PRESERVING AND MAINTAINING THE HIGHWAY SYSTEM

NEW TOOLS AND STRATEGIES

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The nearly 4 million miles of roads that crisscross the United States form a vital lifeline, linking locales throughout a sprawling country and supporting a diverse economy. Maintaining this lifeline is a huge job, requiring major investments in personnel, equipment, and materials. Potholes and cracks must be repaired, treatments that preserve the system must be applied, and roads and bridges must be kept clear of snow and ice. These tasks cost highway agencies in the United States upward of $27 billion each year—almost one-third of the total annual U.S. highway investment. Until recently, however, scant research had been aimed at finding ways of improving pavement maintenance.

In recognition of this need, state highway agencies established the highway operations component of the Strategic Highway Research Program. The program's highway operations research focused on three key areas: snow and ice control, traveler and work crew safety in temporary work zones, and pavement maintenance techniques. The ultimate goal of the program was to find more effective and efficient technologies and techniques for maintaining pavements not only to preserve the highway system but also to help save lives and money.

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SNOW AND ICE CONTROL

Each winter most states grapple with the treacherous combination of snow and ice. Because roadways must be kept open to commercial and personal travel, highway agencies budget enormous amounts for winter maintenance. In fact, snow and ice control is typically the largest single item on a highway agency's budget, with nationwide costs topping $2 billion. Yet despite this investment, before SHRP, not much research had been conducted on techniques for snow removal and control.

The SHRP research plan focused on finding more effective and efficient ways of controlling and moving snow and of preventing ice and packed snow from bonding to the pavement. The aim was not only to increase safety but also to reduce dependence on deicing treatments. Four key snow and ice control products emerged from SHRP: strategies for effective anti-icing operations, enhanced road-weather information systems (RWIS), new snow fence designs, and improved snowplow designs.

Anti-Icing Techniques and Road-Weather Information Systems Technologies

In anti-icing operations, a chemical freezing-point depressant is applied to the road to prevent snow and ice from bonding strongly to the pavement. The depressant must be applied about an hour before the pavement reaches the freezing point. When detailed information about when and where a storm will hit—and what effect it will have on the pavement—is lacking, a highway agency will understandably be reluctant to send crews and trucks to treat the road. This hesitation often makes snow and ice removal more difficult than necessary.

Road-Weather Information Systems stations can help highway agencies make quick and smart decisions about where anti-icing operations should be concentrated and where plows should be sent by providing a variety of information, such as where most of the precipitation from a storm will fall, the form that the precipitation will take in various locations, and the roads and bridges that are likely to freeze first.

Road-Weather Information Systems stations are usually located along primary roads and at typical trouble spots, such as bridges. Each station consists of sensors that collect data on pavement and atmospheric conditions, including changing temperatures; wind direction and velocity; the rate of falling snow, rain, or sleet; and the amount of deicing chemicals remaining on the pavement. These real-time measurements are combined with meteorological information from the National Weather Service and other more localized forecasts to form predictions about where and when precipitation is likely to freeze to the pavement.

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SHRP-developed snow fences prevent blowing and drifting snow from encroaching on U.S. Route 18 in Iowa.

The predictions, usually generated twice daily, are transmitted to a computer at the highway agency's winter maintenance center. Using portable computers linked by modem or by a satellite to a central computer, maintenance managers can access this information and pinpoint the time and place to begin anti-icing operations.

With road-weather information systems, highway agencies can make more informed decisions about the deployment of materials, crews, and equipment. Used to predict which roads are likely to be trouble spots, such systems give crews a jump on storms. False alarms can be prevented, forestalling unnecessary chemical applications and crew time. And indications of when chemicals need to be reapplied make winter maintenance operations more efficient.

A study conducted for SHRP by the Midwest Research Institute found that by switching from deicing operations to anti-icing operations, a highway agency can save from $63 to $1,507 per lane-mile each winter (*1*). If anti-icing operations were implemented by all highway agencies in all storm situations, according to a recent economic study conducted by the Texas Transportation Institute, the total annual savings, based on reductions in overtime labor, vehicle operations, and chemical usage, could climb to $108 million. The roadways would also be safer for travel, producing a $447 million reduction in accident costs (*2*).

