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COVER: Lake Street-Marshall Avenue bridge near St. Paul Minesota

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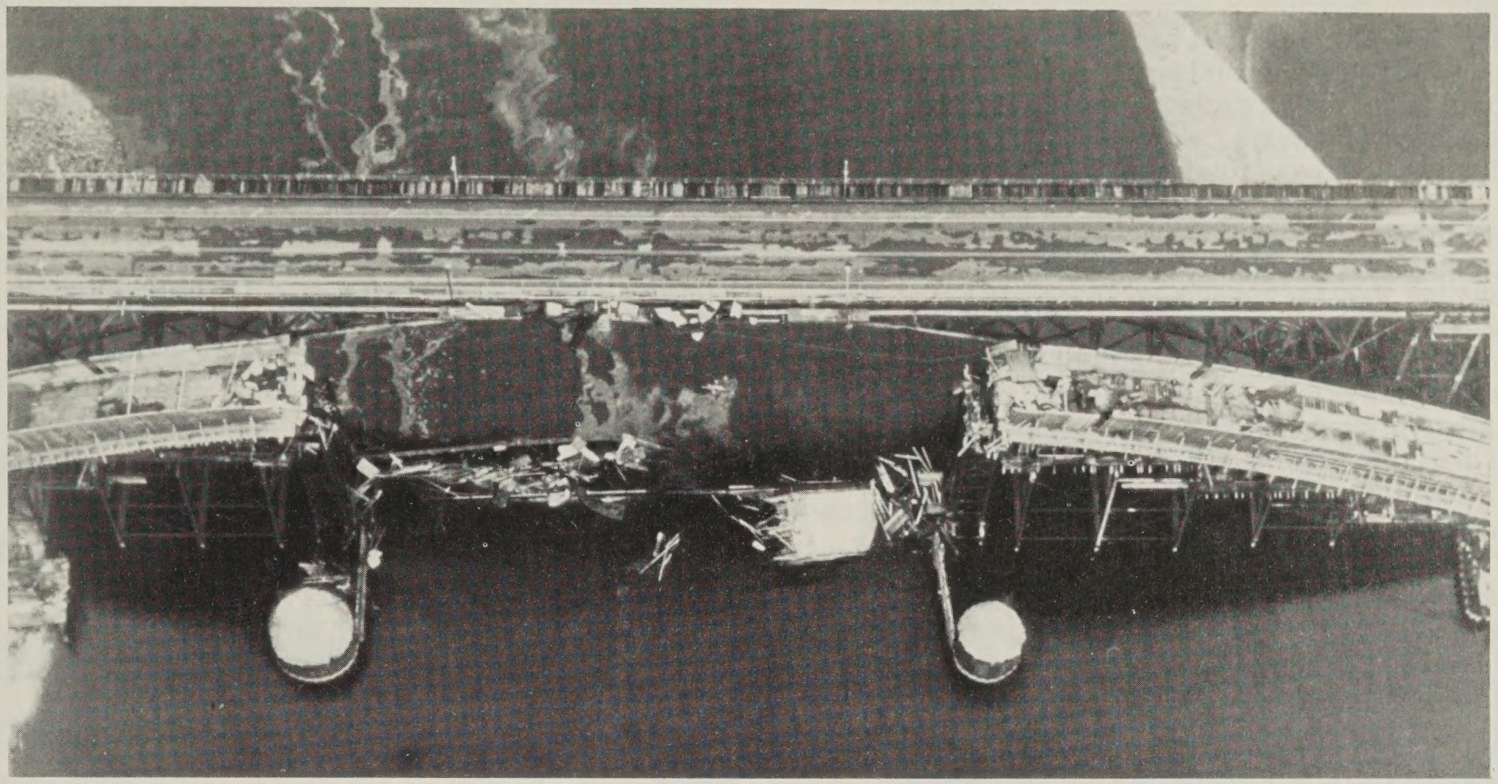
The Secretary of Transportation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.



Bridge Temporary Works Research Program

by Sheila Rimal Duwadi, P.E.

Introduction

On August 31, 1989, the Route 198 bridge over the Baltimore-Washington Parkway collapsed, injuring nine workmen and five commuters—one critically—when 400 tons (363 Mg) of steel and concrete fell on the parkway without warning (figure 1). The collapse was subsequently and independently investigated by the Federal Highway Administration's (FHWA's) Federal Lands Division and a private consultant. Upon completion of the investigation, the FHWA Administrator established an impartial board of review to study and evaluate all aspects of the two investigations, determine the basic cause for the failure, and provide recommendations to prevent future occurrences. The board members represented Federal and State governments and private industry.

Based on the reports submitted by the investigators, the board concluded that the failure probably ocurred because the shoring tower assemblies were not constructed in accordance with the falsework plans approved by the Federal Lands Division. (*1*)[1] The board went on to recommend that, to prevent such occurrences in the future, falsework specifications should be revised to better define the responsibilities of material suppliers, contractors, and engineers.

This recommendation was signed into law by the Department of Transportation and Related Agencies Appropriations Bill of Fiscal Year 1991, which states in part that ". . . the Committee on Appropriations directs the Federal Highway Administration to undertake the research project recommended in the report entitled 'Investigation of Construction Failure Maryland Route No. 198 Bridge Over the Baltimore-Washington Parkway'" (*2*)

Figure 1.—Collapsed Route 198 overpass on the Baltimore-Washington Parkway.

[1]Italic numbers in parentheses identify references on page 40.

The bill goes on to specify that the research project should produce approved guidelines, improved specifications, and a falsework construction handbook. The guidelines and specifications should apply both to construction projects under direct FHWA supervision and those carried out by the States with Federal-aid highway funds. (*2*)

Given the complexity of the work involved in developing a specification, the Committee has set a final due date of December 1992 for the research program's report. This article describes recent falsework failures since the Baltimore-Washington Parkway incident which emphasize the even greater need for better guidelines on bridge temporary works and progress to date in fulfilling the Committee's research program mandate.

Recent Falsework Failures

Several other collapses have occurred since the Baltimore-Washington incident. These recent failures have motivated the task group in their mission. They are described below:

- On April 24, 1990, falsework for the Lake Street-Marshall Avenue bridge near St. Paul, Minnesota, collapsed, killing one worker (figure 2). An estimated 300 tons (272 Mg) of steel and 1,100 (998 Mg) tons of concrete fell into the Mississippi River. According to the State bridge engineer, the failure was related to human design error. (*3*)

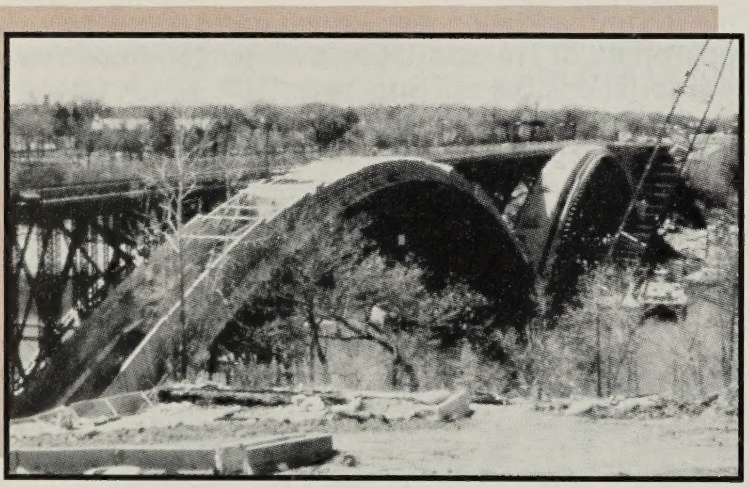


Figure 2.—Lake Street-Marshall Avenue bridge near St. Paul Minnesota.

- On June 18, 1990, the falsework supporting one section of a 63-ft (19.15-m) welded plate tub girder being erected at N 370 and U.S. 75 in Bellevue, Nebraska, collapsed, dropping the girder. There were no injuries. Investigation and analysis showed that the collapse was initiated by lateral loads on the false work caused by strong southwest winds. The failure of the falsework was progressive, ending with the collapse of the girder. (*4*)
- On July 13, 1990, the U.S. 45 bridge under construction over Spring Brook in Antigo, Wisconsin, collapsed as placement of deck concrete was nearing completion. The cause of the collapse is believed to be shear failure of the 48 bolts connecting the deck form supports to substructure abutment walls. This initial failure led to subsequent shear failure of all but one of the remaining bolts. (*5*)
- On October 10, 1990, a section of the superstructure falsework for an elevated connector ramp of the I-880/SR 238 interchange in San Leandro, California, collapsed (figures 3 and 4). Three workers were injured but there were no fatalities. The accident occurred during the erection of a falsework beam over an existing ramp. The cause of the collapse is being investigated by the California Department of Transportation and the California Department of Occupational Safety and Health. (*6*)

Figure 3.—I 880 and SR 238 interchange before collapse.

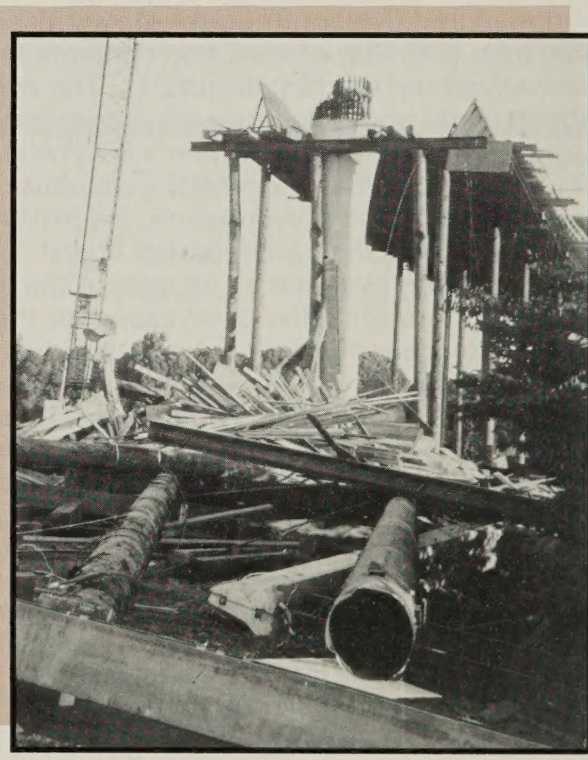


Figure 4.—I 880 and SR 238 interchange after collapse.

Research Program

In March 1990, the FHWA established a multidisciplinary Scaffolding, Shoring, and Forming Task Group to develop and guide the mandated falsework research program. The task group includes representatives from the FHWA, the American Association of State Highway and Transportation Officials (AASHTO), the Associated General Contractors, the American Road and Transportation Builders Association, the Transportation Research Board, and the Scaffolding, Shoring, and Forming Institute.

The first meeting of the task group was held on April 17, 1990. During this meeting the task group identified the following as priority activities:

- Survey existing specifications on bridge temporary works, synthesize them, and identify any gaps.
- Establish a standard construction specification dealing with bridge temporary works.
- Develop a comprehensive design manual on temporary works for bridges.
- Develop recommendations for industry guidelines for a certification program on suppliers' products.
- Develop a construction manual.

