelligent Transportation Systems (ITS) Joint Program Office at the Federal Highway Administration (FHWA) established the national Intelligent Vehicle Initiative (IVI). A significant new direction for USDOT safety programs, the IVI focuses on preventing crashes by helping drivers avoid hazardous mistakes.

(Above) Intersections like the one shown offer logical settings for deploying intelligent vehicle technologies.

Other partners in the project include the Federal Motor Carrier Safety Administration, the National Highway Traffic Safety Administration, the Federal Transit Administration, the American Trucking Associations, ITS America, the motor vehicle industry, seven universities, and 10 State and local transportation agencies. A departure from the past, the initiative looks at "preventing" crashes, rather than "reducing the severity" of crash-related injuries to people and property.

"The mission of the IVI is to reduce the number and severity of

crashes through the application of advanced driver assistance systems," explains Ray Resendes, IVI program manager at FHWA. "Through the IVI program, the Federal government, and FHWA along with its partner agencies, is helping the transportation industry produce better safety systems more quickly."

During the summer, a 3-day national IVI meeting and vehicle demonstration was held at FHWA's Turner-Fairbank Highway Research Center. Several State departments of transportation (DOTs), local transportation agencies, and members of the private sector displayed intelligent vehicle technologies developed under the IVI. The technologies included an avoidance system for intersection collisions, a bus equipped with an innovative frontal collision warning system, cars with adaptive cruise control and lane-departure warning systems, and a tractor-trailer truck featuring onboard trucker safety advisory and automatic crash notification systems. Products in testing are expected to appear soon in passenger cars, including rear-end collision-avoidance systems and roadway-departure warning systems. Eight IVI operational tests also are underway.

An outgrowth of the IVI initiative, FHWA's new intelligent intersection testing facility at the Turner-Fairbank Highway Research Center in McLean, VA, opened during the national IVI meeting and demonstration in the summer. The intersection—the first of its kind in the United States—will be used to develop and evaluate vehicle-based and vehicle-roadway cooperative systems that can save lives by helping drivers avoid intersection crashes.

Intelligent Intersections

In 2002, more than 9,400 people were killed and 1.4 million injured in crashes at intersections. To prevent intersection crashes, drivers need warning systems that alert them to the potential for a collision or tell them when it is safe or unsafe to pass through an intersection.

At FHWA's intersection testing facility, researchers from the California Partners for Advanced Transit and Highways (PATH) program, the Intelligent Transportation Systems Institute at the University of Minnesota, and Virginia Polytechnic Institute and State University's (Virginia Tech) Transportation Institute demonstrated new technologies that provide drivers with these warnings.

Researchers from the California PATH program—a collaboration by the University of California and the California DOT—designed their system to prevent drivers from being broadsided by vehicles on cross streets or making left turns when oncoming vehicles are approaching. The system uses a combination of millimeter wave and laser radar sensors, plus in-pavement loops to detect other vehicles. A wireless communication system that operates in the 5.9 gigahertz band, and is dedicated to highway communications, transmits information from the sensors to a computer located at the roadside.

Using a timing algorithm, the roadside computer monitors the speeds of the approaching vehicles and determines when a left turn would not be safe. During the

This illuminated display (the no-left-turn sign) warns drivers that it is unsafe to make a left turn at the intersection.

California PATH

Virginia Tech Transportation Institute

This electronic stop sign between the traffic signals illuminates during the red light phase.

demonstration, as one vehicle approached an intersection in preparation to make a left turn, a large road sign reading "No Left Turn" flashed to warn the driver in the left-turning vehicle of an approaching vehicle that could not be seen. The message on the sign seemingly grew 50 percent in size as it flashed. The researchers found that this type of sign is especially visible to drivers when placed just above eye level on the opposite corner of the intersection. In specially equipped vehicles, the computer also can trigger an in-vehicle display to warn drivers of the intersection hazard.

In developing these technologies, the California researchers decided to focus on human-centered technologies rather than on changes to the roadway infrastructure. "We understand that traffic engineers have worked assiduously to develop and implement a host of important tools in making intersections safer, such as channelization, protected left turns, warning signals, and timing plans," says Jim Misener, the leader of the Transportation Safety Research Program at California PATH. "However, a significant number of intersection crashes still occur because the driver is decidedly human and capable of making perception and judgment errors."

Improving Rural Intersections

Although crashes at rural intersections occur less frequently than those at intersections in urban or suburban areas, rural crashes tend to be more severe due to high speeds. In addition, many rural intersections involve major roads with higher speeds and volumes crossing more minor roadways with lower speeds and volumes. This geometry leads to frequent collisions caused by drivers on the minor roads selecting unsafe gaps in the traffic stream on the major roads as they attempt to cross or turn into the intersections.

To mitigate this problem, researchers at the University of Minnesota demonstrated the use of an Intersection Decision Support (IDS) system during the IVI meeting. Minnesota's system helps drivers identify unsafe gaps in high-speed traffic at two-way, unsignalized intersections in rural areas. The IDS system, which consists of an array of ground-mounted radars interconnected through wireless technologies, collects and sends data on the speed and location of approaching vehicles to a central processing unit, which calculates and identifies unsafe gaps in the approaching traffic. When the system detects an unsafe gap, it triggers an illuminated roadside sign to warn the waiting traffic that it is dangerous to enter the intersection.

"The decision to use a sign that comes on only when it is unsafe for the stopped driver to cross an intersection, rather than a traditional traffic signal, was based on the fact that the traditional signal can stop traffic unnecessarily on the high-speed leg of the intersection," says Max Donath, director of the Intelligent Transportation Systems Institute at the University of Minnesota. "Large trucks often travel on these rural, high-speed roads and when they are forced to stop at a traffic signal, it can take them a long time to get going again, which can impede traffic flow through the intersection."

Infrastructure Approaches

Researchers from Virginia Tech demonstrated infrastructure-only and infrastructure-cooperative approaches to preventing the most common type of intersection crashes. "Virginia Tech is focusing on 'straight crossing path' crashes, which account for approximately 30 percent of all intersection crashes and occur when a driver continues into an intersection against a red light and collides with a crossing vehicle," explains Vicki Neale, leader of the Safety and Human Factors Engineering Group at Virginia Tech. "We are working on technologies to warn drivers before they violate a signal or stop sign so they can come to a safe stop prior to entering an intersection."

Virginia Tech's infrastructure-only approach uses an IDS (infrastructure-to-vehicle communication) system to alert drivers of an imminent traffic signal violation. Using a signal controller to provide information about signal phase and timing, sensors detect a vehicle's location and speed, and the IDS system determines whether a vehicle will cross into an intersection during the red light phase of a traffic signal. If the system predicts a violation, an electronic stop sign hanging between the traffic signal heads illuminates as a warning to the violating driver approaching the intersection.

Virginia Tech's infrastructure-cooperative system contains the following components: a roadside traffic signal

California PATH

Three San Mateo County Transit District buses like this one are equipped with frontal collision warning systems.

controller that provides information about signal phase and timing, an infrastructure-to-vehicle communications system, an in-vehicle global positioning system (GPS) receiver and associated roadway map representation, and an in-vehicle computer and driver-vehicle interface. With the information provided by these components, the system recognizes that the driver is not going to stop for the red light, then emits an audible tone and displays a stop sign icon on the dashboard to alert the driver to a hazardous situation.

Although these three projects are still in development, they are making progress toward full-scale deployment. In California, the researchers' next step will be to conduct field operational tests with drivers at real intersections. Researchers in Minnesota also will be testing at actual intersections, in addition to developing a driver simulator to determine how motorists will react to the system and convening a national panel of experts to help with deployment. At Virginia Tech, the researchers believe that the infrastructure-only system will be deployable in the near future. They anticipate that the roadside cooperative system portion could be in place by the time auto manufacturers complete development and begin installation of the in-vehicle technologies that they are working on currently.

Preventing Transit Crashes

Frontal collision crashes account for nearly 30 percent of all transit vehicle-related crashes and often lead to property damage, service interruptions, injuries, and increased traffic congestion. At the IVI demonstration, participants had the opportunity to ride a bus equipped with a prototype warning system designed to prevent frontal collisions. Developed by researchers and officials from the San Mateo County (California) Transit District (SamTrans), the California PATH program, Gillig Corporation (a transit bus manufacturer in California), and several local transit agencies, the system provides drivers with an alert if it detects a collision hazard in front of the vehicle or that a crash may occur.

To develop the system, the researchers began by collecting data on transit crashes to identify the magnitude and consequences of frontal collisions and to understand the conditions that lead to frontal collisions. Data-acquisition systems also were installed on buses in the SamTrans fleet to collect information on the movement of surrounding vehicles and stationary obstacles. In addition, researchers studied the needs of the bus drivers who will operate the system, including an evaluation of how to present warnings to drivers, and the types of audible or visual alerts that would be most effective.

Using the collected information, the researchers identified a set of scenarios that could result in frontal collisions and developed a warning system based on those scenarios. Currently, three buses operated by SamTrans are equipped with prototype collision warning systems, which include frontal obstacle and corner detection sensors that search for hazards in front of the bus and monitor for "cut-in" vehicles that change lanes too closely to the bus.

If the sensors detect potential hazards, the system sends a warning consisting of a series of illuminated

The computer that controls the frontal collision warning system on this SamTrans bus is housed inside the vehicle.

Gerald Stone, California PATH

California PATH

Light-emitting diode panels on either side of the front windshield warn the bus driver of collision hazards.

light-emitting diodes (LED) positioned inside the bus near the driver. The LEDs increase in brightness as the bus moves closer to the hazard and turn off as the hazard is avoided. Audible tones were not used as warning signals because the researchers determined that passengers might find the tones to be annoying and potentially alarming. However, the researchers currently are evaluating the viability of some audible warnings to determine whether there are any that could be used to warn the driver, while not alarming passengers.

The California researchers are working to integrate the frontal collision warning system with a side collision system under development in a partnership with Pennsylvania. The research includes collaboration with manufacturers and suppliers of transit buses to increase deployment and commercialization of the warning systems.

Collision-Avoiding Cars

Not just for transit vehicles, collision warning and avoidance systems also can improve the safety of passenger vehicles. The National Highway Traffic Safety Administration is working with an automobile manufacturer to develop and test an Automotive Collision Avoidance System (ACAS). At the IVI meeting, a vehicle equipped with ACAS was on hand for participants to view.

Consisting of a rear-end collision warning system and an adaptive cruise control system, ACAS provides drivers with visual and audible warnings when it detects an imminent crash with the rear of another vehicle. The adaptive cruise control system also helps drivers maintain a set speed when there is no impeding traffic and reduce their speed when slower moving traffic is detected.

Although researchers and auto manufacturers previously have tested adaptive cruise control and rear-end collision warning systems, ACAS is the first to combine the two into a single integrated system. In addition, previous rear-end collision warning and adaptive cruise control systems were limited in their ability to detect vehicles. Many of the previous systems detected vehicles by transmitting microwaves from the front of a host vehicle and measuring the time it takes for the microwaves to return after striking a vehicle in their path. Other systems used lasers to detect the reflection of traffic ahead of the host vehicle and measure the distance to the traffic.

Studies have shown, however, that microwave- and laser-based systems sometimes have difficulty identifying which vehicles on a roadway are in the path of the host vehicle. The systems can be particularly inaccurate during lane changes or as road segments change from straight to curved or curved to straight.

