Creating a New Generation of Concrete

Public-Private Partnership Sets Research Agenda

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The Federal Highway Administration (FHWA) and the concrete paving industry—through the Innovative Pavement Research Foundation (IPRF)—have developed a partnership for concrete pavement research and technology development, with funding from the Transportation Equity Act for the 21st Century (TEA-21). The Concrete Pavement Technology Program (CPTP) is pursuing four goals for the U.S. highway system: reduce delays, reduce cost, improve performance, and foster innovation.

Establishing a Tradition

The concrete pavement industry's tradition of applied research dates back to 1889, when George W. Bartholomew proposed the first concrete pavement to city officials of Bellefontaine, Ohio. Although the first automobile would not appear for another 10 years, Bartholomew was convinced that the cement he had produced in his small laboratory could form a hard, durable paving surface.

After two years of convincing citizens and city officials and after agreeing to donate the materials, Bartholomew received permission to build America's first concrete pavement. He also posted a $5,000 performance bond and a guarantee that the pavement would last for five years.

The first section of concrete pavement, an 8-ft-wide strip of Main Street along Bellefontaine's Courthouse Square, was completed in 1891 and became an immediate success. Local businessmen petitioned to pave the entire block around the square with concrete. America's first concrete pavement is still in service, a testament to the industry's commitment to research and to the durability of concrete pavement.

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Today's Challenge

In the 20th century, research and innovation have produced impressive technical advances as the concrete paving industry has helped to create the most extensive and efficient surface transportation system in the world, the U.S. highway network. Research and development is essential not only to the construction of America's surface transportation system, but also in maintaining the system to serve ever-increasing traffic.

Aging concrete highways have carried more traffic loads than they were designed to accommodate. Today's challenge for long-lasting pavement repair and replacement is complicated by traffic congestion and by the imperative for worker and public safety.

Applied research must develop and refine new design methods and improve concrete pavement materials, construction, and rehabilitation techniques. The solutions also must be cost-effective, providing the maximum value for the dollars invested in the rehabilitation and expansion of highways and airport pavements.

Partnering for Better Pavement

In TEA-21, Congress designated $30 million to conduct applied research for improved methods of using concrete in the construction, reconstruction, and repair of federal-aid highways. This provided an excellent opportunity for the public and private sectors to work together to improve the transportation system.

In 1999, FHWA entered a cooperative agreement with IPRF, a nonprofit organization chartered in 1997 and jointly sponsored by the American Concrete Pavement Association, the Portland Cement Association, and the National Ready Mixed Concrete Association. The public-private partnership developed CPTP to leverage public funds from TEA-21 and contributions from the private sector for research, development, and technology to improve the performance and cost-effectiveness of concrete pavements.

State Involvement

Because state highway agencies have primary responsibility for the design, construction, and operation of the highway system, their full and active participation is imperative in implementing new and improved technology. At the request of FHWA and IPRF, the Transportation Research Board (TRB) has formed the Committee for Research on Improved Concrete Pavements for Federal-Aid Highways to ensure that CPTP is responsive to states' needs.

The TRB committee of 18 members—representing state agencies, industry, and the academic community—reviews the long-range work plan of CPTP, advising on the suitability of the overall goals and the likelihood for success of the identified tasks. The committee also conducts regular progress reviews, commenting on course corrections, promising opportunities, and significant findings.

Four Goals

CPTP has set four goals that address the needs of state highway agencies, the concrete pavement industry, and highway users:

- Reduce user delays,
- Reduce costs,
- Improve performance, and
- Foster innovation.

These goals require CPTP to produce practical, readily useable tools and guidelines, including educational materials, to transfer the new products and techniques into practice.

Reducing User Delays

Although much of the highway system requires pavement rehabilitation or reconstruction, the motoring public objects to frequent repairs and unnecessary delays. The public demands long-lasting pavement repair, resurfacing, and reconstruction completed as rapidly as possible.

