PB98-156987

1997 achievement report

TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

This 1997 report is the 21st in a series of annual reports highlighting the achievements of the Turner-Fairbank Highway Research Center (TFHRC). TFHRC is operated by the Federal Highway Administration's Office of the Associate Administrator for Research and Development. This report, Publication No. FHWA-RD-97-156, covers the period October 1, 1996, to September 30, 1997.

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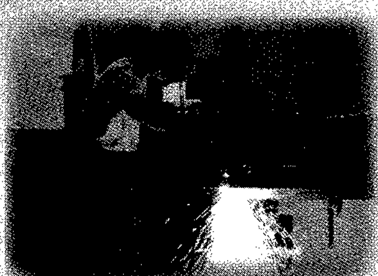
Public and private partners gather for the AHS "Demo '97." *page 4*

Site tour during the Virginia HPC Showcase, June 1997. *page 12*



Working with high-performance steel in the TFHRC Structures Lab. *page 23*

contents

Robert J. Betsold,
Associate Administrator

statement associate

Turner-Fairbank Highway Research Center (TFHRC) is continuing to make significant contributions toward solving the Nation's highway-related problems. At TFHRC we are constantly striving to achieve the highest possible quality in all aspects of research and to make TFHRC a center of special expertise and leadership in highway research.

Fiscal year 1997 (FY 97) was a year of advancement. We have moved forward by expanding partnerships, by showing the value of our research through technology demonstration projects, and by effectively meeting the needs of our customers.

Improving upon what we do each year is the charted course of our Quality Journey. We ensure constant progress. We have begun benchmarking our work so that we can become "the best of the best." However, our success is not achieved alone. Sharing information and working with our partners in government, industry, and academia help us to achieve our goals.

This year, we have maintained our existing partnerships and created several new relationships, both domestically and abroad. Recently, we signed a cooperative research agreement with GEOPAK Corporation, a leading developer of civil engineering software, to aid in the development of the Interactive Highway Safety Design Model, which evaluates the safety implications of alternative highway designs. In early FY 97, we renewed our cooperative agreement with the Japanese Ministry of Construction. This agreement provides an exchange of highway transportation and safety-related information through yearly workshops or other forums. We also signed a cooperative research agreement with France to further develop traffic models with artificial intelligence. Through these strategic partnerships,

from the administrator

we are able to enhance the safety and operations of our highways.

The Federal Highway Administration is also involved in cooperative activities with the National Highway Traffic Safety Administration through the National Crash Analysis Center at The George Washington University, Virginia campus. This work includes finite element analyses to reduce the number of actual crash tests required to verify the performance of roadside safety hardware. This super-computer center can perform crash analysis much faster and more efficiently than ever before. The analysis that took 4 weeks for one run in 1993 can now be done in only 8 hours because of advancements in super-computer power.

Helping to advance our research toward practice is an exciting aspect of our work. The success of the Automated Highway System (AHS) proof-of-technical-feasibility demonstration this August in San Diego is a good example. This demo showed that AHS is a viable option for meeting travel demands, enhancing mobility, and increasing safety. AHS will be one of the building blocks of the Department of Transportation's Intelligent Vehicle Initiative. This was a dramatic step from idea to application: working with outstanding State, academic, and industry partners, we delivered what we set out to do. Also, in partnerships with State departments of transportation, we have made significant progress in the implementation of high-performance concrete (HPC); currently, 10 States are constructing or planning to construct bridges with HPC. These structures promise greater long-term performance and reduced life-cycle cost.

To maintain quality in every sphere of the industry, accurate and thorough testing must be completed to develop guidelines and standards. This ensures consistency so that we can effectively meet the needs of the States. For example, developing standards for intelligent transportation system applications and integrated systems, and establishing priority needs for Long-Term Pavement Performance data ensure the quality of our products. We are preparing the products and materials our customers need for a durable, safe transportation infrastructure.

Continuing our emphasis on education is another way we meet the needs of our customers. Many staff members have completed their doctoral degrees this year. Their ability and knowledge increase the quality and capability of the staff, thereby enabling us to provide better quality products.

We at TFHRC have transformed concepts into realities, focusing on technologies and innovations that will make a better transportation system. We have progressed significantly as a result of collaborating and exchanging information, developing new technology, and striving to provide the best possible customer service. We are committed to a leadership role in the national and international efforts to make roads safer and better. ■

Operations

IN THIS SECTION:

The FHWA R&T Program: Where TFHRC Fits In

The Role of TFHRC

Communication Services

The ribbon is cut at Demo '97.

The Turner-Fairbank Highway Research Center (TFHRC) is the Nation's most advanced surface transportation research and development facility. As the research and development center for the Federal Highway Administration (FHWA), it strives to show the world how roads and bridges can be made better through the use of contract-sponsored research, application of new and emerging technologies to highway problems, onsite laboratory testing, field evaluations, concept demonstrations, and application assessments. The results are transferred to State, local, and international highway communities.

THE FHWA R&T PROGRAM: WHERE TFHRC FITS IN

TFHRC, also known as the FHWA Office of the Associate Administrator for Research and Development, is part of FHWA's Research and Technology (R&T) program.

The Research and Technology Executive Board (RTEB) manages the R&T program internally, providing policy direction for the R&T program. Chaired by FHWA's Executive Director, RTEB is composed of the Associate Administrator for Research and Development at TFHRC, along with five other Associate Administrators, two Regional Administrators, and the Director of the Joint Program Office for Intelligent Transportation Systems.

In addition, various Research and Technology Coordinating Groups (RTCG's), made up of technical staff within the organization, develop the R&T program budget and coordinate the implementation of the R&T program.

RTCG members also work with State and local officials and the private sector to introduce technological advances into practice.

Finally, FHWA has an external coordination group, the Research and Technology Coordinating Committee (RTCC), convened by the Transportation Research Board, which helps FHWA identify gaps in research; develop ways to increase State, local, and private-sector participation in research; and address issues related to research implementation. Researchers, administrators, research users, and practitioners from the public, private, and academic sectors make up RTCC.

THE ROLE OF TFHRC

TFHRC performs or manages most of the research and development work for FHWA's R&T program. Turner-Fairbank researchers also regularly work in collaboration with FHWA program offices in Washington, DC, and in the field. TFHRC also assists in the efficient and cost-effective transfer of technology by disseminating research and technical information to a variety of audiences, including senior legislative or U.S. Department of Transportation decisionmakers, the FHWA community, professional organizations, industry, academia, consumer groups, and the general public.

COMMUNICATIONS SERVICES

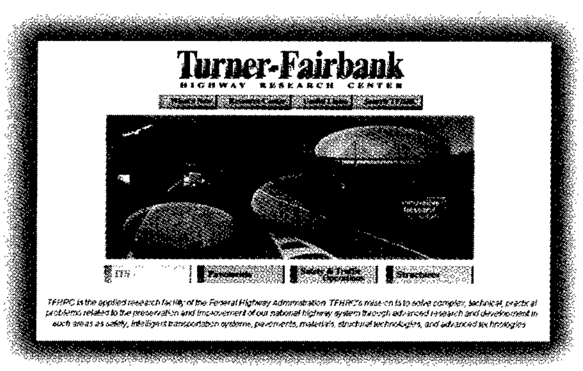
A primary mission of FHWA for more than 100 years—from the very beginning of its original predecessor, the Office of Road Inquiry, in 1893—has been to conduct research and to share information (now often called technology transfer) about how to build better roads. This long-time mission is taking on a new emphasis and a new look as researchers face the dual dynamics of the need to compete for attention in an information age that places an increasing importance on promoting their products and of new technologies and media—primarily the Internet—that are available to share the results of TFHRC research to an ever-broadening audience.

TFHRC is responding to these dynamics by expanding its communication services. For the past several years, the publications office has been evolving into an office of communication services by offering not only the traditional publication services of editing, print processing, and distribution, but also by providing additional communication services: electronic services—electronic publishing and placement on the TFHRC web site and via CD-ROM—and marketing services—the planning and coordination of tours, meetings, and conferences; video-teleconferences; exhibits; and other outreach activities. The logical extension of this evolution is in the area of managing information services to ensure that available information can be quickly and efficiently retrieved by everyone—internally and externally—who seeks it.