The effectiveness of anti-icing techniques was demonstrated during two years of SHRP field studies and two additional years of testing and evaluation sponsored by the Federal Highway Administration. Nine states participated in the original SHRP field studies. Those nine states were joined by an additional six for the follow-up test and evaluation project, which concluded in 1995. One of the main objectives of the studies was to give state highway agencies hands-on experience in procedures for efficient and effective snow removal and ice control. Various types of chemical treatments, including liquid calcium chloride, liquid magnesium chloride, and liquid sodium chloride, were studied to determine the most successful anti-icing strategies over a range of climate, traffic, and topographical conditions. As the field-study participants learned, an effective anti-icing operation will reduce the effort needed to clear highways, require smaller amounts of chemicals and abrasives, lessen the environmental impact of snow and ice control, and improve traffic safety—good news for travelers, maintenance managers, highway budgets, and the environment.

The U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory, under contract to FHWA, analyzed the data collected in the studies. The results were used to develop a new report, *Manual of Practice for an Effective Anti-Icing Program: A Guide for Highway Winter Maintenance Personnel* (*3*).

Improved Snow Fence Designs

Anti-icing technologies are effective at preventing snow and ice from adhering to the pavement. However, blowing snow poses another problem—one that can best be solved by a specially planned arrangement of snow fences.

Snow that blows and drifts across roadways can temporarily blind drivers and make clearing roads difficult. For years, highway agencies used 1-meter-high (4-foot) vertical slat fences placed in contact with the ground to keep snow off roadways. But these fences did not always work very well. SHRP researchers studied the science of blowing snow and developed an improved fence design. The new fences, which are 2 meters (8 feet) and taller and constructed of wood or plastic,

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The Iowa Department of Transportation has outfitted its interstate-bound snow and ice control trucks with liquid applicators.

can be easily installed and removed. They create a natural storage spot for the snow and prevent it from blowing or drifting onto the roadway.

Although purchasing and installing the new fences increase up-front expenses, over the long term, these activities can save highway agencies money. The SHRP researchers found that storing a ton of snow with a snow fence costs 3 cents, given a 25-year fence life; plowing the same amount of snow would cost 100 times as much.

In 1993 the Iowa Department of Transportation installed 792 meters (2,600 feet) of snow fence on Highway 9 and Highway 18 in the northern part of the state. Both roads were particularly troublesome during snowstorms because blowing snow cut visibility. Since the snow fences were installed, however, winter visibility on the roads has dramatically improved, making travel much safer. Use of the fences has also cut winter road maintenance costs by keeping the snow off the road.

Utah is another state using the new snow fence designs to ease winter travel and snow removal efforts. In the farming regions of the state, highways often pass through large open fields, where blowing snow can create tremendous drifts across the road. Removing those drifts is a cumbersome process, sometimes necessitating the use of bulldozers.

The Utah Department of Transportation installed the SHRP-tested snow fences in 1990. By all measures, the snow fence project is a success: travel conditions have improved and the amount of wear and tear on the department's winter maintenance equipment has been reduced. Farmers, who traditionally have been opposed to snow fences on their land, are also enthusiastic about the lightweight plastic fences, which can be easily removed before the spring planting season begins.

Snowplows

SHRP researchers studied ways to improve the operation of a basic winter maintenance tool—the snowplow. The goal was to develop a more efficient snowplow that would require less energy and create less turbulence and hence fewer clouds of snow around the plow.

Three main innovations came out of this plow research: new cutting edges, designed to remove snow and ice more efficiently; new snowplow designs, which incorporate deformable moldboards to increase efficiency and improve visibility for the operator and driving public; and the snow scoop, which lifts the snow in front of the plow up onto the moldboard, where it efficiently slides across the plow before being deposited on the roadside. By lessening the force required to plow snow, these innovations give the snowplow driver better control. And by reducing the cloud of snow around the plow, these innovations improve visibility for the snowplow driver and nearby motorists.

