Highway Operations:

Progress and Products Update

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Highway Operations: Progress and Products Update

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Strategic Highway Research Program Highway Operations Advisory Committee

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Foreword

Highway Operations: Progress and Products Update describes the Strategic Highway Research Program's (SHRP's) projects in the Highway Operations area. Highway Operations is one of four technical program areas within SHRP. The other three are: Asphalt, Concrete and Structures, and Long-Term Pavement Performance.

The introduction explains the structure and overall objectives of SHRP's Highway Operations Program. The main body of the report is divided into two sections: one covering the Maintenance Research, and the other covering the Snow and Ice Control Research.

A list of contractors' names, addresses, and telephone numbers is included in the Appendix.

I. Introduction

Maintenance

Highway maintenance costs local and state governments $20 billion a year -- accounting for about one-third of total annual highway expenditures. Due to inflation and additions to highway systems, maintenance expenditures have grown at a rate of over 8 percent a year during the past 15 years. If past rates of growth continue, maintenance costs will double in 8 to 10 years.

Two major factors drive highway maintenance costs upward. The first is the increasing size and complexity of the highway system. Modern highway maintenance includes a broad scope of activities ranging from repair of electronic equipment to routine cleaning, painting, mowing, collecting, sweeping, and plowing. The number of lane-miles of paved surface and the number and complexity of signs, signals, lighting, electronic detectors, guardrails, and energy attenuation devices are increasing rapidly; all need upkeep.

Second, maintenance workloads and costs are increasing as the highway system ages and traffic levels increase. During the 1950s and 1960s highway resources were poured into new construction. During the 1970s and 1980s, the system aged, and the size, weight, and volume of traffic have increased. The compound effects of age and service are increasing maintenance needs and maintenance costs.

Despite the growing economic significance of highway maintenance activities, the relative cost-effectiveness of various maintenance technologies has not been assessed uniformly. SHRP is evaluating the performance of maintenance materials, methods, and equipment, and developing criteria for their cost-effective use under specific conditions. SHRP also is developing technological improvements in maintenance equipment, materials, and processes, including a worker safety project that is developing innovative devices to protect workers in short-term maintenance work zones.

Snow and Ice Control

Snow and ice control is one of the most expensive maintenance functions for many northern states and cities. Nearly every state experiences at least occasional economic disruption due to winter weather, when road travel stops until pavement surfaces can be returned to a functional condition. Although government agencies spend over $2 billion each year on snow and ice control, there has been relatively little research directed toward improvement of equipment, materials, and techniques.

SHRP's snow and ice control research is developing better-designed snowplows and snow fences, better storm forecasting and communication methods, and is searching for ways to minimize use of harmful deicing chemicals. The research will pay off in reduced costs for materials, labor, and equipment, and in mitigation of the harmful effects of deicing chemicals on the environment, and on pavements, structures, and vehicles.

The Highway Operations contract expenditures are budgeted to total $22.3 million; $15.3 million for Maintenance, and $7 million for Snow and Ice Control. This is a long-needed and substantial funding commitment for research in an area that consumes almost one-third of all highway expenditures. In both of these areas, the research emphasis is on improved equipment, materials, and processes.

II. The Maintenance Research

SHRP's maintenance cost-effectiveness program is producing three types of products: *Cost-Effectiveness Evaluations*; *Engineering Guidelines*; and *New Equipment*.

Cost-Effectiveness Evaluations: SHRP is evaluating the effectiveness and cost of alternative methods, materials, and equipment for preventive pavement maintenance and for pavement surface repair under a range of climate and load conditions. This information will assist highway agencies in making technical and budget decisions at both the project and agency-wide levels.

Engineering Guidelines: SHRP's maintenance research is developing guidelines for selection of the most effective materials, processes, and equipment for preventive maintenance and for pavement surface repair.

The guidelines will address factors such as climate, traffic, and soil condition, and help highway agencies select the best approach for a specific situation.

New Equipment: The maintenance portion of SHRP's Highway Operations Program is developing new equipment for:

- Pavement Condition Measurement: Automated pavement condition measurement devices will make it easier for maintenance technicians to keep track of the condition of a road network. This equipment will assist in both project-level and network-level decision-making about preventive maintenance.

- Worker Protection: The worker protection devices are being developed to protect workers in short-term maintenance work zones, where accident rates have reached alarming levels.

- Pavement Repair Equipment: Automated pavement surface repair equipment can reduce labor costs and reduce the exposure of maintenance workers to risk. A crack-filling robot and an automatic pothole repair machine are under development.

The research products discussed above are being developed under nine separate research projects, which are numbered H-101 through H-109. A tenth project (H-110) provides for development of videos, technical briefs, and other communications materials. The chart below shows how the contracts relate to the major products. The work being conducted under each of the contracts is discussed in more detail below.