The scope of these activities and progress to date in each of these areas is delineated in the following sections and shown in figure 5.

Survey existing specifications

The first task of the research program is to survey and locate all existing information on temporary works for bridges. To perform this work the task group let a 4–month contract, administered by the FHWA and conducted from January to April 1991.

The study synthesizes all existing codes and specifications dealing with bridge temporary works in the United States and abroad; it also identifies gaps and inconsistencies in these specifications. This study forms the basis for other research program activities, such as the development of the design specification and the construction manual. (7)

Establish standard specification

The task group has developed a standard specification for bridge temporary works which will soon be issued by the FHWA. Among other issues, the specification sets out the following requirements and responsibilities:

- The contractor is responsible for designing and constructing safe and adequate temporary work systems.
- The contractor is responsible for selecting material suitable for falsework, subject to the approval of the owner's engineer.
- Falsework design must conform to that specified in the *Design Manual on Temporary Works for Bridges,* which is now being developed.
- The contractor shall prepare working drawings under the guidance of a registered professional engineer.
- The contractor shall certify that the manufactured devices have been maintained in a condition to carry their rated loads safely.
- Each piece of the manufactured device shall be clearly marked so that its rated capacity can be readily determined at the jobsite.

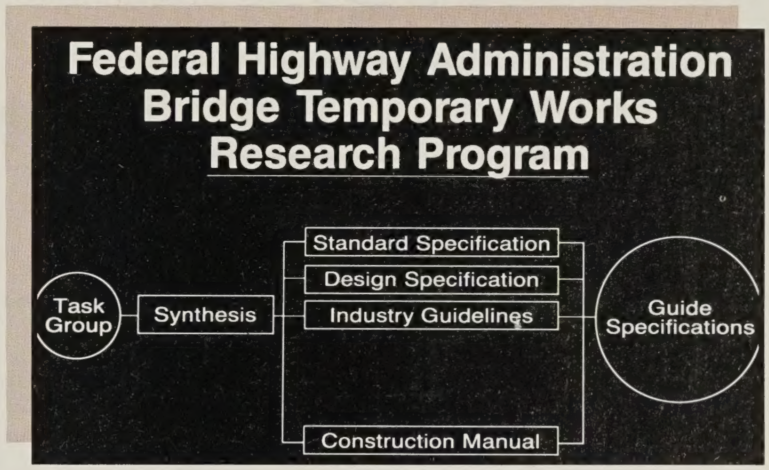


Figure 5.—FHWA Bridge Temporary Works Research Program.

Develop design manual

In recognition of the need for a clear, practical design specification based on the best current technology, the task group has developed an outline for a *Design Manual on Temporary Works for Bridges.* The manual will address design considerations regarding such temporary structures as scaffolding, shoring, forming, and cofferdams. The manual will include comprehensive commentary to identify the origin and clarify the intent of key provisions. The *AASHTO Standard Specification for Highway Bridges, Division I, Design* will be used as a model in developing the *Temporary Works* manual.

Develop recommendations for industry guidelines

The private industry members of the task group were asked to develop a set of criteria for a certification program on equipment used on bridge temporary works acceptable to the industry. They responded that a certification program was not needed, rather the codes of the American National Standards

Institute and the Occupational Safety and Health Administration would be acceptable standards for incorporation into our specifications. The task group has determined these codes are not applicable to bridge construction, since these were originally written for building construction.

The task group sees a definite need to develop a certification/quality control program for products supplied to job sites. This would include the manufacturer if the manufacturer is the supplier.

Develop construction manual

The last task to be performed under the research program is the development of a bridge temporary works construction manual. Because some States have comprehensive construction manuals, this task has been deferred until the task group can determine if it is necessary to develop an original manual or an existing State manual can be adopted for use.

Summary

The collapse of the falsework on the Route 198 overpass over the Baltimore-Washington Parkway precipitated an official recommendation that the FHWA develop better specifications and guidelines. Several subsequent falsework collapses—some design-related, others the result of poor construction practices—have underscored the need for such specifications and guidelines.

The end products of the FHWA program will be a synthesis of all codes and specifications dealing with the subject, a standard specification, and a design manual on bridge temporary works with comprehensive commentaries, and—if necessary—a construction manual. These products are being developed with input from representatives of AASHTO, private industry, and the FHWA. The work of the task group should be completed by December 1992.

Scaffolding, Shoring, and Forming Task Group

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American Association of State Highway and Transportation Officials
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References

(*1*) FHWA Board of Review. *Report of the Investigation into the Collapse of the Route 198 Baltimore-Washington Parkway Bridge*, Publication No. PR-90-001, Federal Highway Administration, Washington, DC, December 1989.

(*2*) "Investigation of Construction Failure Maryland Route No. 198 Bridge Over the Baltimore-Washington Parkway," Department of Transportation and Related Agencies Appropriations Bill, Senate Report No. 101-398, 101st Congress, 2nd Session, 1991.

(*3*) "Falsework Design Takes Rap," *Engineering News-Record,* Vol. 225, No. 15, October 11, 1990, p. 13.

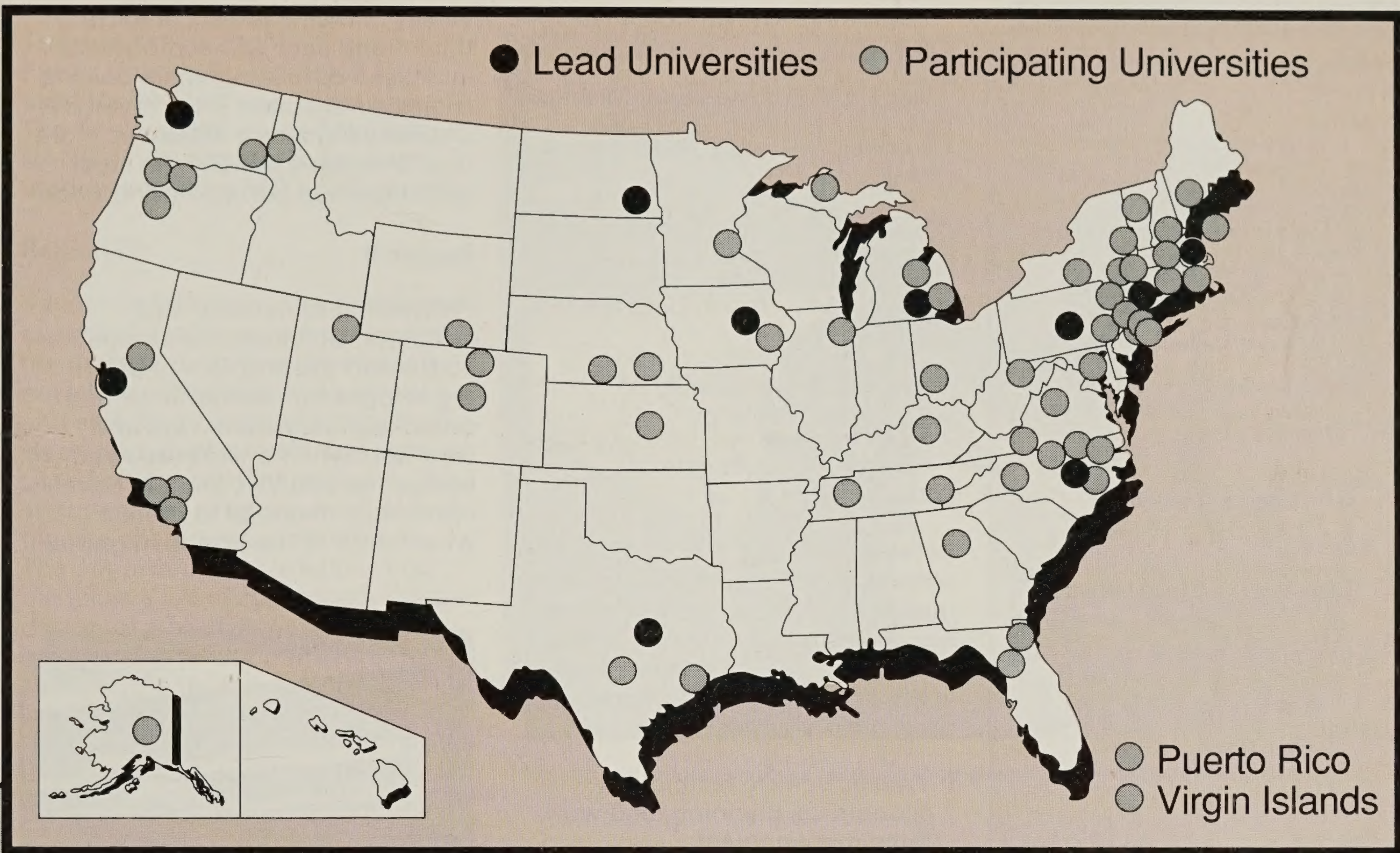
(*4*) *Bellevue Interchange, Phase 2, Investigation of Falsework Failure*, Publication No. F-370-7(113), Wells Engineers, Inc., Omaha, NE, September 5, 1990.

(*5*) The FHWA Weekly Report to the Secretary of the Department of Transportation, Federal Highway Administration, Washington, DC, July 20, 1990.

(*6*) The FHWA Weekly Report to the Secretary of Department of Transportation, Federal Highway Administration, Washington, DC, October 12, 1990.

(*7*) *Synthesis of Falsework, Formwork, and Scaffolding for Highway Bridge Structures*, Publication No. FHWA-RD-91-062, Federal Highway Administration, Washington, DC, September 1991.

Sheila Rimal Duwadi is a research structural engineer in the Structures Division, Office of Engineering and Highway Operations Research and Development, Federal Highway Administration (FHWA). Ms. Duwadi is a graduate of the FHWA Highway Engineer Training Program. She has a masters degree in civil engineering from Oregon State University and a bachelors degree from Washington State University. Her primary responsibilities are the Timber Bridge and Temporary Works research programs. She is a registered professional engineer in the State of Virginia.



University Transportation Centers Program

Education and Research for the 21st Century

by Harry H. Hersey

Introduction

Thomas D. Larson, Federal Highway Administrator, in the 1991 Francis C. Turner Lecture, described innovation as "the introduction of something new, something that deviates from established doctrine or practice, from existing forms in the technical, economic, or social spheres." The University Transportation Centers Program exemplifies this concept and represents the Federal Highway Administration's (FHWA's) commitment to developing and promoting innovative problem- solving methods for the transportation community. Specifically, this program (again in the words of Thomas Larson) reaches out "to the university community to bring in a bright new generation of transportation leaders."

The Department of Transportation started the University Transportation Centers Program in 1988. Two years later, the Department promoted increased educational activities in the program to develop highly skilled and knowledgeable professionals who could address transportation problems from a broad multimodal and multidiscipilinary perspective.

The program's work is conducted at 10 regional centers, several Advanced Institutes throughout the country, and 3 newly proposed National Centers for Transportation Management, Research, and Development. This article presents an overview of ongoing and planned program activities occurring at these centers and institutions.

