Long-Term Pavement Performance Program

Reaping Large Rewards from Small Improvements

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For the past 10 years, highway agencies in the United States, Canada, and other countries have been involved in the Long-Term Pavement Performance (LTPP) program, a massive study of in-service pavements. This program is the largest and most comprehensive pavement performance study ever, collecting uniform, comparable data to indicate how variations in maintenance, loads, climatic factors, and subgrade soils affect the performance of asphalt concrete and portland cement concrete pavements. The LTPP test sections are located on in-service pavements in a wide range of climatic zones and geographical regions.

Each year highway agencies in the United States alone invest upward of $40 billion building and maintaining 6 million kilometers (4 million miles) of roads. The goal of the LTPP program is to learn how we can do a better job protecting that investment.

The LTPP program is costly—$50 million under the Strategic Highway Research Program, approximately $50 million from states and provinces, and another $50 million provided under the Intermodal Surface Transportation Efficiency Act of 1991. All told, the program will probably end up costing about $250 million, making it the largest highway research project ever undertaken. That investment could reap huge rewards, even if the research leads to only a small improvement in pavement performance.

At the midway point in its 20-year life, the program is already yielding products aimed at improving the selection and effectiveness of pavement maintenance strategies, the performance of various pavement rehabilitation techniques and materials, and the design features for new construction or reconstruction of pavements. Highway agencies are using these products to improve their pavement design, construction, and management systems.

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Customer-Driven Program

The idea for the LTPP program originated with highway agencies across the nation that were having to repair and replace large numbers of pavements failing prematurely under the stress of increasing traffic loads and volumes. Recognizing the need for an extensive, long-term program of research into pavement performance, these agencies outlined a work plan, invested their federal-aid funds, and provided additional financial and staff support to get the program rolling.

The LTPP program is eminently practical and results-driven. State highway agencies are both owners of the program and customers for its products. They designate the test sites, construct and monitor the test sections, supply test materials, and collect traffic and other data from the test sites.

The LTPP program was established in 1987 and initially operated as part of the Strategic Highway Research Program. In 1992, when the research phase of SHRP concluded, the Federal Highway Administration agreed to serve as steward of the program, coordinating its activities for the states and handling its day-to-day operations.

The products emerging from LTPP research are expected to be useful to a broad spectrum of the transportation community, including industry, toll facilities, state and local agencies that own and operate roads, colleges and universities that conduct transportation research, the American Association of State Highway and Transportation Officials, the Transportation Research Board, the Federal Highway Administration, and the international pavement engineering community.

The TRB LTPP Committee provides top management input on LTPP research operations. The committee is composed of representatives from states and provinces in the United States and Canada and from 15 other countries, industry, and academia. In addition, several task groups of technical managers and experts from highway agencies, industry, and academia provide technical advice on collecting and analyzing data.

Four LTPP regional offices serve as the Federal Highway Administration's primary liaisons with state and provincial highway agencies, collecting performance-related data, assisting highway agencies in collecting materials and traffic data, and assembling and processing data for quality-control checks.

Research Plan

The original SHRP research plan set forth six objectives for the LTPP program:

- Evaluate existing design methods.
- Develop improved design methodologies and strategies for the rehabilitation of existing pavements.
- Develop improved design equations for new and reconstructed pavements.
- Determine the effects of loading, environment, material properties and variability, construction quality, and maintenance levels on pavement distress and performance.
- Determine the effects of specific design features on pavement performance.
- Establish a national long-term pavement data base to support SHRP objectives and meet the future needs of the highway industry.

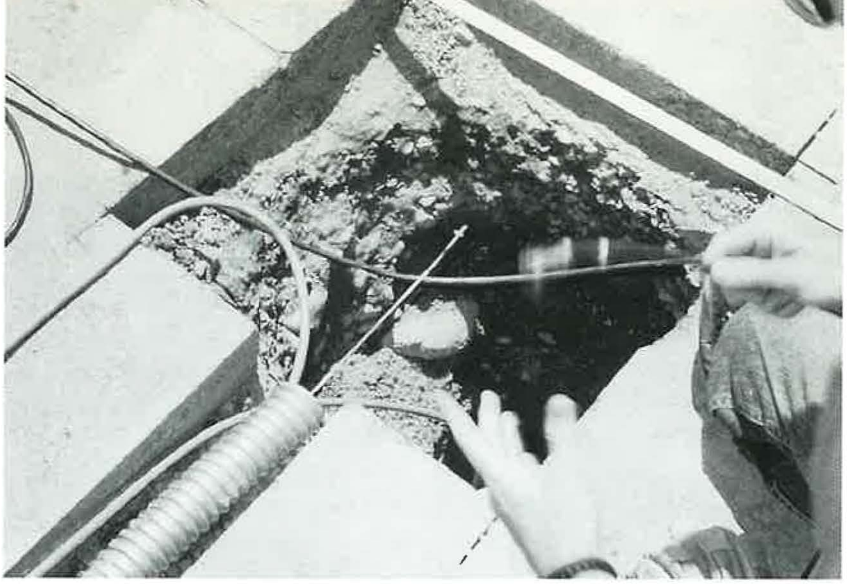
To support these objectives, the plan established two types of studies: general pavement studies (GPS) and specific pavement studies (SPS). Test sections are being monitored to determine just how long pavements last and what causes them to fail.