Several CPTP initiatives address this issue. A major IPRF study, "Traffic Management Studies for Reconstructing High-Volume Roadways." conducted by the Texas Transportation Institute, has two primary objectives:

1. Study successful projects that have used innovative concrete pavement techniques to rebuild urban highways rapidly; and
2. Conduct feasibility studies as part of the planning of urban reconstruction projects to determine the most effective methods of managing traffic during construction.

55-Hour Interstate Reconstruction

The first of these studies documents a dramatic reduction in user delays on I-10 near Pomona, California, as 2.8 km of concrete pavement, one lane wide, was replaced in a 55-hour period (see top photo, next page). Like many other states, California is experiencing the effects of an aging urban freeway system. With 3,000 lane-kilometers of pavement requiring rehabilitation, California's Department of Transportation (Caltrans) decided to research the best methods for constructing long-life pavement while minimizing traffic delays and inconvenience to the public.

For the initial study, Caltrans selected a 5-km (8-mile) stretch of I-10 near Pomona for rehabilitation,

Near Pomona, California, 2.8 lane-km of concrete pavement was replaced and opened to traffic after a single weekend.

using a series of repeated nighttime closures and one 55-hour weekend closure. The section of concrete pavement, in service since the early 1960s, carries an estimated 240,000 vehicles per day—far more than anticipated for its 20-year design life. Through IPRF, a research team from the University of California–Berkeley observed the 55-hour reconstruction, documenting the activities and the rate of productivity.

The weekend closure of the two outside lanes of eastbound I-10 lasted from 10:00 p.m. Friday until 5:00 a.m. Monday. Public traffic continued in the two inside lanes, separated from the construction zone by a movable concrete barrier. The contractor could earn a $500,000 incentive award for removing and replacing a single lane of concrete pavement 2.8 km (1.7 miles) long during the 55-hour period. If all lanes were not ready for public traffic at the end of the period, damages would be assessed at a rate of $10,000 for each 10-minute period.

The paving contactor, Morrison-Knudsen Corporation of Highland, California, completed the entire pavement replacement within the specified period, qualifying for the $500,000 incentive. The University of California–Berkeley team concluded that, under ideal conditions, as much as 3.4 lane-km could have been replaced.[1]

Weekend Intersection Replacement

CPTP also is demonstrating methods to reduce user delays and public inconvenience during work on urban streets that carry heavy traffic (see photo, below). In Kennewick, Washington, three distressed asphalt intersections recently were replaced with concrete pavement, each during a three-day closure. The intersections were closed on Thursday night, rebuilt with full-depth concrete pavement, and then opened for traffic by the following Monday morning.

Through IPRF, the University of Washington and the Washington Department of Transportation (DOT) documented the construction techniques. The final report will describe the traffic management plan, the high early-strength concrete mixture, the construction techniques, the production rates, and other details for public agencies and road builders undertaking similar projects. A videotape will document the process step by step from the intersection closure through the opening of the new concrete pavement to traffic.

[1] The research report and summary reports are available from IPRF at www.iprf.org.

CPTP includes studies of rapid intersection reconstruction to meet one of the program's goals: reducing delays.

Maturity testing—a simple and rapid method for determining concrete pavement's early strength—is a technique that shows exceptional promise.

Rapid Testing and Construction

Although CPTP is focusing on faster rehabilitation and reconstruction techniques to minimize the impact to road users and adjacent property owners, the quality of the pavement also is a consideration. Quality assurance is needed to assess the pavement's properties; rapid nondestructive testing is important for accelerated paving techniques.

As part of CPTP, FHWA is organizing a hands-on workshop to demonstrate nondestructive testing techniques for concrete pavement. State highway agencies and paving contractors will be able to try out the nondestructive testing equipment and, in some cases, to borrow the equipment from FHWA for use on projects.