In FY 97, the communication services staff assisted in "telling the TFHRC story" by editing and publishing 212 research reports, TechBriefs, and special publications, as well as 2 FHWA periodicals—the monthly *Research and Technology Transporter* newsletter and the bimonthly magazine *Public Roads.*

Research & Technology Transporter

The *Research and Technology Transporter* is recognized as a convenient, comprehensive source of information about FHWA research and technology programs. The



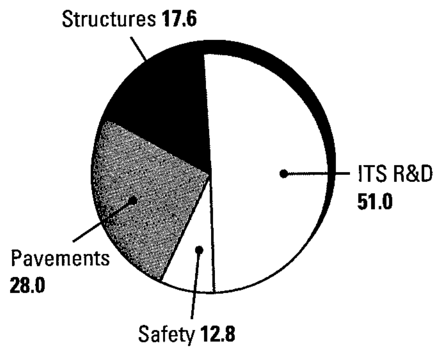
A new look for the TFHRC web site at http://www.tfhrc.gov.

monthly *Transporter* increased its circulation by 10 percent this year, now reaching more than 2,670 subscribers.

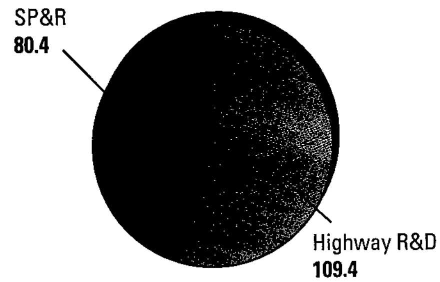
Public Roads

After 25 years as a quarterly publication, *Public Roads* became a bimonthly magazine of FHWA this year. The magazine features

Funds directly managed by TFHRC
(in millions of dollars)



Funds administered by TFHRC
(in millions of dollars)



developments in Federal highway policies, programs, and research and technology. *Public Roads* emphasizes intermodalism—highways as part of a comprehensive transportation system that includes all modes of transportation—and supports the continuing commitment of FHWA to be a world leader in promoting highway research and technology transfer.

Expanding Our Reach

By the end of FY 97, the TFHRC web site was receiving more than 19,000 hits per month, and in July, the site was selected by the *Los Angeles Times* as an outstanding "Times Pick." During the year, TFHRC hosted more than 11,600 people in meetings, conferences, and tour groups. In conjunction with our publications, these efforts contribute to effectively educating and expanding our audience.

BUDGET

In FY 97, FHWA had about $348 million available for its R&T program, $109 of which was spent on fundamental and applied research and development. The remainder of the funding was used for intelligent transportation systems (ITS) and technology applications. Through the State Planning and Research (SP&R) Program and the National Cooperative Highway Research Program (NCHRP), the States had an additional $80 million available to them.

TFHRC directly managed $109.4 million, most of which was designated for research studies and related technology development and evaluation activities (in millions):

Pavements	**$ 28.0**
Structures	**17.6**
ITS Research and Development	**51.0**
Safety	**12.8**
Total	**$109.4**

Funds administered by TFHRC were divided as follows (in millions):

State Planning and Research	**$ 80.4**
Highway Research and Development	**109.4**
Total	**$189.8**

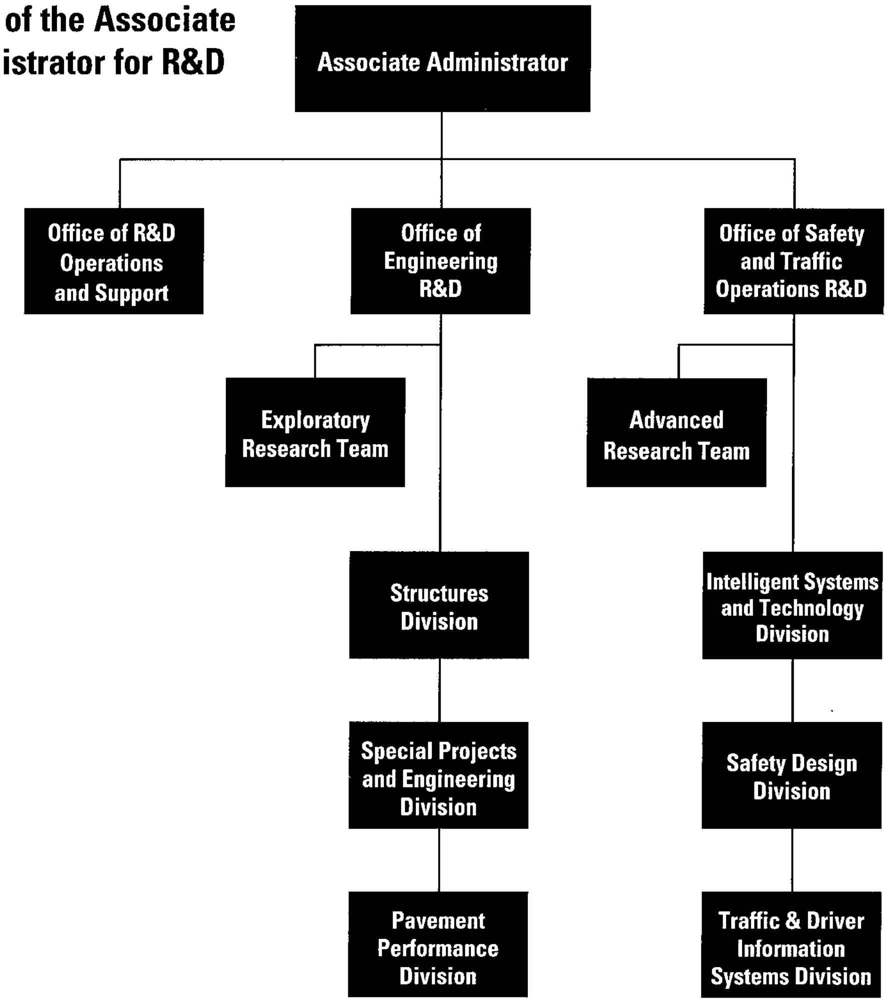
STAFF AND ORGANIZATION

TFHRC's staff of 105 Federal employees is supplemented by more than 220 onsite contract employees. The professional staff includes engineers, geologists, mathematicians, chemists, metallurgists, psychologists, scientists, and technical editors. In addition to these professionals, there are usually from six to eight visiting researchers (on loan or detailed from various universities, government agencies, or foreign countries) and graduate research fellows working at TFHRC facilities.

Visiting Scholars and Temporary Exchange Assignments

In fulfillment of its mission to exchange transportation technology, TFHRC participates in a variety of programs, including temporary assignments for staff on loan from other countries, rotational assignments for FHWA field staff, Inter-governmental Personnel Act assignments for State and university staff, and temporary details for specialists from other Federal agencies.

Office of the Associate Administrator for R&D



Other Professional Activities

Many TFHRC engineers, researchers, and staff are active participants on boards and committees of professional or other transportation organizations, including the American Association for Artificial Intelligence, American Chemical Society, American Society of Civil Engineers, American Society of Mechanical Engineers, American Society for Training and Development, American Society for Testing and Materials, Institute of Transportation Engineers, Intelligent Transportation Society of America, National Association of Government Communicators, Society for Automotive Engineers, Transportation Research Board, and Women's Transportation Seminar. Members of TFHRC's professional staff are actively involved in organizing symposiums with transportation groups, and they also participate in continuing professional development activities.

Outstanding Achievements

One way FHWA recognizes outstanding research achievements is by publically presenting awards to an individual or team. At times, other organizations in the industry also distribute awards to highlight exceptional work. The following awards were given to TFHRC researchers:

FHWA Administrator's Award for Superior Achievement. Individuals who have demonstrated outstanding performance are selected for the FHWA Administrator's Award for Superior Achievement. This is the highest award given within FHWA. The winners of this year's award are Michael E. Curtis of the Intelligent Systems and Technology Division, Office of Safety and Traffic Operations Research and Development and Monte Symons of the Pavement Performance Division, Office of Engineering Research and Development.

Mike Curtis teamed with the Office of Motor Carriers and played an instrumental role in the Intelligent Transportation System/ Commercial Vehicle Operations Program, developing and implementing the Commercial Vehicle Information Systems Network (CVISN). He devised the system, planned the program, gained the necessary support in the public and private sectors, tested the prototype system, and brought the project to its current state of pilot testing, which is now operational in more than 10 States.

Monte Symons' excellent program management and technical expertise made an impressive impact on the Long-Term Pavement Performance (LTPP) project. He initiated and orchestrated the development and implementation of a set of multiyear contracts and performed an analysis of the LTPP seasonal monitoring program flexible pavement section. Mr. Symons' analysis of the pavements led to an improved equation to determine the design low pavement temperature for selection of Superpave binders.

Other organizations in the industry also distribute awards to draw attention to exceptional work.