The general pavement studies focus on the most commonly used structural designs for pavement. Eight types of existing in-service pavements —in either original or rehabilitated condition— are being monitored at nearly 800 sites throughout North America. The performance of these structural designs is tested against an array of climatic, geologic, maintenance, rehabilitation, traffic, and other service conditions.

In contrast, the pavement test sections in specific pavement studies have been specially constructed to investigate certain pavement engineering factors. These particular test sections allow critical design factors to be controlled and performance to be monitored from the initial date of construction. It is expected that the results will provide a better understanding of how selected maintenance, rehabilitation, and design factors affect pavement performance. More than 1,000 SPS sites exist at approximately 200 locations throughout North America.

LTPP Data Base

At each GPS and SPS site, information on distress, roughness, structural capacity, traffic, and other variables is systematically collected. In addition, work groups of highway engineers periodically visit the sites to get a firsthand look at the pavements and to record their subjective observations. Both the objective and subjective data are entered into the LTPP data base.



Sensors buried in LTPP test sections are used to collect data on pavement response to variations in temperature and moisture.

Data are being collected in seven categories:

- Inventory—Geographical and historical information, obtained from state records, on each test section's location, material properties, composition, construction improvements, and type and thickness of each pavement layer.
- Materials Testing—Material properties and physical characteristics of the pavement, identified in field and laboratory tests.
- Climate—Estimated monthly values for temperature, precipitation, humidity, and solar exposure at each site as well as actual values collected at nearby weather stations.
- Maintenance—Information on every routine maintenance procedure, such as crack sealing and pothole patching, that has been applied to each test section since its inclusion in the LTPP program.
- Rehabilitation—Information on any major improvements to each test section since its inclusion in the LTPP program.
- Traffic—Yearly estimates of traffic volumes, axle loads, and equivalent single-axle loads for each site.
- Monitoring—Periodic measurements of pavement deflection, profile, surface distress, friction, and rutting.

The information is being used to construct a comprehensive data base on pavement performance. The data base, known as the LTPP National Information Management System, is the most comprehensive source of site-specific information on pavement performance. It allows tracking of a pavement's performance over time and provides information that will be used to predict the performance of specific highway projects and networks and to help pavement engineers explore and choose from a variety of pavement management options.

Most of the data collected at the LTPP test sections are first entered into four regional information management systems, which are maintained by the LTPP regional offices. At these offices the data undergo rigorous quality control checks before being uploaded to the National Information Management System. Additional quality control checks are conducted before the data are released to the public. Data on traffic volumes and loads at the test sites are initially stored in a central traffic data base, and then summarized and transferred to the National Information Management System.

Data Analysis

In line with the first objective of the LTPP program, namely, to evaluate existing design methods, the first analysis of the program data included evaluation of the AASHTO design equations for rigid and flexible pavements. This analysis, conducted under the Strategic Highway Research Program, confirmed that the design equations for both flexible pavements and rigid pavements still do not fully explain the performance data being collected from the test sites. Reports on the analysis included recommendations for improving the equations.

The data analysis plan has been modified and updated to reflect shifting priorities and needs. The most recent version of the plan is laid out in *The Long-Term Pavement Performance Program Roadmap: A Strategic Plan.* Other researchers will no doubt develop their own plans for the program data.

The data analysis plan will be continually adjusted and refined in response to feedback from participants in the LTPP studies, budgetary constraints, the evolution of AASHTO's process for development of new pavement design procedures, and findings from other pavement research projects.