Maturity testing—a simple and rapid method for determining concrete pavement's early strength—is a technique that shows exceptional promise. The procedure relates the concrete's time and temperature history to its early strength. Concrete test specimens are made in the laboratory, the temperature of the specimens is monitored and recorded, and the strength is tested at various ages. The relationship between the concrete's age, temperature, and strength—or maturity—is determined.

The concrete pavement's time and age are recorded in the field with a maturity meter, which records the pavement's temperature and age. Comparing the field readings with the laboratory results allows for the calculation of early concrete strength. This technique is better than traditional strength testing of concrete beams or cylinders when rapid results are needed or when testing facilities are unavailable during nighttime operations.

Reducing Costs

Using limited resources to the maximum advantage requires careful attention to the immediate construction costs and the life-cycle costs of the pavement. Most agencies seek to reduce costs as much as possible and to compromise pavement performance as little as possible, gaining the longest-term performance and the lowest life-cycle costs for the budget.

CPTP is working to reduce the immediate and life-cycle costs of building and maintaining concrete pavements by creating a better understanding of what influences cost, developing cost-effective design options, and eliminating unnecessary design features and construction requirements.

Life-Cycle Costs

Most state highway agencies use life-cycle cost procedures in selecting a pavement section for new and reconstructed roadways. In most cases, the collective judgments of state highway officials have produced the procedures; few studies have sought to determine the actual life-cycle cost of in-service highways.

As part of CPTP, IPRF is evaluating the life-cycle costs and service life of highways. ERES Consultants, Inc., a division of Applied Research Associates, is conducting the study. Records from state DOT files are being compiled to determine the actual cost to build and maintain sections of interstate highways. The information will be summarized to determine life-cycle costs, rehabilitation frequency, and pavement life. The studies will provide insight to state highway agencies to evaluate, verify, and modify life-cycle cost models. IPRF is conducting three studies, building on knowledge gained from earlier studies of Interstate pavement in Tennessee, Utah, Oklahoma, and Georgia.

Cost-Effective Design

Concrete pavement design involves more than determining the appropriate pavement thickness for specific site, traffic, and climatic conditions. The pavement engineer also must select other design features, including the type and amount of reinforcement (if any), base type, joint spacing, joint sealant, type of shoulder, concrete strength, drainage characteristics, and other properties. The pavement designer must make informed choices, selecting features necessary for good performance while avoiding features that are not cost-effective.

An IPRF study is evaluating the design options available to the concrete pavement design engineer. The goal is to compare benefits of improved performance with the cost of each feature, enabling the most cost-effective concrete pavement design. Features that impart value—that improve performance at the least cost—can be included, and features that add considerable cost with less impact on pavement performance can be avoided. The result will be more cost-effective concrete pavement. Applied Pavement Technology, Inc., Oakbrook Terrace, Ill., is conducting the research.

Concrete Overlays

Concrete overlays are a proven procedure for rehabilitation, widely used throughout the United States for well-worn concrete and for distressed asphalt pavement. Concrete overlays on asphalt pavement—commonly called whitetopping—are one of the fastest-growing concrete overlay options.

Pavement design procedures, however, do not fully account for the complex interaction between the concrete overlay and the underlying pavement. The procedures treat the underlying material as a firm base, often ignoring the structural value of the underlying concrete or asphalt roadway.

IPRF is developing new design procedures for concrete overlays over concrete and over asphalt. Advanced modeling techniques, high-speed computers, and new mechanistic design principles are producing more sophisticated design procedures to meet expected traffic loads. The result will be lower-cost concrete overlays without compromising long-term performance. Transtec Group, Inc., Austin, Texas, is conducting the study for concrete over asphalt; a research team for the study of concrete overlays on concrete pavement is to be determined.