Regional Centers

Most of the work performed under the University Transportation Centers Program takes place at the 10 regional centers. These centers, which operate under competitively procured grants are consortiums led by the following universities:

- Region I—Massachusetts Institute of Technology.
- Region II—City University of New York.
- Region III—Pennsylvania State University.

University Transportation Centers

Region I
University Transportation Research Center
Director
Tom Humphrey,
Mass. Institute of Technology
(617) 253-4978

Region II
University Transportation Research Center
Director
Neville Parker,
City University of New York
(212) 690-8393

Region III
Mid-Atlantic Universities Transportation Center
Director
James Miller,
Pennsylvania State University
(814) 863-1909

Region IV
Southeastern Consortium of Univ. Trans. Centers
Director
Gorman Gilbert,
University of North Carolina
(919) 878-8080

Region V
Great Lakes Center for Truck Transportation Research
Director
Thomas D. Gillespie,
University of Michigan
(313) 936-1064

Region VI
Southwest Region University Transportation Center
Director
Conrad Dudek,
Texas A&M University
(419) 845-1727

Region VII
Midwest Transportation Center
Director
Thomas H. Maze,
Iowa State University
(515) 294-8103

Region VIII
Mountain-Plains Consortium
Director
Gene Griffin,
North Dakota State University
(701) 237-7767

Region IX
Transportation Research Center
Director
Mel Webber,
University of California
(415) 642-4874

Region X
Transportation Northwest (TransNow)
Director
Nancy K. Nihan,
University of Washington
(206) 543-8268

- Region IV—University of North Carolina.
- Region V—University of Michigan.
- Region VI—Texas A&M University.
- Region VII—Iowa State University.
- Region VIII—North Dakota State University.
- Region IX—University of California, Berkeley.
- Region X—University of Washington.

Between FY 1988 and FY 1990, the centers together received approximately $20 million. With this funding, the centers started 15 educational programs. The universities in the program initiated research projects in the following areas:

- *Transit:* vehicle technology, economics, planning, and work force management.
- *Railroad:* economics, planning, productivity, and high-speed rail.
- *Maritime:* landside operations of ports.
- *Multimodal:* hazardous materials, planning, and intermodal trips.
- *Highway:* intelligent vehicle-highway systems (IVHS), safety, traffic operations, economics, planning, pavements, structures, materials, environment, and heavy trucks.

Highlights of various programs in these research areas are presented in the next section.

Success Stories from the Regional Centers

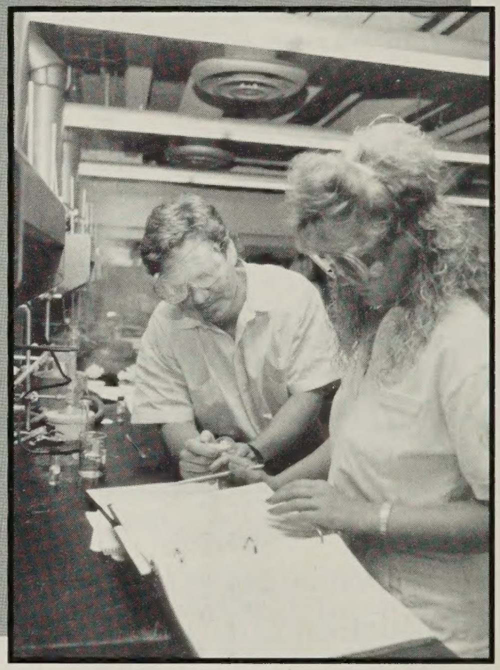
Key accomplishments of the University Transportation Centers Program follow.

Region I

The Maine Department of Transportation has decided to build an experimental bridge with reduced isotropic (i.e., equal in both directions) deck reinforcement. A University of Maine project predicts this bridge deck will demonstrate increased durability where deicing chemicals are used. The Province of Ontario estimates it has saved more than $1 million annually in steel reinforcement costs with this deck.

Region II

Polytechnic University and Princeton University have together addressed the problem of prioritizing bridges for maintenance and rehabilitation in New York and New Jersey. The work involved bridge risk analysis and the development of methods to predict when parts of the bridge might fail.



Laboratory facilities at Texas A&M University.

Region III

Morgan State University, a minority institution, has continued to improve its highly successful and innovative career development and training project. This project recruits and places minority students in internships with State and local transportation organizations.

Researchers at the West Virginia university have developed a microcomputer program to determine if trucks with low ground clearances will hang up at railroad grade crossings of various profiles. The West Virginia Department of

Transportation and the Oregon Public Utilities Commission have used the program on a trial basis. The final version of the program, HANGUP, is planned to be distributed through the McTRANS Center.

Region IV

Vanderbilt University has developed an expert system to advise personnel in State departments of transportation in the task of warranting and selecting roadside safety hardware. The expert system is composed of two primary modules—the appurtenance selection module and the site characterization module. The appurtenance selection module takes a list of constraints on the design of a roadway and searches for roadside safety hardware that satisfies the design constraints. After the search produces a set of technically feasible solutions, the best alternative is recommended on the basis of least installed cost.

Faculty and students discuss transportation alternatives at Texas Southern University.

Region V

The University of Michigan has found that a good design for truck weigh-in-motion systems is to use three sensors spaced evenly along a road. The load-estimating errors for such a system are one-third to one-half that of a single-sensor system.

Region VI

Texas Southern University, a minority institution, is studying a variety of mass transportation options—including high-occupancy vehicles facilities—to redevelop an old railroad corridor. The resulting facility would improve mobility in this Houston corridor.

Region VII

A University of Iowa study has found that the damage done to pavements by trucks is more a function of pavement roughness than was previously expected. This finding may lead to increased maintenance to keep pavement surfaces smooth and increase pavement life on highways with a high volume of heavy trucks.

Region VIII

The University of Wyoming has developed a computer program that enables an expert to prepare a data input template for complex computer programs. Using the template to enter data is much simpler than creating the data file directly, thereby permitting less experienced or infrequent users to enter data without taking extensive time to learn complex procedures. The American Association of State Highway and Transportation Officials (AASHTO) Bridge Design

The Pennsylvania State University.

System Task Force has requested that the University of Wyoming team develop a production version of the program for use with the Bridge Design System.

Researchers at the University of Wyoming and the Wyoming Highway Department have developed improved equations for predicting the resilient modulus of soils in the Rocky Mountain and Great Plains regions. These equations yield resilient modulus as a function of soil type, the state of stress in the pavement, the degree of soil saturation, and the resistance value. The improved prediction equations will provide State highway department officials in the North Central Region with reliable information on the resilient modulus of representative subgrade soils. This will enable them to make informed decisions on how to incorporate the recommendations of the *AASHTO Guide for Design of Pavement Structures* into their pavement design procedures.

Region IX

The University of California studies performed in the wake of the October 17th California earthquake highlighted the importance of redundancy in the transportation network. Alternative transportation routes to the closed San Francisco Bay Bridge included Bay Area Rapid Transit (BART), the quickly installed ferries, and the other bridges across San Francisco Bay.

In the Los Angeles area, the South Coast Air Quality Management District has imposed the Nation's first regulation aimed at improving air quality by modifying commuter behavior. Employers are required to reduce morning peak-period auto trips by providing incentives for alternative travel methods.

The Region IX center research project seeks to determine which incentives work best in changing travel behavior. Parking subsidies provide an example of how the program works. The researchers proposed that the District require those employers that provide a parking subsidy to also provide an alternative cash equivalent subsidy. Thus, the employee would have a choice between receiving a parking subsidy or cash to use toward alternative modes of transportation.

Region X

According to a Portland State University study, using automatic passenger counters to sample and estimate transit ridership promises to reduce sampling requirements and costs by over 30 percent.

The University of Washington is developing a real-time commuter information system for the Puget Sound area. The system, called Traffic Reporter, presents current information on freeway travel time and speed through a microcomputer equipped with a modem and mouse. The monitor screen shows a selected portion of a freeway with speed ranges identified by different colors. The mouse may be used to select an entry ramp and an exit ramp on the screen and Traffic Reporter will display the latest travel time and average speed between the selected ramps. This and other features will enable commuters to select the most favorable routes before leaving their homes or offices.

University of Texas at Austin.

Advanced Institutes

The Advanced Institutes of the University Transportation Centers Program expand graduate-level transportation education in the United States and advance the state of transportation knowledge within a particular area of concentration. Following are brief descriptions of some of the Advanced Institutes and their areas of concentration.

The Advanced Institute for Intelligent Commercial Vehicle Highway Systems at the University of Michigan has chosen to concentrate its education and research programs on two categories of IVHS technology. The first is advanced traveler information systems for buses and heavy trucks. The second is freight and fleet control operations. The Institute has focused on these categories because they hold the most promise for improving the productivity of commercial vehicles in future years.

The Vanderbilt Information Systems in Transportation Academy (VISTA) at Vanderbilt University is designed to provide advanced education in IVHS in the area of transportation information management and decision support. In addition to IVHS, Vanderbilt's program covers information systems related to environmental protection and vehicle and system safety.

The Advanced Transportation Engineering Center at Utah State University provides education and research in traditional transportation engineering. The program emphasizes engineering for rural and urban fringe transportation facilities and the use of computers in rural transportation agencies.

The Advanced Institute at Iowa State University and the University of Iowa focuses on policy planning related to rural freight and agriculture transportation issues. Institute work concentrates on four subareas: public policy formulation, transportation planning, transportation economics and finance, and logistics.

The Advanced Institute at the University of Washington centers its work on operations management and planning. Major subareas of this effort are traffic operations (including IVHS applications), transit operations, and intermodal freight operations. Several of the research projects at the Institute are part of the Washington State Department of Transportation's program, the Freeway and Arterial Management Effort.

National Centers

The current highway and mass transportation reauthorization bill provides for the establishment of three National Centers for Transportation Management, Research, and Development. The first 10 centers were required to be regional, but these new centers will be at large. Each center will address one or more major transportation problem. Examples of potential problems are:

- Urban congestion.
- Transportation and economic competitiveness.
- Transportation financing, planning, and management.
- Transit industry competitiveness, efficiency, and productivity.
- Human factors and safety issues.

The three new centers will develop advanced educational programs to introduce students to the cross-disciplinary knowledge required to solve the Nation's transportation problems in the 1990's and into the next century.

Additionally, as minorities and women become an increasingly significant part of the work force, the new centers will foster major initiatives to increase the diversity of students and faculty in the University Transportation Centers Program over the next 5 years. In fact, in selecting the sites of these new centers, the Department will give special consideration to those universities that propose innovative concepts for increasing diversity in their programs. It is anticipated that the Secretary of Transportation will announce the selection of these new centers about 7 months after the reauthorization legislation is signed into law.

Conclusion

The University Transportation Centers Program is attracting new students into transportation education and research at the participating universities. Upon completing their academic programs, these students will start applying their knowledge and skills in the transportation community. They will help alleviate the loss of experienced professionals who are retiring in record numbers.

As the results of the longer-term research projects become available, it is hoped that the transportation community will acknowledge the significance of the Centers' problem-solving work and provide more non-federal funding for the program. With this support, the program will therefore grow and become a significant source of transportation creativity and innovation.

