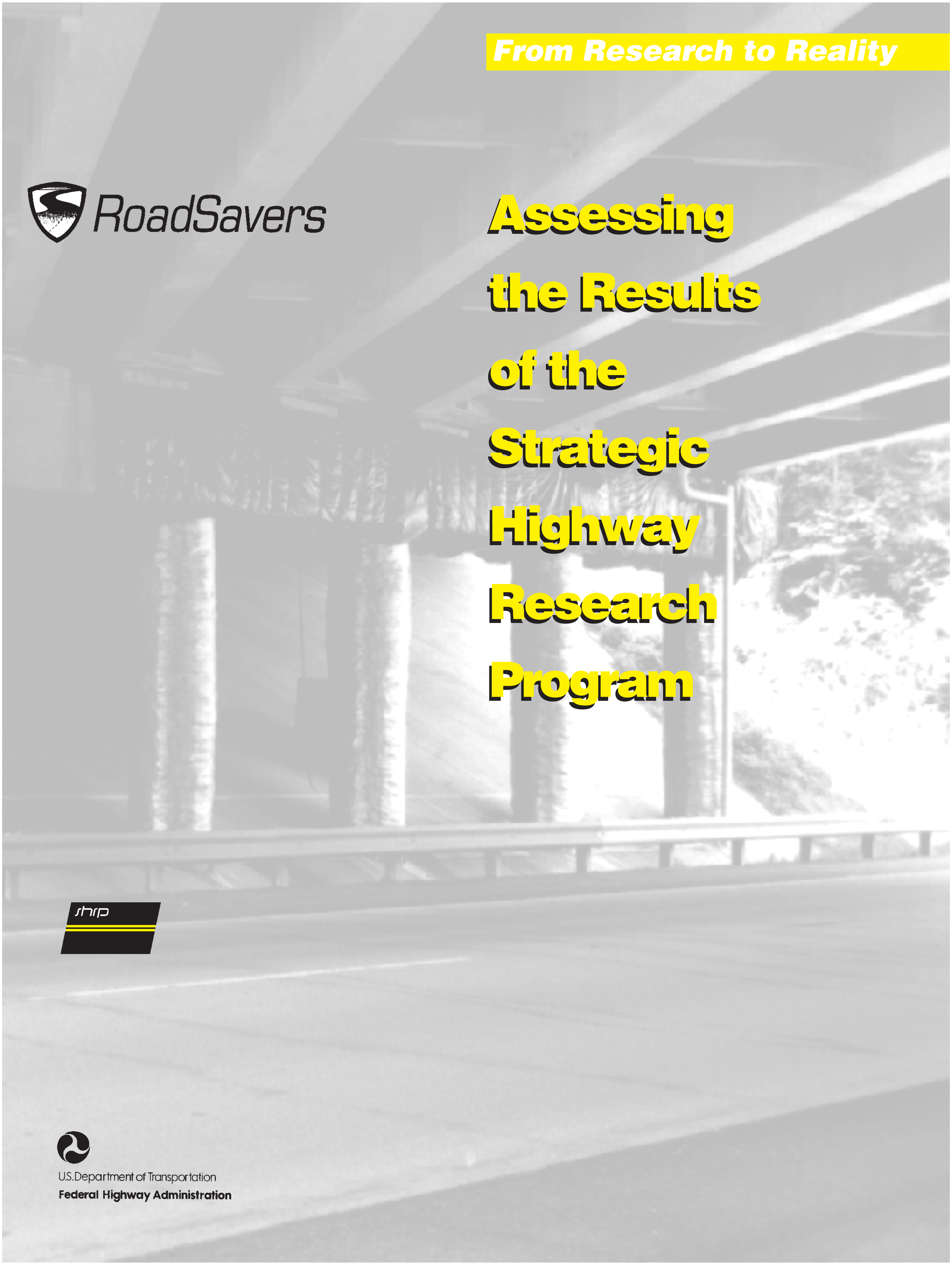


From Research to Reality

RoadSavers

Assessing the Results of the Strategic Highway Research Program

shrp

U.S. Department of Transportation
Federal Highway Administration

Contents

Further information on the SHRP assessment project is available on the Web (www.ota.fhwa.dot.gov/roadsvr).

Preface

In 1995, shortly after the 5-year Strategic Highway Research Program (SHRP) concluded and during the early stages of the national program to encourage the implementation of SHRP products, the Transportation Research Board (TRB) SHRP Committee suggested that a benefits-versus-costs study of SHRP be undertaken. The committee members felt that an objective assessment of the project and the products was needed, to determine if the investment had been a wise one.

This report summarizes the results of that study, which was conducted during 1996 and 1997. The overarching conclusion of the study: the economic and safety benefits of SHRP clearly outweigh the research and implementation costs. As a result, SHRP products have been dubbed *RoadSavers*, as they save money, time, and lives on the Nation's highways.

The study was a large task, requiring close coordination and cooperation among a number of organizations across the country. The Federal Highway Administration (FHWA) launched and funded the project and, assisted by the SHRP Assessment Project Steering Group (composed of transportation consultant Gary Byrd, Michael Cuddy of the New York State Department of Transportation, Charlie Potts of APAC Inc., Bob Templeton of the Texas Department of Transportation, and William Weseman of FHWA), provided overall direction for the project. The transportation technology transfer center at the University of Nevada-Reno (UNR) managed the project. The transportation technology transfer centers in Florida, Indiana, Minnesota, Pennsylvania, and Texas assisted UNR in compiling information on how State and local highway agencies were using SHRP products. This information served as grist for the more than 100 case studies published to date of how SHRP products are being used to build, maintain, and operate safer, smoother roads. State and local agencies provided invaluable assistance by supplying information for the case studies and then reviewing them for accuracy.

The information collected by the technology transfer centers was turned over to a team of economists and engineers at the Texas Transportation Institute. This team conducted the economic analysis that formed the basis for the benefits-versus-costs report.

From all of this information, Harrington-Hughes & Associates, Inc., prepared the RoadSavers case studies, brochures, videotape, and other publications summarizing the study results.

The Strategic Highway Research Program

In 1987, in response to a growing national concern over the condition of the highway system, the U.S. Congress established a 5-year, large-scale, applied research program aimed at improving the performance, durability, safety, and efficiency of the Nation's highway system.

Called the Strategic Highway Research Program (SHRP), it operated as a unit of the National Research Council and under the direction of an executive committee consisting of top-level managers from State highway agencies, industry, and academia. Program funding came from the States, who agreed to contribute one-quarter of 1 percent of their federal-aid highway funds for SHRP.

The SHRP staff included dozens of highway professionals "loaned" to the program from highway agencies in the United States, as well as 12 other countries.