Due to these inaccuracies, the ACAS researchers have focused on improving how the system recognizes curves in the roadway. Traditional sensors detect curves by measuring the yaw rate. In addition to yaw-rate sensors, ACAS uses three other detection methods. First, the vehicles are equipped with a GPS that can locate the vehicle's position on a digital map of the roadway. Based on the geometry of the roadway on the digital map, the GPS can predict the curvature of the road ahead of the host vehicle. Second, ACAS uses video cameras installed on the windshield to view the scene in front of the vehicle. A special vision system installed with the cameras then can find the lane markings on the video and use them to estimate the forward road geometry. Finally, ACAS uses radar to detect and analyze the tracks of other vehicles using a patented technique called scene-mapping.

Based on information from these four methods, ACAS can predict the curvature of the upcoming roadway more accurately, locate the closest vehicle in the path of the host vehicle, provide warnings to the driver about potential hazards via a driver-vehicle interface, and control the speed of the host vehicle through the brake and throttle when the driver uses the adaptive cruise control. The driver-vehicle interface includes warning icons about speed and potential collision hazards. As the potential for a collision increases, the warning icon becomes larger and more noticeable. The final icon flashes and is accompanied by an audible warning.

In a recent round of controlled testing, 12 drivers took turns driving the ACAS prototype vehicle two times around a 93.4-kilometer (58-mile) route accompanied by a researcher. The goal of the test was to gather feedback on the quality of the images on the in-vehicle display, the feel of the adaptive cruise control, and the accuracy of the rear-end collision warning system. Based on the results, the ACAS researchers began a small-scale field operational test in March 2003 where drivers are given test vehicles for approximately 4 weeks to use as their personal vehicles. Researchers anticipate that the test results from all the drivers will be complete in February 2004, with final results available later in 2004.

Trucks with a Brain

In addition to buses and passenger cars, several tractor-trailer trucks were on display at the IVI meeting. Mack™

Trucks and McKenzie Tank Lines, Inc.—primary members of the Mack Trucks IVI partnership, whose membership also includes AssistWare Technology, Inc., XATA Corporation, Vehicle Enhancement Systems, Inc. and Richard Bishop Consulting—demonstrated the use of several new technologies.

The two companies have developed a trucker advisory system (TAS) that will provide drivers unfamiliar with an area with an advance alert about upcoming hazardous roadway features such as extra-tight ramps or work zones. In cooperation with several State DOTs, the two companies identified more than 500 "trucker advisory zones" in 10 States, determined the latitude and longitude of the zones, and created a database of the areas.

Trucks participating in the test are equipped with an onboard computer, the database, and GPS. Using this equipment, TAS identifies whether drivers are in close proximity to any of the hazardous driving areas and shows an alert message on an in-vehicle display that indicates the type and location of the hazard based on crash history for the location.

"These days, truck drivers are traveling fewer set routes and increasingly are traveling in unfamiliar territory to pick up freight," says Jim Kennedy, director of maintenance for McKenzie. "TAS familiarizes drivers with these unknown areas and decreases the risk of crashes in locations known for rollover hazards, steep grades, or other dangers."

Because TAS employs computer technology that many truck fleets already are using, Kennedy considers TAS to be highly deployable in the near future. When testing is complete, if it shows that the technology increases safety, the key to widespread deployment will be ensuring that each truck has enough memory space on its onboard computers to hold the TAS database.

In addition to TAS, the researchers are testing an automatic collision notification (ACN) system. Each truck in the test is equipped with front, rear, and tilt sensors that are activated when the truck suddenly accelerates or decelerates and then abruptly stops. If the system is activated, an e-mail about the incident and the truck's location is sent via wireless technologies to the company's Central Network Center in Tallahassee, FL. Using the information in the e-mail, personnel at the center can notify local authorities about the incident, the commodities being transported, and any dangers associated with a release of the commodities.

"The ACN system is most beneficial for trucks carrying hazardous materials, which, if released, could be harmful to the environment and surrounding populations," says Kennedy. The system enables authorities to take faster control of spills and alert communities sooner about the potential danger posed by the materials or the need to evacuate. In addition, because authorities can start to clean up spills more quickly, ACN will help protect animals, plants, and wildlife more effectively. After hearing about incidents, authorities also can alert roadway authorities about potential traffic delays and ensure that motorists have sufficient warning to avoid traffic caused by an incident.

The partnership currently is operating a fleet of trucks equipped with TAS, ACN, and other intelligent safety systems. The partnership is collecting data on the operation of these systems, along with information about other hazardous areas to add to the TAS database. The researchers also are studying the value of the alerts currently sent through the ACN program. The partnership anticipates that it will complete the data analysis and issue a final report by 2005. By then, the partnership will have collected 19 months of test data on 36 trucks, equaling more than 11.3 million kilometers (7 million miles) of information.

A Safer Future

The idea of preventing vehicle crashes is not new. The technologies that the researchers demonstrated at the IVI meeting are innovative because they focus on a new side of crash prevention—the human side. These intelligent technologies will help improve driver performance—and therefore, increase safety on the roads.

"Systems to save lives are available today," says FHWA's Resendes. "However, the IVI partnership is helping to ensure that better systems will be commercially available tomorrow and into the future."

The onboard computers shown here operate trucker advisory and automatic collision notification systems.

McKenzie Tank Lines, Inc.

Keri A. Funderburg is a contract writer for FHWA and a contributing editor with PUBLIC ROADS.

For more information about the IVI partnership or intelligent transportation technologies, visit www.its.dot.gov/ivi/ivi.htm or contact Ray Resendes at 202-366-2182 or raymond.resendes@fhwa.dot.gov.

Memphis Braces for

A bridge on the Mississippi River in Elvis' hometown of Memphis gets a seismic retrofit.

On the road to fulfilling the Federal Highway Administration's (FHWA) strategic goals of safety, environmental stewardship, and congestion mitigation, some milestones are noticeable to the motoring public—such as new traffic lights, native landscaping, or new highways. Some projects are not so visible to the naked eye, yet they demonstrate the commitment of Federal and State transportation agencies to enhance the long-term safety of the public.

In Memphis, TN, the Hernando DeSoto Bridge carries Interstate 40 over the Mississippi River. The bridge also sits on the southeast edge of the New Madrid Seismic Zone, which is considered to be the highest earthquake risk in the United States apart from the West Coast. The fault itself runs approximately 193 kilometers (120 miles) from Illinois to Arkansas, and the full seismic zone covers a much broader area.

(Above) Overview of the Hernando DeSoto Bridge over the Mississippi River looking north. The skyline of Memphis, TN, is on the right. *Photo: Imbsen & Associates, Inc.*

Recognizing the potential seismic danger, FHWA, the Arkansas State Highway and Transportation Department (AHTD), and the Tennessee Department of Transportation (TDOT) joined forces to provide a seismic retrofit for the well-traveled bridge. The objective was to minimize the chances of potential closures that could affect Interstate 40 in the event of an earthquake.

A Vital Link

For 5 months in 1811–1812, the Great New Madrid Earthquake sent a series of shocks that rang church bells as far away as the eastern seaboard. The quake was several times larger in magnitude than the San Francisco earthquake of 1905. Even today, the risk for a damaging earthquake is high and increases with time as the stresses in the seismic zone build.

The Hernando DeSoto Bridge is one of only two Mississippi River crossings in the Memphis area and is a vital link for transportation, commerce, and defense. The bridge was designed and built in the late 1960s with little seismic protection. The likelihood that it would not continue serviceably if a damaging earthquake occurred is high.

"The closest alternate river crossing is in Helena, AR, approximately 70 miles [112 kilometers] south," says Ed Wasserman, director of the Structures Division at TDOT, "and the closest interstate river crossing is on Interstate 155, approximately 95 miles [152 kilometers] north. Based on these facts, if a sizable earthquake were to occur, TDOT and AHTD estimate that [the costs from] the resulting detour would pay for the initial investment in the seismic retrofit on the Hernando Desoto Bridge in only 40 days."

After considering the regional and national impacts that could result from closure of I–40 over the Mississippi River, FHWA and the two State transportation agencies identified the bridge as a high priority and took action. In June 1992, the team conducted a seismic evaluation, prepared a retrofit design, and oversaw construction of the retrofit.

Description of Bridge

The bridge is 5.3 kilometers (3.3 miles) long and contains 164 spans, 160 piers, and 10 abutments. The

a Lot of Shaking

by Rebecca Jaramilla

main spans over the channel consist of two tied arch truss spans and five steel box girder spans. Each tied arch truss span is 274 meters (900 feet) long and is composed primarily of built-up steel box sections. Piers support the spans, which are made up of 38-meter (126-feet)-tall tapered concrete columns connected by a 1.8-meter (6-foot)-thick webwall, which is a structural wall that adjoins adjacent pier columns to create a single pier unit. The columns taper from a 5.5-meter (18-foot) diameter at the bottom to a 4.3-meter (14-foot) diameter at the top. The piers sit on distribution blocks and are supported by concrete footings on rectangular concrete-filled steel caissons.

The steel box girder spans are continuous and located west of the tied arch spans. Of the five spans, two are 100 meters (330 feet) long, and the remaining three are 134 meters (440 feet) in length. The spans are supported by piers composed of tapered concrete columns varying in height and connected by a 1.2-meter (4-foot) concrete webwall, which originally extended approximately 75 percent of the height of the column. The piers sit on distribution blocks and are supported by concrete footings on top of a concrete seal and steel H-piles.

The original bridge incorporated three steel-plate finger expansion joints. Each joint allowed a maximum of 0.33 meter (13 inches) of longitudinal movement but did not permit any transverse movement.

The approaches and connecting ramps to the west consist of prestressed concrete I-beams and steel-plate girders. To the east, the approaches and connecting ramps consist entirely of steel-plate girders. These spans are supported primarily by multipost bents. The bents are supported by footings and concrete piles.

Deficiencies

The Hernando DeSoto Bridge is vital to the region and must remain serviceable after the maximum probable "contingency-level earthquake" in a 2,500-year return period (or a 2 percent probability of exceedance in 50 years).

Assuming a contingency-level earthquake, the bridge's original design had a number of deficiencies. Using a three-dimensional modeling program, the contractor analyzed the original structure and specified the deficiencies. The results showed overstressed truss members and connections, insufficient resistance in the deck in both transverse and longitudinal directions, and excessive plastic hinges with poor confinement at the base of pier columns and webwalls (which could cause the bridge to collapse).

The original structure had an inadequate amount of steel reinforcements in the footings to resist rocking on top of the caissons or longitudinal seismic overturning. In addition, the contractor determined that the joints and bearings were inadequate. The existing expansion finger joints would not withstand the expected seismic displacement. Finally, the existing bearings were tall and poorly braced and had the potential to tumble over or displace laterally, which could cause the bridge spans to drop.

Performance Goals

Because of the bridge's importance to mobility in the region, Tennessee and Arkansas jointly decided that the bridge must remain operational and

Imbsen & Associates, Inc.

The friction pendulum bearing is shown offsite before installation.

serviceable after the maximum probable contingency-level earthquake mentioned earlier.

The agencies recognized that the bridge inevitably would need to be closed and inspected after a major event; however it was decided that closure of the bridge would be limited to 2–3 days. Lastly, any damage found during inspection of the bridge would need to be minimal and repairable without closing the bridge to traffic.

Retrofit Design Strategies

The team considered two retrofit strategies. The first was the traditional *strength and ductility* strategy. "Ductility" is the property of a material enabling it to undergo large permanent deformation without failure. The strategy involves adding strength to bridge components to transfer all loads through the entire system. This approach required extensive strengthening or complete replacement of numerous components, including the bearings, truss members, and connections; bottom lateral bracing and connections; and the entire deck system, pier columns, webwalls, footings, and distribution blocks. The estimated cost of the retrofit for just the main channel spans using the strength and ductility strategy quickly added up to more than $45 million.