At present, the research performed at the centers is providing innovative solutions to such transportation problems as urban congestion, rural accessibility, air quality, needs of the elderly and disabled, highway safety, and rehabilitation of existing facilities. The resulting transportation improvements will contribute to the economic competitiveness of the Nation.

Harry Hersey is the coordinator of the University Transportation Centers Program for the Federal Highway Administration (FHWA). Previously he worked on the Rural Technical Assistance Program and the State Training Course Program. He is a 1965 graduate of the FHWA Highway Engineer Training Program and a professional engineer registered in the State of Illinois.

Portland Cement Concrete Pavement:

Rehabilitation Challenges and Recommendations

by Nita Congress and Michael I. Darter, Ph.D., P.E.

Introduction

The most challenging and pressing issue facing highway engineers today is rehabilitation of our Nation's highway infrastructure. Pavement rehabilitation is a relatively new and rapidly developing technology. It is only in the last few years that a variety of field and laboratory equipment, materials, design procedures, standards, and computer software has become available to aid the engineer in evaluating the pavement and design of several rehabilitation techniques such as overlays, full-depth repairs, and recycled mixtures.

With all these advances, however, many unanswered questions remain about pavement rehabilitation techniques and their effectiveness. Because pavement rehabilitation is still largely an art, the Federal Highway Administration sponsored a 3-day workshop in March 1990 to examine the state of the practice of concrete pavement evaluation and rehabilitation strategy selection. This article summarizes key workshop findings and recommendations. (*1,2*)[1]

Rehabilitation Strategies Should Be Selected Systematically

How does a highway agency select the most appropriate rehabilitation strategy for a given stretch of pavement? Ideally, this determination should be made in an organized and systematic manner, taking into account all relevant parameters and their respective impacts (e.g., existing pavement distress and initial cost, anticipated maintenance and future rehabilitation requirements, anticipated pavement serviceability, agency experience, and constructability for the given traffic and geometrics).

Many computerized (i.e., artificial intelligence systems) and manual programs are available to help agencies make informed decisions about rehabilitation. Most of these systems are based on a formal decision-making process, such as that recommended by the American Association of State Highway and Transportation Officials (figure 1).

The Expert System for Pavement Evaluation and Rehabilitation (EXPEAR) is a particularly noteworthy computerized system. EXPEAR leads engineers through a comprehensive evaluation of a pavement's present condition and development of one or more feasible rehabilitation strategies. The FHWA considers EXPEAR an excellent training tool for new engineers. Some modifications would be needed, however, to make the program applicable for routine design use with a particular State.

Regardless of the specific system used, the decision-maker should consider each project and pavement distress condition on its own merit. The decision-maker must assess the effectiveness of each treatment in terms of the project conditions, the cost involved (including initial cost, life-cycle costs, and user costs), constraints on strategy selection (including traffic volume), and various technical issues related to the specific strategy. The decision-maker must also know

[1]Italic numbers in parentheses identify references on page 52.

the repair's desired life expectancy and understand the effects on performance if the repair is not done.

Timing of Rehabilitation Is Linked to Strategy Selection

Besides the challenge of selecting the most appropriate type of rehabilitation for a particular pavement, the engineer faces the equally difficult decision of when to rehabilitate. These two decisions are inextricably linked: There is no one right time to rehabilitate a pavement, nor is there only one correct rehabilitation strategy to select at a particular time.

The type of rehabilitation that is most appropriate changes during the pavement's life as its condition declines. A tradeoff always exists between rehabilitating now and rehabilitating in the future when the pavement's condition will invariably be worse and will, therefore, require a more substantial improvement (figure 2). Each rehabilitation treatment raises its own issues regarding timing. Pavement design engineers and pavement management engineers should coordinate information during the process to select the appropriate rehabilitation treatments.

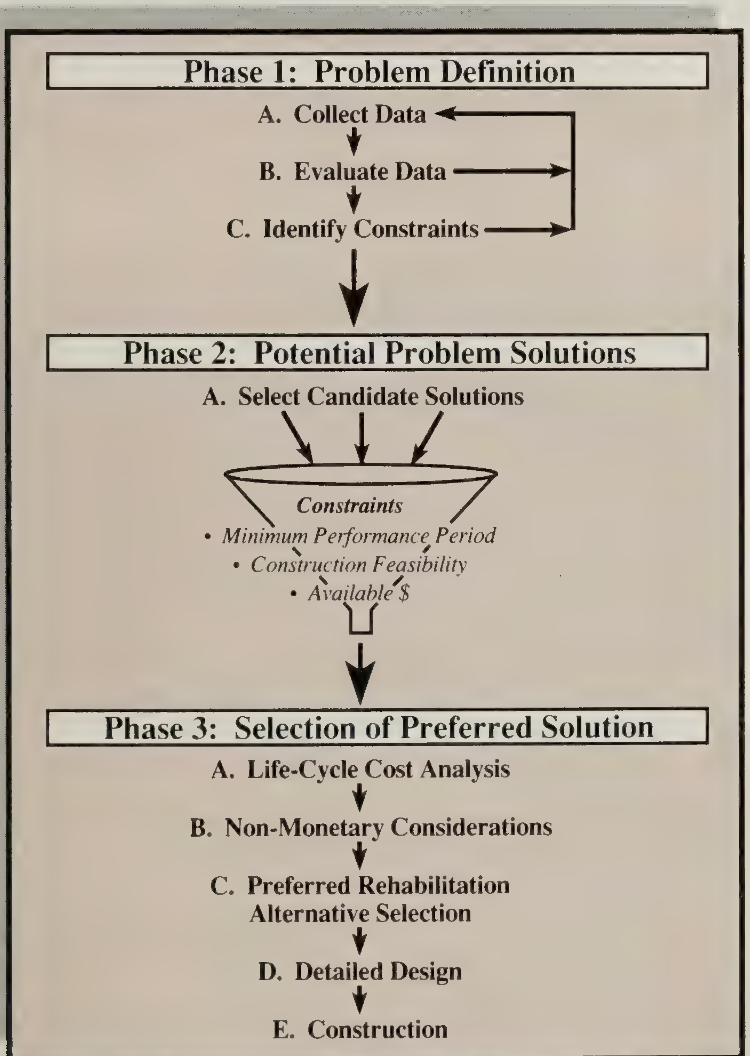


Figure 1.—Decision-making process.

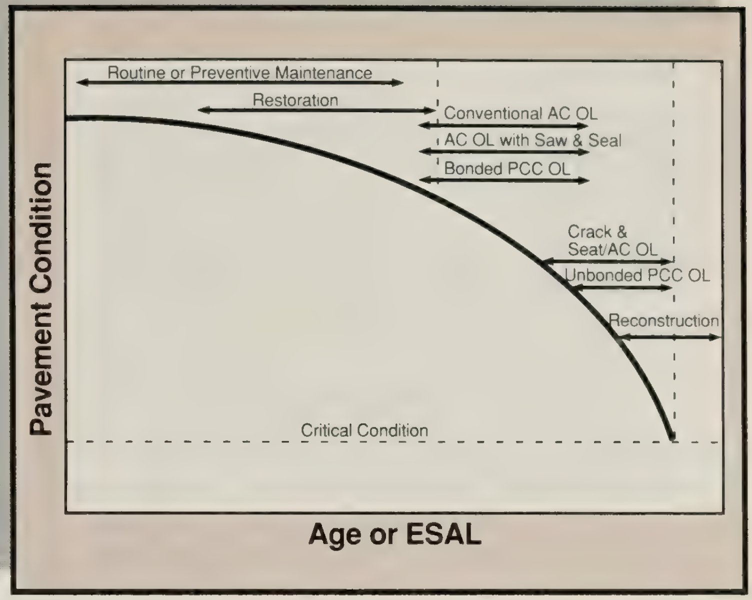


Figure 2.—General pavement performance curve related to rehabilitation alternatives.

Predicting Rehabilitation Performance Requires Extensive Data

Perhaps the most challenging aspect of selecting a rehabilitation strategy is trying to predict how the rehabilitated pavement will perform. Rehabilitation performance prediction is much more difficult than new pavement performance prediction. This difficulty is due largely to the shortage of long-term performance data on rehabilitation projects and the many variables affecting a particular project's performance (e.g., traffic loading, materials variation, design features, quality of maintenance). The experience of specific agencies with certain rehabilitation techniques provides some guidance, as do national studies. However, these performance models need to be calibrated to rehabilitation practices within each State, thus reflecting the State's practices. These models must also be continually refined based on feedback from the State's pavement management program.

Custom Design Is Vital to Successful Pavement Rehabilitation

Successful rehabilitation depends on both the condition of the existing pavement and the selection of a strategy that is truly appropriate and cost effective for that pavement. Careful consideration and thorough evaluation is thus required for each individual pavement section. At a minimum, engineers should:

- Do a distress survey, noting distress types, rates of change, severities, and quantities. Most PMS's only sample pavement distresses. Therefore, the pavement designer should perform a more detailed distress survey for the total project section.

- Identify the causes of distress.
- Collect data on insitu structural condition using a heavy load deflection device, such as a falling weight deflectometer.
- Collect data about past and current truck volumes in order to estimate truck loading to date and future.
- Collect data about climate.
- Collect data about pavement materials and soil.

A pavement management system may recommend a pavement preservation treatment for a candidate project as part of the network analysis, but this does not replace the need for a custom design. This methodical approach, therefore, leads to *custom design* of the rehabilitation for a specific project. Applying the same rehabilitation treatment to every concrete pavement has led to poor overall performance and many early failures, because no rehabilitation design will work everywhere.

EXPEAR, mentioned above, uses a 10-step process for custom designing a rehabilitation project (figure 3). If these steps are followed, pavement engineers may be able to achieve a reliable and cost-effective customized rehabilitation design.

10 Key Steps to Successful Customization of Pavement Evaluation and Rehabilitation

Step 1.	**Collect and Enter Data.**
Step 2.	**Extrapolate the Overall Project Condition.**
Step 3.	**Evaluate the Present Condition.**
Step 4.	**Predict the Future Condition Without Rehabilitation.**
Step 5.	**Recommend Physical Testing.**
Step 6.	**Select the Main Rehabilitation Approach.**
Step 7.	**Develop a Detailed Rehabilitation Strategy.**
Step 8.	**Predict the Rehabilitation Strategy Performance.**
Step 9.	**Analyze the Cost of the Selected Rehabilitation Strategy.**
Step 10.	**Select the Preferred Rehabilitation Strategy.**

Figure 3.—EXPEAR: a 10-step process.

Each Rehabilitation Technique Raises Different Considerations

Highway engineers have a broad range of options available to them in selecting an appropriate rehabilitation strategy for portland cement concrete (PCC) pavement projects. When making their selection, engineers should be aware of the various design factors and technical considerations associated with each rehabilitation technique, as highlighted in the following paragraphs.

Routine or preventive maintenance only

This rehabilitation technique may be the most appropriate action for some projects. In general, rehabilitation is not warranted until annual maintenance costs exceed the cost savings of deferring rehabilitation. Generally, good maintenance will significantly extend the time before a rehabilitation alternative is needed.