According to state highway agencies that have tested the snow scoop, it works best in dry, non-compacted snow and at speeds greater than 40 kilometers per hour (25 miles per hour). The SHRP snowplow innovations are being further assessed in test and evaluation projects sponsored by FHWA.

Safer Work Zones

The Strategic Highway Research Program also focused on the safety of workers and motorists in temporary work zones. Although familiar, everyday sights to most motorists, work zones can be dangerous places. The zones are always clearly marked, but distractions make warning signs less noticeable to drivers, with potentially deadly results. According to the Federal Highway Administration, approximately 70 highway workers and more than 600 motorists are killed each year in work-zone accidents.

To make maintenance work safer, SHRP launched a national design competition for new work-zone safety devices. Ideas poured in from maintenance workers and transportation officials as well as contractors and others in private industry. Eight of the work-zone safety products developed under SHRP are now commercially available: a flashing Stop/Slow paddle, a portable rumble strip, an opposing-traffic-lane divider, a direction-indicator barricade, a portable all-terrain sign and stand, an intrusion alarm, a queue detector, and a mounting bracket for the truck-mounted attenuator behind a chemical spreader.

The flashing Stop/Slow paddle, the most popular of the SHRP safety devices, was designed to help flaggers get the attention of drivers approaching a work zone. If an oncoming vehicle does not

appear to be slowing down or stopping, the flagger can switch on the paddle's high-intensity flashing lights, which are visible both night and day. The lights grab the driver's attention, possibly preventing an accident.

The portable rumble strip was also designed to aid in flagging operations. The strip, which is made of virgin and recycled plastic, is placed about 100 meters (328 feet) ahead of the flagger. As motorists travel over the strip, they experience a slight jolt and an audible rumble, alerting them to changes in the traffic pattern. The rumble strip works best under low-speed traffic conditions because high-speed traffic or heavy truck volumes cause it to shift out of position.

The opposing-traffic-lane divider has upward- and downward-pointing arrows on its sign face, which indicate that traffic is moving in two directions. When work crews temporarily need to convert a one-way road to a two-way road, a series of the dividers is placed along the new centerline to remind drivers that the roadway is now carrying two-way traffic.

For temporary closure of a traffic lane, the direction-indicator barricade helps guide motorists into the adjacent lane. The plastic barricade has a horizontal-arrow panel 60 centimeters by 30 centimeters (24 inches by 12 inches) and a bias-striped panel 60 centimeters by 20 centimeters (24 inches by 8 inches) affixed to one side. The arrow panel is reversible, allowing the barricade to be used to close the right or the left lane.

Another relatively simple but highly effective device is the portable all-terrain sign and stand. Conceived by the Montana Department of Highways and evaluated under SHRP, the sign, which alerts motorists to work zones ahead, was designed for roads with no shoulders and a narrow right-of-way. Its stand has adjustable legs that can be angled to conform to any slope. Stakes driven through the legs fasten the sign to the ground.

The intrusion alarm is a high-tech solution to work-zone safety problems. The device monitors the perimeter of the buffer zone that separates work crews from traffic. If a vehicle enters this zone, a piercing siren is triggered immediately, warning crew members of the danger. The intrusion alarm is currently available in several different models that use pneumatic tubes, infrared beams, and other means to monitor the buffer zone.

The queue detector is used to warn motorists that traffic ahead—and out of view—has slowed or come to a stop. The extra seconds of warning can mean the difference between a controlled slowing and a panic stop, with possible disastrous consequences. A transmitter and a receiver are

Faster and Easier Spring Snow Clearance

Alaska's Nome Council Highway is battered by harsh storms every winter. As a result of heavy snow accumulations, the road is normally closed from mid-October until April, when it must be cleared by maintenance crews.