The second strategy combined strength, ductility, and *isolation*. Isolation bearing technologies enable engineers to limit the structural stresses on the bridge components during an event by increasing the amount of displacement the structure can withstand. The two types of isolation bearings considered for the Hernando DeSoto Bridge were the friction pendulum bearing and the lead-core rubber bearing. The contractor analyzed the bridge model using isolation bearings in place of the existing bearings, and the results showed a significant reduction of stress levels in both the superstructure and substructure. The estimated cost for the seismic retrofit using the isolation strategy for the main spans totaled $27 million. Because this approach offered nearly a 40 percent reduction in construction costs without compromising structural safety or serviceability, FHWA and the two State agencies selected the isolation strategy for the project.

Overview of Design Features

Using the isolation strategy, the contractor completed the final design, plans, specifications, and estimates for the retrofit. Major design features included replacing the existing bearings with isolation bearings, strengthening footings and columns, enlarging column caps (to accommodate the new isolation bearings), and tying the tops of the webwalls to the columns.

Other enhancements included replacing or strengthening the bottom lateral bracings, strengthening the steel cross-frames, replacing the existing finger joints with modular

TDOT

Workers install a friction pendulum bearing on a column.

Imbsen & Associates, Inc.

This column cap retrofit shows workers tying steel on the rebar cage around an existing column before placing the concrete.

swivel-expansion joints, and retrofitting the trusses (adding members to brace the portal frame posts).

Isolation Bearings

According to Fred Stephenson, P.E., the resident engineer on site, "Friction Pendulum™ bearings are on the leading edge of innovative seismic design." Typical applications include construction of buildings, industrial facilities, and bridges.

The Hernando DeSoto Bridge incorporates the largest vertically loaded friction pendulum bearings used to date anywhere in the world. The bearings consist of three major components: (1) a top guide plate mounted to the superstructure, (2) a concave bottom plate mounted to the substructure, and (3) an articulated slider fitted to the top plate and resting on the bottom plate.

During an earthquake, the articulated slider will move along the concave surface of the bottom plate, which will guide the top plate (and connected superstructure and deck) in small pendulum motions. The pendulum relies on friction and gravity to help resist and dampen earthquake motions (absorb damaging earthquake energy). This absorption reduces lateral loads and shaking movements throughout the structure.

The main channel spans will require a total of 18 friction pendulum bearings. The contractor specified four sizes of pendulum bearings for the bridge. Types 1 and 2 are the larger bearings and will support the tied arch spans. The Type 1 bearings (the largest) have a maximum vertical load capacity of 5.7 million kilograms (12.6 million pounds), which easily qualifies as the largest vertical load capacity of any friction pendulum bearing in the world. They have an inside diameter of 20–25 centimeters (8–10 inches) and a bearing height of 2–25 centimeters (1–10 inches), and they can withstand a lateral seismic force of more than 590,000 kilograms (1.3 million pounds). The smaller Type 3 and 4 bearings that support the steel box girder spans will allow up to 73–76 centimeters (29–30 inches) in lateral displacement.

The team also is using 12 lead-rubber bearings in the retrofit project. Lead-rubber bearings consist of a core cylinder of pure lead closely surrounded by layers of rubber and steel bonded together. Under normal loads, the rubber allows lateral and longitudinal displacements while the steel plates strengthen the bearing vertically. The lead core strengthens the system laterally against wind and other nonseismic loads. During an earthquake, seismic loads cause the rubber and steel layers to push and deflect the lead core laterally, dampening and dissipating the quake's damaging energy. The bearings can withstand a lateral load of 249,000 kilograms (550,000 pounds) and a lateral displacement of 57 centimeters (22.5 inches) during an earthquake.

Lead-rubber bearings have been installed on more than 100 bridges and 70 buildings worldwide and proved their effectiveness during the

Imbsen & Associates, Inc.

Workers pour concrete around a new swivel joint to complete the joint installation.

TDOT

On the suspended platform under the superstructure, workers are removing the existing lateral bracing.

1994 earthquake in Northridge, CA, which measured 6.7 on the Richter scale. The University of Southern California (USC) University Hospital, for example, uses lead-rubber bearings. Although other buildings and infrastructures in southern California were damaged severely, the hospital survived the quake without harm to the structure or its contents.

Spans in the Main River Channel

FHWA and the two State transportation agencies subdivided the retrofit construction into several contracts. The first two, for work in the main river channel, were awarded in December 1999 and December 2000. The contractor completed work on these two contracts in January 2003 and March 2003, respectively. Construction under a third contract, awarded to the incumbent contractor in December 2002, is progressing rapidly, and the team expects the project to be completed by the end of 2005.

All 18 friction-pendulum bearings and the 12 lead-rubber bearings were installed on the spans crossing the main river channel. The contractor used hydraulic jacks during installation of the new bearings to maintain traffic flow on the bridge. Hydraulic jacks with vertical lift capacities ranging from 4.5–10.9 million metric tons (5–12 million tons), placed on either side of the existing bearings, lifted and supported the bridge while the contractor removed the rocker bearings and replaced them with new isolation bearings.

Stiffener plates and other strengthening components were added at several locations to provide adequate jacking points. The contractor extended many of the column caps to accommodate the new bearings and retrofitted four of the webwalls by extending them vertically and connecting them to the column caps.

The workers performed the work on the superstructure and deck while maintaining four lanes of traffic at all times. (The bridge accommodates six lanes of traffic under normal conditions.) One key feature of the superstructure retrofit was the replacement of the existing finger joints with swivel joints. Swivel joints will foster additional ductility in the superstructure by allowing 57 centimeters (22.5 inches) of longitudinal movement and 46 centimeters (18 inches) of transverse movement during an earthquake.

Additional retrofitting activities for the superstructure included strengthening diaphragms, adding direct connections between the deck and box girders, stiffening the connections between stringers and the floor beams, and replacing cross frames and lateral bracing members. The contractor used a moveable suspended work platform to perform the majority of the superstructure retrofit. The platform enabled the crew to work underneath the structure rather than from above, which would have required removing large portions of the deck.

Strengthening the footings and columns also is underway in the main river channel. To date, workers have retrofitted two footings and begun constructing a second pair. Cofferdams—some of the largest ever constructed in the State of Tennessee, standing up to 17 meters (55 feet) above the riverbed—are required to perform the substructure work "in the dry." The cofferdams were constructed on a river barge and then launched from the barge into place around the piers. Once the cofferdams are completed and dewatered, the footings and columns will be prepared for concrete encasement. Each of the footing encasements consists of approximately 2,190 meters (2,400 yards) of concrete, poured continuously over a 12-hour period.

Spans in the East Approach

In addition to work on the main river channel, the team awarded the contract for five spans on the east approach in October 2001, and the job was completed in March 2003.

The retrofit work on the substructure included strengthening the footings, columns, and pier caps. The contractor installed cast-in-drilled-hole piles around the perimeter of the existing footings, drilling and bonding bars to the footings, and then forming and placing reinforced concrete to encase the new piles, bonding bars, and footings.

The columns were retrofitted by erecting a steel casing around the existing column and then forming and placing reinforced concrete between the existing column and the steel casing. Workers braced the pier caps by casting reinforced concrete around the existing cap to increase the width.

Imbsen & Associates, Inc.

Jacks support the superstructure after workers removed the existing bearing and before the installation of the new friction pendulum bearing. Friction brackets have been installed around the column to accommodate the jacking system.

Retrofit work also included replacing the existing bearings with Disktron bearings, custom designed for this application, and strengthening the cross-frame system. The cross frame consists of upper and lower bearing plates mounted to the superstructure and resting on a slide plate. The bearing plates (with the superstructure) are allowed to move longitudinally across the slide plate up to 30.5 centimeters (12 inches) but are restrained in the lateral direction. The new bearings are designed to withstand a maximum vertical load of 72,500 kilograms (160,000 pounds), a transverse load of 113,400 kilograms (250,000 pounds), a longitudinal load of 31,700 kilograms (70,000 pounds), and an uplift load of 4,500 kilograms (10,000 pounds).

As with the main spans, hydraulic jacks enabled the workers to install the bearings in the eastern approaches under normal traffic flow. The jacks—supported by the newly retrofitted footings and cross frames—required a maximum jacking load of 45,400 kilograms (100,000 pounds).

The contractor removed and replaced the existing cross-frame system. The new cross frame, located at every pier location, consists of built-up steel I-beams bolted between each steel girder and drilled and bonded to the bridge deck. Shear blocks also were installed at several locations to control lateral movement during a seismic event.

Seismic Monitoring

In conjunction with the retrofit, The University of Memphis will install a seismic instrumentation system to monitor the performance of the Hernando DeSoto Bridge during an event. The system will consist of 114 sensors at 38 locations on the main channel spans. The Hernando DeSoto Bridge will be the first existing long-span bridge in the New Madrid Seismic Zone to be instrumented for seismic monitoring.

The data collected from the sensors during small seismic events will be used to verify or enhance the current mathematical models that researchers use to predict movements under larger events. The project not only will improve predictions of the performance of this particular bridge but also will help advance seismic codes and future bridge designs.

"To date, there is little data available describing the response of long-span bridges to seismic activities," says Paul Sharp, team leader for technical programs at FHWA.

"The installation of a seismic instrumentation system to monitor this structure's response to smaller events should prove to be invaluable toward predicting the effectiveness of an isolation-based design for future retrofit projects. Future plans may include an early warning system that would be based on exceeding certain thresholds, alerting DOT engineers of a need for response."

Looking Ahead

Work completed to date on the bridge already has made this project a pioneer in seismic design and construction. Upon completion, the Hernando DeSoto Bridge will safely endure an earthquake with a magnitude of 7.0 on the Richter scale with little to no damage.

Presently, State and Federal sources have invested almost $72 million in combined funds for the construction.

FHWA and the Arkansas and Tennessee agencies are working closely to achieve goals that can benefit the transportation system as a whole, preparing the region to endure and recover quickly in the event of an earthquake. This project demonstrates that new technology and teamwork within the transportation community can build a healthier, safer future.

Rebecca Jaramilla, P.E., currently serves as the assistant bridge engineer in the FHWA Tennessee Division Office. Her role covers all aspects of bridges including design, construction, and in-service inspection. Prior to her current position with FHWA, Jaramilla worked for the U.S. Army Corps of Engineers as a structural engineer in Chicago. She holds a professional engineering license in Tennessee and has a B.S. in engineering from the University of Illinois at Chicago.

For more information, contact Becky Jaramilla at 615-781-5758 or rebecca.jaramilla@fhwa.dot.gov.

New Faces, New Ideas

by Richard A. Livingston and Ernest J. Bastian, Jr.

Postdoctoral associates push the boundaries of advanced highway research at FHWA.

Howard Lewis

The headquarters of the National Academies on Constitution Avenue in Washington, DC. The National Research Council, a branch of the National Academies, sponsors the Research Associateship Programs.

"Fresh perspectives, that's what postdoctoral researchers offer," says Paul Teng, director of the Office of Infrastructure Research and Development (R&D) at the Federal Highway Administration (FHWA). The postdoctoral researchers are invited to FHWA's Turner-Fairbank Highway Research Center (TFHRC) in McLean, VA, through the Research Associateship Programs, administered by the National Research Council (NRC) of the National Academies. The program seeks researchers from across the country and around the world to engage their talents in new research applications.

"The research fellows who tenure at TFHRC," says Paul Zielinski, program administrator for the Research Associateship Programs, "are among the successful applicants in a worldwide competition to recruit the best young scientists and engineers to work at Federal laboratories."