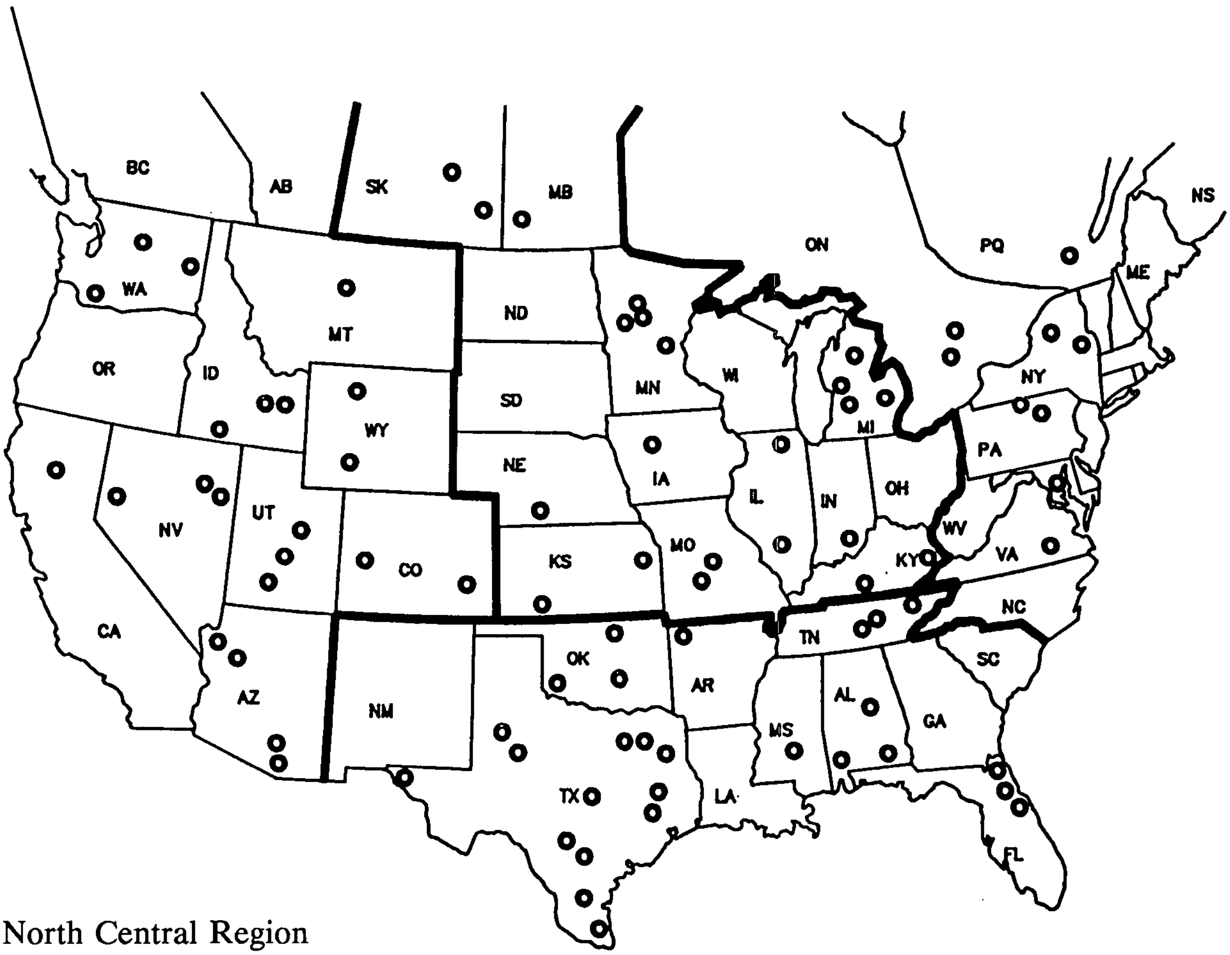
	Pavement Maintenance H-101	Pavement Condition Measurement H-103/H-104	Innovative Repair Equipment H-105/H-107	Innovative Materials H-105/H-106	Worker Protection H-108/H-109
Effectiveness Evaluations	X			X	
Engineering Guidelines	X			X	
New Equipment		X	X		X

Preventive Maintenance: H-101

Which treatment processes are the most effective in prolonging pavement life? How does the answer vary in different climates, for pavements in different stages of distress, or for highways with different traffic levels? To find out, SHRP is assessing the effectiveness of six specific preventive maintenance treatments by testing them on in-service state highways (Figures 1 and 2). Treatments for both asphalt and concrete pavements are being evaluated.

It is important to note that the effectiveness of various pavement treatments depends on the specific conditions of use. The effectiveness of a treatment is affected by how and when it is applied, by climate, traffic, and a number of other variables. The goal of SHRP's preventive maintenance experiments is to determine which treatment is best for use at a particular site, how and when it should be applied.

For asphalt (flexible) pavements, the project is assessing chip seals, thin overlays, slurry seals, and crack sealing. For rigid pavements, joint and crack sealing, and undersealing are being assessed. The individual treatment materials are not being compared directly; rather the entire treatment processes (including preparation, labor, etc.) The performance of the treated sections will be compared to that of the untreated sections in order to determine the effectiveness of the individual treatment processes in extending service life.