Concrete pavement restoration

Concrete pavement restoration (CPR) is a system of repair methods to restore jointed concrete pavement to a high level of serviceability without an overlay. Individual CPR techniques have long been applied as maintenance. Today, CPR is considered to be a set of needed techniques that can provide a long-term pavement rehabilitation strategy. CPR may add significantly to a pavement's service life if it is applied, correctly and using proper techniques, before the pavement begins to manifest significant structural distress. CPR does not improve a pavement's structural capacity. Moreover, if signs of structural inadequacy are starting to appear at an increasing rate, CPR may not be the most cost-effective approach.

Pavement rehabilitation experts disagree as to which CPR methods should be used, when to use them, or whether to use them at all. Consequently, clear rules do not exist for determining what CPR should be done and when. To determine the need for any CPR technique, project conditions should be evaluated along with the extent and rate of change of the critical distress type. Decisions regarding what should be done must be based on an evaluation of expected traffic loadings, pavement design features, past repair history, current pavement condition, ability to handle traffic during repairs, and the estimated remaining performance life.

Conventional asphalt concrete overlay

Conventional asphalt concrete (AC) overlays may be effective in improving pavement structure and should be considered when there are structural deficiencies. However, reflection cracking is frequently a controlling factor in AC overlay performance life. This type of overlay typically requires thorough preoverlay repair.

Rutting can also reduce its life. Thus, the service life of conventional AC overlays has often been less than expected. AC overlays, when applied in a timely manner, have been very effective in extending continually reinforced concrete pavement (CRCP) life, possibly because the increased thickness they provide reduce both daily temperature stresses and the stresses caused by traffic loads and minimal reflection cracking.

Saw and seal with AC overlay

This approach to reflection crack control has been used predominantly in the northeast section of the United States. It has been found to be very beneficial on moderately deteriorated jointed reinforced concrete pavements. However, the cost effectiveness of this approach on shorter jointed plain concrete pavements is still being debated.

Break and seat with AC overlay

This reflection crack control technique involves destroying slab action of jointed reinforced concrete pavements by reducing crack spacing and breaking the bond between the concrete and the reinforcing steel. Opinion is currently divided as to the overlay thickness over such pavements. Another question is whether the long-term reflection crack occurrence differs significantly from that of conventional AC overlay. It is recommended that States using this technique construct an uncracked control section with the same overlay thickness to verify that the procedures used are extending service life cost effectively. The Strategic Highway Research Program and other ongoing research should provide additional guidance in this area.

Crack and seat with AC overlay

This is the title given to the technique of controlling reflection cracks for jointed plain concrete pavements. The technique involves cracking the unreinforced slab into pieces about 2 to 3 ft. (.6 to .9 m) in length, seating the pieces and placing an AC overlay. This technique has achieved success in some States. There is divided opinion as to the required overlay thickness, with some believing it should be as thick as that placed over a rubblized concrete and others somewhat thinner. Additional research is needed to establish overlay thickness requirements for specific traffic levels.

Rubbilization with overlay

This approach involves reducing the existing concrete pavement almost to a granular base. To do this, the overlay must be designed as a new pavement. Overlays are predominantly AC, although PCC overlays can also be placed on rubbilized pavements. Rubbilizing *must* be uniform across the slab.

Bonded PCC overlay

This technique is most appropriate for pavements in relatively good condition; it requires a thorough preoverlay repair. Use of a bonded PCC overlay should

also be considered if the existing pavement is structurally inadequate for anticipated heavy traffic loadings. The specific reduction in service life due to debonding of the overlay has not been determined, although it is considered undesirable. Every effort must be made to achieve a full permanent bond; this may be particularly effective in extending the service life of thinner CRCP.

Unbonded PCC overlay

Unbonded overlays are most appropriate for pavements with a greater degree of structural or other deterioration. The technique uses a separation interlayer to absorb slab movement and prevent reflection cracking. This technique also has significant advantages where the base/subbase/subgrade material is very poor. Caution is advised, however, if the existing support is very non-uniform (i.e., unsupported joints in the old pavement). Also, when placed over a rigid base (old PCC or an AC pavement) shorter slabs and dowels are needed and drainage should be carefully considered. The performance of unbonded PCC overlays has been very good.

Reconstruction

Because of its high cost, reconstruction is often considered a last resort unless it is warranted by other factors, such as the need for geometric improvements or maintenance of the existing pavement surface elevation. Reconstruction may also be the rehabilitation strategy of choice for pavements with very high traffic volumes, because of its long performance life and low maintenance requirements. Cost savings may be realized if the existing pavement can be recycled into the new pavement structure.

Numerous Technical Issues Affect Successful Rehabilitation

Careful evaluation of PCC rehabilitation strategies entails the consideration of a wide variety of technical issues. Some of the more significant of these issues include the following:

Drainage

Opinion is divided as to whether drainage should be included on rehabilitation projects. At one time, drainage was included on every job as a form of "cheap insurance." Drains on some projects, however, have clogged, turning into moisture retention systems. Engineers have thus come to believe that in some instances drainage, rather than being either useful or harmless, can actually accelerate pavement deterioration. This perception underlines the need for indepth research in the area of drainage and edge drain design. The design of underdrains should be carefully engineered to take into account the existing condition at each proposed rehabilitation project.

Preoverlay repair

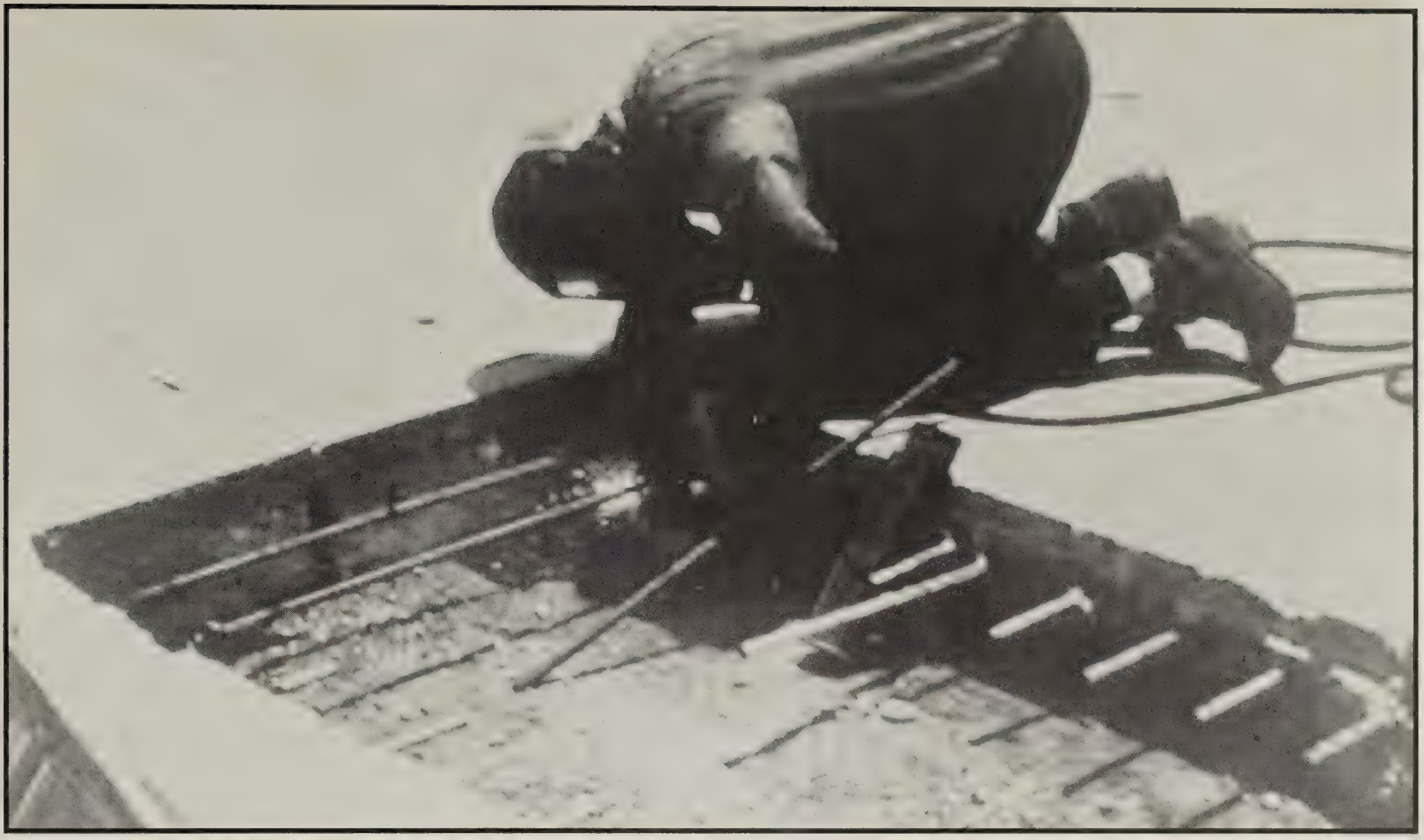
A correlation may exist between the types and amounts of preoverlay repairs made to a pavement and the thickness needed for the eventual overlay as well as the overlay's ultimate service period and life. It may be true that the better and more extensive the preoverlay repair, the thinner the overlay required. Engineers will need to assess this tradeoff between the extent of preoverlay repair and overlay thickness when considering this rehabilitation option.

Reflection cracking

Although several research studies have been conducted on various reflection crack control treatments, few, if any, techniques have proved reliably effective for high-traffic-volume pavements, and few States routinely incorporate reflection crack control treatments in overlay construction. Considering the substantial impact that reflection cracking often has on overlay life, this area deserves further investigation. The use of sawing and sealing of AC overlays has proved to be effective in several States.

Structural capacity of break/cracked and seated and rubbilized PCC

A significant unknown factor in designing overlays of break/cracked and seated and rubbilized PCC pavement is the structural capacity of the altered PCC layer. It is extremely difficult to directly assess a broken or rubbilized PCC layer's structural capacity after breaking from either visual examination or deflection testing. The current practice in some States is to measure deflections after the overlay is placed



and to interpret the PCC layer's properties from these data. Additional research on the design of these overlays clearly is needed.

Management and Logistic Considerations Also Hamper Successful Rehabilitation

The challenges of pavement rehabilitation stem not only from technical issues, but also from management and logistic issues; some of these are explored below.

Fragmented lines of responsibility and communication

Within most agencies, responsibility for pavement rehabilitation is diffused among several different units or divisions. Each unit is responsible for a different aspect of maintenance or rehabilitation. In many cases, the units do not communicate during the rehabilitation process, and each, thereby, loses the opportunity to take advantage of expertise within the other units. The implementation of an effective pavement management system will do much to improve this situation.

Inadequate funding

A constraint that applies to all rehabilitation projects is availability of funding. The amount of funding appropriated for a given project is often inadequate. This can lead to serious problems in rehabilitation design and construction. In those States that have the capability to analyze either optimum or near-optimum strategies, the PMS recommendations should be used as input when analyzing the options and consequences when budget constraints prevail.