Improving Performance

Better Concrete, Better Roads

Concrete mix design and concrete material performance are receiving increased attention. FHWA has several studies under way at the Turner-Fairbank Highway Research Facility in McLean, Virginia, to improve the performance of concrete in pavement, including the development of

- A test for concrete's coefficient of thermal expansion;
- A way to assess the freeze-thaw durability of concrete that has marginal entrained air content;
- A mix-specific alkali-silica reactivity test;
- Concrete mixtures that minimize shrinkage; and
- A test to evaluate the workability of concrete mixtures.

IPRF also is sponsoring research to improve the concrete used in pavement. In recent years, concrete mixture proportioning has become more complex. In addition to cement, water, and aggregate, concrete often contains fly ash, ground granulated blast-furnace slag, or other cementitious supplements. Various chemical admixtures also are used in types and doses adjusted to the temperature and climate at the paving site. High early-strength concrete usually requires chemical accelerators and—in some cases—special cements or thermal insulation to meet early-opening-to-traffic criteria.

Although most concrete mixtures perform well during construction, occasional problems arise. Some mixtures may exhibit early stiffening, retarded setting, loss of air entrainment, excessive shrinkage, early cracking, or premature deterioration from freezing temperatures. These results may occur when materials individually acceptable in concrete combine or react in an unexpected way.

Through IPRF, Construction Technology Laboratories, Skokie, Ill., is developing practical test procedures and criteria to assess the effects of combinations of materials for concrete pavements. The objective is to identify and avoid potential problems with combinations of materials before the concrete is mixed and delivered to the paving site.

FHWA is striving to improve ultrathin whitetopping performance through accelerated pavement testing at the Turner-Fairbank Highway Research Facility, McLean, Virginia.

Rehabilitation Options

Many alternatives are available for the repair and rehabilitation of concrete pavements. Although several studies have examined various aspects of these alternatives, a systematic process is not available to select the most appropriate. Sponsored by FHWA, work is now under way at Texas Transportation Institute to guide pavement engineers through a series of decisions to identify the proper technique for repair or rehabilitation. The guidelines will include

- Evaluating the pavement condition and type of distress;
- Choosing pavement repair, rehabilitation, or reconstruction; and
- Selecting the best specific materials and techniques.

The final guidelines will be issued in a user-friendly computer program for use by public agencies.[2]

Ultrathin Whitetopping

Ultrathin whitetopping (UTW) is a pavement rehabilitation technique that has expanded rapidly since its inception in the early 1990s. UTW is a concrete overlay, 2 to 4 inches thick, with short joint spacing bonded to an asphalt pavement. It has been

[2] For more information on the guidelines, contact Jim Sherwood, Highway Research Engineer, FHWA, 202-493-3150.

Field demonstrations, such as ultrathin whitetopping repair, are important in the Concrete Pavement Technology Program's education and training efforts.

used to rehabilitate distressed asphalt pavement at intersections, bus stops, urban streets, and general aviation airfields throughout North America.

Much has been learned about UTW in the last decade, but few controlled experiments have evaluated the factors that affect performance. As part of CPTP, FHWA has tested 8 sections of UTW using the Accelerated Loading Facility (ALF) device at the Turner-Fairbank Highway Research Facility (see photo, page 19). Each UTW section was carefully instrumented with strain gauges to provide researchers with better performance data. Transtec Group, Inc., is analyzing the results.

Fostering Innovation

The final goal of CPTP is to incorporate research findings and other innovations into practice. This will be accomplished in two ways: first, educating pavement practitioners about new findings and best practices from concrete pavement research and technology efforts; second, encouraging the development of promising technology for concrete pavement design, construction, and rehabilitation.

High-Performance Concrete

FHWA's High-Performance Concrete Pavement initiative is one of the most successful CPTP partnering efforts, providing opportunities for state highway agencies to try out innovative concrete pavement design and construction concepts on selected portions of highways. By actually building highways with innovative features, states gain first-hand knowledge of the advantages and constraints of new design and construction methods. Paving contractors learn the best techniques for incorporating the new technology into the construction process.