In 2003 TFHRC celebrated FHWA's 10th anniversary of participating in the program. During that time, eight postdoctoral research fellows have tenured with TFHRC, representing a range of disciplines from chemistry to nuclear engineering. They have contributed depth and breadth of perspective to TFHRC's traditional focus on civil engineering. Their cutting-edge research has ranged from controlling deterioration of reinforced concrete to using nuclear radiation as a nondestructive testing method and developing a new quality control parameter for pavement.

"The National Research Council's postdoctoral research fellowship program is an excellent way to get highly learned professionals to conduct highway infrastructure research

and development activities," says Teng. "The Office of Infrastructure R&D has had several outstanding NRC postdoctoral fellows who did and are doing superb research for our program. Many times, the research fellows' exploratory work produces new ideas or tools for our applied research and technology program to put into practice."

Controlling Corrosion

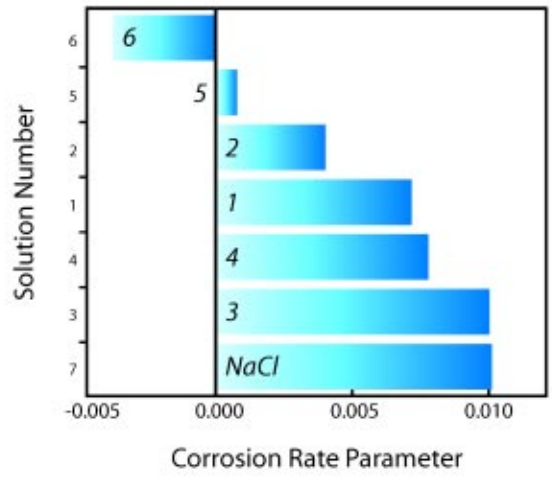
In 1993, the first year that TFHRC participated in the program, postdoctoral researcher Ugo Bertocci conducted a study to evaluate the effectiveness of various chemical deicers in preventing corrosion in chloride-contaminated reinforced concrete.

Dr. Bertocci, an electrochemist formerly with the National Institute of Standards and Technology, performed research on the potential *passivating* effect of a new chemical deicer—calcium magnesium acetate—on the corrosion potential of rebars embedded in concrete containing sodium chloride (rock salt). Passivation, an inhibitor property of rendering steel rebars less susceptible or completely insusceptible to corrosion, is of particular interest to State highway agencies that manage older bridge decks that are contaminated with salt.

Using electrochemical impedance spectroscopy, Bertocci evaluated calcium magnesium acetate and other commercial passivators and sodium chloride solutions. During a simulation of field conditions where salt has contaminated reinforced concrete, Bertocci exposed embedded steel rods to various deicers and took measurements over a period of 11 months to determine the progress of corrosion.

Bertocci's results showed that, as a corrosion inhibitor, calcium magnesium acetate proved superior to all other materials tested. In fact, it demonstrated a negative corrosion rate (a passivating effect).

"Dr. Bertocci's results document that calcium magnesium acetate, in addition to its deicing ability, has the capacity to retard or inhibit corrosion of salt-contaminated bridges," says W. Clayton Ormsby, Ph.D., a geotechnical research specialist at Soil and Land Use Technology, Inc. "This is in sharp contrast to deicers



This bar graph shows that deicing solutions 1 through 5, representing proprietary corrosion inhibitors, are not as corrosive as NaCl. But solution 6, calcium magnesium acetate, actually reduces corrosion of steel bars in reinforced concrete.

Source: Impedance Spectroscopy for the Evaluation of Corrosion Inhibitors in Highway Deicers (FHWA-RD-96-178)

Research Associateship Programs Celebrate 50th Anniversary

In November 2004, the National Research Council's Research Associateship Programs will celebrate 50 years of operation. Since 1954 the program has expanded to include 30 Federal agencies with research opportunities in virtually all disciplines in science and engineering.

The Research Associateship Programs provide postdoctoral and senior scientists and engineers with an opportunity to perform research of their own choosing at a participating government laboratory. Applicants apply to the program by preparing a proposal, typically involving close collaboration with a research adviser. A list of participating laboratories and advisers is available on the Web at www4.nationalacademies.org/pga/rap.nsf.

J.D. Talasek, National Academy of Sciences

The Albert Einstein Memorial Statue (copyright 1978 by Robert Berks) on the grounds of the National Academies headquarters.

Nearly 4,000 research opportunities exist at participating laboratories. A panel of subject matter experts drawn from academia, industry, and government review the proposals and other application materials, including transcripts, letters of reference, and an evaluation by the prospective host laboratory. Due to the competitive nature of the program, for most agencies, only the highest ranked applicants are chosen.

The Research Associateship Program is a continuation of an earlier program launched by the National Bureau of Standards in 1919 and funded by the Rockefeller Foundation. The earlier program awarded fellowships in mathematics and the biological, medical, and physical sciences. In 1954 the Rockefeller Foundation asked the National Research Council to identify a new sponsor, and the National Bureau of Standards (now the National Institute of Standards and Technology) took over.

In November 1954, the National Bureau of Standards selected 6 research associates from a pool of 21 applicants. In 2002 NIST awarded 391 associateships from more than 900 applications.

Paul Zielinski

University of Cincinnati

Former TFHRC research fellow Rita Hessley, now a chemistry professor at the College of Applied Science at the University of Cincinnati, was "struck by how an organization like TFHRC differs from academia. Specifically, TFHRC pursues a highly singular focus [highways] . . . from a variety of perspectives, and all the operations and support structure serve that singular focus."

such as sodium chloride, which *promote* corrosion of the reinforcing steel in bridge decks. This corrosion causes expansion, spalling, and failure of bridge decks."

FHWA published the results of Bertocci's research in a report, *Impedance Spectroscopy for the Evaluation of Corrosion Inhibitors in Highway Deicers (FHWA-RD-96-178).*

Assessing Pavement Deterioration

Is there a structural feature in asphalt binders that causes pavements to age and deteriorate over time? If so, can researchers develop a cost-effective chemical treatment to prevent deterioration caused by long-term exposure to heat, sunlight, water, salt, and ice? These are the questions that research fellow Rita Hessley sought to answer during her tenure at TFHRC from mid-1994 until July 1995.

A chemistry professor at Western Kentucky University at the time, Dr. Hessley focused her professional interests on how the chemical structures of materials affect their behavior in the environment in which they are used. Hessley says, "I had looked at how modifying the original structure through oxidation could alter the material's behavior. Having studied materials as different as coal and milkweed floss, turning to asphalt was a natural extension of my interests."

Previous FHWA studies led chemists to believe that particular portions of asphalt structures are uniquely susceptible to oxidative alteration. Hessley's goal was to determine cost-effective modifications that could protect the structures.

Although Hessley's tenure expired before she could achieve substantial results, her work showed that a technique called attenuated total reflectance infrared spectroscopy (ATR) could be used to monitor a tag introduced into the asphalt. A tag is an atom, or group of atoms, that are not present naturally in asphalt. In this case, Hessley used bromine, which is known to attach to some of the same structural sites believed to react when asphalt is subjected to oxidative breakdown. Hessley theorized that once a tag was in place, controlled oxidation reactions could be carried out. The effect of oxidation could be monitored with ATR, and the effect on the performance of the oxidized material could be monitored using established mechanical tests. Depending on the nature of the correlation between the tagged site and the tests, preventative treatments could be designed to block the reactions leading to pavement loss.

"Coming to a research facility like TFHRC," Hessley says, "that is highly focused on one topic—improving highway pavements—after 20 years in academia was an exciting and challenging cultural and professional shift. The experience provided me with numerous insights to take back to the university setting. I try to convey such differences about professional settings to students as they develop their career ideas."

Habeeb Saleh is measuring the chloride concentration in a concrete sample, using an analysis technique known as gamma neutron activation on equipment that he developed in-house as part of his associateship program.

Nondestructive Testing for Concrete

Sodium and calcium chloride (from seawater and road deicing) can damage reinforced concrete structures by promoting corrosion of the steel reinforcements. The common methods for measuring chlorides in concrete involve drilling cores to perform chemical analyses. Habeeb Saleh, a research fellow from 1995 to 1998, sought to develop nondestructive methods for testing concrete using nuclear radiation.

Dr. Saleh, who holds a Ph.D. in nuclear engineering from Texas A&M University, used a weak source of neutrons—produced by the radioactive decay of the element californium—to perform a nondestructive test for measuring chlorides in hardened concrete. Saleh beamed neutrons into the hardened concrete where they were captured by atoms of chlorine or other elements. During the capture process, the atoms emit gamma rays with characteristic energies that travel out of the concrete, where researchers can measure them with detectors. Using advanced software developed at Los Alamos National Laboratory, he modeled the neutron- and gamma-ray characteristics and evaluated his results experimentally using test concrete slabs constructed in the laboratory. Saleh demonstrated that it was possible to devise a test method that met all the specifications, including radiation safety.

"Some of these methods have been used for field applications," Saleh says, "and some are in the developing stages for potential field applications."

After completing the research associateship, Saleh remained at TFHRC as a contractor working in the Nondestructive Evaluation Validation Center. He continues developing neutron-based testing methods and also helped establish an advanced facility for making three-dimensional x-ray images, or computerized axial tomography (CAT) scans, of highway materials.

New Specification Parameter for Pavement

Aroon Shenoy, a research fellow from February 1998 to August 2001, determined that a paving material's volumetric flow rate could be used to determine the performance-grade specification of asphalt—thus identifying a new parameter for quality control and quality assurance as well as for the fundamental specification.

Aroon Shenoy observes the rheological data being generated by the dynamic shear rheometer in the binder rheology laboratory.

Prior to his associateship, Dr. Shenoy served as a consultant in Pune, India. With a Ph.D. in chemical engineering, Shenoy authored a number of technical papers and books on topics such as thermoplastic melt rheology and processing, filled-polymer rheology, non-Newtonian fluid mechanics, and heat transfer. At TFHRC, he extended the ideas and principles of unifying rheological data that he developed earlier to the specific case of paving asphalts.

Shenoy correlated fundamental rheological data from a dynamic shear rheometer for a number of unmodified asphalt binders. He showed that one curve describes all unmodified asphalts for each rheological parameter, such as the complex modulus and phase angle. The unified curve enables researchers to predict the behavior of unmodified asphalt at any temperature by determining the volumetric flow rate at a particular load condition. Shenoy extended the idea of unification to polymer-modified asphalts and showed that unified curves could be obtained for polymer-modified asphalts using the same method.

The approach offered a simple means to determine the high-temperature specification performance grade of asphalt using an inexpensive and portable flow-measuring device. Unlike other rheological parameters that must be measured in the lab, the volumetric flow rate can be assessed at paving sites or in refineries, making it a more versatile parameter that can be used for routine quality control. Eleven technical papers and one internal report have been published on this project, and they are available at www.tfhrc.gov/pavement/asphalt/labs/binder/brlpubs.htm.

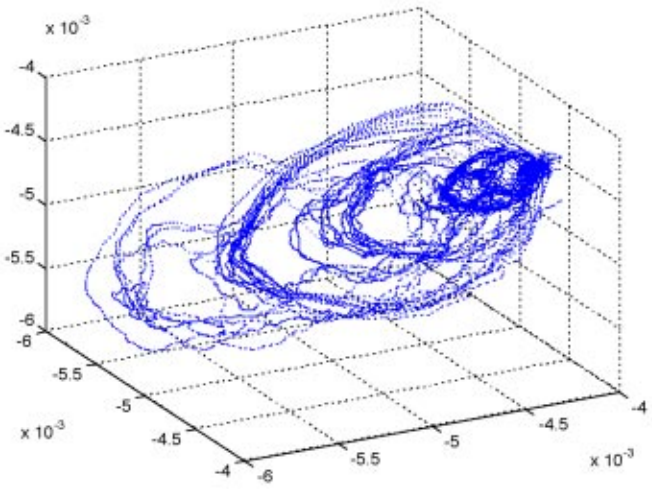
Following his tenure as a research fellow, Shenoy also remained at TFHRC, accepting a position as a senior research rheologist. "The associateship gave me an opportunity to change my research career path from polymer to asphalt rheology," Shenoy says. "The most enjoyable part of the position was that it provided a platform to bring new ideas into asphalt research."