The research was conducted by private organizations and universities who competed for contracts in a formal bidding process. The research projects were concentrated in four areas:

- ❑ Asphalt,
- ❑ Concrete and structures,
- ❑ Highway operations (maintenance and work zone safety), and
- ❑ Pavement performance (the long-term pavement performance study).

The research phase ended in 1992, and SHRP closed its doors in 1993. The Federal Highway Administration (FHWA) then took on the task of coordinating the national program to get the SHRP products into the hands of the users.

Moving SHRP Products from the Laboratory to the Field

The intense, concentrated research phase proved to be only the first step in meeting the goal of building and maintaining more durable roads. Just as important was the far-reaching implementation effort spearheaded by FHWA, which involved making some necessary refinements to the SHRP products and getting the products out to State and local highway agencies, so that they could try them out for themselves. Meeting this challenge involved close partnerships with States, industry, academia, and others.

The SHRP technology transfer effort was funded by the 1991 Intermodal Surface Transportation Efficiency Act. An array of technical working groups (TWGs) and expert task groups (ETGs), composed of representatives from highway agencies, industry, academia, and FHWA, provided specialized guidance on the products.

The American Association of State Highway and Transportation Officials (AASHTO) and the Transportation Research Board (TRB) also placed their resources solidly behind the SHRP implementation effort. AASHTO formed a Task Force on SHRP Implementation to act as a catalyst for implementation. TRB established the TRB-SHRP Committee to monitor the progress of implementation and provide guidance and recommendations.

One of the primary vehicles for introducing highway agencies to the new SHRP technologies has been a series of **showcase workshops**. These regional workshops focus on a group of SHRP products in a particular area, such as concrete durability or pavement maintenance. Each workshop features both classroom instruction and hands-on training, as well as discussion on how the particular technologies might best be implemented in that particular region. Workshop participants can also request to borrow the SHRP equipment, so that they can "test drive" the new technologies on their own, before committing to purchase.

To bring engineers and technicians up to speed on the new Superpave system, FHWA has established the **National Asphalt Training Center**, located at the Asphalt Institute in Lexington, Kentucky. The Center holds training courses and provides technical assistance. FHWA's National Highway Institute also sponsors courses on the Superpave system.

While showcase workshops and training courses have been prime implementation tools, FHWA has also relied on **mobile laboratories** to take the technology to the users. The laboratories contain state-of-the-art equipment and are staffed by experienced instructors and technicians. The laboratories are also used to conduct field evaluations on new equipment.

State departments of transportation have teamed up with universities to open **regional Superpave centers**. Five centers, located in Pennsylvania, Alabama, Indiana, Texas, and Nevada, offer training to engineers, technicians, and other highway workers and provide other services, such as ruggedness, precision, and bias testing of the new procedures and equipment.

Although SHRP was driven by the needs of State highway agencies, local governments have not been forgotten in the SHRP implementation program. A 3-year project sponsored by FHWA's **Local Technical Assistance Program (LTAP)** introduced local governments to a range of SHRP products particularly suited to their needs, such as winter maintenance strategies and pavement maintenance guidelines. Local governments also learned about SHRP technologies through the 57 transportation technology transfer (T2) centers located across the country. These centers, which were established under FHWA in 1982, were each sent samples of SHRP products to use in demonstration and training sessions. Local governments were encouraged to borrow the equipment for field tests.

As more and more SHRP products are tested and adopted by highway agencies, the implementation program continues to acquire new dimensions. For example, through the Lead States program sponsored by AASHTO, States that have moved out ahead of the pack in implementing SHRP products are providing technical support and guidance to their peers in other States. New showcase workshops are also being devised that will draw on users' experiences with SHRP products to expand the depth of instruction.

These new ventures will continue to build on the vital partnerships fostered by SHRP. They will also continue to broaden the potential of the SHRP devices, tests, and specifications, putting them in the hands of even more users. As these products become part of everyday use, State and local governments will move closer to the ultimate goal of a stronger, safer, and more efficient transportation system.

SHRP Assessment Project

The SHRP assessment project was a broad, collaborative effort to determine whether the benefits to be gained from the SHRP products exceeded the SHRP research and implementation costs. The assessment project was suggested by the TRB-SHRP Committee. Project funding came from FHWA. The transportation technology transfer center at the University of Nevada-Reno (UNR) was selected to coordinate and manage the project, under a contract with FHWA.

With the help of the transportation technology transfer centers in Florida, Indiana, Minnesota, Pennsylvania, and Texas, UNR began collecting information on the use of SHRP products by State and local highway agencies across the United States. Through phone and mail surveys, the centers compiled information for more than 100 detailed case studies. Dubbed *RoadSavers*, these reports describe how highway agencies are using SHRP technologies to save money, time, and lives.

Once the initial batch of case studies was compiled, the Texas Transportation Institute (TTI) was contracted to conduct the second half of the project—a macroeconomic analysis of the benefits and costs of SHRP products. A team of economists and engineers at TTI reviewed the information collected by the technology transfer centers and then used their knowledge and expertise to develop a series of reports focusing on five SHRP technology areas:

- ❑ Superpave system.
- ❑ Snow and ice control.
- ❑ Pavement maintenance.
- ❑ Concrete and structures.
- ❑ Work zone safety.

The team evaluated the total nationwide costs of researching, developing, and implementing the SHRP technologies. Realizing that highway agencies are not likely to adopt the products immediately, three timelines, each reflecting a different pace of implementation, were used to estimate the costs and benefits over a 20-year period.

In calculating the financial benefits, the team looked at savings to highway agencies, which result from more durable roads and bridges and more efficient use of staff and materials. Equally important, however, in the total equation were savings to motorists, which result from fewer crashes and delays and lower vehicle operation and repair bills.

The results provided clear evidence that the SHRP technologies not only make roads safer, but also cut costs. For example, TTI predicted that highway agencies can save at least $126 million a year by implementing SHRP's pavement maintenance strategies. The analysis of the pace of implementation also clearly shows that the faster these innovations are implemented, the bigger the return on investment. For example, if States adopt just 6 of the 44 concrete test technologies developed or evaluated under SHRP, their annual savings could range from $4.1 million at a slow pace of implementation to $15.5 million at a fast pace of implementation over the next 20 years.

Implementing SHRP products is proving to be good news for States' roads and their budgets. And with full implementation of most SHRP products still to come, the $150 million invested in SHRP by Congress in 1987 will continue to pay dividends far into the future.

The following sections summarize the key findings of the SHRP assessment project. For more information, see the resources listed on page 20.