In an attempt to keep the road open longer in the fall and to reopen it earlier in the spring, the Alaska Department of Transportation decided to test the snow fences developed under SHRP. In 1993 the department installed 1500 meters (5,000 feet) of the 4.2-meter (14-foot)-high snow fences and used video cameras to record the snow accumulation along the Nome Council Highway.

During the next two winters, video recordings documented the effectiveness of the snow fences. Snow accumulation on the roadway in areas protected by the fences ranged from 0 to 1 meter (0 to 3 feet) but the accumulation on the sections of the road without fence protection reached nearly 3 meters (10 feet). In the spring crews took 2 to 4 days to clear unprotected sections, whereas only 2 hours were needed to clear protected sections.

As a result of the new snow fences, labor costs have been cut by thousands of dollars and the highway has been made more accessible. Benefits also include reduced wear and tear on maintenance equipment and a safer work environment for road crews. The Alaska DOT is now looking into expanding use of the fences on the Nome Council Highway.

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By extending pavement life and maintaining ride quality, preventive maintenance procedures help preserve the highway system.

placed opposite each other on either side of the road. The transmitter projects an infrared beam to the receiver. Each time a vehicle passes the transmitter, the beam is broken. The detector is set to activate an electronic message sign or similar device when traffic slows to a certain speed. The device warns drivers that traffic has slowed or stopped at a point ahead.

Most of the accidents related to winter maintenance operations occur when motorists crash into the back of slow-moving plows and chemical spreaders. Under SHRP, researchers developed a means of attaching a truck-mounted attenuator behind the chemical spreader on the back of maintenance trucks. The attenuator greatly reduces injuries and damage if a vehicle crashes into the rear of a truck.

More and more states are putting the SHRP-developed devices to the test, with positive results. The Pennsylvania Department of Transportation, for example, distributed flashing Stop/Slow paddles to work crews in each of its districts in spring 1995. Crews used the devices at more than 300 work sites on two-lane, two-way highways with a variety of traffic volumes and with speed limits ranging from 57 kilometers per hour (35 miles per hour) to 89 kilometers per hour (55 miles per hour). Flaggers reported that the flashing light caused drivers to slow down. Pleased with the results of the test, the Pennsylvania DOT has approved the flashing Stop/Slow paddles for continued use.

Work crews in Tennessee have reported that they feel better protected as a result of the all-terrain sign and stand. The Tennessee Department of Transportation has found the device to be durable and effective, giving drivers notice that they are approaching a work zone or other hazard on roads where conventional warning signs could not be securely posted.

The safety devices developed under SHRP are finding application beyond work zones. Georgia used the opposing lane divider to keep traffic moving safely through many detours in 1994, when intense flooding made many roads and bridges impassable. The dividers were installed on Route 247 near Macon when waters forced the southbound section of the six-lane highway to be converted to two-way operations.

Two SHRP devices—a portable crash-cushion trailer and a remotely driven shadow vehicle—are still under development but close to commercial availability. The portable crash-cushion trailer is demonstrating promise in field testing. The device consists of a tilt-bed trailer equipped with a pallet of hinged steel plates to which sand-filled barrels are fastened. The barrels are designed to cushion the impact of vehicles that veer off the road. The portable trailer is being tested by highway agencies in Iowa, Alabama, California, Minnesota, and New York.

A shadow vehicle is usually a truck outfitted with an impact attentuator at the rear. The vehicle follows a slowly moving work crew down the road, protecting the crew from traffic but putting the vehicle driver at great risk. To remedy this problem the Minnesota Department of Transportation investigated and SHRP researchers further developed a remotely driven shadow vehicle, which can be operated from the side of the roadway with a hand-held remote-control box, eliminating the need for a driver.

The prototype of the vehicle was built on a truck supplied by the Minnesota DOT and has been demonstrated to highway agencies across the country. Minnesota, along with Iowa, New York, New Jersey, and other states, is now working with a private company to produce a remote-control kit that highway agencies can use to build their own remotely driven vehicles. California already has applied the SHRP concept to a front-end loader to create a teleoperated and automated device for clearing landslides from roadways.