North Central Region
22 sites

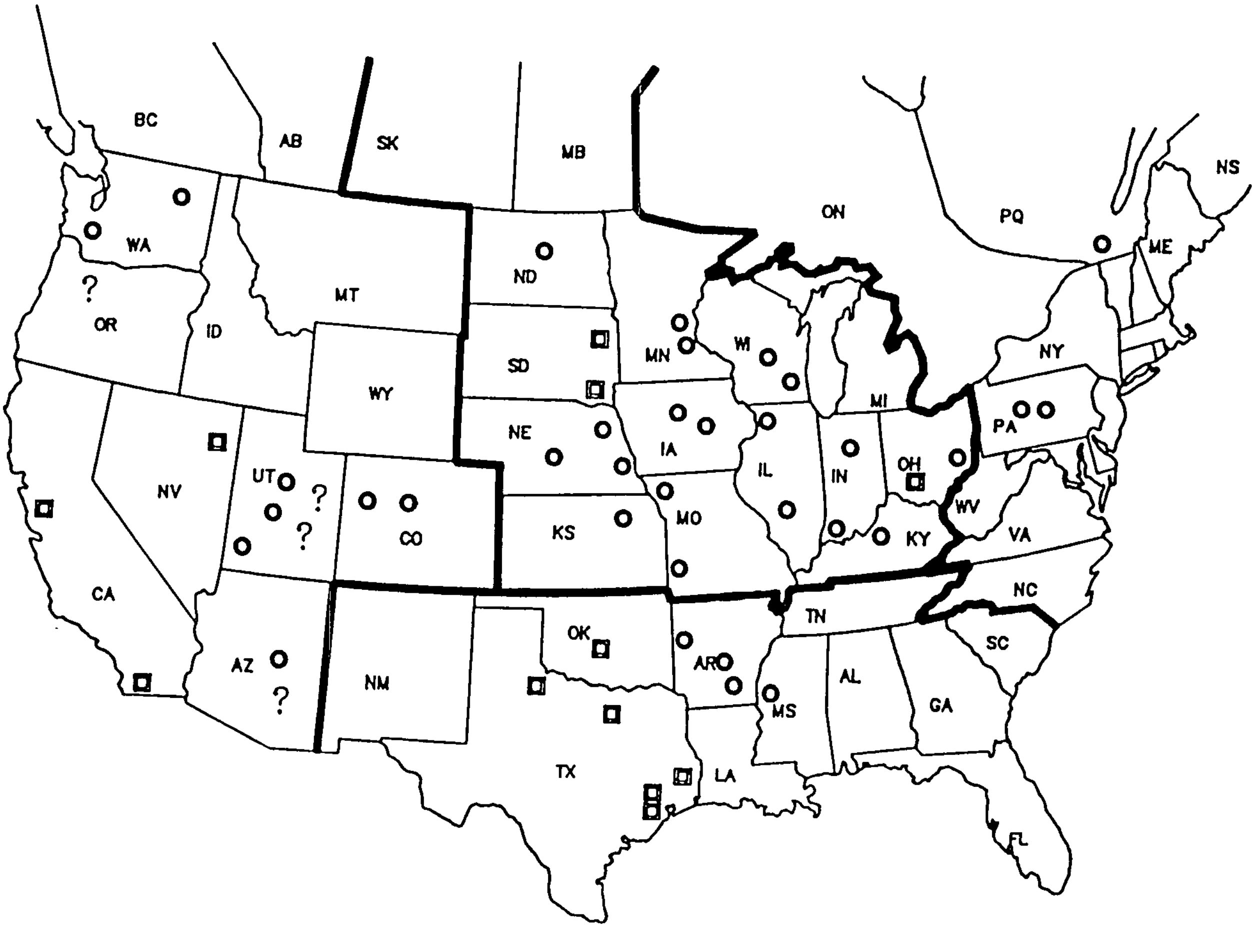
North Atlantic Region
10 sites

Southern Region
27 sites

Western Region
22 sites

Total: 81 sites

Figure 1. SPS-3 test sites for assessment of preventive maintenance treatments for asphalt pavements. Chip seals, thin overlays, slurry seals, and crack sealing are being assessed at each site. Among the factors considered when selecting pavement sections for treatment installation were traffic volume, environment, and pavement condition.



o Joint seal sites
◘ Underseal plus joint seal sites
? Proposed sites

Figure 2. Map of rigid pavement (SPS-4) sites. Joint and crack sealing and undersealing are being assessed.

Design of Preventive Maintenance Experiments

The state highway agencies cooperated by providing more than one hundred test sites to represent a range of traffic volume, environment (climate and soil), and pavement conditions (Tables 1 and 2). In most cases, the test sites are contiguous with test sites for SHRP's Long-Term Pavement Performance (LTPP) General Pavement Studies (GPS) program. The preventive maintenance evaluation project was planned as part of SHRP's Specific Pavement Studies (SPS) program. The flexible pavement studies are designated as SPS-3 experiments, and those on rigid pavements are designated as SPS-4 experiments. SPS-3 and SPS-4 are the only SPS experiments under the Highway Operations program. (All of the rest are part of SHRP's Long-Term Pavement Performance program, except SPS-9, which will be a field validation of the results of SHRP's Asphalt program.) Each SPS-3 test site has five test sections and each SPS-4 test site has three test sections, including control (untreated) sections (Figures 3 and 4).