Equally important, FHWA's initiative requires the routine monitoring of each project to ensure a performance comparable or superior to more common design or construction practices. Thirteen states have taken advantage of this initiative to try out a variety of innovations, such as

- Various types of joint sealants—including a no-sealant option;
- Alternate dowel bar materials and dowel bar spacing at transverse joints;

- Fiber-reinforced concrete pavement;
- High-durability concrete mixes;
- Surface texturing techniques to improve safety and ride, as well as reduce noise;
- Thin concrete overlays;
- Concrete containing recycled asphalt; and
- Pavement with a 60-year design life.

FHWA is compiling a summary report presenting the studies in detail.[3]

Implementing New Technology

IPRF also is evaluating new and promising innovations in concrete pavement design, construction, and rehabilitation. A project, Field Trials of Concrete Pavement Products and Processes, aims to encourage state agencies to partner with local contractors and suppliers of material and equipment to implement new technology or improvements.

Public and private agencies can solicit IPRF funding to try new or improved concrete pavement technologies in field conditions. Reports, photos, videotape, and written reports will capture each effort for education and technology transfer. Field demonstrations have been completed or will soon be made on several promising technologies, including

- Techniques for repairing UTW (see photo, facing page);
- Rapid intersection replacement using concrete pavement;
- Thin concrete overlays of distressed asphalt pavement;
- Precast concrete panels for rapid pavement repair; and
- Performance-related specifications for concrete pavement construction.

This effort specifically aims to try out new technologies in field conditions, not to fund product development or laboratory investigations. Transportation researchers, public agencies, and private firms are encouraged to submit proposals to IPRF for consideration.[4]

Demonstrating Pavement Testing

FHWA's mobile concrete laboratory is an important element of CPTP. Housed in a semi-truck trailer, the laboratory travels throughout the United States, demonstrating the latest technology in concrete pavement testing and mixture proportioning. At job sites, the mobile laboratory's technicians help paving contractors and state DOT engineers test concrete with traditional methods and with new technologies. The hands-on demonstration and training is important for bringing the new technologies into use.

Technology Transfer

Each CPTP project includes technology transfer—for example, through funds for publications, videotapes, presentations, and other educational material. CPTP also sponsors workshops to inform transportation officials and industry representatives about new concrete pavement research results and technology advances. FHWA and IPRF have sponsored or are planning several training sessions, including such topics as

- Concrete pavement smoothness;
- Nondestructive testing for concrete pavement;
- Concrete durability; and
- Concrete pavement design.

Beyond TEA-21

Significant progress is being made toward the four goals of CPTP: reducing delays, reducing cost, improving performance, and fostering innovation in concrete pavement for the U.S. highway system. The close working relationship between FHWA and IPRF is an excellent example of a productive public-private partnership. Significant research and technology development is under way, with guidance from state highway agencies provided through the TRB Committee for Research on Improved Concrete Pavement for Federal-Aid Highways.

The four goals of CPTP involve immediate or short-term needs, but the program also is considering the needs of the highway community in 10 to 15 years. It is clear that the needs for improved concrete pavement technology will exceed available CPTP resources; therefore the TRB committee has recommended the development of a long-term plan for concrete pavement research and technology.

Through IPRF, the Center for Portland Cement Concrete Pavement Technology at Iowa State University is developing a long-term plan to extend beyond TEA-21 and CPTP. The plan will broaden CPTP, building on successes and identifying areas and issues that require more work. The research and technology development under way in CPTP—aimed at today's challenges—coupled with a longer-range plan to address the next 10 to15 years, promises to create a new generation of concrete pavement to meet the nation's highway transportation needs.

[3] For a copy of the FHWA summary report contact Mark Swanlund, Concrete Pavement Engineer, FHWA, 202-366-1323; e-mail: mark.swanlund@fhwa.dot.gov.

[4] More information and proposal procedures are posted at the IPRF website, www.iprf.org.