Monitoring Structural Health

During his tenure as a research fellow from 1999 to 2003, Shuang Jin, a mechanical engineer from China, applied nonlinear dynamics (chaos theory) to monitoring the deterioration of highway structures. After working for several years in ship design, Dr. Jin came to the United States and earned a Ph.D. in mechanical engineering from The George Washington University.

In real structures, the stress-strain relationship may be nonlinear at some points because of cracking or

3-D Plot of Data on Bridge Vibrations



Shuang Jin plotted data on bridge vibration in a special set of coordinates called three-dimensional phase space. The closed loops are the signature of a chaotic system, and the attractor is at the center of the loops.

changes in material properties. Also, in a complicated three-dimensional (3-D) structure, even though the individual members behave linearly, their interactions may lead to nonlinear dynamics for the overall structure.

Jin's approach used chaos theory to refine the analysis of structural vibrations. Earlier approaches such as global monitoring typically examined a structure's fundamental modes of vibration—or resonant frequencies. Significant changes in the resonant frequency, however, usually were not detected until the structure was severely damaged. In chaos theory, the resonant frequencies are not fixed but instead wander in time in a characteristic pattern around a central value, called an attractor. Using data obtained from a computer simulation, Jin plotted a strain in the lower flange of a standard bridge girder under random loading from trucks.

In a chaotic system, a set of parameters called Lyapunov exponents takes the place of fundamental frequencies. The chaos theory approach to structural health monitoring, therefore, involves determining the Lyapunov exponents of a structure and then observing how they change with time in service. Jin demonstrated that chaos theory can describe bridge vibrations and help engineers monitor structural deterioration. Ultimately, his research will lead to more efficient monitoring systems and more effective maintenance and repair programs.

Jin currently serves as an onsite contractor at TFHRC, where he continues to develop algorithms for applying chaos analysis. His most recent work involves analyzing data from actual bridge-monitoring systems, such as one on the Commodore Barry Bridge in Philadelphia, PA, where researchers at Drexel University have been collecting data.

Modeling Aggregate Structures in Asphalt Concrete

Xiaoxiong Zhong, a research fellow from June 1998 through May 2000, modeled asphalt concrete pavements using particulate mechanics. Dr. Zhong earned one Ph.D. in rock mechanics from the Institute of Rock and Soil Mechanics at the Chinese Academy of Sciences in 1991, and another in civil engineering from the University of Massachusetts Amherst in 1998.

The goal of Zhong's research at TFHRC was to calculate the performance properties of an asphalt mixture by applying the principles of mechanics to the detailed mesostructure of a heterogeneous mixture. The micromechanics calculation explicitly utilizes the locations, sizes, and orientations of the aggregate particles. With this type of calculation, researchers can predict pavement performance and create virtual mix designs on the computer using only a few basic measured parameters.

Aggregate structures (the locations and orientations of all the stones in the asphalt mixture) play a major role in supporting traffic loads and can have a significant impact on the performance of asphalt concrete. Conventional means of determining the structure, however, have been limited to empirical methods, which neglect the mesolevel details of stone-on-stone interactions. Zhong studied the structures that enhance performance (to avoid rutting or fatigue) and how to tweak the mix-design and compaction procedures to obtain those structures. His research provided an analytical connection between the observed global properties and the local geometry and material parameters.

Zhong modeled a collection of aggregates without binder using a 2-D discrete-element method, a computer calculation particularly useful for this type of situation. He displayed the values and propagation of force within aggregate packing and obtained a preliminary contact model that enabled him to calculate stone-stone interactions in the asphalt more precisely. He validated the model by using the force distribution in a 2-D representation of asphalt concrete that his colleagues developed using photo-elastic imaging. Photo-elastic imaging enables researchers to obtain optical images of stress-strain paths using an assemblage of glass discs under load as a representation of the aggregate structure.

Zhong developed a simulation model for 3-D aggregate packing that shows graphically the stress distributions from different directions with light intensity proportional to the magnitude of the stress. Researchers now are using more advanced forms of 3-D models to distinguish between various aggregate gradations used in the asphalt concrete industry.

Classifying Fly Ash

From 2000 to 2003, Walairat ("May") Bumrongjaroen used advanced characterization methods to classify fly ashes used in mortar. A native of Thailand, Dr. Bumrongjaroen earned a bachelor's degree in environmental engineering from Chulalongkorn

University in Bangkok, followed by a master's and Ph.D. from the New Jersey Institute of Technology.

Pavement designers often specify mixes of portland cement, fly ash, and silica fume to create high-performance concretes that offer increased compressive strength and improved durability. The existing classification method for fly ashes—Class C or Class F—is based on chemical composition, depending on the sum of the chemical constituents silicon dioxide (SiO_2), aluminum oxide, and iron oxide. This method, however, is insufficient for predicting mix performance because the reactivity of fly ash depends significantly on its mineralogical composition, especially on the amount of glassy or amorphous material. Silicon dioxide, for example, in the form of mineral quartz is relatively unreactive compared with SiO_2 glass. Moreover, fly ash is not a homogeneous material but rather a variable mixture of minerals and glass phases with a range of particle sizes and densities.

Bumrongjaroen's research involved advanced centrifuge methods, automated elemental analysis with a scanning electron microscope, Rietveld X-ray diffraction, and automated glass refractometry. In collaboration with the National Institute of Standards and Technology, she measured fly ash reactivity nondestructively, using inelastic and small-angle neutron scattering. She also investigated the application of glass durability theory to model the reactivity of fly ash Finally, to present the information in a format that would be easy to understand, Bumrongjaroen developed software for displaying several independent variables in an appropriate ternary diagram.

The standard method for characterizing fly ash mineralogy is x-ray diffraction. In a typical spectrum, minerals show up as individual peaks. The glassy mineral phases, which do not have a crystal structure, appear as a broad hump. Bumrongjaroen applied an advanced mathematical method called Rietveld analysis to quantify the glassy region in the spectrum. Since the glassy phase represents the reactive component of fly ash, researchers can deduce that the less durable the glass, the higher is its reactivity. Bumrongjaroen plotted the durability index of individual fly ash particles based on analysis of data generated using an automated scanning electron microscope.

Bumrongjaroen's research demonstrated the feasibility of developing an improved classification system for fly ash. The improved classification in turn will enable pavement engineers to optimize concrete mixes for better performance in bridges and pavements—ultimately leading to significant cost savings.

Bumrongjaroen presently works at the Hawaii Institute of Geophysics and Planetology at the University of Hawaii, where she is preparing the results of her research for publication and continuing to develop advanced methods for characterizing fly ash.

Understanding Alkali-Silica Reactions

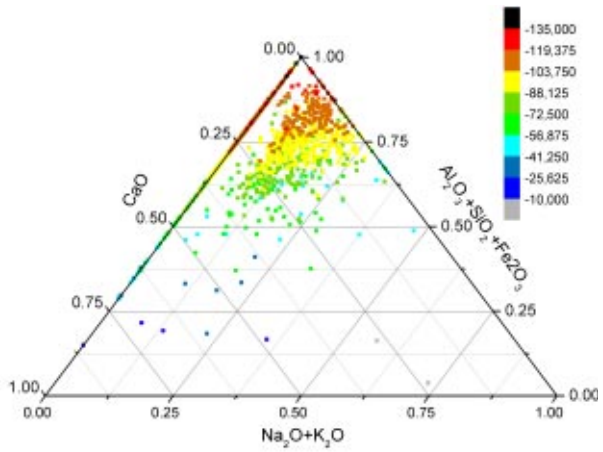
John Phair, a chemistry Ph.D. from the University of Melbourne in Australia, is the current resident associate at TFHRC. Having arrived in November 2001, he recently completed his second year of tenure with FHWA. Dr. Phair's postdoctoral work focuses on characterizing the damaging gels that form due to a reaction between the alkalis (potassium and sodium) in cement and certain types of silicate rocks used as aggregates in concrete. The gel created during the alkali-silica reaction swells and exerts expansive stresses that can crack concrete in highways, pavements, bridges, and dam walls.

"By characterizing the swelling properties of these gels at the nanoscale level as a function of composition," Phair says, "it will be possible to determine under what circumstances the gels swell and why. This provides invaluable information for the development of predictive tools and standard tests to monitor and prevent the occurrence of alkali-silica reactions in concrete structures."

Although previous researchers identified alkali-silica reactions as a major problem, many questions remain. What proportions of alkalis cause gel formation? Why do certain gels swell while others do not? What are the physical and mineralogical characteristics that make silicate rocks reactive?

The extremely fine colloidal particles that make up the gels have dimensions of around 10 nanometers. Because of the difficulty of observing and measuring the particles, much of Phair's research deals with applying advanced methods for materials characterization. Using neutron scattering and x-ray diffraction, he measured the rate of reaction of certain types of silicate materials with solutions of different chemical compositions. The results show that under certain conditions the alkali-silica reaction gel transforms from an amorphous material into a microcrystalline, layered

Triaxial Plot of Fly Ash Particles



Walairat Bumrongjaroen created this triaxial plot to show the chemical composition of several hundred individual fly ash particles. The color scale displays the reactivity of the particles based on glass durability models, with the more negative values indicating lower reactivity.

John Phair, current research fellow at TFHRC, checks a differential scanning calorimetry instrument before conducting an experiment.

material that may be more prone to swelling. These findings are consistent with research conducted at the University of Illinois at Urbana-Champaign using other instrumental methods.

Phair also investigated the pore-size distribution of these gels using a positron annihilation facility at Lawrence Livermore National Laboratory. At the mineral physics laboratory at the University of Hawaii, he studied the gels' elastic properties using Brillouin scattering. In addition, he is developing a laboratory method to measure the swelling pressure of the gels based on dialysis membrane technology.

After completing his tenure at TFHRC, Phair plans to continue research in either industry or academia and eventually pursue a career in academia. "The most enjoyable aspect of conducting research at TFHRC," Phair says, "has been the helpful people and the camaraderie. My colleagues and advisor constantly present me with new challenges, suggesting new approaches to tackling old problems. This has pushed me to develop a more critical understanding of the subject matter."

A Win-Win Opportunity

Each year, FHWA staff members propose new ideas for potential research opportunities at TFHRC. The National Research Council advertises the opportunities in printed booklets and, more recently, online at www4.nationalacademies.org/pga/rap.nsf.

"All the previous fellows have focused on asphalts and concrete," says FHWA's Paul Teng, "because the research ideas were generated in the Office of Infrastructure. But there are plenty of things that could be done in other focus areas like traffic control, bridges, and intelligent transportation systems. The sky is the limit."

Research fellows may be true postdoctoral students—that is, scientists and engineers who recently received their doctorates—or senior associates who are at a later stage in their careers. For recent doctoral graduates, the program provides an opportunity for concentrated research in collaboration with selected members of the permanent professional laboratory staff. For established scientists and engineers, the participation offers the chance to conduct research without making long-term commitments and without the interruptions and distracting assignments typical of permanent career positions. TFHRC benefits from the new ideas, techniques, and approaches offered by intelligent, highly motivated, recent doctoral graduates and senior investigators with established records of research productivity.