In July 1991, all eighty-one of the asphalt test sites had been constructed. The concrete test sites were scheduled for construction during the 1991 construction season. The materials used for the treatments were specified according to the consensus of participating agencies in each region. The asphalt sites were constructed by SHRP-selected regional contractors under the direction of FHWA's Federal Lands Highway Division. The work was paid for by the cooperating states. The concrete sites will be constructed by the state agencies through construction contracts arranged individually by the states in cooperation with the Federal Lands Highway Division of the FHWA. The states purchase materials according to SHRP-supplied specifications.

> For more information on SHRP's preventive maintenance work, contact the Principal Investigators at Texas A&M, R.L. Lytton and Roger Smith; or SHRP Project Manager S.C. Shah. An information video is planned for production in 1992.

The preventive maintenance test sections are being monitored using distress survey (manual and photographic), profile measurements, and structural evaluation with the falling weight deflectometer. Monitoring is being conducted by the same contractors that are used in SHRP's Long-Term Pavement Performance program, and supervised by SHRP's regional engineering contractors. The data are entered into the National Pavement Performance Data Base at the Transportation Research Board along with the data from the SHRP Long-Term Pavement Performance experiments.

The test sections will be monitored until failure. The amount of time until failure will depend on such factors as the number of freeze-thaw cycles each year. It is anticipated that the preventive maintenance test sections may begin to deliver failure data in 1995. Some treatments could last as long as twenty years (to the year 2010).

Preventive Maintenance Research Products

Preventive Maintenance Guidelines--1996: The principal product of the preventive maintenance project evaluation will be engineering guidelines

Cell Number — 48 | WA — State

MOISTURE		WET							
TEMPERATURE		FREEZE				NO-FREEZE			
SUBGRADE		FINE		COARSE		FINE		COARSE	
TRAFFIC		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
CONDITION	**SN RATIO**								
G	≤1	1 IL KY NY	7 IL ON	13	19	25 TX	31 AR	37 MS AL•	43 AL•
G	>1	2 PA	8	14 KY MD MI	20 VA	26	32	38 TN TX	44 AL
F	≤1	3 MI MO	9 IN IO	15 NY	21	27 OK TX	33 TN	39	45
F	>1	4 MI	10 PQ	16	22 MI	28	34	40	46 FL
P	≤1	5 MO	11	17 MN	23 ON	29 TN	35 OK TX	41	47 FL FL
P	>1	6 MN	12	18 MN	24 MN	30	36	42 WA	48

MOISTURE		DRY							
TEMPERATURE		FREEZE				NO-FREEZE			
SUBGRADE		FINE		COARSE		FINE		COARSE	
TRAFFIC		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
CONDITION	**SN RATIO**								
G	≤1	49 KS NE	55	61 UT•	67	73 TX TX	79 TX TX	85	91
G	>1	50 ID MB	56 CO	62 ID	68 WA	74 CA	80	86 TX	92 AZ
F	≤1	51 CO	57	63	69	75 OK	81 TX•	87	93 TX
F	>1	52	58	64	70	76	82	88	94
P	≤1	53 NV WY	59 SK SK NV	65 UT•	71	77	83	89	95
P	>1	54 KS MT	60	66 UT WA WY	72 ID NV	78 AZ	84	90 AZ	96 AZ TX

Table 1. All eighty-one flexible pavement experiments (SPS-3) have been constructed.

Pavement	Moisture	Base Type	Freeze – Fine	Freeze – Coarse	No-Freeze – Fine	No-Freeze – Coarse
PLAIN	WET	DENSE	1: IA+, PQ+, KY	3: WI, WI	5: (AL), (WA), (GA)–3	7: WA
PLAIN	WET	STAB	2: IN, IN, OH	4: IA	6: OK, TX	8: (FL)–4, (GA)–3, (MS) (SC)
PLAIN	DRY	DENSE	9: CO+, KS, NE, NE	11: NE, SD, SD, ND, WA	13: TX	15: AZ, AZ
PLAIN	DRY	STAB	10: UT+, UT+	12: CO+, UT+, NV, UT+, UT+	14: CA	16: CA
REINFORCED	WET	DENSE	17: PA+, PA+, MO, MO	19: MN, MN	21: AR	23: AR+
REINFORCED	WET	STAB	18: IL, IL	20: OH	22: MS+, TX, TX	24: AR+, TX

\+ Joint seal only
() Potential site

Table 2. Twenty-four test sites are needed for the rigid pavement experiment (SPS-4). In July 1991, thirty sites had been nominated, but four of the experimental cells still needed to be filled.