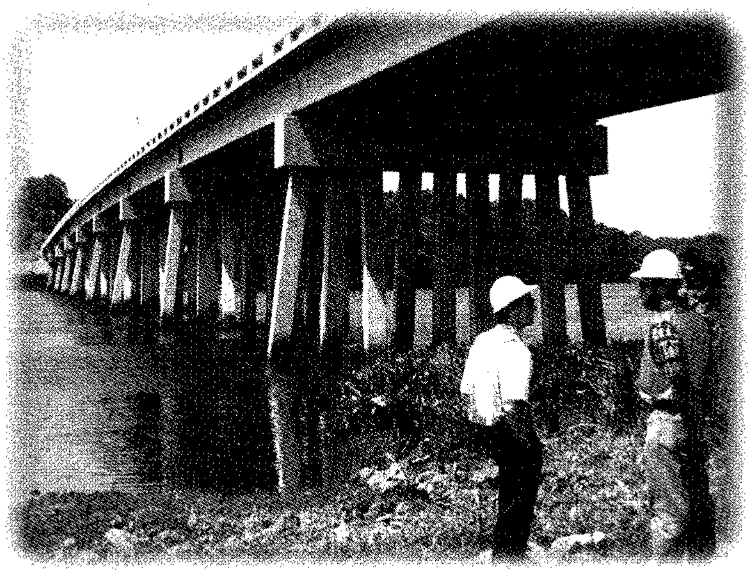
Outstanding Technical Accomplishment Award. An individual or group of individuals is annually presented with the Outstanding Technical Accomplishment Award. Dr. Ray Bonaquist, Special Projects and Engineering Division, was the recipient of Research and Development's Outstanding Technical Accomplishment Award for his paper, "A Comprehensive Constitutive Model for Granular Materials in Flexible Pavement Structures." This paper summarizes the results of a 5-year research program conducted in the Geotechnical Laboratory Complex of TFHRC to better understand and model the behavior of granular bases and subgrade soils. The research program used plasticity theory to produce a comprehensive constitutive (stress-strain) model for these materials. It is a significant advancement over current granular material models and can be used to predict pavement performance, to select layer thicknesses to resist permanent deformations, and to select material properties to ensure adequate performance.

FHWA Research Wins Civil Engineering Research Foundation (CERF) Innovative Awards. An FHWA research effort on high-performance steels for highway bridge applications won the CERF 1997 Charles Pankow Innovative Applications Award. Partners receiving the award in conjunction with FHWA are the Department of the Navy and the American Iron and Steel Institute. FHWA also was honored as a collaborator on a new, simplified monitoring system for which Strain Monitoring Systems won the 1997 Pankow Innovative Concept Award.

The high-performance steel project, led by research engineer Bill Wright, developed new steel compositions that have high strengths, significantly higher toughness, and greater corrosion resistance. Use of these steels, with yield strengths of 485 to 690 MPa, will reduce cost and improve the safety and performance of highway bridges. Development and research on the 485-MPa steel have reached the stage where it is already being fabricated into girders for use on major steel bridges in Tennessee and Nebraska.

The simplified monitoring system for civil structures developed by Strain Monitoring Systems won the 1997 CERF Pankow Innovative Concept Award. FHWA collaborated on the system by contracting for its development through the contract research program. Research engineers Dr. Steve Chase and Dr. Hamid Ghasemi led FHWA's effort in creating a monitoring system that uses "smart" metal alloys that can track and report damage done to various structures. This technology combines a series of metal alloys trademarked as the "IntelliSense" device that, when strained or stretched, becomes magnetized. The resulting ferromagnetism is directly relational to the amount of strain.

The Innovative Applications Award recognizes the contribution of an organization or collaborative team that demonstrates innovative approaches to design, materials use, or the construction process that have been transferred into practice. ■



IN THIS SECTION:

research accomplishments

It is the Turner-Fairbank Highway Research Center's (TFHRC) vision to be the nationally recognized source for highway technology leadership, innovation, and advancement providing solutions with a national perspective for both today's and tomorrow's problems. Through research, training, and support for highway policy decisions, TFHRC discovers, develops, tests, demonstrates, and evaluates improved methods for designing, constructing, operating, and maintaining highways and bridges. Research highlights from the past year are presented in the following pages.

TFHRC RESEARCH OBJECTIVES

TFHRC's priorities for FY 1997 were derived mainly from the provisions of the Intermodal Surface Transportation Efficiency Act of 1991. Specific TFHRC research objectives included the following:

- Improve mobility.
- Enhance safety.
- Protect the environment.
- Develop new technology.
- Improve quality of program delivery.

These objectives were the motivating force that infused the full range of research accomplishments described below.

WORKING SMARTER THROUGH NEW TECHNOLOGIES

Congestion, aging infrastructure, and environmental and safety concerns impede mobility, driving the country to find solutions that will achieve improved safety and capacity, cleaner and more efficient vehicles, and a regeneration of the transportation infrastructure.

Innovative research and new technologies allow Federal Highway Administration (FHWA) researchers at TFHRC to work smarter and develop transportation-related products and practices that will improve mobility for all. Advanced transportation technologies and concepts are playing an important role in closing the gap between the state of the art and the state of the practice in resolving transportation concerns related to congestion, maintenance, health, and safety. Much of this research is focused on systems called Intelligent Transportation Systems.

Automated Highway System Goes Live at Demo '97 on I-15 in San Diego. The National Automated Highway System Consortium (NAHSC) Technical Feasibility Demonstration, held August 7 through 10 in San Diego, gave transportation decisionmakers a look at the future of highway travel.

A series of live demonstrations of Automated Highway System (AHS) technologies on Interstate 15 established near-term applications to improve highway safety and efficiency. These potential benefits of AHS technologies were detailed through exhibits, automated vehicle and equipment displays, computer simulations, vehicle demonstrations, and presentations.

FHWA staff members at the AHS Demonstration in San Diego, CA. Left to right, George Ostensen, Dick Bishop, Tony Kane (FHWA Executive Director), Paula Ewen, and John MacGowan.

NAHSC is a public and private partnership designed to promote the development of AHS. AHS will become one of the foundation programs for the Department of Transportation's (DOT) Intelligent Vehicle Initiative. The program is supported, in part, with Federal research and development funding. The Federal participation was coordinated at TFHRC. The consortium began operations in 1994 and is slated to continue the development and demonstration of AHS technologies through the year 2002.

Relieving Congestion With Real-Time Traffic Adaptive Control Strategies. FHWA has made progress in developing an innovative system to improve traffic control by effectively managing traffic signals in response to rapid variations in traffic conditions. To accomplish this goal, a system known as the Real-Time Traffic Adaptive Control Strategy (RT-TRACS) is being developed and implemented jointly by FHWA and PB Farradyne. RT-TRACS is a concept that will eventually provide regional traffic control by operating various control strategies concurrently. RT-TRACS consists of a number of real-time control prototypes that each function optimally under different traffic and geometric conditions. When conditions dictate, RT-TRACS can automatically switch to another appropriate strategy.

In FY 97, TFHRC's Intelligent Systems and Technology Division, Office of Safety and Traffic Operations Research and Development, began the first field test of RT-TRACS on Reston Parkway in Reston, VA. In cooperation with the Virginia Department of Transportation, researchers instrumented a 16-intersection portion of Reston Parkway with additional loop detectors upstream on all approaches. Also, 2,070 type controllers and software were procured for use on the project, making the United States the first country to use this new technology.

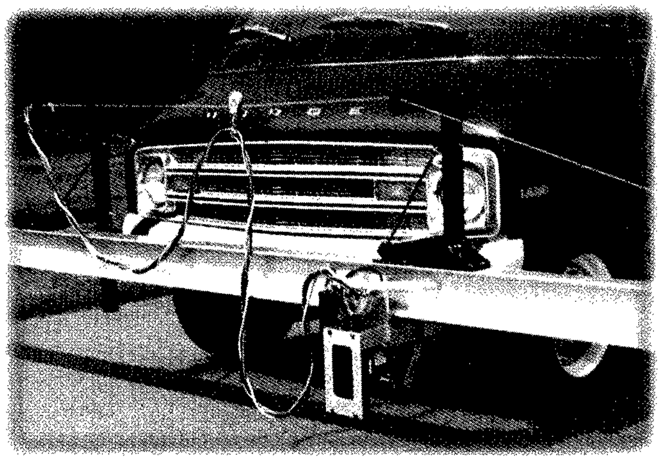
Safety Issues Arising From New Automobile Designs. FHWA and the National Highway Traffic Safety Administration

(NHTSA) are set to examine potential safety issues arising from the development of new automobiles being designed by the Partnership for a New Generation of Vehicles (PNGV). This arrangement is the result of an interagency agreement between FHWA and the Department of Energy's Office of Advanced Automotive Technologies. This work is being conducted at the National Crash Analysis Center, a specialized and unique laboratory, which is supported by FHWA and NHTSA but located offsite because of its extensive size.

PNGV is a collaborative research and development program between the U.S. Government and the U.S. Council for Automotive Research, which was formed by three automobile manufacturers: Chrysler, Ford, and General Motors. The program plan calls for development of production prototype cars that can achieve three times the fuel efficiency of the current class of vehicles. This new generation of vehicles should maintain the performance, passenger capacity, and utility standards of today's vehicles, while meeting or exceeding safety and emissions requirements.