John Phair describes his experience as a research fellow at TFHRC as an enriching one. "Not only have I been able to collaborate with and learn from world leaders in cement research," he says, "but I have had the opportunity to broaden my experimental expertise to include a range of cutting-edge techniques. I also have been given numerous opportunities to interact with colleagues in my field of research and to present my work at international conferences."

Who should apply to become the next research fellow at TFHRC? According to Aroon Shenoy, "Any researcher who believes that he or she has ideas to push the frontiers of road research in a new direction." The invitation is on the table.

Richard A. Livingston, Ph.D., is the TFHRC liaison for the Research Associateship Program. He is a senior physical scientist in FHWA's Office of Infrastructure Research and Development. Livingston's professional interests concern the materials science and nondestructive testing of construction materials. He has a bachelor's in medieval history from Dartmouth College, a bachelor of engineering degree from the Thayer School of Engineering at Dartmouth College, a master's in nuclear engineering from Stanford University, and a Ph.D. in geology from the University of Maryland.

Ernest J. Bastian, Jr., Ph.D., is a senior research chemist at TFHRC. He joined FHWA in 1986 to work in the areas of asphalt chemistry and pavement science. His assignments have included managing the Binder Rheology Laboratory, reviewing contracts for the Strategic Highway Research Program, and serving as the technical representative for several congressionally mandated research projects with the Western Research Institute. Bastian earned his Ph.D. in physical chemistry in 1969 from Carnegie Mellon University.

For more information about postdoctoral research opportunities at TFHRC, visit www4.nationalacademies.org/pga/rap.nsf or contact Dick Livingston at 202-493-3063 or dick.livingston@fhwa.dot.gov.

Along the Road

Along the Road is the place to look for information about current and upcoming activities, developments, trends, and items of general interest to the highway community. This information comes from U.S. Department of Transportation (USDOT) sources unless otherwise indicated. Your suggestions and input are welcome. Let's meet along the road.

Policy and Legislation

Federal Agencies Advance Wetlands Protection Goals

Recently, the Federal Highway Administration (FHWA) joined the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers in issuing new guidance on the effective replacement of wetlands affected by Federal-aid highway projects and will improve regulatory decisionmaking in the permit process.

The Transportation Equity Act for the 21st Century (TEA-21) established a preference for mitigation banking to compensate for unavoidable losses of wetlands or other natural habitat caused by transportation projects receiving Federal assistance. Mitigation banking is a system of balancing losses and gains by restoring, improving, or creating wetlands through cooperative efforts. Normally pooled funds are used, but wetlands banking projects also are eligible for Federal funding.

The new guidance will help agency field personnel and the sponsors of Federal-aid highway projects by clarifying the factors to consider when implementing mitigation banking, such as onsite mitigation rather than offsite, in-kind instead of out-of-kind, and the appropriate use of vegetated buffers and preservation.

The guidance, formally known as "Federal Guidance on the Use of the TEA-21 Preference for Mitigation Banking to Fulfill Mitigation Requirements under Section 404 of the Clean Water Act," is available on the Web at www.fhwa.dot.gov/environment/wetland/wet_guid.htm.

Management and Administration

USDOT Awards $5.4 Million for Research and Education

In September 2003, U.S. Transportation Secretary Norman Y. Mineta announced five grants totaling $5.4 million for advanced research at university transportation centers nationwide. More than 75 colleges and universities throughout the United States operate transportation centers that conduct combined programs of research, education, and technology transfer.

The Department awarded $2 million to Northwestern University for its Infrastructure Technology Institute. Grants of $906,000 went to each of the following: University of California at Berkeley for the University of California Transportation Center, Texas A&M University for the Southwest Region University Transportation Center, and University of Washington for the Transportation Northwest Regional Center. Also, the Department awarded $652,700 to the North Carolina Agricultural and Technical State University for the Urban Transit Institute.

The Research and Special Programs Administration of USDOT administers the grants. Recipients must match the grants dollar-for-dollar at a minimum, leveraging the value of the Federal investment.

For more information on the university transportation center program, visit http://utc.dot.gov.

Technical News

Best Practices for Managing Roads for Inclement Weather

Weather threatens surface transportation nationwide and affects roadway safety, mobility, and capacity. A new CD-ROM of best practices highlights three types of strategies that transportation professionals can use to manage roads during inclement weather: advisory, control, and treatment.

"Best Practices for Road Weather Management—Version 2.0" contains 30 case studies of systems in 21 States. Each case study has six sections: a description of the system, its components, operational procedures, resulting transportation outcomes, implementation issues, and contact information and references. Topics covered include fog, high winds, rain, snow, ice, flooding, tornadoes, hurricanes, and avalanches. The CD-ROM also includes a Web-based user interface, a listing of more than 200 publications about roads and weather, and online resources (including 39 statewide Web sites on road conditions).

PB Farradyne

Road managers can use variable message signs like this one on I–90 across Snoqualmie Pass in Washington to reduce speed limits during winter weather conditions.

For a free copy of the CD-ROM, contact FHWA Team Leader Paul Pisano at 202-366-1301 or paul.pisano@fhwa.dot.gov or order a copy online at www.nawgits.com/fhwa/rw_mgt_cd_req.html.

Web Site Puts Highway Specifications Under One Roof

Federal Highway Administrator Mary E. Peters recently announced that FHWA and the American Association of State Highway and Transportation Officials (AASHTO) launched a new Web site that—for the first time—lists all the specifications for highway construction from the 50 States, the District of Columbia, and Puerto Rico.

Previously, locating and retrieving current specifications was a time-consuming process. Although many State highway agencies have posted their construction specifications online, finding and navigating the various sites can be challenging. In addition, more than 20 national trade organizations and several Federal agencies also issue specifications and rules that affect highway construction.

In addition to State-specific construction specifications, the site includes approved specifications, supplements, and guidelines from FHWA's Federal Lands Highway Program office, AASHTO, and the American Society for Testing and Materials. The site also features discussion forums on topics like performance-related specifications, design-build, warranty specifications, and quality assurance.

For more information, visit www.specs.fhwa.dot.gov.

Public Information and Information Exchange

New Jersey Cracks Down on Drowsy Driving

New Jersey recently became the first State in the Nation to pass a law specifically stating that sleep-deprived drivers who cause fatal crashes can be convicted of vehicular homicide.

Governor James E. McGreevey signed Senate Bill S–1644, known as "Maggie's Law," which imposes jail time and steep fines (up to $150,000) for sleep-deprived drivers who cause fatal crashes. The bill was drafted after 20-year-old Maggie McDonnell was killed by a driver who fell asleep behind the wheel in 1997.

Research has shown that the effects of sleep deprivation are similar to those of alcohol. Sleeplessness increases attention lapses while slowing reaction time and cognitive processing. The National Highway Traffic Safety Administration estimates at least 100,000 crashes and 1,500 deaths each year in the United States are the result of drivers falling asleep.

New Jersey Department of Transportation

Report on Bridge Security Now Available

A new report published by FHWA and AASHTO provides guidance on investing in strategies and countermeasures that mitigate risks to critical transportation infrastructure, particularly bridges and tunnels, in the event of terrorist attacks. The report, *Recommendations for Bridge and Tunnel Security (FHWA-IF-03-036),* includes policies and actions to reduce the probability of structural damage that could result in human casualties, economic losses, and sociopolitical damages.

Among the countermeasures identified in the report are: (1) updating planning and coordination measures, (2) reviewing and sanitizing Web sites for information that may be beneficial to terrorists, (3) enhancing site layouts (such as improving lighting and eliminating access to critical areas), and (4) installing retrofits (such as using energy-absorbing bolts to strengthen connections and adding stiffeners and lateral bracing on steel members).

The report is available online at www.fhwa.dot.gov/bridge/security/brpcover.htm.

For more information about the report or the activities of the Blue Ribbon Panel, contact Steven Ernst at 202–366–4619 or steve.ernst@fhwa.dot.gov.

Personnel

Mineta Appoints Chief Counsels for FHWA, FMCSA

Recently, U.S. Transportation Secretary Norman Y. Mineta appointed chief counsels for FHWA and the Federal Motor Carrier Safety Administration (FMCSA).

D.J. Gribbin is the new chief counsel for FHWA, and Brigham A. McCown will assume that role for FMCSA. As chief counsels, they will be in charge of the legal activities of their operating administrations.

Gribbin comes to FHWA from Koch Industries, Inc., where he directed public sector business development and government affairs. Previously, he was national field director of the Christian Coalition of American and legislative representative of the National Federation of Independent Business. Gribbin earned his bachelor's degree in 1985 and his law degree in 1992, both from Georgetown University.

McCown joins FMCSA from the Dallas office of the law firm Winstead Sechrest & Minick P.C., where he practiced since 2001 as a member of the firm's litigation and government affairs sections. He served as a special legal counsel to the Bush-Cheney 2000 campaign during the Florida recount process. As an aviator in the U.S. Navy, McCown accumulated more than 1,500 flight hours during Operation Desert Storm and other deployments. He earned a bachelor's degree from Miami University, in Oxford, OH, in 1988 and a law degree from Northern Kentucky University in 1997.

Corrections

January/February 2003, "Driving After Dark." Under the subhead, "Fixed Roadway Lighting," the sentence referencing the names of the organizations that completed the study should have read: "FHWA and The Last Resource, Inc., of Bellefonte, PA, recently completed a long-term research project on night driving and highway lighting requirements for older drivers."

September/October 2003, Internet Watch department, "Transportation Libraries Help Keep DOTs Up to Date." In addition to those mentioned in the article, the Midwest Transportation Knowledge Network (MTKN) includes the following organizations: the University of Michigan Transportation Research Institute Library, Northwestern University Transportation Library, and the Center for Transportation Studies Library at the University of Minnesota. Seed funding to help create the MTKN and funding for some of the cataloging completed by the MTKN members was provided by the National Transportation Library.

Internet Watch

by Keri A. Funderburg

FHWA Honors Top Traveler Information Sites

Traffic congestion is a fact of life for many people, particularly those living in urban areas. According to the Texas Transportation Institute's *2002 Urban Mobility Study*, the average delay per road traveler during peak travel periods is 62 hours per year—that adds up to more than 2.5 days per year spent sitting in traffic. These days, many agencies and organizations post traffic information on the Internet, such as interactive route maps and live photos and videos showing traffic hotspots.

In September 2003, the Federal Highway Administration (FHWA) announced the winners of the third annual national awards for traveler information Web sites. These sites provide easy access to up-to-the-minute information about safety and mobility on U.S. roadways. This year's winners are the Georgia "NAVIGATOR" site; the Washington State Department of Transportation's "WSDOT Traffic and Weather" site; the "TRIMARC" Web site, operated by the Kentucky Transportation Cabinet and the Indiana Department of Transportation (DOT); and the "GCM Travel" site, covering the Gary-Chicago-Milwaukee area.

Georgia on My Mind (and in My Car)

In 1996 the Georgia DOT launched NAVIGATOR (www.georgianavigator.com) in preparation for the Olympic Games in Atlanta. The original site primarily featured event-related traffic information. Since the conclusion of the Olympic Games, Georgia DOT has kept the site active and now provides statewide traffic and travel information. The site features up-to-date information on incident locations, interactive maps showing work zones and areas of congestion, customized trip times, weather and roadway conditions, and real-time video from traffic surveillance cameras. A seasonal section features maps of evacuation routes and procedures for use in the event of a hurricane.