The Superpave System

Asphalt concrete is a major component of the highway system in the United States, covering more than 90 percent of the Nation's paved roads. Every year, State and local highway agencies spend $10 billion on asphalt pavements, and private sector expenditures total an additional $5 billion. Steadily increasing traffic volumes and loads are taking their toll on these roads, forcing highway agencies to commit extensive resources to rehabilitation projects. As a result, motorists frequently encounter work zones that disrupt traffic, as well as rough pavements that pose safety risks and damage tires and suspensions.

SHRP's solution was to develop a completely new approach to asphalt mix design—the Superpave system. The Superpave system provides designers with the tools to custom-design an asphalt pavement for the specific weather and traffic conditions at a particular job site, instead of simply replicating a mix that has served reasonably well in the past.

The Superpave system has three components:

- ❑ An asphalt binder specification.
- ❑ A design and analysis system based on the volumetric properties of the asphalt mix.
- ❑ Mix analysis tests and performance prediction models.

Materials engineers use these components to select materials and a mix design best able to resist two key types of pavement distress: permanent deformation and low-temperature cracking. Permanent deformation can result when a pavement is exposed to heavy traffic and hot weather and lacks the strength to withstand rutting. Low-temperature cracking occurs when the pavement shrinks in cold weather.

The Superpave system requires a new array of equipment for testing and evaluating asphalt binders and mixes. By mid-1997, all State highway agencies had five of the six pieces of equipment needed to test binders. The sixth binder test device is in the final stages of development. All States also have at least one Superpave gyratory compactor, the device used in the volumetric mix design procedures to simulate the effects of construction and traffic on an asphalt mix.

Case Studies

Highway agencies that have built Superpave pavements report that the new system is producing more durable pavements. On highways across the country, Superpave pavements are holding up well to heavy traffic and extremes of climate.

In 1995, for example, the Alabama Department of Transportation (DOT) resurfaced 8 km (5 mi) of badly rutted Route 165 with a Superpave mix. Despite heavy truck traffic and extremely hot weather, the pavement showed virtually no signs of rutting 2 years later, and Alabama DOT expects the pavement to last longer than it would have if it were constructed with the State's conventional mix.

A Superpave overlay under construction on Interstate 10 in Arizona. The overlay is performing well despite heavy traffic loads and high air temperatures in excess of 43 °C (110 °F).

In a similar case, Arizona DOT used a Superpave mix to construct an overlay on a section of Interstate 10 near Phoenix in 1995. In its first summer, the pavement withstood heavy traffic loads and 17 consecutive days of temperatures above 43 °C (110 °F). The pavement's performance to date indicates that it will be very resistant to permanent deformation.

Superpave pavements have also proven durable in cold climates. After 4 years of cold weather and heavy traffic, early Superpave test sections constructed on Interstate 43 in Waukesha County and on Interstate 94 in Monroe County, Wisconsin, are holding up better than adjacent sections constructed using Wisconsin's conventional mix. Cold weather is also no problem for an overlay built using a Superpave mix on a rural road in Blue Earth County, Minnesota, in August 1995: The overlay is suffering less low-temperature cracking than a nearby, same-age overlay built using Minnesota's conventional mix.

After building several pavements using binders that meet the Superpave specification, Texas DOT predicts that the specification will have tremendous benefits. Darren Hazlett of Texas DOT says, "Using the conservative assumptions that 25 percent of the asphalt Texas now uses doesn't meet the specification and that pavement life will gain about 2 years where we use binders that meet the Superpave specification, I came up with an extremely rough estimate of $2.2 billion in savings over 30 years."

The Benefits

The economic assessment of the Superpave system focused exclusively on the role that the asphalt binder plays in mix performance. Based on States' experiences to date, TTI estimated that one-fourth of the asphalt paving projects in the United States use binders that do not meet the Superpave specification for the particular site. Because the properties of the binder have a significant effect on the performance of an asphalt mix, the analysis found that switching to the Superpave binder specification could increase the service life of an asphalt overlay by 25 percent (to 10 years from 8 years). Adopting the Superpave binder specification would thus increase the service life of one in four overlays by 25 percent.

The analysis also considered the following factors:

- ❑ Traffic loads and volumes are expected to increase by 2.1 percent annually.
- ❑ Based on early projects, Superpave binders are, on average, more expensive than other grades of binders, increasing the cost of overlays by about 7 percent.
- ❑ As States implement the Superpave system, they will have higher costs for purchasing and maintaining equipment and for employee training. These costs were subtracted from the projected benefits.

The assumptions about the effect of the Superpave binder specification are fairly conservative. Even so, those assumptions yield tremendous potential savings over a 20-year period. For example, if all highway agencies adopt the Superpave binder specification (which is only one component of the Superpave system) within 5 years, the increase in pavement service life could save highway agencies nationwide $637 million per year. If it takes highway agencies 10 years to implement the specification, the annual savings could still reach $484 million.

The potential savings to motorists are more impressive. Because longer-lasting overlays will mean improved pavement conditions, and thus fewer maintenance-related delays and less wear-and-tear on vehicles, motorists could save as much as $1.7 billion per year over a 20-year period if highway agencies were to adopt the Superpave binder specification within 5 years. If it takes 10 years to adopt the technology, the savings to motorists could reach $1.3 billion per year.

Superpave research was the single biggest item in the SHRP budget, costing $53 million. The research, development, and implementation costs for the Superpave binder specification are estimated at $230 million over 20 years. This cost pales in comparison to the expected benefits, however; if it takes highway agencies 10 years to fully implement the Superpave binder specification, they will save more than twice the total cost of implementation every year for the next 20 years. The annual savings to motorists are more than five times as much as the total cost of implementing the Superpave binder specification.

Concrete and Structures

Portland cement concrete has served as a key construction material for more than 2,000 years. Today, it is used in virtually all bridge decks and piers in the United States. Concrete is also used to pave many high-volume roads and for most curbs, sidewalks, and median dividers. In all, highway agencies spend $6.5 billion a year on portland cement concrete bridges, pavements, and structures.

Many of the concrete bridges and pavements constructed between the 1950s and the mid 1970s are showing signs of severe damage from traffic, weather, and other factors. By the late 1980s, highway agencies faced $20 billion worth of needed repairs on steel-reinforced concrete bridges alone.

SHRP investigated ways to address and prevent the problem of deteriorating concrete bridges and pavements. Researchers developed or evaluated 44 products for concrete and structures, including:

- ❑ Nondestructive tools and procedures for assessing the condition of concrete structures and pavements.
- ❑ New strategies for protecting and rehabilitating concrete pavements and structures, including the use of cathodic protection and electrochemical chloride extraction on steel-reinforced concrete bridges.
- ❑ Guidelines for designing concrete mixes to make them less susceptible to spalling, cracking, and other common problems.
- ❑ Ways to detect, mitigate, and prevent alkali-silica reactivity (ASR), a chemical reaction that can cause severe damage to concrete.
- ❑ Guidelines for using high-performance concrete in bridges and pavements.