Lack of performance standards

A lack of State-specified performance standards results in contractor-dependent rehabilitation quality. States tend to get what they ask for: If they do not set standards, they get poor work performance; if they impose high standards, contractors generally meet them. States must provide contractors with specific work standards, guidance, and criteria that have been shown to be cost effective.

User considerations

What is a human life worth? What is convenience worth to the user versus the cost of additional delays caused by road repairs? Such concerns are very difficult to quantify, but represent a significant consideration when planning and performing a rehabilitation. Agencies must be aware of these considerations when determining rehabilitation timing and techniques and recognize that these concerns can affect rehabilitation cost.

Public perception of a State highway agency must also be taken into account. Some agencies opt to close a road once completely rather than close sections of the road every year. However, the public often sees no difference between full and partial closure, because both represent a significant inconvenience.

Rehabilitation Problems Will Increase in the Future

In the coming decade, pavement rehabilitation will become increasingly important and increasingly difficult due in part to two ongoing national trends: rising traffic levels and a dwindling pool of trained pavement engineers.

Increasing truck loadings

The loads applied to highway pavements are rising rapidly. For instance, truck loadings today on the Interstate system have often been three times as high as those estimated when the pavement was initially designed. Many highways have consequently reached and exceeded the end of their design life. Increasing truck axle weights are also causing rehabilitation treatments to deteriorate more quickly and underlying roadway problems to return much faster than in the past. This situation will be further exacerbated in the years to come.

Nevertheless, many current rehabilitation designs do not consider actual truck traffic volume or predicted growth. Such considerations are vital to ensuring a reasonable service life for proposed projects. Using automatic vehicle classification and weigh-in-motion equipment to determine on-site and network-level conditions will provide more accurate measures of actual and forecasted truck traffic loadings.

Deficit of trained engineers

Experienced engineers are retiring in large numbers, taking with them a wealth of knowledge and expertise that is not easily transferred to the next generation of pavement engineers. One way to help address the resulting shortage in qualified pavement engineers is to develop and improve the state of the art of pavement engineering and develop improved pavement rehabilitation advisory systems.

The development of effective pavement management systems, including feedback of performance information, will greatly assist in determining the most appropriate timing of maintenance and rehabilitation activities and determining the most cost-effective rehabilitation strategies.

These systems, however, cannot do the job alone. Trained personnel are needed to perform system analyses and provide input for improving systems. Therefore, the industry must attract engineering students to the pavement field. More courses in pavement rehabilitation and pavement management are greatly needed at both the undergraduate and graduate levels. Further, practicing engineers must keep up to date on the latest available technologies.

Conclusions

Perhaps the most significant conclusion reached at the workshop was that each rehabilitation project is unique and should be engineered and custom designed to achieve a reliable and cost-effective solution. The following are also needed to ensure highest-quality rehabilitation efforts:

- Implementation of an effective pavement management system, including performance feedback.
- Improved coordination among the units of a high way agency in project selection, timing, cost estimation, design, and construction.
- Direct consideration of current and projected truck traffic loadings.
- Improved rehabilitation construction control and practices.
- Continued training to take advantage of improvements to the state of the art in pavement design and rehabilitation procedures.
- Techniques, equipment, and materials that can reduce the amount of time a traffic lane is closed for testing or repair or that can improve the reliability and service life of rehabilitation.

In addition, various research and development efforts (some of which are already under way) will provide useful information and results for extending the service life of PCC pavements:

- Using advisory systems in the area of pavement evaluation and rehabilitation.
- Examining full-depth repair design guidelines.
- Studying the use of retrofit edge drains to determine when and why they work.
- Studying the use of AC and PCC overlays in different climates and pavement types.

References

(*1*) Workshop on Evaluating Portland Cement Concrete Pavement Rehabilitation Strategy: Summary Report. Federal Highway Administration, Washington, DC, March 1990

(*2*) Workshop Proceedings, March 27 through 29, Federal Highway Administration, Washington DC, March 1990

Nita Congress is a senior writer for Walcoff & Associates, a management consulting firm in Alexandria, Virginia, that specializes in technology transfer. She has written and edited numerous technical documents for the Departments of Transportation and Energy, the National Science Foundation, and the U.S. General Accounting Office.

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Recent Publications

The following are brief descriptions of selected publications recently published by the Federal Highway Administration, Office of Research and Development (R&D). The Office of Engineering and Highway Operations R&D includes the Structures Division, Pavements Division, Materials Division, and Long Term Pavement Performance Division. The Office of Safety and Traffic Operations R&D includes the Intelligent Vehicle-Highway Systems Research Division, Design Concepts Research Division, and Information and Behavioral Systems Division. All publications are available from the National Technical Information Service (NTIS). In some cases, limited copies of publications are available from the R&D Report Center.

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Requests for items available from the R&D Report Center should be addressed to:

Federal Highway Administration
R&D Report Center, HRD-11
6300 Georgetown Pike
McLean, Virginia 22101-2296
Telephone: (703) 285-2144

Instrumentation for Flexible Pavements, Publication No. FHWA-RD-89-084

by Pavements Division

This report documents a literature search on the subject of instrumenting flexible pavements. Sensors for measuring strain, pressure, deflection, moisture, and temperature are described and critically discussed. Problems of each sensor type concerning the installation at and below the pavement surface, the durability, reliability, and selection of the data acquisition equipment are discussed. The report also includes a discussion on measuring wheel loads and locating the wheel load relative to the embedded sensors. Finally, pavement performance models and backcalculation techniques for estimating the resilient moduli are reviewed.

Limited copies of this publication are available from the R&D Report Center. Copies may also be purchased from the NTIS. (PB No. 91-162909/AS, price code: A08.)

Lab Report for the Acosta Bridge Scour Study, Publication No. FHWA-RD-89-114

by Structures Division

This study investigated the relative effects of a new commuter bridge on scour at two existing bridges. The bridge spans the St. Johns River in Jacksonville, Florida. Physical modeling of the study area—performed at the Federal Highway Administration's Hydraulics Laboratory—was the study's focus.

Wooden scale models of bridge piers were placed in a sand-filled recess within a flume. Many different configurations of bridge piers were placed in the flume, and the resulting scour holes were measured and compared.

Other nonsite-specific scour issues were also investigated. Experiments were run which tested the influence that pile spacings have on scour. Scour resulting from equivalent width piers versus pile groups was also investigated. Finally, riprap tests were performed for comparison with empirical formulas for establishing stability.

Limited copies of this publication are available from the R&D Report Center. Copies may also be purchased from the NTIS. (PB No. 91-174052/AS, price code: A05.)

Performance of Alternate Coating in the Environment (PACE)—Volume I: Ten-Year Field Data, Publication No. FHWA-RD-89-127; Volume II: Five-Year Field and Bridge Data of Improved Formulation, Publication No. FHWA-RD-89-235

by Materials Division

Volume I presents results from a 10-year field study which compared environmentally acceptable coating systems for steel with standard

U.S. industry and Government systems. The test included four major branches:

- Alternate primer pigments.
- Alternate surface preparation abrasives.
- Water-borne coatings.
- Alternate pigments and vehicles in vinyls.

The codings were applied to steel panels and exposed at three outdoor sites. The panels were rated at least once per year for surface rusting and scribe undercutting. The major analytical method was failure-survival analysis. The failure level selected was the time to reach a rust rating of 7 or scribe undercutting of 1/4 in (6.3 mm).

The report compares trends among coating groups; lists top performing coatings; assesses the influence of test site, film thickness, degree of cleaning, and mode of failure, (i.e., rust or scribe undercutting); and the effect on performance trends. The report also recommends implementation of the findings and additional studies needed.

Volume II presents results from a 5-year field study on advanced formulations and surface cleaning techniques for coating systems for steel bridges. The test branches included:

- Alternate blast and nonblast cleaning methods: The effectiveness of alternative metallic and nonmetallic abrasives, newly developed power tools, and citric acid cleaning was evaluated for five standard coatings at three test sites. Also investigated was the effect of rust grade and pre-rust location sites.
- New experimental coatings: The 100 coating systems tested included lead-containing and lead- and chromate-free oil alkyds, acrylic and styrene acrylic latex, petroleum wax coatings, chlorinated rubber, water-borne epoxies, vinyl, epoxy, urethane, zinc-rich, and others. Each coating was applied over hand- and blast-cleaned p anels and exposed at three test sites.
- Bridge site exposures: Eight highway coatings systems were exposed over blast- and hand-cleaned test panels and at 10 representative bridge sites.

The 2,800 test panels were rated over a period of 5 years for rusting and scrit undercutting. Failure/survival analysis was conducted of the relative performance of the coatings, cleaning methods, test sites, and film thickness.

These reports are part of a series. Volumes I and II are reported here, Volume III: Executive Summary, FHWA-RD-89-236, will soon be available.

Limited copies of these publications are available from the R&D Report Center. Copies may also be purchased from the NTIS. (Vol. I: PB No. 91-174169/AS, Price code: A03; Vol. II: PB No. 91-174177/AS, price code: A06.)

Design, Develop, and Fabricate a Prototype Nondestructive Inspection and Monitoring System for Structural Cables and Strands of Suspension Bridges, Volume I: Final Report, Publication No. FHWA-RD-89-158

by Structures Division

This report describes the development of a prototype magnetic perturbation nondestructive evaluation (NDE) system for inspecting and monitoring structural cables and strands of suspension bridges. Although this method has been applied successfully to a variety of NDE problems, application to larger diameter cables was more difficult.

A limited parametric laboratory investigation was conducted using a rudimentary system consisting of a 200-lb (91-kg) electromagnet. A Hall probe was attached to measure the magnetic perturbations while a simulated cable was scanned. The first specimen consisted of 370 steel rods. Magnetic anomalies in the steel pipe obscured flaw signals except for very large ones. After many changes in the experimental arrangement, detection of a 0.27 percent cross-sectional area flaw at a depth of 1.9 in (4.8 cm) was achieved.

Subsequently, a prototype magnetic perturbation cable NDE system was constructed, and field demonstrations were successfully conducted on the 6.3-in (16-cm) diameter Luling Bridge stay cables from December 12 through 15, 1988. Approximately 420 data scans (each 100 in [2.5 m] long) were recorded. Analysis disclosed the possibility that grouting was so thin in several regions on top of a cable that segments of wires were moved by the magnetic attractive forces at each poleface.

The magnetic perturbation cable incorporates the high sensitivity, excellent resolution and long-term stability of the magnetic perturbation method with modern microprocessor control, digital communication, computer archival storage, and digital signal analyses routines. This integrated, state-of-the-art, automated NDE system applies modern quantitative structural lifetime assurance strategies to suspension bridge cables.

This publication may only be purchased from the NTIS. (PB No. 91-174078/AS, price code: A03.)

Durability/Corrosion of Soil Reinforced Structures, Publication No. FHWA-RD-89-186

by Materials Division

This report provides criteria in evaluating potential corrosion losses when using coated or uncoated steel reinforcements, and in determining aging and construction damage losses when using geosynthetic reinforcements. To monitor insitu corrosion rates of bare or galvanized steel reinforcements, remote electrochemical measurement equipment has been developed, evaluated, and demonstrated on seven field sites. The prototype equipment has been delivered to the Federal Highway Administration for further use.