Defining Sustainable Transportation at TFHRC. During his graduate research fellowship assignment with TFHRC's Advanced Research Team of the Office of Safety and Traffic Operations Research and Development, University of Pennsylvania master's degree candidate Dominic Spaethling worked on defining sustainable transportation and on how to achieve it. He found that sustainability cannot be interpreted as maintaining the status quo. Although it relies heavily on a conservative approach to planning and infrastructure development, it can be pro-growth. Coordinated planning in congested settings is recommended to achieve sustainable transportation.

New Road Surface Analyzers (ROSAN). The Pavement Surface Analysis Laboratory at TFHRC has debuted its series of ROSAN devices. Each device electronically records the surface macrotexture depth of any transportation surface while traveling at highway speeds. This promotes safety while eliminat-



ROSAN is an electronic method to evaluate pavement.

ing an operator's influence on test procedure and site selection and eliminating costly traffic control. Besides measuring macrotexture, ROSAN can measure faulting, grooving/tining, rutting, slope, and road profile, making manual pavement testing obsolete.

The ROSAN devices developed at TFHRC incorporate the following components in various combinations: laser sensors, accelerometers, distance pulsers, bumper-mounting hardware, a vehicle-mounted beam, and a motorized trolley. These are controlled by a user-friendly Windows™-based software program developed under the direction of the Advanced Research Team in collaboration with the Pavement Surface Analysis Laboratory. Currently, two types of ROSAN series devices, with their accompanying software, are available for loan as they undergo the patent application process.

First Neural Net-Based Vehicle Detector Developed. Orincon Company, under the direction of the Advanced Research Team, Office of Safety and Traffic Operations Research and Development at TFHRC, developed the first neural net-based vehicle detector. Intersection Development Corporation will manufacture this smart-loop detector, which will provide accurate vehicle speed and classification from a single loop. This will allow cities and States to obtain more vehicle surveillance information from their existing inductive-loop infrastructures.

Dynamic Interaction Vehicle Infrastructure Experiment (DIVINE). During FY 97, an FHWA truck/pavement interaction team played a central role in an ambitious international cooperative research project focused on how roads and bridge structures are affected by heavy vehicle traffic. Other major participants in this DIVINE program, sponsored by the Organization for Economic Co-operation and Development, included Australia, Canada, Finland, France, Germany, Great Britain, Japan, The Netherlands, New Zealand, Sweden, and Switzerland. The FHWA team completed extensive technical work in pavement variability, response, and vertical dynamics. Testing of flexible pavements was completed at TFHRC, and the National Research Council of Canada hosted the concluding conference in Ottawa in June 1997. The Associate Administrator for R&D served on the Executive Committee for this major project.

NDE technologies are useful for evaluating bridges and pavements and providing objective and quantitative data more quickly, efficiently, and accurately than before.

Laser-Based Range Measurement for Nondestructive Evaluation Applications. Researchers at TFHRC have tested and evaluated a laser-based precision range-measurement device developed by Coleman Research. This advanced coherent laser radar system can accurately measure distances with a resolution better than 0.5 mm out of a maximum range of 30 m. One of the main application areas will be deflection measurements of bridge girders. Initial field testing by TFHRC was successful for this useful system, which can measure bridge deflections with minimal setup time and from locations that do not require altering traffic flow.

BUILDING IT BETTER AND MAKING IT LAST

In FY 1997, researchers at TFHRC continued to discover new methods and media to help build better highway pavements and bridges and to extend the life of the existing infrastructure. Research programs investigated pavement performance under various conditions, physical and chemical behavior of construction materials, and criteria and test methods to ensure quality construction and maintenance for pavements and structures.

Program research areas also included hazard mitigation and development of technology to evaluate highway infrastructure and reduce maintenance requirements. An emphasis on nondestructive evaluation (NDE) technologies will help achieve better management of the country's aging transportation system. NDE technologies are useful for evaluating bridges and pavements and providing objective and quantitative data more quickly, efficiently, and accurately than before.

Developing New Technologies and Materials for Bridges

New Bridge Deck Inspection System. One of the most pressing needs identified by bridge owners is for a method to quickly and accurately evaluate reinforced concrete bridges covered with asphalt. Half the bridge decks in the country are made of reinforced concrete covered with asphalt. TFHRC's nondestructive evaluation team has sponsored the development of a new high-speed, radar-imaging system for this type of bridge inspection. It underwent full-scale field testing on two bridges in California this year with excellent results. It uses an array of 64 specially designed radar antennas to scan a bridge deck at high speed, then stores the data, and produces two- and three-dimensional images of the concrete bridge deck interior. The current method of inspecting interior damage to concrete and reinforcing bars is slow, difficult, and less reliable. Further field testing on this much needed advanced technology tool for bridge owners is scheduled.

Report Supports Deployment of Micropile Technology. Foundations research by TFHRC has resulted in publication of a comprehensive four-volume, state-of-the-practice report on micropiles. This type of pile, long used in Europe, is drilled, rather than driven, with shafts that are filled with grout and that contain steel reinforcement. Its value is in its overall versatility and its efficiency in difficult situations. In an effort to deploy micropile technology on a wider scale, this report by the TFHRC Structures Division, Office of Engineering Research and Development, provides comprehensive design guidelines and aids, and it offers recommendations on construction, specification, and quality control. It also presents successful applications in the form of case studies. It is hoped that this report will help bring this innovative and efficient technology into widespread use in the United States as a cost-effective alternative to our present dependence on large piles.

Nondestructive Evaluation (NDE) Technologies. Can cracks in welded steel structures be detected without taking the structure apart? The TFHRC Special Projects and Engineering Division, Office of Engineering Research and Development, has been developing a new method for using traditional eddy current techniques to detect cracks in welded steel structures. The traditional eddy current technique, as used on nonferromagnetic materials in the aerospace and power industries, involves inducing a magnetic field in the surface of a metal and measuring perturbations in the field caused by cracks or other defects.

New research by the TFHRC NDE team examines the use of a bi-directional differential probe specially designed for use on ferromagnetic weld metal. The probe has been tested to determine its effectiveness for detecting surface-breaking cracks in the weld metal and heat-affected zones. Research includes tests of the effects of conductive and nonconductive coatings typically used on bridges. TFHRC research to date shows that the eddy current method can be used to detect transverse cracks in weld crowns and longitudinal cracks at the toe, as well as many other defects.

Measurement of Portland Cement Rate Constants by Neutron Scattering. TFHRC and the Cold Neutron Research Facility at the National Institute of Standards and Technology have applied neutron-scattering techniques to nondestructively measure the portland cement hydration process. The neutron-scattering technique makes it possible to accurately measure the progress of the hydration reaction, which has a complex dependence on temperature and mixing conditions. This information provides a clearer understanding of the various chemical and physical processes involved in the setting and hardening of concrete.

The data obtained on the reaction rate constants for tricalcium silicate, the major constituent of portland cement, have made it possible to develop an accurate mathematical model of the reaction. This will be used to improve computer models that predict the development of strength and measurement methods. The results were presented at the International Conference on Neutron Scattering in Toronto, Canada, in August 1997.

Design Specifications for Curved Steel Bridges. Since 1992, FHWA has been conducting research in the TFHRC Structures Laboratory on theoretical, analytical, and experimental research findings concerning horizontally curved steel bridges. Curved steel bridges represent about 20 to 25 percent of the market for steel structures; yet, there are no standard specifications for designing them. The initial theoretical and analytical work has been completed, and the TFHRC Structures Laboratory has begun testing the first ever, full-size bridge beams inserted into a test frame designed to simulate an actual structure. This is being done in preparation for the testing of a full-size, curved steel bridge. The project at TFHRC is funded through a cooperative effort among

Nondestructive technologies are used to evaluate concrete damage.

TFHRC Structures staff checks out the components of their new, full-scale, curved, steel bridge model.

FHWA, the steel industry, and 13 States under a pooled-fund study.

New Grade of High-Performance Steel (HPS) Commercially Available. The TFHRC Structures Division, Office of Engineering Research and Development, has introduced a new grade of HPS that is now commercially available. This advanced product is the culmination of a 5-year research program sponsored by FHWA in cooperation with the U.S. Navy and the American Iron and Steel Institute. The product is HPS-70W. HPS is designed to improve both the cost-effectiveness and safety of bridges through higher strength, excellent weldability, and enhanced ability to tolerate defects and damage. The first 2 HPS-70W bridges were constructed in Tennessee and Nebraska, and at least 12 more are scheduled for construction in 1998 with very significant projected cost-savings. The Tennessee bridge, for example, used the high strength of HPS-70W to reduce the weight and the costs of steel fabrication by more than 16 percent compared with traditional steels.