Case Studies

The Kentucky Transportation Cabinet, for example, has been evaluating the hydraulic fracture test chamber developed under SHRP. The device simulates the effect of freeze-thaw cycles on aggregates, allowing highway agencies to screen out aggregates susceptible to D-cracking. Where the conventional test method takes weeks, the new method requires only days, saving money on labor and helping the State to quickly assess the quality of aggregate.

In another case, the Nevada DOT evaluated the surface air-flow permeability meter, a new tool for assessing the permeability of concrete over reinforcing steel. The highway agency found the device to be quick, easy to use, and dependable.

The case studies also describe State highway agencies' successes with SHRP products not considered in the TTI analysis. For example, Alaska DOT bridge inspectors have adopted a test developed by SHRP to measure the chloride content of steel-reinforced concrete bridges. Because the test can be conducted in the field, rather than in the laboratory, it requires less time and labor than the previous method. Alaska DOT says the $2,000 chloride content test kit saves the agency about $1,400 per bridge, which meant a savings of $95,000 in just 1.5 years.

In Virginia, electrochemical chloride extraction technology, another product evaluated by SHRP, has added 12 to 15 years to the service life of two concrete bridges. As a result, the State has avoided the traffic delays and huge costs associated with replacing a bridge.

In Idaho, the Transportation Department is using SHRP's chemical test to detect ASR in portland cement concrete pavements and structures. Previously, the State took concrete samples to a private laboratory for analysis, which cost $300 to $400 per sample and could take a month or more. By switching to the SHRP test, says Al Stanley of the Idaho Transportation Department, "We spend perhaps $40 to $50 per sample, and we know the results within hours."

Electrochemical chloride extraction technology has added 12 to 15 years to the service life of this bridge near Charlottesville, Virginia.

The Benefits

The cost-benefit analysis covered only 6 of the 44 test methods and guidelines developed under SHRP for concrete and structures (see sidebar, page 10). Yet highway agencies can reap substantial savings by adopting just those six test methods and guidelines, which allow highway agencies to:

- ❑ Design concrete mixes that will be more resistant to freeze-thaw cracking (D-cracking).
- ❑ Quickly assess the condition of existing concrete structures.
- ❑ Mitigate the effects of ASR and D-cracking in structures and pavements.

Using the six test methods and guidelines, State highway agencies can extend the service life of bridges and cut bridge monitoring and maintenance costs. The extent of a highway agency's savings will depend on how quickly it adopts these guidelines and test methods. The economic analysis found that even if the six products were adopted by only *one-fourth* of all highway agencies over a 20-year period, the savings could total $4 million per year. And if *all* highway agencies began using the new tests and guidelines, the savings could reach $15 million per year over a 20-year period.

Researchers also took a look at the SHRP guidelines for mitigating damage from ASR and D-cracking in concrete pavements. These conditions affect about 10 percent of the Nation's 208,000 km (129,000 mi) of concrete pavements. On average, those pavements require extensive rehabilitation after 10 years of service.

The analysis assumed that the SHRP guidelines could extend the service life of affected pavements by 70 percent (to 17 years from 10 years), thus delaying the need for expensive rehabilitation work. If only one-quarter of highway agencies were to implement these strategies in 20 years, the savings could average $13 million a year. If all agencies were to adopt these tools over that period, the savings could reach $48 million per year.

Longer-lasting concrete pavements will have even bigger benefits for motorists. Because pavements will be in better condition, there will be less wear-and-tear on vehicles. And motorists will encounter fewer delays caused by road work. As a result, motorists could save between $38 million and $143 million a year over a 20-year period, depending on how quickly highway agencies adopt the new guidelines.

Highway agencies should see a quick return on the cost of researching, developing, and implementing the SHRP tools and guidelines for concrete structures and pavements, which is estimated at $55 million over 20 years. Even if highway agencies implement the products slowly, they could still recover that cost in less than 4 years.

More Innovative Products Lie Ahead

Many of the products SHRP developed or evaluated for concrete structures are relatively complex and expensive and are therefore difficult to implement. Several ongoing initiatives are helping State highway agencies to overcome the implementation hurdles.

One such product is high-performance concrete, which can be used to build bridges and pavements that are more durable and cost-effective than bridges built with conventional concrete mixes. FHWA is helping to fund construction of bridge and pavement projects that demonstrate the capabilities of high-performance concrete.

In another example, FHWA is facilitating loans of a van-mounted ground-penetrating radar (GPR) system. The GPR technology is a nondestructive way to collect information on pavements and concrete bridge decks at highway speeds. But the equipment's high cost can be a barrier to implementation. The equipment loan program allows highway agencies to decide if the technology is worth the cost—before committing any funds.

TTI's analysis of SHRP's concrete and structures research covered the following six products.

- Hydraulic fracture test chamber, a relatively quick way to screen aggregate supplies for materials likely to fracture under freeze-thaw conditions.
- Maturity meter, one of the field tests evaluated by SHRP for estimating the early-age strength of newly constructed concrete structures.
- Modified freeze-thaw resistance test, an alternative to current tests of a concrete sample's susceptibility to freeze-thaw damage that better reflects real-world conditions.
- Surface air-flow permeability meter, a quick method for determining the permeability of the top 13 mm (0.5 in) of a concrete pavement or structure. The device helps highway agencies plan bridge and pavement maintenance projects.
- Guidelines for mitigating damage caused by ASR in existing concrete pavements and structures.
- Guidelines for mitigating cracks in concrete pavements and bridges that are caused by freeze-thaw cycles.

Highway Operations
(Maintenance and Work Zone Safety)

Nearly one-third of the $90 billion spent every year on the Nation's highway system goes to the critical tasks of snow and ice control and pavement maintenance and repair. Snow and ice control operations keep roads passable and safe during winter storms. Pavement maintenance and repair operations help pavements stay in good condition for longer periods—which means smoother roads and less wear-and-tear on vehicles.

The products of SHRP's highway operations program fall into three general categories:

- ❑ Pavement preservation.
- ❑ Work zone safety.
- ❑ Snow and ice control.

Pavement Preservation

Highway agencies in the United States spend $25 billion annually on pavement maintenance. But soaring traffic volumes and truck loads make it more and more difficult to keep up with maintenance needs. As a result, many highway agencies face a backlog of maintenance tasks, which means more pavements are in need of repair. Poor pavement conditions can impair highway safety, damage vehicle tires and suspensions, and annoy motorists.