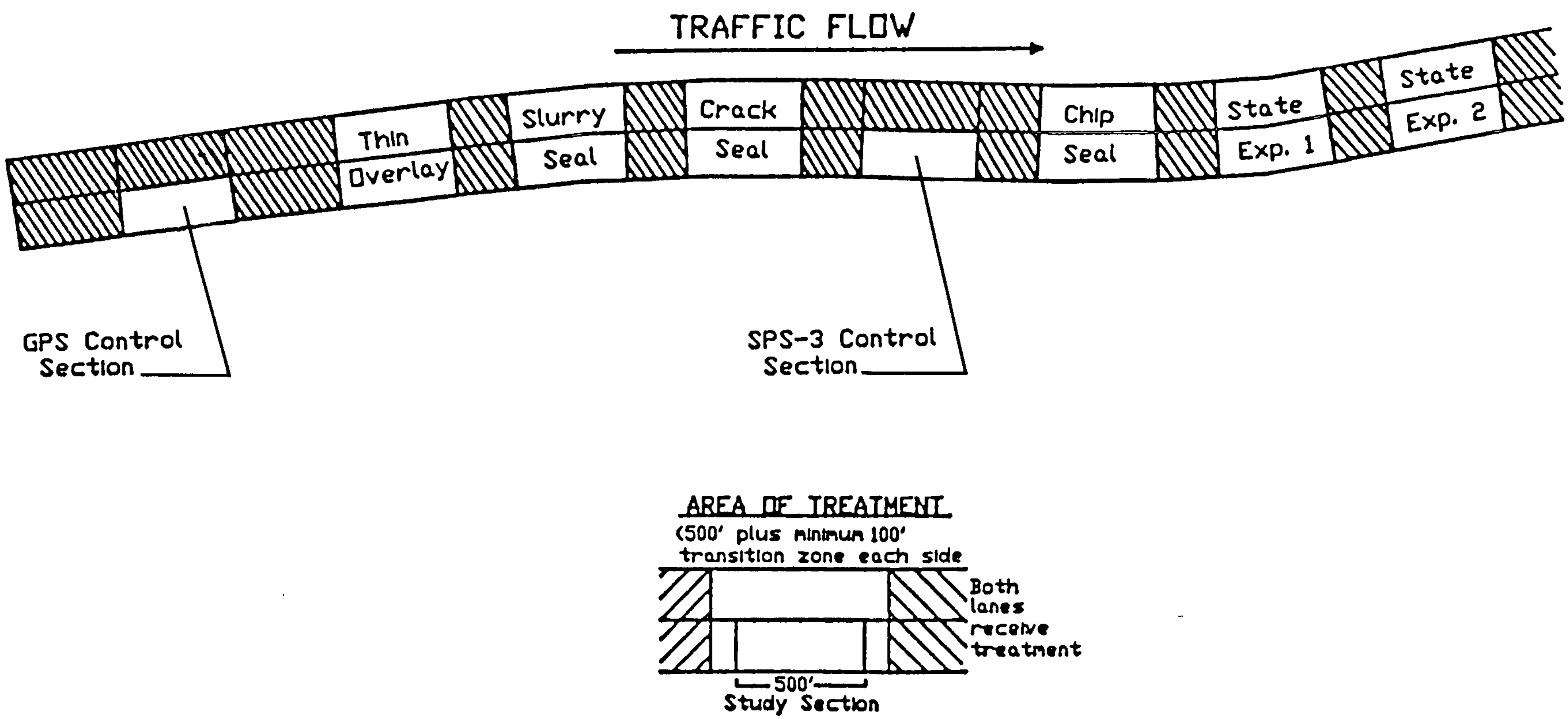


Figure 3. Layout of SPS-3 test sections for flexible pavements. Each test site has five test sections, including an untreated control section.