States Implement High-Performance Concrete (HPC). This year, a total of 10 States are participating in the High-Performance Concrete Program. The program was instituted to implement the new technology using HPC, and the program showcased bridges constructed with the material. Three TFHRC researchers are members of an interdisciplinary FHWA Technology Delivery Team for HPC in bridges. That team is charged with helping the States use this concrete to provide greatly improved durability and strength in their bridges. TFHRC offers technical assistance as well as research funding for design and construction issues in the HPC implementation program. This year, four additional States are participating in the program: Alabama, New Mexico, North Carolina, and South Dakota.

Corrosion Inhibitors for Reinforced Concrete. How best to inhibit corrosion in chloride-contaminated reinforced concrete was the subject of an FHWA-National Academy of Science/National Research Council postdoctoral associate study. The study, conducted by Dr. Ugo Bertocci at TFHRC's Structures Laboratory under the Special Projects and Engineering Division, evaluated the inhibiting/passivating effects of calcium magnesium acetate (CMA) compared with other proprietary additives used as corrosion inhibitors in reinforced concrete. Road salt was included in the study for comparison purposes. The study found that CMA is superior to all other materials tested as a corrosion inhibitor. In fact, a negative corrosion rate (passivating effect) was suggested. This is particularly important for older bridge decks contaminated with salt. Details of the study are contained in the final report entitled *Impedance Spectroscopy for the Evaluation of Corrosion Inhibitors in Highway Deicers* (FHWA-RD-96-178).

Bridge Scour and Stream Instability Countermeasures. More bridges fail each year due to scour than to any other cause. Highway Bridge Circular 23 (HBC 23), *Bridge Scour and Stream Instability Countermeasures*, describes eight measures that can be taken to prevent scour damage and channel instability, plus recommendations for monitoring structures. It was developed from questionnaires and site visits, research performed at the TFHRC Hydraulics Laboratory and other laboratories, and feedback from State highway agencies following the FHWA Hydraulics Engineering Workshops. It meets an urgent need to provide bridge owners with information to safeguard the traveling public, especially on bridges evaluated as scour-critical. HBC 23 disseminates better ways of understanding and treating bridge scour to practicing engineers and highway managers.

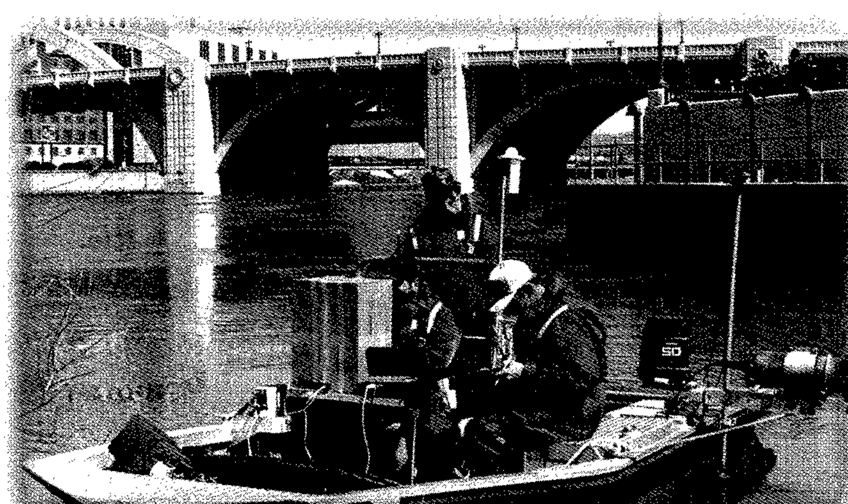
TFHRC-Managed Bridge Scour Research Team Helps Avert Catastrophe. When early spring flooding threatened the stability of bridges in Minnesota, the FHWA-sponsored bridge scour research team was rapidly deployed. Two hours after the team found scour under the abutment foundation and closed the Highway 212 bridge, the approach span of the bridge near the Minnesota River collapsed. Another inspection found the Swift County Bridge in over the Pome de Terre Creek to be in similar danger of collapsing. The bridge was immediately closed.

The bridge scour research team operates under contract to TFHRC. The team is well equipped with the following state-of-the-art tools to head off disaster: a high-tech Acoustic Doppler Current Profiler capable of measuring three-dimensional velocities along an entire water column and flow depths; a digital echo sounder, an OmniStar global positioning system, a remote-controlled boat for monitoring under bridges with low clearance, a scour board for quick and easy visually positioned measurements, a boom truck with 50-kg sounding weight and Price AA velocity meter, and a handheld laser range finder capable of calculating horizontal distance and vertical displacement of objects within sight. With this equipment and the experience and skill of the TFHRC-managed team, disaster was averted.

New Sediment Transfer Model for Bridge Scour Simulations. FHWA Graduate Research Fellow (GRF) Xibing Dou conducted a study through which he developed new empirical sediment transport functions and incorporated them into a three-dimensional computer model. This model accounts for the effects of vorticity and extreme turbulence around bridge piers and abutments by simulating local bridge scour processes very accurately. This information will be published as an FHWA GRF fellowship report, providing leading-edge hydraulics technology that combines theory and empirical knowledge into a powerful new analytical tool for researchers and bridge designers concerned about bridge scour processes.

Creating Innovations on the Road

Automated Crack Sealing Developed at TFHRC. Pavement crack sealing is a dangerous, costly, and labor-intensive operation. Now, research on automated crack sealing, developed through a series of Government- and industry-funded projects, has culminated in a promising prototype. Field trials of this automated road maintenance machine began last fall at the University of Texas at Austin. The work is funded through the Priority Technology Program and involves a public-private partnership of the private-sector company Crafco, Texas DOT, and FHWA. TFHRC test results indicate that the new equipment can be twice as productive as conventional, labor-intensive crack-sealing methods. Adoption of this new technology could produce significant savings in the $200 million spent annually on crack-sealing operations nationwide.



TFHRC's bridge scour research team check the stability of flood-damaged bridges.

Performance-Related Specifications (PRS) for Concrete Pavement Construction. Motorists want a smooth, enjoyable ride. States want top-quality, long-lasting pavements. FHWA is focusing on ways to achieve both objectives with the use of PRS for concrete pavement. The Office of Engineering Research and Development at TFHRC, in conjunction with the FHWA Office of Technology Applications, is evaluating PRS by simulating its use under field conditions. PRS is an improved quality-assurance specification based on mathematical models that include pavement performance and certain key materials and construction quality characteristics, such as strength, thickness, air content, and rideability. The models predict when and to what extent the constructed pavement will exhibit distresses, and thus they predict the pavement's life-cycle costs. With the Office of Research and Development in a lead role, PRS field simulations have been conducted in Iowa and New Mexico, and projects in at least three additional States are planned.

Long-Term Pavement Performance (LTPP) Data Used to Improve Pavement Design. FY 97 marked the 10th anniversary of the inception of the LTPP program and the fifth anniversary of TFHRC's assumption of responsibility for its management. Data collection and performance monitoring of the 2,300 LTPP test sections on highways throughout North America continued to provide the foundation for LTPP research. Also, additional LTPP data were made available to the public this year through the LTPP Customer Service Representative.

LTPP test sections across the United States continue to provide data.

Analysis of the LTPP data for jointed concrete pavements (JCP) led to the adoption by the American Association of State Highway and Transportation Officials (AASHTO) of a new supplement to its *1993 Guide for the Design of Pavement Structures*. This new procedure more carefully considers the design details that ultimately control the overall performance of JCP. This allows the engineer to tailor the design for optimum performance at a particular site, reducing life-cycle costs.

Guidance to improve the design of asphalt concrete pavements was delivered in the form of a series of three brochures: *Design Pamphlet for the Determination of Layered Elastic Moduli for Flexible Pavement Design in Support of the 1993 AASHTO Guide for the Design of Pavement Structures, Design Pamphlet for the Determination of Design Subgrade in Support of the 1993 AASHTO Guide for the Design of Pavement Structures, and Design Pamphlet for the Backcalculation of Pavement Layer Moduli in Support of the 1993 AASHTO Guide for the Design of Pavement Structures.* These guidelines, developed through analysis of the LTPP data, will help engineers develop more reliable pavement designs and enable more realistic estimates of pavement performance.

Repeatability and Reproducibility of Superpave Binder Specification Tests. The Special Projects and Engineering Division of the Office of Engineering Research and Development has determined, through a series of round-robin studies within and between laboratories, the acceptable error in the measurement of the Superpave binder specification parameters. The findings are being presented to the Superpave binder expert task group, which will recommend their inclusion into the American Association of State Highway and Transportation Officials provisional specifications of Superpave tests and procedures. These findings will help States implement Superpave technology.