Georgia DOT uses a three-step process to gather information for NAVIGATOR. First, employees at the transportation management center monitor roadways and collect real-time travel, congestion, and incident information from video cameras along the interstates and telephone calls to a special traffic hotline. They then confirm each incident by identifying the problem, the cause, and the effect on the roadway. Finally, the traffic managers communicate the information to travelers via the Web site and dynamic message signs.

Georgia DOT continually searches for ways to improve the site. "Future enhancements to NAVIGATOR will enable users to customize their visits to the Web site," says Charlene F. Njoroge, public relations specialist for Georgia DOT. "Users will be able to use a 'My Navigator' link to create their own favorite routes, camera images, maps, and travel time links."

A Washington Winner

In Washington State, the WSDOT Traffic and Weather site (www.wsdot.wa.gov/traffic) provides travelers with reports and forecasts on statewide traffic, weather, and road conditions, including roadway temperatures, incident blockages, construction, and highway advisories along mountain passes. The site also features a clickable map that integrates data from satellites, radar, road temperature models, and other sources onto one screen. Using the link "Puget Sound Flow Map," visitors can find real-time travel times and live camera stills for the 10 most popular commutes in the Seattle area. And a link to travel routes provides reports on heavily traveled sections of the State's highway network.

According to Laura Merritt, interactive communications manager at WSDOT, the site launched in 1996. "Some really smart WSDOT engineers recognized they had access to traffic information that the public might find useful," she says. "The engineers then started spending time in their off-hours developing the first Web interface to display the traffic information."

Georgia DOT's "NAVIGATOR" Web site.

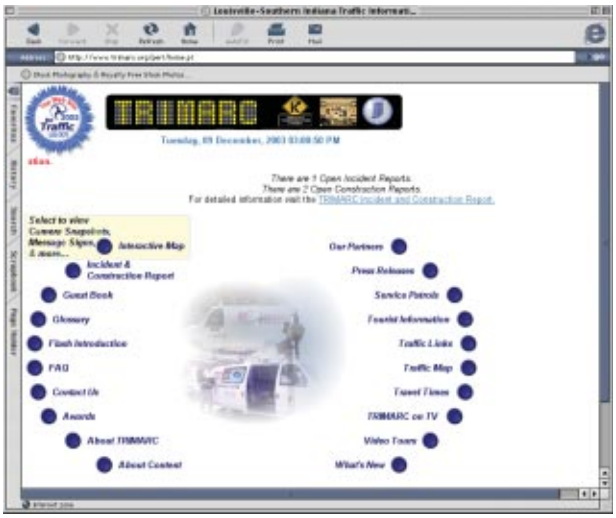
Washington State's "Traffic and Weather" Web site.

Since the site went live, travelers are not the only group to find the site useful. Many transportation managers also visit the site to help make decisions about deploying snowplows and other road-clearing devices and when and where to apply deicing compounds.

TRIMARC Hits Its Mark

Developed through a cooperative effort between the Kentucky Transportation Cabinet and the Indiana DOT, TRIMARC (www.trimarc.org) is short for Traffic Response and Incident Management Assisting the River Cities. The Web site features traffic information for the interstate highway system within the greater Louisville, KY, and southern Indiana urban area. An interactive map enables users to access travel times, information posted on dynamic message signs, real-time images from traffic cameras, and information on the location of construction and incidents.

In addition to providing regular, daily travel information, TRIMARC also has been instrumental during special events in the Louisville area. During a fireworks festival, Thunder Over Louisville, for example, the site provided information on parking and traffic routes. In addition, when inclement weather makes aerial surveillance impossible, the private companies that collect and distribute traffic data often use the site because TRIMARC monitors more freeway miles than they do.



Kentucky and Indiana's "TRIMARC" Web site.

The Web site is just one part of the freeway management system in the region. "One of our major objectives is to convey traffic information to the community by various means," says Barney Leslie, TRIMARC program manager. "In addition to the Web site, we also operate dynamic message signs along the roadway, a highway advisory radio system, and even a morning television program on Louisville's government access channel."

A Two-Time Winner

For the second year in a row, FHWA honored the GCM Travel Web site (www.gcmtravel.com). Covering three States and 16 counties, the site features traffic and travel information from the State DOTs in Illinois, Indiana, and Wisconsin for travel in the Gary, Chicago, and Milwaukee transportation corridors. The three agencies distribute travel information through a state-of-the-art data-sharing system that enables users to link to maps covering the three metropolitan areas and the entire travel corridor. The maps display traffic conditions as color-coded congestion levels and use various icons to illustrate incident, construction, transit, and airport data. The icons are organized into graphic layers that users can turn on or off to access more detailed information.

In addition to the maps, text pages on the site provide traffic information in a tabular format. Web users can customize the text pages by selecting their own routes of interest using the "My Travel" feature.

According to David Zavattero, ITS program manager at Illinois DOT, the site received nearly five million hits in September 2003 alone. "Many of these hits were from the media and commercial information services that, in turn, provide the real-time traffic information to the public or through their own Web sites," Zavattero says. "And, of course, there are large numbers of individual travelers using the site every day to help them plan their trips."

To select the winners of the 2003 awards, FHWA reviewed 276 Web sites from across the United States,

The Gary-Chicago-Milwaukee area's "GCM Travel" site.

evaluating them for content and usability. The content evaluation was based on whether the sites provided information on current conditions such as incidents, construction notices, high-occupancy vehicle lanes, and tolls. Usability criteria included the organization of the site, the ease of navigation, and the presentation of information to users.

Keri A. Funderburg is a contributing editor for PUBLIC ROADS.

Communication Product Updates

Compiled by Zac Ellis of FHWA's Office of Research and Technology Services

Below are brief descriptions of products recently published online by the Federal Highway Administration's (FHWA) Office of Research, Development, and Technology. Some of the publications also may be available from the National Technical Information Service (NTIS). In some cases, limited copies are available from the Research and Technology (R&T) Product Distribution Center.

When ordering from NTIS, include the NTIS publication number (PB number) and the publication title. You also may visit the NTIS Web site at www.ntis.gov to order publications online. Call NTIS for current prices. For customers outside the United States, Canada, and Mexico, the cost is usually double the listed price. Address requests to:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703–605–6000
Toll-free number: 800–553–NTIS (6847)

Address requests for items available from the R&T Product Distribution Center to:

R&T Product Distribution Center, HRTS-03
Federal Highway Administration
9701 Philadelphia Court, Unit Q
Lanham, MD 20706
Telephone: 301–577–0818
Fax: 301–577–1421

For more information on research and technology publications from FHWA, visit the Turner-Fairbank Highway Research Center's (TFHRC) Web site at www.tfhrc.gov, FHWA's Web site at www.fhwa.dot.gov, the National Transportation Library's Web site at http://ntl.bts.gov, or the OneDOT information network at http://dotlibrary.dot.gov.

Infrastructure Research and Technology Stakeholder Workshop Summary Report: Workshop Proceedings
Publication No. FHWA-RD-03-071

To meet the challenges for highway infrastructure that lie ahead, FHWA is refocusing and revitalizing its program for research and technology (R&T) to raise the bar in research, technology, and deployment activities. The program represents a new way of doing business for FHWA, with increased emphasis on stakeholder involvement and partnerships. The overall goals are to enhance mobility and productivity, extend the life of pavements and bridges, and improve safety and performance. These goals require investing in four essential elements: information, people, technology, and deployment.

To share its vision with stakeholders, FHWA held a workshop for infrastructure R&T stakeholders in Chicago, IL, on October 31 and November 1, 2002. The workshop drew more than 60 representatives from highway agencies, academia, associations, and industry. The meeting was designed to give FHWA an opportunity to hear feedback from stakeholders, refine its vision, and build stakeholder commitment in achieving infrastructure innovations. This report documents the discussions and stakeholder recommendations. FHWA is using the feedback to revise and sharpen the infrastructure R&T vision and help define stakeholder involvement.

Concrete Mixture Optimization Using Statistical Methods: Final Report
Publication No. FHWA-RD-03-060

This report presents the results of a research project that investigated the feasibility of using statistical experiment design and analysis methods to optimize concrete mixture proportions. As part of the project, the researchers developed an Internet-based software program that optimizes concrete mixtures using those methods. The researchers investigated two approaches to experiment design (classical mixture and factorial-based central composite design) in the laboratory. In each case, they used six component materials and optimized the mixtures for four performance criteria (properties) and cost. Based on the experimental results, the factorial-based approach was selected as the basis for the Internet-based system, the Concrete Optimization Software Tool (COST). The tool employs a six-step interactive procedure starting with materials selection and working through trial batches, testing, and analysis of results. The end result is recommended mixture proportions to achieve the desired performance levels. COST was developed as a tool to introduce the industry to the potential benefits of using statistical methods in proportioning concrete mixtures and to give interested parties an opportunity to try the methods for themselves.

Effects of Geosynthetic Reinforcement Spacing on the Performance of Mechanically Stabilized Earth Walls
Publication No. FHWA-RD-03-048

Researchers investigated the performance of mechanically stabilized earth walls (MSEW) with modular block facing and geosynthetic reinforcement, using numerical models that simulate construction of the wall, layer by layer, until it fails under gravity loading. The two-dimensional finite difference program Fast Lagrangian Analysis of Continua (FLAC), version 3.4, Itasca 1998, carried out the numerical analysis. The material properties were based on data reported in the literature, representing typical values used in design practice. Failure mechanisms of MSEWs were identified as a function of geosynthetic spacing considering the effects of soil strength, reinforcement stiffness, connection strength, secondary reinforcement layers, and foundation stiffness. The effects of reinforcement length on stresses and wall stability also were investigated. The researchers compared the FLAC predictions with the design method used by the American Association of State Highway and Transportation Officials (AASHTO). Additional numerical experiments were carried out to investigate the effects of certain modeling parameters on wall response.

Four failure modes were identified: external, deep-seated, compound, and connection. The reinforcement spacing proved to be a major factor controlling the behavior of the walls. Small and large spacing was considered in the study: less than or equal to 0.4 meter (1.3 feet)—and larger than 0.4 meter (1.3 feet). Increasing reinforcement spacing decreased the wall stability and changed the predominant failure mode from external or deep-seated to compound and connection modes. Similar effects were identified upon decreasing the soil strength, reinforcement stiffness, or foundation stiffness. Connection strength appeared to affect only the behavior of walls with large reinforcement spacing, that is, increased connection strength, decreased wall displacements, improved wall stability, and changed failure mode. Similar effects were identified when secondary reinforcement layers were introduced in a model with large reinforcement spacing. Increased reinforcement length improved wall stability and decreased displacements and reinforcement forces.

Comparing FLAC predictions and AASHTO calculations showed agreement. The comparisons indicated that the existing design method could distinguish the modes of failure identified by FLAC analysis, especially those due to external stability.

Long-Term Performance of Corrosion Inhibitors Used in Repair of Reinforced Concrete Bridge Components
Publication No. FHWA-RD-01-097

In 1987 the Strategic Highway Research Program (SHRP) launched multiple research efforts to study all aspects of the deterioration of reinforced concrete. One of the projects, (SHRP C-103) under the structures portion of SHRP, evaluated the effectiveness of using corrosion inhibitors as a means for mitigating corrosion in reinforced components of concrete bridges. That project, completed in 1993, involved a laboratory study and field validation and concluded that corrosion inhibitors could be applied successfully using repair and rehabilitation techniques in the field.

FHWA initiated a follow-on study in August 1994, which ended in July 1999. The primary objective of this multitask project was to determine the effectiveness of cathodic protection, electrochemical chloride extraction, and corrosion-inhibitor treatment systems installed during the SHRP effort through the long-term evaluation of 32 test sites in the field and several concrete slab specimens in the laboratory.