This publication may only be purchased from the NTIS. (PB No. 91-176610/AS, price code: A03.)

Feasibility Study of Options for the Highway Maintenance and Operations Cost Index, Publication No. FHWA-RD-89-195

by Pavements Division

The Highway Maintenance and Operations Cost Index was developed in 1947. This study evaluated the procedures used to prepare the *Index* and looked into the feasible options regarding the *Index*:

•Retain it in its current form.

•Revise or redevelop it.

•Discontinue it.

This study included several tasks: a literature review of the theoretical aspects of price index development; a detailed survey of State DOT needs for the *Index*, current uses, relationship to maintenance operations, preferences for change, and assessments of the utility of different options; a detailed review of other construction and maintenance indexes and related cost data analyses of current *Index* behavior, and comparisons with several construction indexes; and recommendations regarding the *Index*.

After reviewing the study's findings, and in response to comments received from the American Association of State Highway and Transportation Officials' Highway Subcommittee on Maintenance and FHWA's field offices, the Executive Director determined that the *Index should be discontinued*. The *Index* will be retained through 1991 to accommodate several States that use it for administratively or legislatively mandated functions.

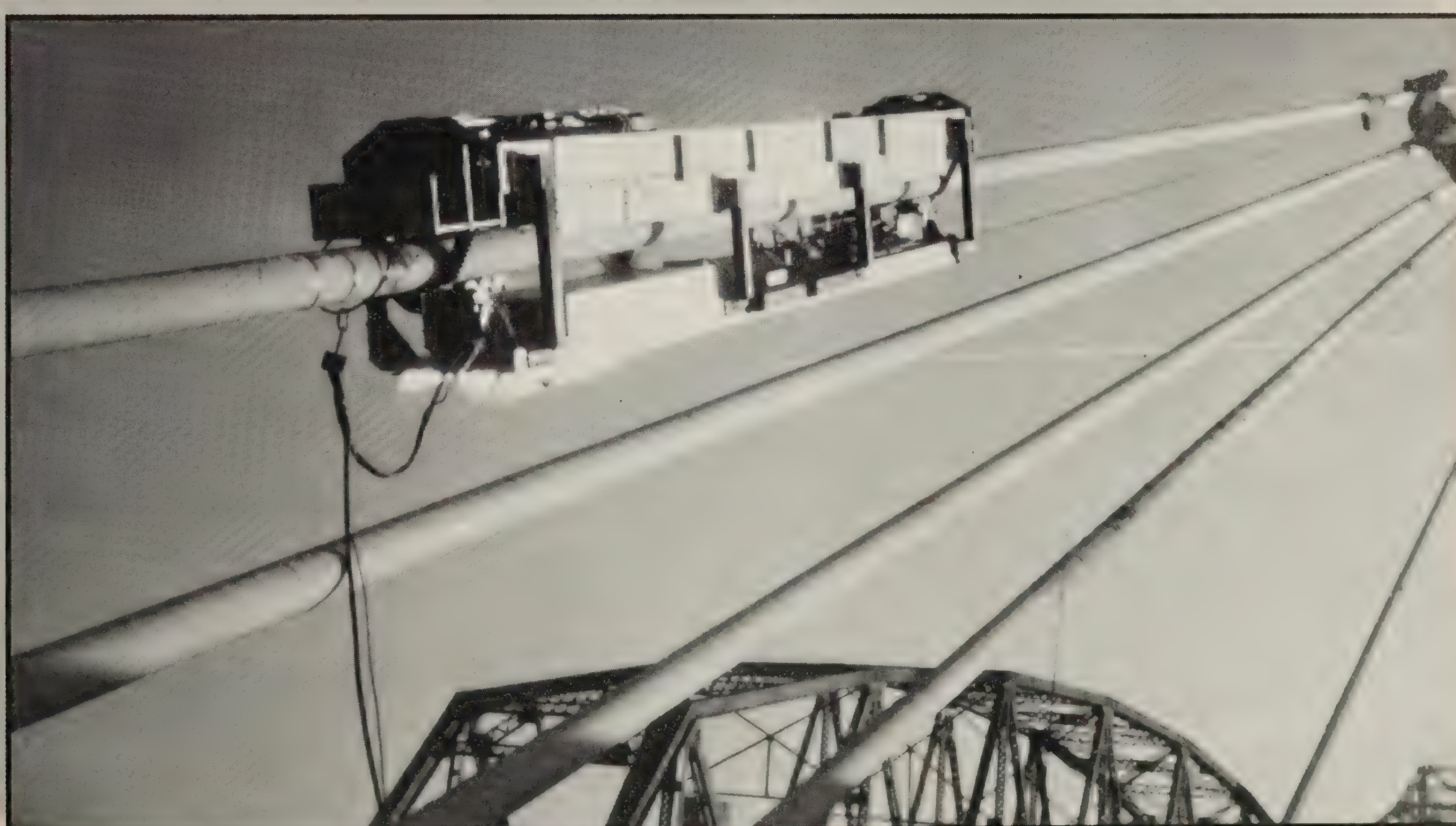
This publication may only be purchased from the NTIS. (PB No. 91-176313AS, price code: A07.)

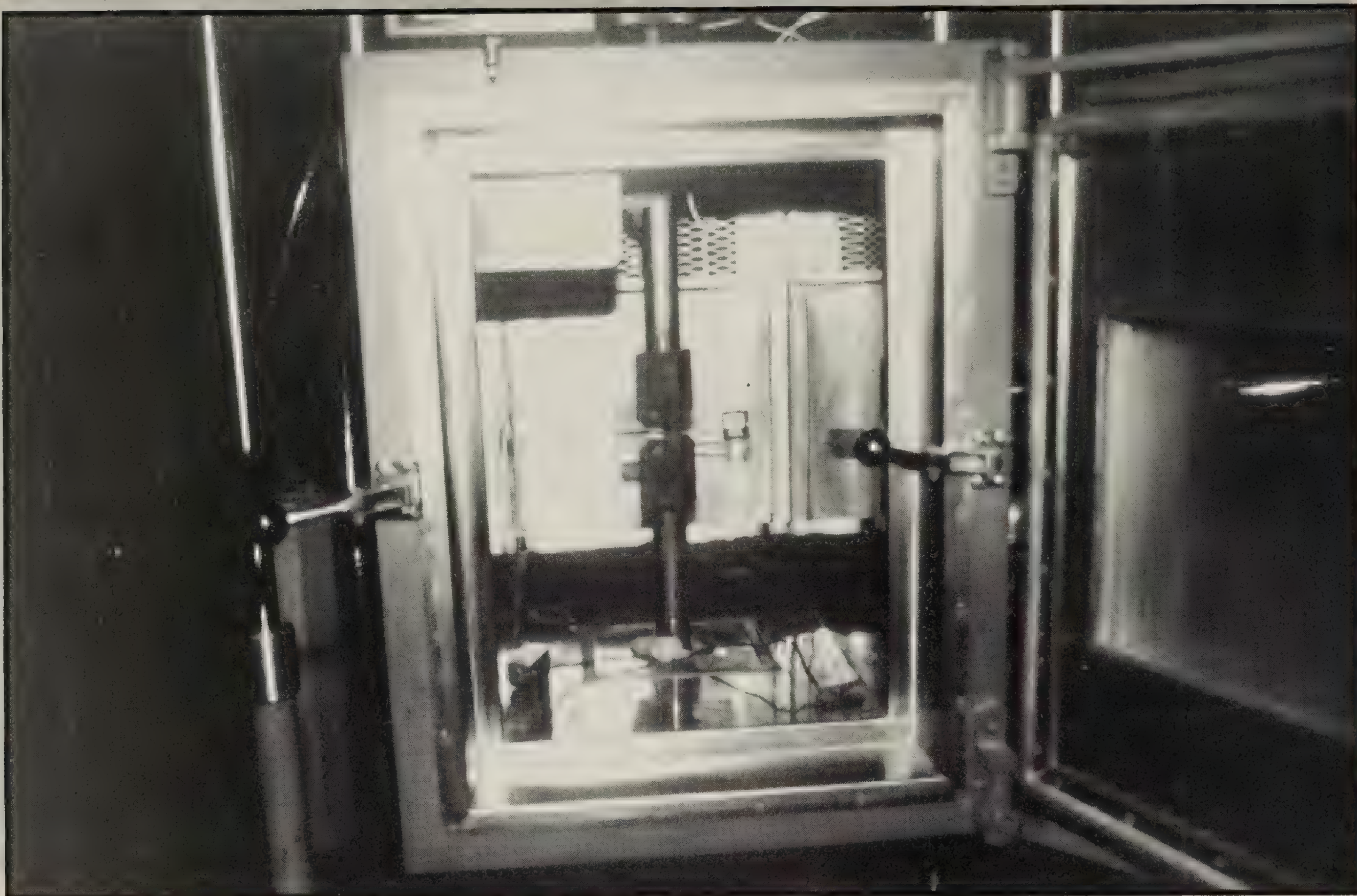
Development of Performance-Related Specifications for Portland Cement Concrete Pavement Construction, Publication No. FHWA-RD-89-211

by Pavements Division

A demonstration of a performance-related specification (PRS) system for portland cement concrete (PCC) pavement construction was the product of this study. The system is designed to consider three key factors—PCC strength, slab thickness and initial serviceability—in assessing an as-constructed pavement delivered by a contractor and in calculating an appropriate reward or penalty.

Many pavement performance prediction relationships and PCC property prediction equations were evaluated to develop the performance-related aspect of the new system. In addition, a rather intense experimental laboratory study of PCC material properties was conducted to develop better multifactor prediction relationships.





The demonstration PRS was developed using a computerized spreadsheet program. It was designed to parallel the demonstration PRS system recently developed for asphalt concrete pavements. Recommendations were made for further research in areas related to PRS systems and field and laboratory studies.

This publication may only be purchased from the NTIS. (PB No. 91-174151, Price code: A12—paper copy, A02—microfiche.)

Brittle-Ductile Transition of Bridge Steels—
Volume I: Final Report, Publication No. FHWA-RD-90-008,
Volume II: Microstructural Aspects of the Ductile-Brittle, Publication No. FHWA-RD-90-009,
Volume III: Executive Summary, Publication No. FHWA-RD-90-010

by Structures Division

The transition behavior of bridge steels and weldments largely determines their toughness, service loading rates, and temperatures. Two aspects of the transition were investigated in the project. The first was to develop a better understanding of the micromechanics of fracture of bridge steels and welds. This study showed that the American Association of State Highway and Transportation Officials (AASHTO) yield strength dependent relation between loading rate and test temperature should be expected.

The second larger study consisted of measuring the fracture toughness of A572, A588, A852 plates at bridge loading rates. The latter were analyzed by elastic-plastic techniques so that testing could be extended into the transit region.

The test results supported an earlier FHWA study and showed that the AASHTO toughness specifications for plates up to 2 in (50.5 mm) thick are satisfactory. However, the specifications were found to be nonconservative for thick, heat-treated plates.