Advances in Pavement Maintenance

A properly planned maintenance program can extend the service life of a pavement. There are two categories of pavement maintenance: preventive and corrective. Many of the same materials are used in both categories; the key difference between the two types of treatment is the time of application.

Preventive maintenance is a carefully planned program to prevent or delay the onset of pavement distress. Preventive maintenance measures, such as crack sealing, joint resealing, and thin hot-mix overlays, are generally applied early in the pavement's life, while the pavement is in good structural condition. In contrast, corrective maintenance procedures are implemented once minor pavement distresses become evident. These procedures include pothole repairs and partial-depth spall repairs.

In 1988 SHRP initiated a nationwide study to identify the best materials and procedures for pavement maintenance. More than 800 test sections at 22 test sites in the United States and Canada continue to be monitored under the Long-Term Pavement Performance (LTPP) program to determine how various maintenance techniques, the timing of treatments, and climatic and traffic conditions affect pavement performance. The study includes assessments of more than 2,800 pothole and spall repairs and more than 12 000 meters (39,360 feet) of crack and joint seals. The test sections continue to be monitored under the LTPP program (see article, page 36).

To date the study has yielded several findings. Results indicated that a chip seal applied as a preventive maintenance treatment performs better than other treatments on cracked pavements, whereas a slurry seal performs better on pavements with little cracking. Preliminary results also substantiate the value of preventive maintenance: in nearly all cases, sections that were given preventive maintenance treatments outperformed control sections where no treatments were applied. The study showed that preventive maintenance works best when used early in a pavement's life. Treatments applied to pavements in good condition have had good results; when applied to pavements in poor condition, however, these same treatments had little effect on pavement performance.

On the basis of these findings, highway agencies increasingly are planning proactive maintenance strategies that extend pavement life and improve ride quality for their customers. By averting problems that would require a full-scale structural overhaul of pavement, these maintenance strategies also cut costs.

Looking Ahead

The landmark SHRP initiative may be over, but the program's research continues to move the United States closer to a more advanced, durable road network. From safety devices to maintenance treatments that extend pavement life, SHRP products are leading the way toward improved highways in the 21st century. The challenge is to continue putting the products of this valuable research program into practice. As highway agencies continue to adapt the products, the public will reap increasing benefits.

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Improved Winter Storm Strategy

On sections of Interstate 35 just west of Des Moines, the Iowa Department of Transportation experimented with an anti-icing strategy using salt brine instead of its traditional mix of salt and sand. Salt brine spreads more evenly and sticks to the pavement better than salt and sand combined. The experiment proved the effectiveness of the new strategy: test sections retained good friction despite the snow and ice.

In another experiment, the department tried prewetting solid chemicals before applying them to roads. Dry materials are often not as effective as they could be because they bounce out of the travel lane when they hit the pavement or are blown off the road by traffic. Prewetting the chemicals helps to keep them in the travel lane and can accelerate both the anti-icing and the deicing processes. As a result of its experience with prewetting, the department has put liquid applicators on all snow and ice control trucks used on interstate highways.

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Anti-Icing Strategy Cuts Costs and Protects the Environment

The Nevada Department of Transportation found that sand from anti-icing operations was running off Route 28 and causing excess amounts of sediment and nutrients to accumulate in nearby Lake Tahoe. Looking for a way to use less sand, the department applied liquid magnesium chloride to roads before storms hit. The new strategy has cut the department's use of road salt by 50 percent and its use of sand by 70 percent.

Nevada's anti-icing strategy is supported by a road-weather information system (RWIS) that lets maintenance crews know when and where to apply liquid deicing chemicals. To date the state has a network of 18 RWIS sites and plans to add as many as 10 sites along the Sierra Nevada range. The state estimates that during the next 25 years anti-icing techniques will save it $7 million in materials and personnel costs and will prove better for the environment.

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