SHRP researchers developed and evaluated ways to make pavement maintenance and repair operations more effective and efficient. Using the SHRP guidelines on preventive maintenance strategies and pavement repair methods, highway agencies can select the optimal method for repairing potholes and cracks in asphalt pavements and cracks and spalls in portland cement concrete pavements. They can also select the most effective preventive maintenance treatments. The result is a comprehensive pavement maintenance strategy tailored to the traffic, climate, and financial realities facing a highway agency.

Case Studies

The experiences of State and local highway agencies show that SHRP has helped to make pavement repairs and maintenance more durable and cost-effective. For example, Alaska DOT's Glennallen District decided several years ago that it would no longer use expensive, poorly performing cold mix materials for pothole repairs. The district decided to switch to a patching material custom-made for conditions in the area, as recommended by SHRP. The custom mix is performing extremely well—pothole repairs now last two to four times as long as they used to. In addition, the new material can be stored for extended periods of time, allowing the district, which is located in a remote area, to buy materials in bulk.

In Larimer County, Colorado, the Road and Bridge Department has adopted another pothole repair technique highly rated by SHRP—namely, the spray-injection method. "There is absolutely no comparison between the spray-injection method and conventional pothole patching methods," says crew leader Ken Mosness. "Not only is the machine faster and easier to use, but the finished work is also very durable and longer lasting."

The Benefits

The analysis focused on the economic benefits to be gained from using SHRP's guidelines on pothole patching techniques and preventive maintenance strategies. The other products of SHRP's pavement maintenance research have not yet been used extensively enough to allow benefits-versus-cost comparisons.

Pothole Patching

Each year, State highway agencies spend $300 million to $400 million to fix potholes. Local highway agencies, which are responsible for three-fourths of the roads in the United States, spend about twice that much annually.

In most cases, highway agencies patch potholes using locally available cold-mix materials applied with the semi-permanent method or the throw-and-roll method. SHRP found that quality materials applied with either the throw-and-roll method or the spray-injection method can produce repairs that last as long as those made using the more costly and time consuming semi-permanent method. It is the quality of the materials, not the repair method used, that determines how well the patch will hold up.

The analysis assumed that highway agencies could cut repair costs by 25 percent by switching to high-quality materials and using either the throw-and-roll method or the spray-injection method. The result—a savings of between $24 million and $89 million per year, depending on how quickly the new methods are applied over a 20-year period.

Preventive maintenance treatments such as crack sealing, shown here, can dramatically extend the life of asphalt and portland cement concrete pavements.

Preventive Maintenance

In analyzing the economic benefits of preventive maintenance, the study assumed that most pavements receive a preventive maintenance treatment after 10 years of life, then have an overlay applied 5 years later. Following SHRP's recommendations, highway agencies would instead apply a preventive maintenance treatment at 7 years in the pavement's life and again at 14 years; this would likely delay the need for a costly overlay until the pavement has been in service for 19 years—which could save highway agencies nationwide between $102 million and $384 million annually, depending on how quickly they adopt this strategy.

Improved preventive maintenance strategies will save motorists money also. Because roads will be in better condition, drivers won't have to slow down for rough pavement, and vehicles will suffer less damage. As a result, motorists nationwide could save between $167 million and $627 million per year, depending on how quickly highway agencies implement the SHRP guidelines.

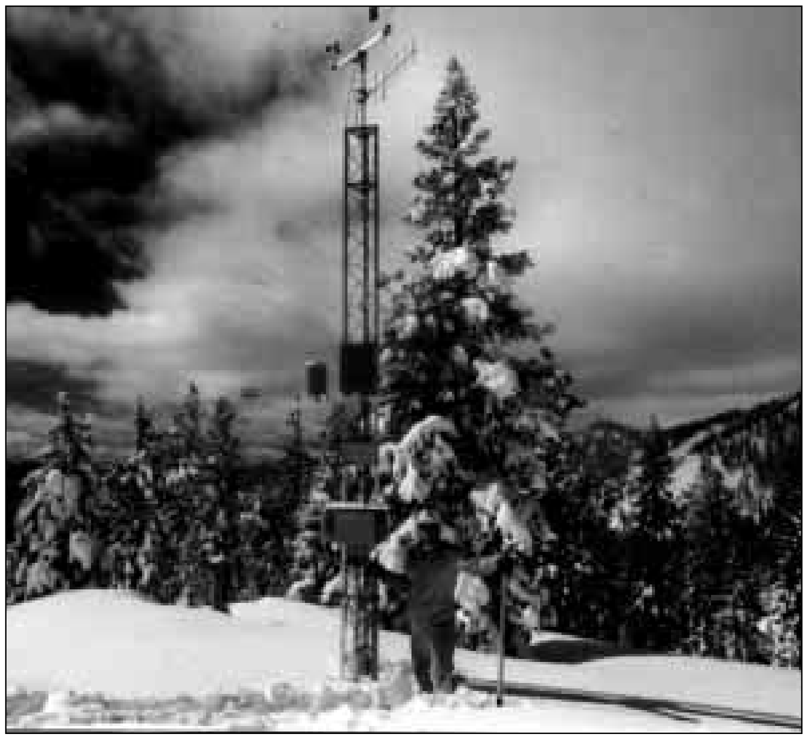
The study's findings confirm that highway agencies will get their money's worth from SHRP research on pavement repairs and preventive maintenance. Research, development, and implementation costs for the SHRP pavement maintenance products are estimated to be $45 million over 20 years. Using the SHRP pavement maintenance products, highway agencies could easily save twice that much every year.

Snow and Ice Control

State and local highway agencies spend about $2 billion a year on winter maintenance, keeping roads open and safe for travel during winter storms. Traditional maintenance operations involve waiting for snow or sleet to begin sticking to roads, then deploying plows and trucks loaded with salt and other chemicals to clear the pavement. This approach is effective, but not particularly efficient, because it allows ice to form a strong bond with the pavement. Breaking that bond requires many hours of crew and equipment time, and lots of salt and sand are required to clear the pavement and ensure safe travel conditions. These factors make conventional winter maintenance methods tough on budgets and on the environment.

SHRP sought ways to make winter maintenance more efficient, less harmful to the environment, and less costly in terms of equipment and crew time. For example, SHRP researchers developed snowplow designs that made plowing more effective and efficient, and they produced guidelines for more effectively using snow fences to keep roads clear of drifting snow and improve visibility.

RWIS stations, such as this unit in Nevada, supply highway agencies with information that is extremely useful in winter maintenance.