The Superpave tests were developed to measure the ability of the binder to resist common distresses such as rutting, fatigue cracking, and low-temperature cracking. In 1995, the Special Projects and Engineering Division refined these test procedures with use of an interlaboratory testing procedure called ruggedness testing (*Ruggedness Testing of the Dynamic Shear Rheometer and the Bending Beam Rheometer Test Procedures,* FHWA-RD-95-079). An ongoing round-robin study involves another interlaboratory study to determine the repeatability and reproducibility of measurements made using this refined procedure. The repeatability and reproducibility values help determine the acceptable error in the measurement of these Superpave binder specification parameters.

ENHANCING SAFETY

TFHRC researchers and engineers continue to strive for safer highways through data collection and analysis; design, development, and testing of materials and technologies; and improvements in highway-related design. Research priority areas include the following:

- Developing highway safety information systems.
- Improving traffic control devices and methods.
- Studying driver and vehicle interactions with the highway.
- Improving pedestrian and bicycle facilities.
- Creating better predictive models through crash analysis.

Further significant progress has been made in the development of the Interactive Highway Safety Design Model, a tool with great promise for highway designers evaluating the safety of alternative alignments and design elements.

Working to Reduce Work-Zone Injuries. Highway construction workers experience more than twice the number of fatal occupational injuries compared with all construction workers and more than eight times those that would otherwise be expected among all workers. The data indicate that highway construction workers account for about 12 percent of all serious construction accidents, but they only make up 4 percent of the construction workforce.

In 1993, FHWA offered a 4-year research grant through the TFHRC Office of Safety and Traffic Operations Research and Development to pursue the reduction of work-zone injuries. The grant was awarded to Laborers' Health and Safety Fund of North America to perform a "Work-Zone Injury Evaluation." To date, this effort has involved developing a comprehensive understanding of the magnitude of work-related injuries and fatalities among construction laborers employed on highway projects, the causes of such injuries and fatalities, and the solutions for reducing these injuries and fatalities. A $25,000 competition was conducted by the researchers to gain new ideas for improving work-zone safety procedures and for reducing worker injuries. Some 33 proposals were evaluated by a panel of experts, and 3 promising ideas are currently being developed further.

Significant progress has been made in the development of the Interactive Highway Safety Design Model, a tool with great promise for highway designers.

Ultraviolet (UV) Headlamp Evaluation. FHWA's Traffic and Driver Information Systems Division, Office of Safety and Traffic Operations Research and Development, is conducting an evaluation of UV headlamp technology that is used in conjunction with low-beam headlamps. Prototype UV headlamps were installed on a Volvo 964 and on a Ford Taurus station wagon. The unique facilities and equipment of the TFHRC Photometric and Visibility Laboratory are being used for the evaluation of headlamp output, alignment, and effectiveness.

A preliminary evaluation of UV headlamps yielded promising results: a greater than 40-percent increase in the visibility distance of pavement markings. Current research efforts are focusing on expanded delineation benefits and potential pedestrian safety benefits. Since the UV light is invisible to the human eye, there is very little glare, unlike high-beam headlamps. Highway markings and pedestrians are clearly delineated by the UV light. Standard laundry detergents, which leave a residue on clothes, contain materials that react with the UV light to create visible

Pedestrian safety is a research priority.

light. Pedestrians whose clothing has this residue will be easy to see when exposed to UV light.

At-Grade Intersection Accidents. Efforts to relate multivehicle accidents to highway design elements of at-grade intersections are detailed in a new TFHRC Safety Design Division report entitled *Statistical Models of At-Grade Intersection Accidents* (FHWA-RD-96-125). The models are an important step in developing the Accident Analysis Module within the Interactive Highway Safety Design Model (IHSDM). IHSDM, which interfaces with a computer-aided design package, is composed of five modules related to various aspects of safety: consistency, policy review, traffic, driver-vehicle dynamics, and accident analysis.

Condition-Responsive Work-Zone Traffic Control. TFHRC provided funding and contract management for development of an innovative and portable condition-responsive, work-zone, traffic-control system. The system has been developed through a cooperative agreement between FHWA and the Maryland State Highway Administration. The system's hardware and software components were successfully tested, and it was deployed on an approach to Ocean City, MD, to alert high-speed traffic of stopped or slow-moving traffic ahead. The system collects data on traffic conditions through traffic sensors located before a work zone and analyzes the traffic data to predict delay and to detect dangerously high differential speeds between traffic around a worksite. It also employs the central system controller to select and display appropriate messages on variable message signs to warn drivers of hazardous speeds, lengthy delays, and lane closures.

Human Factors Field Research Vehicle Developed. The Human Factors Field Research Vehicle, recently developed by Veda, Inc., and delivered to FHWA, is a completely self-contained research laboratory. It supports highway safety and ITS research and has the capability of collecting driver performance measures (e.g., lateral placement, acceleration/deceleration, eye movement). With its reconfigurable dashboard, the vehicle has the capability of displaying navigation, route guidance, in-vehicle warnings, and signs in various locations, including a head-up display. At present, programming is underway to ready the car for its first experiment at TFHRC.

Intersection Collision Countermeasure System Installed. The Traffic and Driver Information Systems Division of the Office of Safety and Traffic Operations Research and Development at TFHRC helped make a busy intersection safer by fielding a potentially revolutionary safety warning system. In fall 1997, this new dynamic traffic warning system became operational at the intersection of Aden Road and Fleetwood Drive in Prince William County, VA. The system consists of an advanced intersection sign on the main roadway that is actuated to warn approaching drivers if traffic ahead is turning left.

This intersection was chosen because it suffers from poor sight distance and, although the speed limit is 60 km/h, vehicles on the main road travel at relatively high speeds. Traffic loop sensors were installed on both roadways to detect traffic, and a controller was installed at the intersection to operate the system. The loop-information and sign-activation data will automatically be collected by the system. The evaluation will include conflict counts before and after the signs were installed.

New Software for Accident Data Collection. Recently, advanced data collection technologies (pen-based computers, global positioning systems, and geographical information systems) used in Iowa, New Jersey, Washington, and Wisconsin were evaluated from a benefit/cost perspective. In an ongoing FHWA study, accident data collection techniques that employ an expert systems approach have been developed to work on pen-based computers. Expert system modules are being tested in Iowa to demonstrate how the quality of police-reported accident data can be improved by using the knowledge of experts to guide users through selected parts of the on-scene data collection process.

Advanced Composite Materials. A unique composite traffic barrier was tested at TFHRC's Federal Outdoor Impact Laboratory (FOIL). This barrier is a highway guardrail system constructed of composite material, developed as part of an ongoing cooperative agreement between FHWA and The Catholic University of America. Creative Pultrusions, Inc., supplied the composite material and hand-fabricated the sample rail system used in the test. FOIL's large outdoor pendulum roughly simulated a small- to mid-size automobile colliding with the composite rail system at a speed of 100 km/h and an approach angle of 20° to 25°.

Tests at FOIL focused on impact, behavior, and performance of prototype composite guardrails to be used as roadside barriers. The pendulum tests indicated that it is technically feasible to produce a composite rail that can safely redirect vehicles on the roadside. Still to come are optimization of the rail's cross-section to ensure maximum energy absorption, optimization for manufacturing, subsequent production of prototypes, additional pendulum testing, and full-size vehicle crash testing at the FOIL.

CURBING POLLUTION AND CONSERVING RESOURCES

During the past 6 years, FHWA's Office of Environment and Planning and its Federal Transit Administration counterparts have developed many products and services to support the requirements of the Intermodal Surface Transportation Efficiency Act and the Clean Air Act Amendments. Early in FY 97, the two organizations issued a Planning and Environmental Resources Catalog to guide customers through the vast array of resources in this field. The database has been made available online as a service to the transportation planning and environment community worldwide, as have electronically accessible versions of the documents it references.

In addition, TFHRC continues to research new materials and methods for maintaining highway infrastructures that minimize environmental impact, extend transportation resources, and decrease the effects of pollution.

Testing Recycled Waste Materials Protects the Environment. FHWA is involved in a study exploring the use of waste materials as possible construction and repair materials for highways and the effects that these materials might have on surface water and groundwater quality. At TFHRC, waste materials were selected and collected from concerned groups from several States (California, Florida, Indiana, Massachusetts, Minnesota, Ohio, Oregon, Wisconsin, and the province

TFHRC continues to research new materials and methods that minimize environmental impacts.

Bridge construction practices are observed in Japan on a recent scan tour.

of Ontario) and were sent to Oregon State University for toxicity evaluation. This project was designed to help develop testing procedures that assure that these waste materials could be used without undesired impacts on water quality or to flows in surface water and groundwater. TFHRC has been active in locating and evaluating full-scale field sites, where materials such as foundry sands, scrap rubber tire pieces, coal ash, municipal solid waste ash, blast furnace slag, and phosphogypsum are being or have been used.