These volumes form a series on Brittle-Ductile Transition of Bridge Steels:
Volume I: Final Report, FHWA-RD-90-008,
Volume II: Microstructural Aspects of the Ductile-Brittle, FHWA-RD-90-009,
Volume III: Executive Summary, FHWA-RD-90-010.

Limited copies of these publications are available from the R&D Report Center. Copies may also be purchased from the NTIS.
(PB No. 91-165134/AS, price code: A06.)
(PB No. 91-165142/AS, price code: A03.)
(PB No. 91-165159/AS, price code: A03.)

Technology Applications

The following are brief descriptions of selected items that have been completed recently by State and Federal highway units in cooperation with the Office of Safety and System Applications and the Office of Research and Development (R&D), Federal Highway Administration. Some items by others are included when they are of special interest to highway agencies. All publications are available from the National Technical Information Service (NTIS). In some cases, limited copies of publications are available from the R&D Report Center.

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6300 Georgetown Pike
McLean, Virginia 22101-2296
Telephone: (703) 285-2144

A Guide to Wetland Functional Design, Publication No. FHWA-IP-90-010

by Office of Technology Applications

This guidebook was developed as a conceptual approach to wetland design, based on functions identified using the Wetland Evaluation Technique (WET, Publication No. FHWA-IP-88-029). Slightly modified, the functions include nutrient removal/transformation, sediment/toxicant retention, sediment stabilization, floodflow alteration, groundwater recharge, production export, aquatic diversity, and wetland dependent bird habitat diversity. This book offers guidelines for developing both site selection and site design features and includes a discussion of designing for multiple functions.

The information presented is intended as a starting point in wetland functional replacement mitigation. The information, however, should be augmented with site specific and project specific design information.

This publication may only be purchased from the NTIS. (PB No. 91-110569/AS, price code: A11.)

Traffic Detector Handbook, Second Edition, Publication No. FHWA-IP-90-002

by Office of Technology Applications

Originally published as Implementation Package FHWA-IP-89-1, the second edition of the Federal Highway Administration's *Traffic Detector Handbook*, is revised and updated. It has been restructured and corrected to discuss concepts and equipment that reflect the current state of the art, particularly as it relates to the revolution in microprocessors, advances in control technology, and experiences in real-world application.

The overall objective of this *Handbook* is to provide a single resource and basic reference to aid the practicing engineer and technician in planning, designing, installing, and maintaining detectors. Best current practices are described with emphasis on proper design, applications, and installation processes and techniques.

This publication may be purchased from the NTIS. (PB No. 91-164228/AS, price code: A16.) Also, a hardcover edition is available for purchase from the Institute of Transportation Engineers.

Automated Pavement Distress Data Collection Equipment Seminar, Publication No. FHWA-TS-90-053

by Office of Technology Applications

Pavement rehabilitation decisions require reliable performance data that can be used to establish current and predicted conditions of a highway system. Collection of this data by manual methods is usually costly, involves high personnel safety risks, and tends to be very subjective. The development of automated procedures that use cameras and microcomputer technology helps solve many of these problems.

Some 275 participants, representing State and local highway agencies and countries from around the world attended a seminar sponsored by the Federal Highway Administration, the Iowa Department of Transportation, and Iowa State University. This seminar provided a look at the state of the art in automated pavement distress data collection equipment and analysis systems. Several equipment manufacturers were present to demonstrate their systems. Experts in the pavement distress identification and analysis area presented papers dealing with various aspects of the subject.

This publication includes copies of all the presented papers, a list of seminar participants, summary information, sample output for several devices, and questions and answers concerning the topic.

This publication may only be purchased from the NTIS. (PB No. 91-161794/AS, price code: A99.)

Quality Assurance in Highway Construction, Publication No. FHWA-TS-89-038

by Office of Technology Applications

This report contains the reprint of six articles on the subject of quality assurance that have appeared in the past issues of *Public Roads, A Journal of Highway Research and Development.*

The articles are divided into the following sections:

- Introduction and concepts.
- Quality assurance of embankments and base courses.
- Quality assurance of portland cement concrete.
- Variations of bituminous construction.
- Summary of research for quality assurance of aggregate.
- Control charts.

This publication may only be purchased from the NTIS. (PB No. 91-176321/AS, price code: A04.)

Subject Bibliography

GPO Subject Bibliography

To get a complete free listing of publications and periodicals on highway construction, safety, and traffic, write to the Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328, and ask for Subject Bibliography SB-03 Highway Construction, Safety, and Traffic.

Software Directory

The 1990 PC's in Transportation Software Directory update is available for distribution. This update has brought some new listings into the directory, dropped some obsolete programs, and upgraded other programs. The directory still has over 600 transportation-related software programs covering the areas of Civil Engineering, Facilities Management, Freight Transportation, Transportation, Traffic Engineering, Transit & Paratransit Operation, Transportation Planning, Utility and Miscellaneous programs.

These software programs are set up to be located by either title or key words. The key words allow you the advantage of finding all the programs that would deal with a specific function. The directory is available in either hard copy in a three-ring binder or diskette format.

Basic Subscribers to PC-Trans who already have the directory will receive their updated version for free. Newsletter/Magazine Only subscribers and other non-subscribers who have purchased the original directory, can purchase the update for $15. For more information, call Eileen McNichol at (913) 864-5655 or write PC-Trans, Eileen McNichol, 2011 Learned Hall, Lawrence, Kansas 66045.

New Research

> The following new research studies reported by the FHWA's Office of Research and Development are sponsored in whole or in part with Federal highway funds. For further details on a particular study, please note the kind of study at the end of each description:
>
> • FHWA Staff and Administrative Contract Research: contact Public Roads.
>
> • Highway Planning and Research (HP&R): contact the performing State highway or transportation department.
>
> • National Cooperative Highway Research Program (NCHRP): contact the Program Director, NCHRP, Transportation Research Board, 2101 Constitution Avenue, NW, Washington, DC 20418.
>
> • Strategic Highway Research Program (SHRP): contact the SHRP, 818 Connecticut Avenue, NW, 4th Floor, Washington, DC 20006.

NCP Category C—Pavements

C.2: Evaluation of Flexible Pavements

Title: Rehabilitation of Asphalt Concrete-Overlaid PCC Pavements (NCP No. 4C2C1182)

Objective: Develop practical procedures and guidelines for evaluation and rehabilitation of inservice asphalt-overlaid concrete pavements. Specifically, review performance of these pavements in Illinois; develop guidelines for second rehabilitation and alternatives; develop procedures for field evaluation; develop procedures for structural analysis; and demonstrate the application of the developed procedures and guidelines.

Performing Organization: University of Illinois, Urbana, IL 61801

Funding Agency: Illinois Department of Transportation

Expected Completion Date: March 1993

Estimated Cost: $192,000 (HP&R)

C.4: Pavement Management Strategies

Title: Phase II of Concrete Pavement Management Systems (PMS) Development (NCP No. 4C4C3252)

Objective: Evaluate the applicability of an automated pavement distress data collection system for long-term use in Virginia. Assess the feasibility of implementing the micropaver pavement management system as Virginia's concrete PMS. Develop a condition index priority assessment model.

Performing Organization: Virginia Transportation Research Council, Charlottesville, VA 22903

Funding Agency: Virginia Department of Transportation

Expected Completion Date: April 1993

Estimated Cost: $136,000 (HP&R)

Title: Pavement Management Information System—Phase II (State In-house Support for MS-100) (NCP No. 4C4C3242)

Objective: Develop a pavement management system for the Mississippi State Highway Department (MSHD). Allow for periodic assembling of an advisory committee to review the study progress and to make recommendations as necessary. Randomly check the collected data, for correlation of contractor's equipment to MSHD equipment, and for further investigation of the reliability of the South Dakota Road profiler on roughly textured surfaces.

Performing Organization: Mississippi State Highway Department
Jackson, MS 39202

Expected Completion Date: January 1994

Estimated Cost: $74,985 (HP&R)

NCP Category D—Structures

D.1: Bridge Design

Title: Dynamic Field Testing of Bridges (NCP No. 4D1A1082)

Objective: Evaluate the dynamic response of both simple span and continuous span bridges in Virginia. Determine natural frequencies and mode shapes and evaluate forced response from heavy vehicular traffic. Identify those design features associated with the bridge/vehicle system that are most significant in their effect on dynamic response. This is done to compare field measurements with analytical predictions, and to evaluate the feasibility of developing simple, dynamic-based design criteria that could assist in identifying and controlling unwanted bridge motion.

Performing Organization: Virginia Transportation Research Council, Charlottesville, VA 22903

Funding Agency: Virginia Department of Transportation

Expected Completion Date: March 1993

Estimated Cost: $110,000 (HP&R)

NCP Category E—Materials and Operations

E.3: Geotechnology

Title: Characterization of Ohio Subgrade Types (NCP No. 4E3B0782)

Objectives: Define characteristic behavioral models for typical subgrades found in Ohio and determine whether these models are applicable, in conjunction with known pavement analysis computer codes, in the backcalculation process of soil and materials from nondestructive testing surface defection measurements. Determine the effect of moisture on the stress dependent behavior of the characteristic groups, by laboratory testing of specimens prepared at different moisture contents. Record moisture/temperature variations throughout the year at automatic stations located at sites representative of typical subgrade soils.

Performing Organization: Case Western Reserve University, Cleveland, OH 44106

Funding Agency: Ohio Department of Transportation

Expected Completion Date: April 1993

Estimated Cost: $163,800 (HP&R)

E.5: Highway Maintenance

Title: Establishment of Underdrain Maintenance Procedures (NCP No. 4E5D2542)

Objective: Conduct a Statewide survey of present underdrain and outlet conditions. Classify current problems. Develop and recommend methods to clean or repair underdrains.

Performing Organization: Oklahoma Department of Transportation, Oklahoma City, OK 73105

Expected Completion Date: October 1994

Estimated Cost: $125,000 (HP&R)

Title: Role of Highway Maintenance in Integrated Management Systems (NCP No. 5E5F1152)

Objective: Design an idealized maintenance management information system based on data available from all transportation information systems and develop a guide to assist State transportation agencies toward implementation.

Performing Organization: Cambridge Systematics, Inc., Cambridge, MA 02142

Expected Completion Date: January 1993

Estimated Cost: $225,000 (NCHRP)

E.7: Environmental Design

Title: Wetland Design Based on a Functional Assessment of Borrow Pits (NCP No. 4E7C4442)

Objective: Assess borrow areas in Illinois for their potential for high quality palustrine wetlands. Major questions deal with identification of successful wetland replacement strategies, factors critical to replacement success, and practical engineering design guidelines for wetland replacement associated with highway construction. For high quality constructed wetlands, consider detailed physical, chemical, and biological conditions. Use Illinois Geographic Information System to categorize its size and randomly sample areas of evaluation. Use WET and HEP. Develop a design manual and produce a design guidance document to review the use of constructed wetlands for runoff control.

Performing Organization: University of Illinois, Urbana, IL 61801

Funding Agency: Illinois Department of Transportation

Expected Completion Date: September 1993

Estimated Cost: $177,600 (HP&R)

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