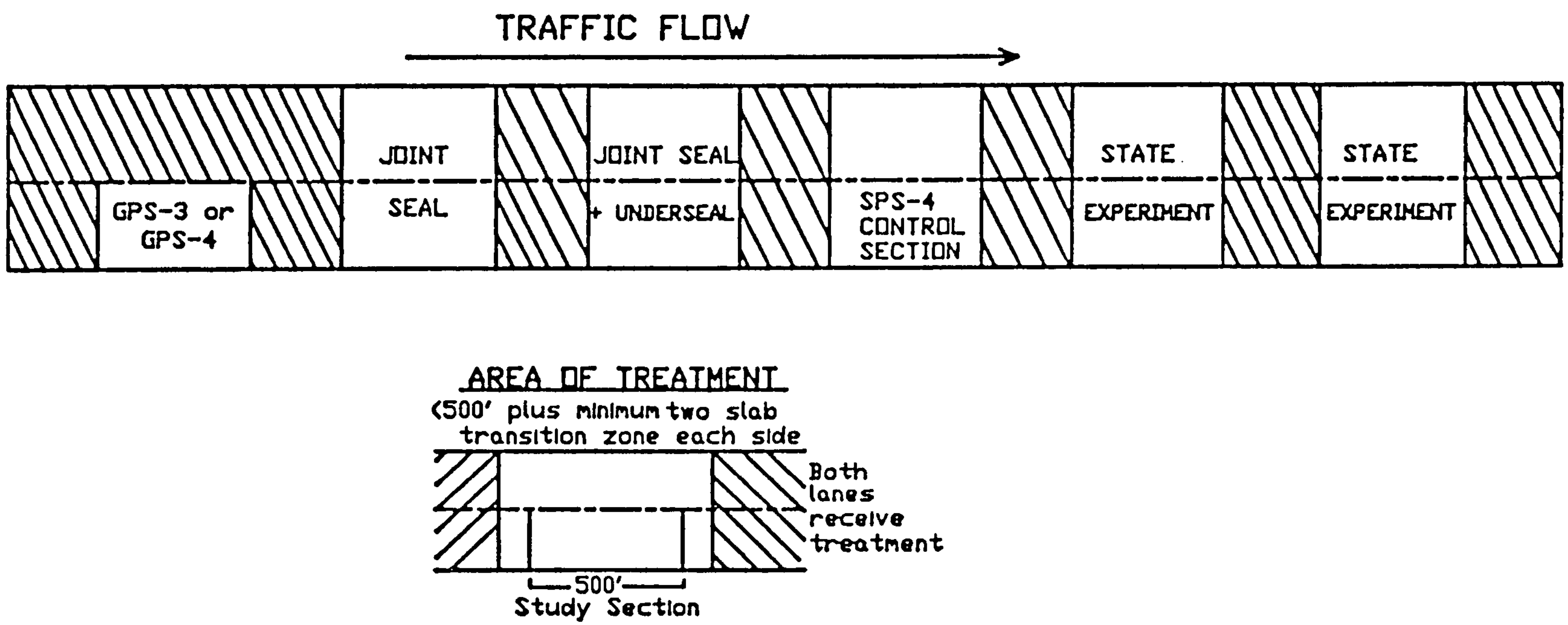


Figure 4. Layout of SPS-4 test sections for rigid pavements.

that cover where it is best to use which maintenance treatments; when the treatments should be applied; and explains proper techniques for treatment application. Development of these guidelines will require analysis of performance data from projects that have failed. It is anticipated that failure data will be available beginning in 1995, and that a first edition of preventive maintenance guidelines might be produced by a SHRP-successor organization (FHWA) shortly thereafter.

Treatment Evaluation Methodology--1993: SHRP plans to publish a methodology for the evaluation of the performance of treatments in 1993. The method will cover how to determine which treatments will work best under given site and climate conditions. It will be based on the evaluation methods used by SHRP, and will provide a uniform model that state highway agencies can use so that data can be compared on a nationwide basis. The methodology will include measurement units, analysis procedures, procedures for use of damage models for selection of alternative pavement maintenance strategies, and pavement damage model modification procedures.

Preventive Maintenance Construction Quality Control Guidelines--1991: Guidelines for *Quality Control for Construction of Preventive Maintenance Treatments* are scheduled for release in 1991. This document will cover quality control measures that can be taken prior to and during construction.

Administration

SHRP's Preventive Maintenance Cost-Effectiveness evaluation project (contract H-101) is being conducted by Texas A&M Foundation of College Station, Texas under a five-year, $1.1 million contract that began in October 1987 and is scheduled to conclude in October 1992.

Because the SHRP contract will end in October 1992, monitoring of the preventive maintenance test sections and analysis of the resulting data must be continued by a SHRP-successor organization. It is anticipated that the Federal Highway Administration will assume this function with the personnel that will be in place for continuation of SHRP's Long-Term Pavement Performance program.

Innovative Materials: H-105/H-106

What are the most effective materials and procedures for repairing pavement surfaces? SHRP is evaluating repair effectiveness, focusing specifically on five common pavement maintenance activities--spall repair, joint resealing, and crack sealing in concrete pavements; and pothole repair and crack sealing in asphalt pavements.

An important goal of the H-105/H-106 research is to determine the total cost effectiveness of a repair technique, considering the costs of labor, materials, and equipment, as well as the costs of traffic interruptions.

The project seeks to provide the most cost-effective options for the particular circumstances surrounding a highway repair project. For example, maintenance engineers have long recognized that the proper technique for fixing potholes involves cutting away the weakened surrounding pavement, cleaning all the loose material, drying the hole, filling it with good-quality hot-mix asphalt, and compacting it properly. But too often during the peak of the annual pothole season, the job cannot be done properly because of intervening circumstances. For example:

- The local hot-mix plant may not be open during the cold season when potholes appear, but no asphalt paving work is being conducted.
- During the peak periods when holes are emerging, new holes may appear faster than the entire work force can handle, and public safety may demand a temporary expedient to postpone "permanent" repairs.
- Some roads may be too congested to permit the lane closure time necessary to cut, clean, dry, fill, and compact the holes.