LTPP Products— Today and Tomorrow

LTPP products include information, computer software, analysis procedures, test procedures, design procedures, and guidelines on pavement performance and design. Some products are already available; others are still being developed. The products fall into four broad categories: pavement design guides and maintenance strategies, pavement monitoring procedures, materials testing, and equipment standards and calibration procedures.

Pavement Design Guides and Maintenance Strategies

Pavement design guides and maintenance strategies form the core of the LTPP initiative. These products are designed to address key deficiencies in the ability to rehabilitate aging pavements and to construct and maintain pavements that will perform well under today's traffic conditions.

An example of this type of product is the SHRPBind software, which aids mix designers in selecting the appropriate Superpave performance-graded binder for a project. Superpave binders are selected on the basis of the lowest and highest pavement temperatures expected at the job site. SHRPBind not only includes all the information contained in the SHRP report *Weather Database for the Superpave Mix Design System*, but also calculates estimated reliability on the basis of weather station temperatures for Superpave binders rated between 50 percent and 98 percent reliable.

Pavement Monitoring Procedures

For a pavement management system to be effective, pavement conditions and traffic volumes and loads must be monitored consistently and the data collected must be accurate. Without consistent and accurate data, establishing the causes and rate of deterioration and selecting the most appropriate maintenance and rehabilitation measures are difficult.

The detailed monitoring procedures developed by the LTPP program will enable highway agencies to improve the uniformity and quality of the data collected. Each agency's own pavement management system will benefit, and the exchange of data with other agencies will be facilitated. The net result will be a better understanding of the causes of pavement problems and how to avoid them.

To improve communication within and among highway agencies and to improve the uniformity of pavement performance evaluations, SHRP issued the *Distress Identification Manual for the Long-Term Pavement Performance Project.* The easy-to-use manual contains instructions, data sheets, and distress maps for manual surveys of pavements surfaced with asphalt concrete, jointed portland cement concrete, and continuously reinforced concrete. A distress dictionary, the manual provides a common language for describing cracks, potholes, rutting, spalling, and other pavement distresses.

Another product, *LTPP Data Sampler and Data Request Program*, is a software demonstration program that provides an overview of the quantity and type of data being collected from the GPS test sections. The software includes information on climate, road profile, pavement materials, pavement deflection, and traffic for each test section. Once the user knows what types of data are available, he or she can request specific information from the National Information Management System, which is continually updated and amplified.

Materials Testing

In some cases the LTPP program has necessitated the refinement of existing procedures for pavement design and materials selection; in other cases, new test procedures have had to be developed. Many of the procedures have already been adopted as provisional standards of the American Association of State Highway and Transportation Officials. Once adopted, the procedures will improve the basis for pavement design and materials selection and will facilitate exchanges of information among highway agencies about material properties and behavior.

The LTPP-developed test for resilient modulus of soils and aggregates is a prime example of a procedure that builds on previous research. The test, which simulates physical conditions and stress states of materials beneath pavements subjected to traffic, is a modified version of a procedure originally developed, and then discarded, by the American Association of State Highway and Transportation Officials. The LTPP program's modification introduced standardization and repeatability into the procedure. The modified test procedure was subsequently approved as an AASHTO provisional standard.

Equipment Standards and Calibration Procedures

The quality of collected data hinges largely on the use of properly calibrated equipment and sound quality control/quality assurance measures. The LTPP program has developed calibration, quality control, and quality assurance procedures that will help ensure the accuracy of the test results. These procedures can be adopted or adapted for use by highway agencies.

The calibration processes for the falling weight deflectometer are examples of such procedures. In the reference calibration procedure, the measurement system of the falling weight deflectometer is calibrated against independent reference systems, which are themselves calibrated to standards traceable to the National Institute of Standards and Technology. The relative calibration procedure involves a statistical comparison of the

Improving Pavement Designs with Falling Weight Deflectometers

The falling weight deflectometer (FWD) traditionally has been used as a tool in pavement research, including the LTPP studies. Many highway departments have recently begun using the deflectometer in their pavement management systems as well. FWD data help to improve pavement designs and optimize pavement rehabilitation schedules.

Without accurate FWD data, pavement designers might recommend an overlay that is too thin for a site, compromising the durability of the pavement, or an overlay that is too thick, making the project more expensive than necessary. The LTPP program has developed two complementary means of calibrating falling weight deflectometers. These calibration procedures are now paying off for highway departments that use the deflectometers for pavement management systems. The Arizona Department of Transportation, for example, has one falling weight deflectometer for measuring the structural strength of 26 000 lane-kilometers (16,000 lane-miles) of pavement. The department uses the data at both the network and the individual project design levels of its pavement management system.