One task involved monitoring the long-term performance of corrosion-inhibitor treatments on selected components of four bridges that were treated and evaluated under SHRP C-103. Over a period of 5 years, researchers conducted three evaluations on structures located in Minnesota, New York, and Pennsylvania, and two evaluations were conducted on a structure in Washington State. An analysis of the results concluded that neither of the corrosion inhibitors evaluated during the study—using the specified repairs and exposed to the specific environments—provided any corrosion-inhibiting benefit.

With the exception of the test site in Washington State, shrinkage cracking plagued repairs at all other sites. The concrete surrounding the patched areas was contaminated with chloride ions to varying degrees. At some test sites, shrinkage cracking allowed faster ingress of chloride ions into the repair patches. At all four sites, the results of the visual and delamination surveys and corrosion-rate measurements did not show any difference between patches containing corrosion inhibitors and those without.

Training Update

NATIONAL HIGHWAY INSTITUTE

NHI to Offer Credits for Continuing Education

The International Association of Continuing Education and Training (IACET) recently approved the National Highway Institute's (NHI) awarding of continuing education units for its courses. As of January 1, 2004, participants will be able to receive IACET continuing education units for successfully completing NHI courses.

IACET is an independent, nonprofit association whose goal is to ensure quality continuing education for professionals. To become a unit provider for continuing education, an organization must demonstrate that it designs and develops training in accordance with proven adult education theory and recognized practices in instructional systems-design.

Mn/DOT

Workers apply a chip seal treatment (a pavement preservation technique) to a State highway in Minnesota.

According to NHI Director Moges Ayele, those who evaluate lifelong learning experiences for professional development recognize the value of training delivered by IACET-accredited organizations. "Our customers expect high-quality, outcome-oriented training," Ayele says. "Being an IACET-authorized provider assures them that we develop and deliver training that meets recognized standards of excellence."

Several factors influenced NHI's decision to become an authorized training provider. First, NHI has a reputation for developing quality training but wanted acknowledgment from the recognized standard bearer in the field. In addition, a trend is growing among States to require annual continuing education for professional employees. Also, States need to make every training dollar count.

Currently, 26 States require professional engineers to participate in annual or biannual professional education. Recognition by the association assures both the professional employee and the employer that taking an NHI course will be a valuable use of time and scarce training dollars.

Accreditation represents another step in NHI's effort to meet the needs of its customers and ensure an environment for continuous improvement. By following IACET guidelines, NHI ensures its customers that they will finish each course having met the learning objectives.

Integrating Pavement Preservation And Management

A new course on pavement preservation will be among the first to offer IACET credit. Available in January 2004, Pavement Preservation: Integrating Pavement Preservation Practices and Pavement Management (#131104) will instruct participants in the benefits of integrating preservation and maintenance activities for roads.

To keep cars running smoothly, auto manufacturers recommend changing the oil every 3 months or 4,800 kilometers (3,000 miles). In the same way, strategies to preserve and protect pavements can help ensure the long-term usability of the Nation's roadways by keeping good roads good.

The new course provides basic information about the types of pavement management decisions made by State and local agencies and the data and tools necessary to support those decisions at the project and network levels. Often, preservation personnel, maintenance managers, and State police, for example, use incompatible referencing systems to identify specific sections of road, intersections, or locations. The course brings together representatives from these different areas to discuss obstacles like these and brainstorm agency-specific solutions, such as using global positioning systems to identify key locations. By the end of the course, participants will be able to develop a useful plan for integrating pavement preservation and management that they can take back to their home agencies.

"Pavement preservation programs provide significant benefits to highway agencies," says Steve Mueller, system preservation engineer at FHWA. "Pavement management systems provide the data that agencies need to measure the benefits. This course provides the essential tools and techniques to integrate the two and assure that the *right* treatment is placed on the *right* road at the *right* time."

The fourth in a series of courses on pavement preservation, this 2-day class targets planning and programming personnel and pavement and maintenance engineers who manage preservation programs. The others in the series are The Preventive Maintenance Concept (#131054), Selecting Pavements for Preventive Maintenance (#131058), and Design and Construction of Quality Preventive Maintenance Treatments (#131103).

For more information on the pavement preservation course, contact Ewa Rodzik at 703-235-0524 or ewa.rodzik@fhwa.dot.gov. For scheduling, contact Danielle Mathis-Lee at 703-235-0528 or danielle.mathis-lee@fhwa.dot.gov. To learn more about transportation-related training courses available from NHI, consult the course catalog at www.nhi.fhwa.dot.gov or contact NHI at 4600 N. Fairfax Drive, Suite 800, Arlington, VA 22203; 703-235-0500 (phone); or 703-235-0593 (fax).

Conferences/Special Events Calendar

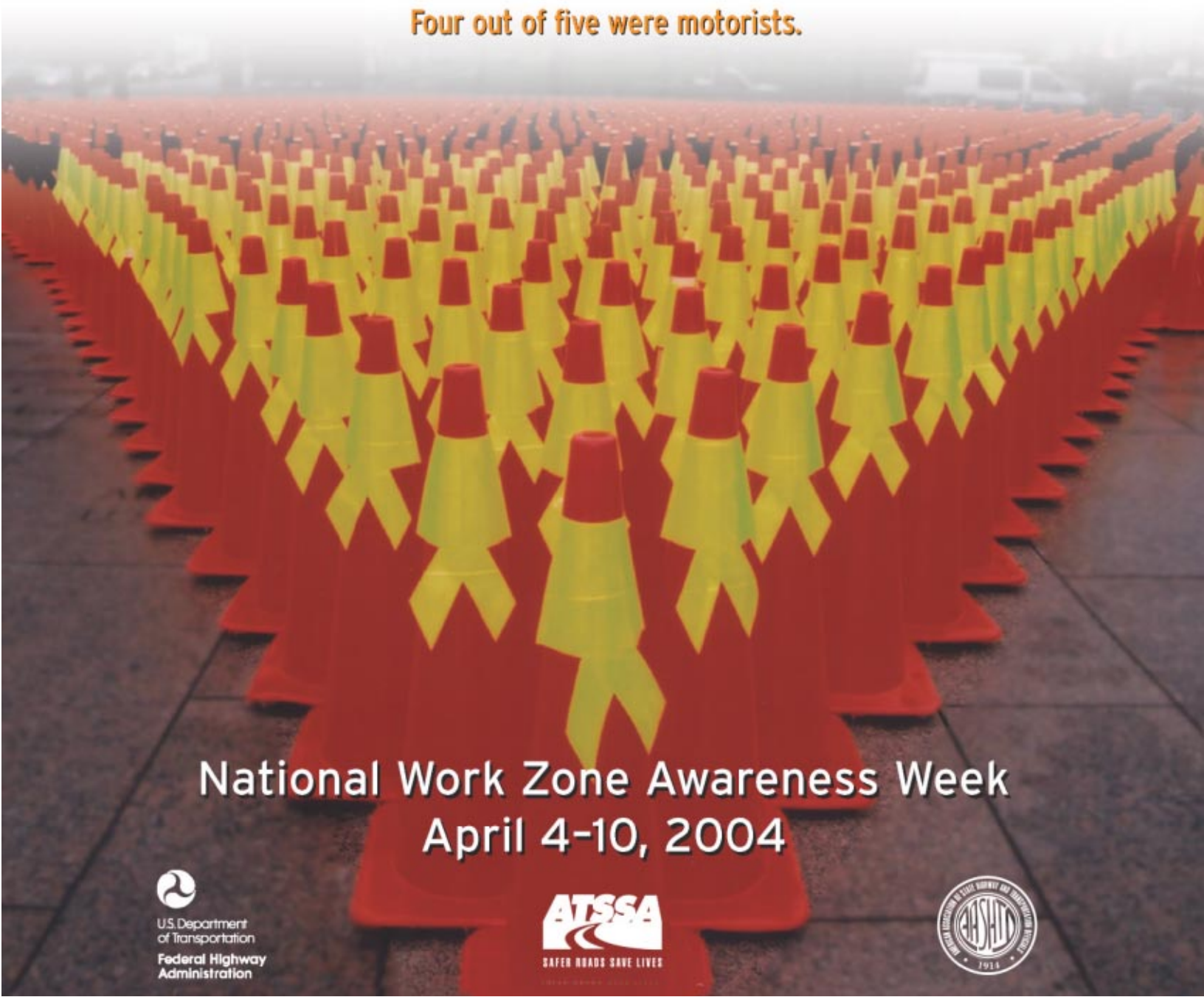
Date	Conference	Sponsor	Location	Contact
March 8–10 2004	AAPT Annual Meeting and Technical Sessions	Association of Asphalt Paving Technologists (AAPT)	Baton Rouge, LA	Eileen Soler 651-293-9188 aapt@qwest.net
March 15–18 2004	World of Asphalt 2004 Show and Conference	National Asphalt Pavement Association	Nashville, TN	Jim Eldredge 414-298-4147 info@worldofasphalt.com www.worldofasphalt.com
March 20–24 2004	IBTTA Organization Management Workshop	International Bridge, Tunnel and Turnpike Association (IBTTA)	Long Beach, CA	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
March 28–31 2004	GIS for Transportation Symposium	American Association of State Highway and Transportation Officials	Rapid City, SD	Roger Petzold 202-366-4074 roger.petzold@fhwa.dot.gov www.gis-t.org/index.htm
March 28–31 2004	ITE 2004 Technical Conference and Exhibit	Institute of Transportation Engineers (ITE)	Irvine, CA	Lisa Zahurones 202-289-0222, ext. 136 lzahurones@ite.org www.ite.org
May 18–19 2004	National Highway Visibility Conference	Wisconsin Department of Transportation and Federal Highway Administration (FHWA)	Madison, WI	Todd Szymkowski 608-263-2684 szymkowski@engr.wisc.edu www.smartways.org
May 22–26 2004	Facilities Management Workshop	IBTTA	Denver, CO	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
June 1 2004	6th International Symposium on Snow Removal and Ice Control Technology	Transportation Research Board (TRB)	Spokane, WA	Frank Lisle 202-334-2950 flisle@nas.edu http://gulliver.trb.org/calendar/event.asp?id=53
June 13–15 2004	Technology Workshop	IBTTA	Miami Beach, FL	Nicole Neuman 202-659-4620 nneuman@ibtta.org www.ibtta.org
June 27–30 2004	North American Travel Monitoring Exposition and Conference (NATMEC) 2004	FHWA and TRB	San Diego, CA	Thomas Palmerlee 202-334-2907 tpalmerlee@nas.edu www.natmec.org
July 21–24 2004	Highway Capacity and Quality of Service Committee (A3A10) Midyear Meeting and Conference	TRB	State College, PA	Richard Cunrad 202-334-2965 rcunard@nas.edu http://gulliver.trb.org/calendar/event.asp?id=55
July 27–31 2004	Geo-Trans 2004	American Society of Civil Engineers	Los Angeles, CA	Leonore Jordan 703-295-6110 ljordan@asce.org www.asce.org/conferences/geotrans04
August 1–4 2004	ITE 2004 Annual Meeting and Exhibit	ITE	Lake Buena Vista, FL	Lisa Zahurones 202-289-0222, ext. 136 lzahurones@ite.org www.ite.org

Help Keep Motorists Alive

Promote Safe Driving and Work Zone Habits

Each cone represents a life lost in a work zone in 2002.

Four out of five were motorists.



National Work Zone Awareness Week
April 4-10, 2004

U.S. Department of Transportation
Federal Highway Administration

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USPS NO. 516-690

FHWA-HRT-04-002
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