This study was an addition to a National Cooperative Highway Research Program investigation being conducted at Oregon State University, which examined the surface water and groundwater impacts of ordinary construction and repair materials such as portland cement concrete. By joining the investigation, FHWA is taking a more active role than usual, recognizing the importance of finding uses for waste materials in highways without undesired impacts to surface water and groundwater.

New Understanding of Particulate Impacts. A study completed this year by the TFHRC Office of Engineering Research and Development concerning the impacts of particulate matter in highway environments has found that most particulate accumulations appear not to be the product of highway operations as many people have presumed. Most seem to be natural deposits of atmospheric dust and dirt. There are certain notable exceptions, such as areas where diesel exhaust is a major factor.

Waste Not What You Can Recycle. FHWA has sponsored a pooled-fund study to investigate the feasibility of using recycled materials in such roadside appurtenances as guardrail posts, noise barriers, and posts for right-of-way fences. This State Planning and Research pooled-fund study is being funded by 14 States. The contractor, Southwest Research Institute, has conducted a series of pendulum tests at the TFHRC Federal Outdoor Impact Laboratory on prototype guardrail posts made by various manufacturers of recycled plastic products. It was found that none of the prototype recycled posts had the fracture energy characteristics necessary for use in strong-post guardrail systems. In another test, eight sections of a noise wall made of various recycled plastic products were erected in 2 days by a three-person crew without any special equipment. The evaluation of these roadside appurtenances under various environmental conditions is continuing.

EXPANDING PARTNERSHIPS IN TRANSPORTATION

The increasing complexity of transportation research and the expanding global society require open sharing of research results and of new technologies to improve mobility and advancement for all. Reaching out to global partners benefits both sides participating in technological exchanges. TFHRC researchers rely on private, public, and international partners to share costs, expertise, and solutions to transportation problems.

FHWA Signs Cooperative Research Agreement With GEOPAK Corporation. TFHRC and GEOPAK Corporation, a leading developer of civil engineering software, have signed a cooperative research agreement, reaching a critical milestone in the development of the Interactive Highway Safety Design Model (IHSDM). When completed, IHSDM will give highway planners and designers the opportunity to evaluate the safety implications of alternative highway designs within a computer-aided design environment. Now in prototype development, IHSDM focuses on two-lane rural roads. GEOPAK is the first vendor to agree to integrate IHSDM into its civil design software package. This agreement will accomplish an important goal of IHSDM—providing roadway planners and designers with a format that is easy to learn and to use in all commonly used computer-aided design/civil design software.

FHWA Signs Cooperative Research Agreement With Institut National de Recherche sur les Transports et leur Sécurité (INRETS). In January 1997, FHWA and INRETS of France entered into a cooperative research agreement on expert systems research. The goals of the agreement are to perform independent evaluation of the expert system CLAIRE: A Context-Free AI-Based Supervisor for Traffic Control, developed under INRETS sponsorship; to certify mathematical correctness for the verification, validation, and evaluation of expert systems developed by FHWA; and to prepare direction for expert systems development on the basis of existing engineering research.

Part of the research on expert systems is being conducted at TFHRC through the Advanced Research Team, Office of Safety and Traffic Operations Research and Development, and part at INRETS in Paris, under the direction of the Department of Applied Mathematics and Artificial Intelligence. FHWA and INRETS plan to write a joint report on the results of the evaluation.

FHWA and Japanese Agency Renew Pact on Information Exchange. On August 4, TFHRC held the latest in a series of workshops for delegates from the Japanese Government Public Works Research Institute (PWRI) and the Japanese Ministry of Construction (MOC). This environmentally focused workshop addressed noise environment and mitigation, ways to make roads smoother and safer, and methods to reduce environmental impact.

In October 1996, FHWA signed an agreement with PWRI under the general umbrella of the "U.S./Japan Science and Technology Agreement," creating a direct arrangement between the U.S. Department of Transportation and MOC. This agreement is a renewal of a 5-year pact between Japan and the United States that provides for the exchange of highway transportation and safety-related information and technology. The two countries share information on bridge design and wind engineering, pavements, bridge maintenance, tunnel safety, earthquake and geotechnical engineering, intelligent transportation systems, traffic safety, and the environment.

SUMMARY OF ACHIEVEMENTS: MEETING GOALS, ADVANCING PRIORITIES

Throughout the year, TFHRC moved steadily toward a clear set of goals through the efforts of its personnel, laboratories, and public and private partners across the United States and around the world. Significant progress was achieved across a broad range of fronts—from developing new technologies and materials, such as high-performance steels and concrete to advances in intelligent transportation systems (ITS) and to the development and deployment of important collision-avoidance systems and other safety technologies to make highways and bridges more secure for America's highway users.

Mutually productive partnerships were expanded with public, private, and international organizations and highway industry professionals. TFHRC's professional staff continued their traditionally active role on key boards and committees of professional organizations and societies, and the research center benefited from exchanges with visiting scholars and highway technology researchers. Notable publications advanced the state of the art and the state of the practice in highway technologies in key areas, including flexible pavement structures, long-term pavement performance, intersection safety, composite materials, bridge scour simulation, and Superpave testing. Important prototypes were fielded, including an innovative intersection collision countermeasures system, and landmark products were introduced, including a tough new grade of high-performance steel known as HPS-70W.

Mutually productive partnerships were expanded with public, private, and international organizations and highway industry professionals.

Platooning vehicles operate in the express lanes for Demo '97 in San Diego, CA.

Progress continued for ITS, and automated highway systems technology was demonstrated live for key transportation decision-makers. In the Midwest, a TFHRC-managed research team averted potential loss of life by identifying dangerous bridge scour only hours before a highway approach span collapsed. Many TFHRC achievements like these have been recognized with awards in FY 97 within the highway community.

TFHRC advanced its mission as a research organization by operating as a source of critical technologies for both national and international highway agencies and industries. While advancing both enabling technology and program-oriented technology, TFHRC has worked to avoid redundancy of efforts. The immediate importance of satisfying specific customer needs was productively combined with an emphasis on primary research and development. A "good product" is considered to be the primary achievement of TFHRC, whether it is a product of staff research or contract activities. Among the objectives pursued toward this end were the following:

- To make sure that all TFHRC programs and facilities serve our customers well.
- To maintain a reasonable balance among near-term, applied, and long-term basic research.
- To maintain a reasonable balance between staff research and contract research.
- To place emphasis on "development" of concepts and technologies within the research and development mission.

While the ultimate "customers" of TFHRC research and development output are the traveling public, the value of TFHRC products is determined primarily by our partners. These intermediaries in the chain between our laboratories and the roadway are private and academic organizations and public agencies that use the output of TFHRC programs to meet pressing needs, overcome short-term obstacles, and solve long-term problems.

Often, recognition of TFHRC's vital role is lost or forgotten in the lengthy process from research and development to implementation. For that reason and from a sincere desire to determine whether we are meeting our goals, TFHRC launched an effort this summer to create processes and procedures for measuring our success in serving our customers. Criteria for a benchmarking process have been identified, and suitable public- and private-sector organizations have been short-listed as a benchmark.

The process of measuring success is more subtle for a nonprofit Government laboratory organization than it is for commercial enterprises. Consequently, TFHRC has begun consulting with other similar public-sector laboratories and agencies that have already invested considerable time in developing successful performance measurement systems. In this way, TFHRC intends to improve service, refine operations, maximize resource usage, and increase achievements in coming years.

tfhrc research laboratories

Human Factors Laboratories
- Highway Driving Simulator
- Human Factors Field Research Vehicle
- Photometric and Visibility

Intelligent Transportation Systems Laboratories
- Saxton Highway Electronics
- Traffic Research

Working with high-performance steel in the Structures Lab.