FWD calibration is a routine part of Arizona's operations. The reference calibration procedure is regularly performed to determine if the seismic sensors in its falling weight deflectometer produce consistent results and are functioning properly. To determine how readings from Arizona's falling weight deflectometer compare with those from other such deflectometers, the deflectometer is towed once each year to the regional calibration center in Reno, Nevada.

Regional calibration centers allow highway departments to determine if falling weight deflectometers are functioning properly and producing consistent results.

deflection sensors on a single falling weight deflectometer to ensure that the sensors are generating consistent measurements.

Protecting a Huge Investment

The United States spends almost $40 billion annually on pavement construction and rehabilitation, yet a significant number of the nation's roadways were recently rated as being in poor or moderate condition. The LTPP program holds the key to improved techniques for designing, building, and maintaining these roadways. The challenge is to maintain enthusiasm for and commitment to this vitally important program, the ultimate success of which hinges significantly on the continued support and participation of state and provincial highway agencies.

Like most public agencies, highway agencies are being called on to do more with less. The communities they serve demand and deserve smoother, safer roads with fewer delays caused by maintenance and repair work. The job of highway agencies is to provide those roadways, even as the number of vehicles on the road continues to grow and truck weights continue to increase. By supplying information on how and why pavements fail, the LTPP program will help the agencies stretch limited dollars and result in the construction and maintenance of more durable pavements.

SPS Test Sections Shed Light on Preventive Maintenance Practices

As early as 1993 some of the specific pavement studies (SPS) test sections under the LTPP initiative began to bear fruit. The SPS-3 and SPS-4 experiments focus on how various preventive maintenance treatments—applied to roadways of different ages, in different environmental regions, and under different traffic levels—affect pavement performance. The purpose of the two sets of experiments is to collect information on the most effective timing of the application of various treatments, to evaluate the effectiveness of treatments in prolonging the life of pavements, and to share information and experiences among highway agencies and industry. The SPS-3 experiments consist of treatments for hot-mix asphalt (flexible) pavements. The SPS-4 experiments consist of treatments for portland cement concrete (rigid) pavements.

A task group composed of representatives from state highway agencies, the Federal Highway Administration, industry, and academia visited the sites to review the treatments firsthand. Findings include:

- **Pavement sections that received preventive maintenance are generally outperforming sections that did not receive treatments.**
- **Treatment performance is related to pavement condition; that is, a treatment applied to a pavement in good condition will perform better than a treatment applied to a pavement in poor condition.**
- **Crack sealants applied to flexible pavements are performing well. However, these sections may not provide long-term performance data because the seals have not been maintained in many states.**
- **Slurry seals perform better on pavements with few cracks, because cracks tend to reflect through the thin slurry seal.**
- **Thin asphalt overlays perform better than other treatments on pavements in relatively poor condition.**
- **Joint and crack seals applied to rigid pavements perform well.**

These preliminary findings are already finding application in highway agencies' maintenance strategies. But the answer to the final question—what is the most effective maintenance strategy?—will only be answered through the analysis of long-term performance data.

NEW MEXICO DEPARTMENT OF TRANSPORTATION

More than 1,000 specific pavement study test sections are located at 200 sites throughout North America.

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AASHO ROAD TEST—AND THE UNANSWERED QUESTIONS

The road test conducted at Ottawa, Illinois, by the American Association of State Highway Officials (now known as the American Association of State Highway and Transportation Officials) between 1958 and 1960 is the basis of much current pavement design technology. This road test was a massive experiment involving six test loops, each containing pavement sections with different designs and materials. Each loop was subjected to different axle loadings. The experiment produced design equations that related the key variables of design, materials, and traffic. Since 1960 the equations have been broadly applied in highway construction throughout the world, and the AASHTO Road Test is considered to be one of the greatest successes in the history of highway research.

Valuable as they were, the results of this road test were inherently limited, reflecting only one set of climate and subgrade soil conditions. As an accelerated road test, it measured neither the effect of age nor the interaction of age with climate and traffic. Because the test continued until the pavement failed, it may not accurately reflect the effect of standard maintenance practices.

The LTPP program seeks to answer many of the research and application questions left unresolved by the AASHO Road Test. The willingness of the highway agencies in all 50 states, Puerto Rico, and the District of Columbia to participate in the LTPP program indicates the broad-based support for the program, especially considering the financial commitment that must be made.