SHRP also evaluated two new technologies—anti-icing strategies and road weather information systems (RWIS). Anti-icing strategies involve the application of salt and other chemicals to the pavement before a storm strikes. When the snow or sleet begins to fall, the chemicals prevent ice or snow from bonding to the pavement. The snow or ice melts on the pavement, forming a wet or slushy surface rather than an icy surface. To be successful, anti-icing strategies require accurate, real-time information on pavement and weather conditions. This information can be easily collected with RWIS technology, making anti-icing strategies easy to implement on a broad scale. Pavement and atmospheric sensors at each RWIS station monitor weather and road conditions. Real-time data from these sensors are used with improved weather forecasting systems to provide winter maintenance managers the information needed to determine where—and when—to apply chemicals to prevent snow and ice from bonding to the pavement. To help highway agencies adopt these technologies, SHRP developed guidelines on the purchase, installation, and use of RWIS systems and on the implementation of anti-icing strategies.

Case Studies

State highway agencies have reported considerable savings from the use of RWIS networks. Data from an RWIS station enabled the North Dakota DOT to cut back on the use of sand on a bridge on I-94 near Fargo, saving $10,000 to $15,000 in just four storms. Data collected by an RWIS network along the 153-km (95-mi) West Virginia Parkway led to savings of about $2,300 in labor costs and $6,500 in materials costs per storm.

Recognizing the potential for savings, highway agencies are quickly implementing RWIS technology. By 1994, there were already more than 750 RWIS stations in service across the country.

Highway agencies also report big savings from the use of anti-icing strategies. For example, the anti-icing strategy in Boulder, Colorado, has resulted in a 55 percent reduction in sand use. When all related expenses are considered, the anti-icing strategy costs $1,600 per lane-km ($2,500 per lane-mi)—half the cost of the conventional sanding and deicing strategy.

Anti-icing techniques have other advantages. Because Oregon DOT's anti-icing strategy means much less sand is used, the highway agency is helping to minimize air and water pollution. And because it keeps roads clearer and safer, the anti-icing strategy has drawn praise from the State Police.

The Benefits

The study found that an anti-icing strategy coupled with RWIS technology can reduce the amount of time that equipment and crews spend on the road and the amount of salt, sand, and other materials needed. The analysis used data collected as part of SHRP field trials between 1991 and 1993, which reported the annual cost savings per mile of salt or sand truck route as ranging from $650 in areas with 100 hours of storms per winter to $6,850 in areas with 900 hours of storms per winter. The analysis also assumed that these savings would be partially offset by the cost of the equipment needed to implement an anti-icing strategy.

Slightly more than half of the U.S. highway network is located in States hit by at least 100 hours of winter storms each winter. If the State and local highway agencies in these States were to *immediately* begin adopting anti-icing strategies, they could reduce winter maintenance costs by almost $108 million per year. If it took most highway agencies 20 years to switch to anti-icing techniques, the study projects the total agency savings could range between $55 million and $81 million per year. These savings far exceed the cost of researching, developing, and implementing the SHRP winter maintenance products, which are estimated at $45 million over 20 years.

Motorists will benefit far more than highway agencies. Because anti-icing strategies leave roads wet or slushy, instead of icy or snowpacked, the study predicts that the number of accidents can be expected to drop sharply, potentially saving highway users between $229 million and $447 million per year.

Work Zone Safety

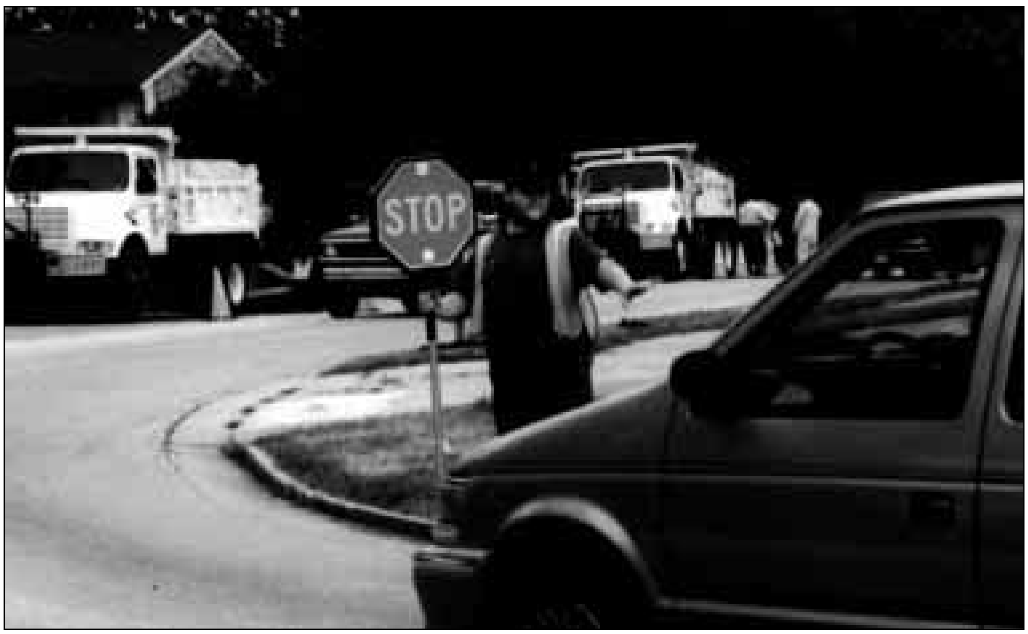
Highway maintenance zones can be hazardous for workers and motorists alike. In 1994, for example, 706 people died and 4,942 people were injured as a result of accidents in highway work zones. The changing traffic patterns in work zones often confuse motorists, which increases the risk of an accident. Unlike construction projects, where workers are protected by massive concrete barriers, crews on maintenance projects are generally protected only by traffic cones and a flagger; because the crew is continually moving down the road, it's difficult to justify the time and expense of installing more permanent protective devices.

SHRP researchers used computer modeling, field tests, and other methods to develop innovative, effective, and economical safety products that would also be easy to install, use, and remove in temporary work zones:

- ❑ Flashing stop/slow paddle.
- ❑ Opposing traffic lane divider.
- ❑ Direction indicator barricade.
- ❑ Truck-mounted attenuator for chemical spreaders.
- ❑ Intrusion alarm.
- ❑ Portable rumble strip.
- ❑ All-terrain sign and stand.
- ❑ Queue length detector.
- ❑ Remotely driven shadow vehicle.
- ❑ Portable crash cushion trailer.

Most of these devices are now commercially available and are being used by highway agencies across the country.

Flaggers throughout Kentucky evaluated the flashing stop/slow paddle and found the device to be highly effective at attracting drivers' attention in work zones.