Pavements Complex
- Bituminous Mixtures
- Chemistry
- Chromatography
- Concrete
- Instrumented Test Roadway
- Materials Characterization
- Pavement Binders
- Pavement Facility
- Pavement Surface Analysis
- Pavement Testing Facility
- Petrographic

Safety Laboratories
- Federal Outdoor Impact Lab
- FHWA/NHTSA National Crash Analysis Center
- Geometric Design
- Highway Safety Information System

Structures Laboratories
- Aerodynamics
- Bridge Management Information Systems
- Concrete Lab Complex
- Geotechnical
- Hydraulics
- Nondestructive Evaluation (NDE)
- NDE Validation Center
- Paint and Corrosion
- Structures

Support Services
- Graphics
- Mechanical Design/Fabrication

reports and periodicals

Office of Safety and Traffic Operations Research and Development

Advanced Research Team

RD-95-100 Detection Technology for IVHS, Final Report
RD-96-109 Detection Technology for IVHS, Vol. II: Final Report Addendum

Intelligent Systems and Technology Division

RD-96-126 Systems Planning for Automated Commercial Vehicle Licensing and Permitting Systems: National ITS/CVO Program Requirements
RD-96-139 Opportunities for Advanced Vehicle Control Systems in Commercial Vehicle Operations and Public Transportation Systems
RD-97-145 FHWA Federal-Aid ITS Procurement Regulations and Contracting Options

Safety Design Division

RD-93-058 Testing of New Bridge Rail and Transition Designs, Vol. I: Technical Report
RD-93-059 Testing of New Bridge Rail and Transition Designs, Vol. II: Appendix A
RD-93-060 Testing of New Bridge Rail and Transition Designs, Vol. III: Appendix B
RD-93-061 Testing of New Bridge Rail and Transition Designs, Vol. IV: Appendix C
RD-93-062 Testing of New Bridge Rail and Transition Designs, Vol. V: Appendix D
RD-93-063 Testing of New Bridge Rail and Transition Designs, Vol. VI: Appendix E
RD-93-064 Testing of New Bridge Rail and Transition Designs, Vol. VII: Appendix F
RD-93-065 Testing of New Bridge Rail and Transition Designs, Vol. VIII: Appendix G
RD-93-066 Testing of New Bridge Rail and Transition Designs, Vol. IX: Appendix H
RD-93-067 Testing of New Bridge Rail and Transition Designs, Vol. X: Appendix I
RD-93-068 Testing of New Bridge Rail and Transition Designs, Vol. XI: Appendix J
RD-93-069 Testing of New Bridge Rail and Transition Designs, Vol. XII: Appendix K
RD-93-156 Testing of New Bridge Rail and Transition Designs, Vol. XIII: Appendix L
RD-93-157 Testing of New Bridge Rail and Transition Designs, Vol. XIV: Appendix M
RD-96-026 Experimental and Numerical Simulation of Glass Fiber-Reinforced Composites for Roadside Safety Structures
RD-96-027 Safety Data: Costs, Quality, and Strategies for Improvement
RD-96-032 Crash Testing and Evaluation of Retrofit Bridge Railings and Transition
RD-96-039 Evaluation of Accident Analysis Methodology
RD-96-040 Measuring the Goodness-of-Fit of Accident Prediction Models

RD-96-059 Preliminary Vehicle Impact Simulation Technology Advancement

RD-96-075 Workshop on Development of the Interactive Highway Safety Design Model (IHSDM)

RD-96-081 Experimental Plans for Accident Studies of Highway Design Elements

RD-96-100 HSIS Summary Report: Investigation of Highway Work-Zone Crashes

RD-96-104 Bicycle Crash Types: A 1990's Informational Guide

RD-96-108 Characterizing Roadside Hardware Materials for LS-DYNA3D Simulations

RD-96-125 Statistical Models of At-Grade Intersection Accidents

RD-96-141 Indirect Methods to Account for Exposure in Highway Safety Studies

RD-96-199 NCHRP Report 350 Compliance Test 5-12 of the 1.07-m Vertical Wall Bridge Railing

RD-96-201 NCHRP Report 350 Compliance Test of the New Jersey Safety-Shaped Barrier

RD-96-212 FHWA Vehicle Crash Analysis Conference Proceedings

RD-97-027 Safety Effects of Cross-Section Design on Rural Multilane Highways

RD-97-078 Pendulum Testing of Fixed-End W-Beam Guardrail: FOIL Test Numbers 96P001, 96P002, 96P003, 96P004, 96P005, and 96P006

Traffic and Driver Information Systems Division

RD-94-145 Pavement Markings and Delineation for Older Drivers, Vol. I: Final Report

RD-95-014 Human Factors of In-Vehicle Driver Information Systems, Executive Summary

RD-95-118 Pavement Markings and Delineation for Older Drivers, Vol. II: Executive Summary

RD-95-176 Development of Human Factors Guidelines for Advanced Traveler Information Systems and Commercial Vehicle Operations: Task Analysis of ATIS/CVO Functions

RD-95-194 An Investigation of Older Driver Freeway Needs and Capabilities

RD-96-066 Drivers' Activities and Information Needs in an Automated Highway System

RD-96-067 Driver's Response to an Automated Highway System With Reduced Capability

RD-96-122 Human Factors Handbook for Traffic Management Center Design

RD-96-132 Intersection Geometric Design and Operational Guidelines for Older Drivers and Pedestrians, Vol. I: Final Report

RD-96-137 Intersection Geometric Design and Operational Guidelines for Older Drivers and Pedestrians, Vol. III: Guidelines

RD-96-138 Intersection Geometric Design and Operational Guidelines for Older Drivers and Pedestrians, Vol. II: Executive Summary

RD-96-161 Delineation of Hazards for Older Drivers, Vol. I: Final Report

RD-96-162 Delineation of Hazards for Older Drivers, Vol. II: Appendixes

RD-96-183 Presenting Hazard Warning Information to Drivers Using an Advanced Traveler Information System

RD-96-187 Visibility and Comprehension of Pedestrian Traffic Signals

RD-97-002 Effects of Raising and Lowering Speed Limits on Selected Roadway Sections

RD-97-033 Safety Evaluation of Ultraviolet-Activated Fluorescent Roadway

RD-97-034 Rural Applications of Advanced Traveler Information Systems: User Needs and Technology

RD-97-042 Rural Applications of Advanced Traveler Information Systems: Recommended Actions

RD-97-074 Minimum Sign Retroreflective Guidelines

RD-97-096 The Visibility and Comprehension of Pedestrian Traffic Signals

Office of Engineering Research and Development

Pavement Performance Division

RD-93-091 Methane Conversion for Highway Fuel Use (Methanol Plantship Project), Vol. I: Final Report

RD-94-177 Performance of Concrete Pavements, Vol. I: Field Investigation

RD-95-172 Load Transfer for Drilled Shafts in Intermediate Geomaterials

RD-96-016 Drilled and Grouted Micropiles: State-of-Practice Review, Vol. I: Background, Classifications, Cost

RD-96-017 Drilled and Grouted Micropiles: State-of-Practice Review, Vol. II: Design

RD-96-018 Drilled and Grouted Micropiles: State-of-Practice Review, Vol. III: Construction, QA/QC, and Testing

RD-96-019 Drilled and Grouted Micropiles: State-of-Practice Review, Vol. IV: Case Histories

RD-96-198 Long-Term Pavement Performance Data Analysis, Phase I: Validation of Guidelines for k-Value Selection and Concrete Pavement Performance Prediction

RD-96-208 Pavement Treatment Effectiveness, 1995 SPS-3 and SPS-4 Site Evaluations

RD-96-211 Long-Term Pavement Performance, "The Bottom Line," Vol. I, No. 1 (October 1996)

RD-97-001 Long-Term Pavement Performance Information Management System Data Users Reference Manual

RD-97-043 Long-Term Pavement Performance Status Report

RD-97-067 Contract Management Techniques for Improving Construction Quality

RD-97-072 Analysis of Pavement Structural Variability

RD-97-073 Pavement Primary Response to Dynamic Loading

RD-97-076 Design Pamphlet for the Backcalculation of Pavement Layer Moduli in Support of the 1993 AASHTO Guide for Design of Pavement Structures

RD-97-077 Design Pamphlet for the Determination of Layered Elastic Moduli for Flexible Pavement Design in Support of the 1993 AASHTO Guide for Design of Pavement Structures

RD-97-083 Determination of Design Subgrade Moduli in Support of the 1993 AASHTO Guide for Design of Pavement Structures

RD-97-086 Backcalculation of Layer Moduli of Long-Term Pavement Performance General Pavement Study Sites

Special Projects and Engineering Division

RD-94-121 Laboratory Development of Third/Fourth-Generation Sulphlex Binders

RD-94-177 Performance of Concrete Pavements, Vol. I: Field Investigation

RD-96-058 Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges

RD-96-095 Retention, Detention, and Overland Flow for Pollutant Removal From Highway Storm Water Runoff, Vol. I: Research Report

RD-96-096 Retention, Detention, and Overland Flow for Pollutant Removal From Highway Storm Water Runoff, Vol. II: Design Guidelines

RD-96-097 Protective Systems for Spills of Hazardous Materials, Vol. I: Final Report

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RD-96-073	Galvanic Cathodic Protection of Reinforced Concrete Bridge Members Using Sacrificial Anodes Attached by Conductive Adhesives, Interim Report
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RD-96-207	Corrosion Protection Systems for Bridges in Corrosive Environments
RD-97-030	High-Performance Concretes: A State-of-the-Art Report (1989-1994)
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