When "doing it right" is not possible, highway agencies often turn to "throw-and-go" methods and materials. "Throw-and-go" patches are just that: the conventional patching material is thrown into the hole, the truck is backed over the hole once or twice to compact it, and then workers move to the next hole. There is no sawing, no removal of loose material, and no drying. The method is quick, inexpensive, and disrupts traffic as little as possible. But the patches don't last. According to a survey of state users (see below), the average repair life of "throw-and-go" patches using conventional patching materials is just four months.

But there is a third option between "doing it right" and "conventional throw-and-go:" use of proprietary high-performance cold mixes that are designed for greater durability under adverse placement conditions such as cold weather; where adjacent material is structurally deteriorated; where dirt and water are in the hole; or where compaction is difficult. About 20 states that use them reported an average patch life of 13 months for some proprietary throw-and-go materials (compared to the four months for conventional materials).

SHRP's survey indicated that when the unit costs per hole for labor, materials, and equipment are considered along with the length of time the patch lasts, proprietary materials may be the least expensive option in terms of cost per year of life per hole. The unit costs come to $7.12 per hole for labor, materials, and equipment for conventional throw-and-go materials, $8.16 for proprietary throw-and-go, and $26.45 per hole for hot mix. But when adjusted for how long the patch lasts, proprietary throw-and-go materials look least expensive. (Table 3).

These survey responses undoubtedly reflect some hearsay and some guesswork, and they say nothing about climate, hole size, traffic, or other factors that could have substantial effects on the results. To obtain more systematic, reliable information on how different techniques perform, SHRP is working with a number of states on the H-106 field tests.

Costs	Conventional Throw-and-Go	Proprietary Throw-and-Go	Doing it Right--Cut/Dry/Compact
Labor costs per hole	$6.67	$6.66	$20.00
Materials cost per hole*	$0.45	$1.50	$0.45
Extra equipment cost per hole	0	0	$6.00
Total cost per hole	$7.12	$8.16	$26.45
Cost per year of life per hole	$22.97	$7.56	$14.86

Table 3. Illustrative cost-effectiveness for patching

Progress To Date

The pavement surface repair investigations began in November 1988 with a two-year, $640,000 contract with ERES Consultants, Inc. of Savoy, Illinois. ERES surveyed existing repair materials and techniques to determine which warranted further field testing under a follow-on contract for materials evaluation (H-106); and they surveyed existing equipment to determine which technologies could be adapted under a follow-on contract for equipment development (H-107).

ERES sent a questionnaire to all state and Canadian provincial highway agencies, to various city highway agencies, toll road authorities, and overseas agencies participating in SHRP's international cooperation program in 1989 to gauge the opinion of highway agency officials regarding which materials were working best, and why. More than 120 responded, including 39 states and 9 Canadian provinces. In addition, the contractor conducted in-depth interviews with forty knowledgeable users and experts, including officials at twelve state departments of transportation.

Results of Survey on Materials Use: The results of the survey are not considered conclusive because the accuracy of the responses and the number of responses to any given question varied tremendously. But the survey responses provided information that was used in selection of materials and procedures to be investigated in follow-on field tests, which are being conducted under contract H-106 with ERES Consultants.
The repair materials are being placed under a number of different climatic and installation conditions, in recognition of the fact that it is often necessary to conduct repair operations under adverse conditions, such as when the pavement is wet or temperatures are near freezing. These conditions are most likely to occur in the winter and early spring, which is a critical time for distress formation. Some materials are not at all suitable for particular applications, and therefore will be tested only under the conditions for which they are recommended.

Material Tested	Average life of repair (in years) Cold/Dry	Warm/Dry
Portland cement concrete	6.4	6.8
Magnesium Phosphate Concrete	5.0*	2.5
Epoxy	2.6*	6.6
Bituminous Hot Mix (temporary)	1.1	1.8
Bituminous Hot Mix (permanent)	1.5	3.1
Bituminous Cold Mix (temporary)	0.5	1.1
Bituminous Cold Mix (permanent)	1.0	1.8
Proprietary Bituminous Cold Mix	1.3	1.7

*Based on only two responses

Table 4. Portland cement concrete spall repair

Spall Repair: The results of a survey of the average life of repair for various options for portland cement concrete (PCC) spall repair showed that repair with PCC gives excellent results--an average repair life of 6.4-6.8 years. (Table 4) But two important disadvantages associated with use of PCC for surface repairs are that it takes too much time to set, which increases the length of time that lanes must be closed and traffic disrupted to allow for the repair; and concrete cannot be poured or set in very cold, very wet, or very hot weather conditions. Options for cost-effective repairs that can be completed within a few hours and under adverse weather conditions are necessary. Looking again at Table 4, options like magnesium phosphate concrete and various polymers seem worth investigating. These materials are generally more expensive, but when the costs of lane closures and frequently repeated repairs are factored in, they may be most cost-effective. SHRP also is testing other innovative materials for spall repair, such as a proprietary flexible polyurethane product called Percol, which has seen limited field experience so far; as well as gypsum cements, high alumina cements, and high molecular weight methacrylates. All of the materials will be compared to a conventional patching mix made with Type III portland cement and a cold-mix patching material.