Case Studies

States report that the SHRP work zone safety devices are making life better for workers and motorists. In Kentucky, for example, where highway agencies have been using flashing stop/slow paddles in work zones on highways and city streets, flaggers are pleased with the device, says John Hibbs of the Kentucky Transportation Center. "There is one general response after flaggers have used the flashing stop/slow paddle for a while: They do not want to give it up." Flaggers in Alabama, Maine, New Mexico, North Dakota, and other States had a similar response.

The Texas DOT is using the opposing traffic lane divider to keep drivers informed when a one-way road has been changed to two-way operation. In addition to providing clear instructions to motorists, the new devices are much easier, faster, and less costly to install than concrete barriers. "Our first concern must be to provide better service to the public," says Thomas Bohuslav of Texas DOT. "The opposing traffic lane divider allows us to do that." The Mississippi DOT agrees that the opposing traffic lane divider is effective. "You have to take extraordinary measures to keep people constantly aware that it's a two-way road, and the opposing traffic lane divider does the job," says Al Crawley of Mississippi DOT.

The benefits for workers and motorists will increase as State and local highway agencies make wider use of the SHRP work zone safety devices. In Minnesota, work crews will be safer once the DOT completes the process of moving the remotely driven vehicle to commercial production. The vehicle, which serves as a buffer between a crew and oncoming vehicles, can be controlled from the safety of the roadside. There is no driver in the truck, which means that no one will be at risk if the shadow vehicle is hit by an errant vehicle—an all-too-common occurrence (in 1991, for example, 25 Minnesota DOT highway maintenance vehicles were rear-ended.) Innovative devices such as the remotely driven vehicle can reduce the risks created by work zones and make life a little less stressful—and lot less dangerous—for workers and motorists alike.

The Benefits

To estimate the benefits and costs of the SHRP work zone safety devices, a panel of safety experts at TTI studied two of the most widely used products—the flashing stop/slow paddle and the opposing traffic lane divider. The flashing stop/slow paddle contains a flashing light that a flagger can activate when a motorist appears not to be noticing the stop or slow sign upon approach to a work zone. The opposing traffic lane divider is placed along the centerline of a roadway to alert drivers of oncoming traffic; the device is particularly helpful when a one-way road is temporarily converted to two-way operation.

For the purposes of the cost-benefit analysis, the researchers assigned each fatality a value of $2.7 million, a generally accepted figure in calculating the monetary losses resulting from an accidental death. Using this figure, the 706 work zone fatalities in 1994 had a financial cost of $1.9 billion to society. Each injury resulting from a work zone accident was assigned a value of $24,800; the total cost in 1994 was $122 million. Property-damage-only costs were estimated at $43 million.

According to the panel of safety experts, adopting just two of the SHRP work zone safety devices—the flashing stop/slow paddle and the opposing traffic lane divider—at work zones around the country could lead to a 5 percent reduction in accidents. Because the vast majority (86 percent) of people killed in work zone accidents are occupants of vehicles, not work crews or pedestrians, 86 percent of the predicted savings were apportioned to drivers and passengers and 14 percent to highway agencies.

The two work zone safety devices will not be implemented overnight. Depending on how quickly they adopt the two devices, State and local highway agencies nationwide could save between $2.1 million and $4.1 million annually over a 20-year period, after subtracting the costs of purchasing the devices. The savings to motorists could range between $15 million and $30 million per year.

Those benefits more than cover the expense to highway agencies of developing and implementing the safety devices. The estimated cost of researching, developing, and implementing the SHRP work zone safety products will total $30 million over 20 years, or $1.5 million per year—less than half of what highway agencies could save every year.

LTPP: Study Continues, Products Roll Out

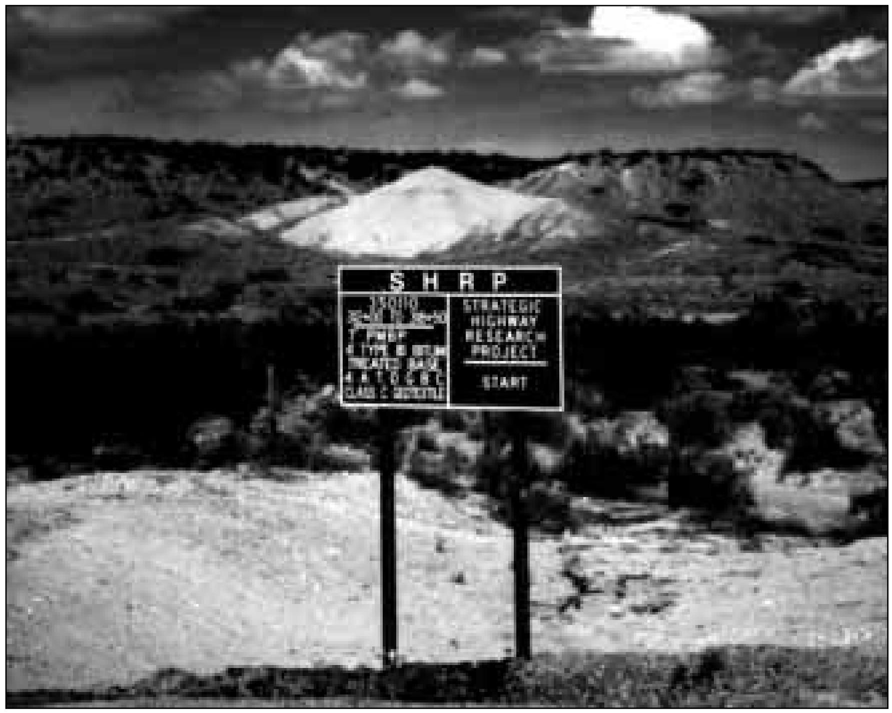
Why do some pavements hold up better than others? To find out, SHRP initiated the world's largest and most comprehensive study of in-service pavements—the long-term pavement performance (LTPP) program. The 20-year program, which began in 1987, is monitoring more than 2,000 test sections on asphalt and portland cement concrete pavements across the United States and Canada.

Although only at its midpoint, the LTPP program is already producing products for highway agencies, industry, and researchers. These products include:

- ❑ Pavement monitoring procedures.
- ❑ Materials testing procedures.
- ❑ Equipment standards and calibration procedures.

Eventually, data from the LTPP experiment will be used to develop improved guidelines for building and maintaining asphalt and concrete pavements.

Because the LTPP program is still active, the SHRP assessment project did not attempt to evaluate costs versus benefits. The RoadSavers case studies do, however, show that State highway agencies are already benefiting from LTPP products. One example is the procedures for calibrating the falling weight deflectometer (FWD), a tool for determining the structural strength of a pavement. The calibration procedures were initially developed to ensure that FWD data collected at different LTPP sites were consistent. The procedures have since proven invaluable to State highway agencies that use FWDs in pavement management. "Now that there is a standard calibration method that every State highway agency has access to, it guarantees a higher level of quality for our pavement tests," says Larry Scofield of Arizona DOT. The end result is more accurate information for highway agencies' pavement management systems.



This site in New Mexico is one of more than 2,000 asphalt and portland cement concrete pavements being monitored as part of the LTPP program.

Another example is the Georgia digital faultmeter. The device, developed by the Georgia DOT and modified by SHRP, is used to measure faulting—the vertical displacement at joints in concrete pavements—and the drop-off between the pavement and the shoulder. The conventional equipment required users to kneel on the road while noting the equipment's readings. The Georgia digital faultmeter means users no longer have to kneel to take measurements, and the reading can be "frozen," so users can record it from the safety of the roadside. Colorado DOT has been using the device since 1994 and says it is faster, safer, and easier to use than conventional methods.

LTPP experiments are helping to validate the Superpave asphalt mix design system and are yielding valuable information on preventive maintenance treatments. The LTPP program is also monitoring steel-reinforced concrete bridges that have been equipped with cathodic protection systems, treated with corrosion inhibitors, or rehabilitated using electrochemical chloride extraction—technologies initially evaluated under SHRP.

Ultimately, the program will supply data that can be used to develop new guidelines for building, maintaining, and rehabilitating asphalt and concrete pavements. Equipped with these guidelines, highway agencies will be able to select the most durable and cost-effective pavement designs and maintenance strategies. The result will be pavements that last longer, require fewer repairs, and stretch highway dollars. For drivers, longer-lasting pavements will mean fewer traffic delays caused by work zones and an end to rough roads that damage tires and suspensions.

From Research to Reality

Ten years after SHRP was launched, the products of its research can be seen in the Superpave pavements being constructed across the country, in the new work zone safety devices that better protect workers and motorists, in new guidelines and test methods for portland cement concrete pavements and structures, and in innovative, cost-effective strategies for pavement maintenance. Far from being mere theories on paper or prototypes in a laboratory, SHRP products are being used today to improve travel conditions and safety and to save money for highway agencies and motorists.

The success of SHRP demonstrates the importance of concentrated and focused research programs that never lose sight of their goals. SHRP stuck to its original objectives of improving the performance of asphalt, increasing pavement life, increasing the cost-effectiveness of maintenance, and improving the durability and versatility of concrete pavements and structures. More than 100 new devices, tests, and specifications later, these objectives still infuse the work of those implementing and further refining SHRP products.

Just as significant as the laboratory results was the full-scale implementation drive mounted by FHWA, AASHTO, TRB, and others. However promising and exciting a product is in the laboratory, it can't begin to fulfill its potential until it is in the hands of the State and local highway agencies that maintain the country's vast road network.

SHRP's implementation effort succeeded, just as its research did, because it was built on partnerships. From the very beginning, SHRP was guided not only by FHWA, AASHTO, and TRB, but also by highway professionals from every region of the country, from academia, and from industry. The products that emerged from this research were not a surprise: rather, they were the culmination of extensive and coordinated planning.

This joint planning smoothed the road to implementation. States knew that the products being rolled out, whether they were improved snow fences or pavement repair techniques, were designed to meet real, identified needs. And because State representatives had been closely involved in all phases of SHRP, from serving on the committee that oversaw the research to lending their technical expertise as loaned staff members, they were ready to support implementation efforts. From pooled-fund equipment purchases to regional Superpave centers, States have been fully engaged in making the goals of SHRP a reality.

Partnerships and planning have put the results of SHRP research into the hands of highway workers in every State. But the story does not end there. Just as a business launching a new product measures its success against the start-up expenses, FHWA analyzed the economic benefits of the SHRP products versus the costs of the program. As outlined in this report and detailed in more extensive documents, the results showed that SHRP was a winner in more ways than one: not only do the new products improve road and travel conditions, but they provide States—and taxpayers—with a substantial return on investment.

Assessing the economic benefits of the SHRP products provided an important culmination to the program's work and an additional validation of the value of its research. In an era of tight budgets for highway agencies and increased cost consciousness, it is not enough to outfit agencies with promising products. As in today's business world, promising products that also pay smart dividends are the ones that ultimately succeed.

SHRP is only one of many highway research programs in the United States. The path blazed by SHRP and the lessons learned from SHRP will prove helpful in planning future research programs. All parties involved have seen the success of focused, practical research that moved steadily toward well-defined goals; diverse partnerships in both research and implementation; and a strong emphasis on analyzing the economic benefits attained. By building on these principles, any future research initiatives will jump-start their chances of success.

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The **RoadSavers** case studies and the reports from the University of Nevada-Reno and the Texas Transportation Institute are available from FHWA's Office of Technology Applications Web site (www.ota.fhwa.dot.gov/roadsvr).

More information on the **Long Term Pavement Performance** program is available on the LTPP Web site (http://www.tfhrc.gov/pavement/ltpp/ltpphome.html).

Focus, a monthly newsletter published by FHWA, covers how innovative products, including the products of SHRP, are being used to build better, safer roads. For more information, contact Harrington-Hughes & Associates, Inc.
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email: kathrynhh@harringtonhughes.com;
Web: www.ota.fhwa.dot.gov/pubs/index.html).

Bibliography

RoadSavers (case studies). Publication No. SA-96-045. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1996.

The Superpave System (brochure). Publication No. FHWA-SA-97-033. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Work Zone Safety (brochure). Publication No. FHWA-SA-97-034. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Snow and Ice Control (brochure). Publication No. FHWA-SA-97-035. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Pavement Preservation (brochure). Publication No. FHWA-SA-97-036. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Concrete and Structures (brochure). Publication No. FHWA-SA-97-037. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Summary of SHRP Research and Economic Benefits of Asphalt. Publication No. FHWA-SA-98-012. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Summary of SHRP Research and Economic Benefits of Concrete and Structures. Publication No. FHWA-SA-98-013. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Summary of SHRP Research and Economic Benefits of Pavement Maintenance. Publication No. FHWA-SA-98-014. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Summary of SHRP Research and Economic Benefits of Snow and Ice Control. Publication No. FHWA-SA-98-015. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Summary of SHRP Research and Economic Benefits of Work Zone Safety. Publication No. FHWA-SA-98-016. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

Economic Benefits of SHRP Research. Publication No. FHWA-SA-98-017. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

From Research to Reality: Innovative Technologies for Saving Money, Time, and Lives on Our Nation's Highways (videotape). Videotape No. 111. Washington, D.C., Federal Highway Administration, U.S. Department of Transportation, 1997.

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