Crack Sealing: For crack sealing (Table 5), the survey indicated that the best performers would be the modified asphalts, which are outperforming asphalt cement by a factor of two, and give three or four times the service of asphalt cutbacks when placed under warm, dry conditions. As with spall repair, the goal is to identify a truly cost-effective sealant material that will give the best performance over the long run. Because crack repair is generally not an emergency repair, it can be scheduled to occur under optimal conditions, so achievement of a repair lasting 4 years seems within reach. SHRP is investigating several promising commercially available sealant materials, including polymer-modified asphalt conforming to ASTM D 3405, low-modulus polymer-modified asphalt, fiberized asphalt, and silicone. At each of the test sites, polymer and fiber-modified asphalt sealants will be placed using four different configurations and two different preparation procedures. The control material in this experiment will be asphalt cement.

Material Tested	Average life of repair (in years) Cold/Dry	Warm/Dry
Asphaltic cement	1.7	2.1
Asphalt rubber	2.2	4.3
Polymerized asphalt rubber	2.8	4.0
Fiberized asphalt	2.8	3.1
Emulsified asphalt	2.2	2.3
Asphalt cutback	1.0	1.2

Table 5. Performance of crack-sealing materials

Joint Sealing: Joint preparation and sealant configuration can significantly affect the bonding capabilities and the stress conditions of joint sealant materials. Three sealant configurations will be tested for each of the materials included in SHRP's field tests, and each requires a different type and amount of joint preparation. The materials to be tested included materials conforming to ASTM D-3405, non-self-leveling silicone, self-leveling silicone, including some that will extrude over a wide temperature range and cure to form a low-modulus silicone rubber seal.

Pothole Patching: The pothole experiment (Table 6) is testing both conventional and innovative materials for both rapid (emergency) and semi-permanent repairs. New, open-graded crushed aggregate materials, and improved asphalt binder materials are included. A number of proprietary and agency-developed materials including a ready-to-use, premixed cold patch designed for use on wet or dry pavement, in hot or subfreezing temperatures on either an asphalt or concrete base will be tested against conventional cold mixes. The use of a heat lance for drying out holes, and an automated device for placing repair materials also will be evaluated to determine their effects on repair life.

The H-106 project is a $2.3 million effort that began in October 1990 and is scheduled for completion in March 1993.

Material Tested	Average life of repair (in years) Cold/Dry	Warm/Dry
Bituminous Hot Mix (temporary)	0.3	1.4
Bituminous Hot Mix (permanent)	0.3	1.8
Bituminous Cold Mix (temporary)	0.3	0.8
Bituminous Cold Mix (permanent)	0.6	1.0
Proprietary Cold Mix	1.1	1.8

Table 6. Performance of pothole repair materials

For more information on the pavement surface repair work, contact Russell Romine or David Peshkin, principal investigators for ERES Consultants, or SHRP Program Manager S.C. Shah. A three-volume report on results of the H-105 project is available on request from Lisa McNeil at (202)-334-1450. Titles are: *Innovative Materials and Equipment for Pavement Surface Repairs Volume I: Summary of Material Performance and Experimental Plans*, SHRP-M/UFR-91-504, 205 pages; *Innovative Materials and Equipment for Pavement Surface Repairs Volume II: Synthesis of Operational Deficiencies of Equipment Used for Pavement Surface Repairs*, SHRP-M/UFR-91-505, 233 pages; and *Innovative Materials and Equipment for Pavement Surface Repairs Volume III: Data Base Users Guide*, SHRP-M/UFR-91-506, 83 pages.

An informational video on the pavement surface repair work is scheduled for production in 1991.

All twenty test sites have been built. The states installed the treatments according to guidelines prepared by the research contractor (Table 7).

The test sites (Figure 5) will be monitored by the consultants (ERES) beginning three months after the completion of each installation, and every three months thereafter through the end of 1992. Visual distress monitoring and manual measurements are the predominant monitoring techniques.

The materials will be monitored until the end of their service life (failure) to establish a basis for determining their cost-effectiveness. It is anticipated that about half of the crack-sealing and pothole patching materials will reach failure before the SHRP project ends in March 1993. The spall repairs are not expected to begin to fail until somewhat later. The post-SHRP successor organization (FHWA) will continue to monitor these sites.

Pavement Surface Repair Research Products

The principal products of the pavement surface repair materials research will be engineering guidelines.

Interim Guide--1993: SHRP plans to develop an *Interim Guide for the Use of Repair Materials for Cost-Effective Pavement Repair* based on the laboratory and field test data that will be available by 1993. The guide will cover selection and use of those materials determined to be most cost-effective.

Final Guide: A final *Guide* will be published by a post-SHRP organization when more data are available.

Innovative Repair Equipment: H-105/H-107

Under contract H-105, ERES also conducted a survey of existing equipment for the selected surface repairs (spall repair, joint resealing, and crack sealing in concrete

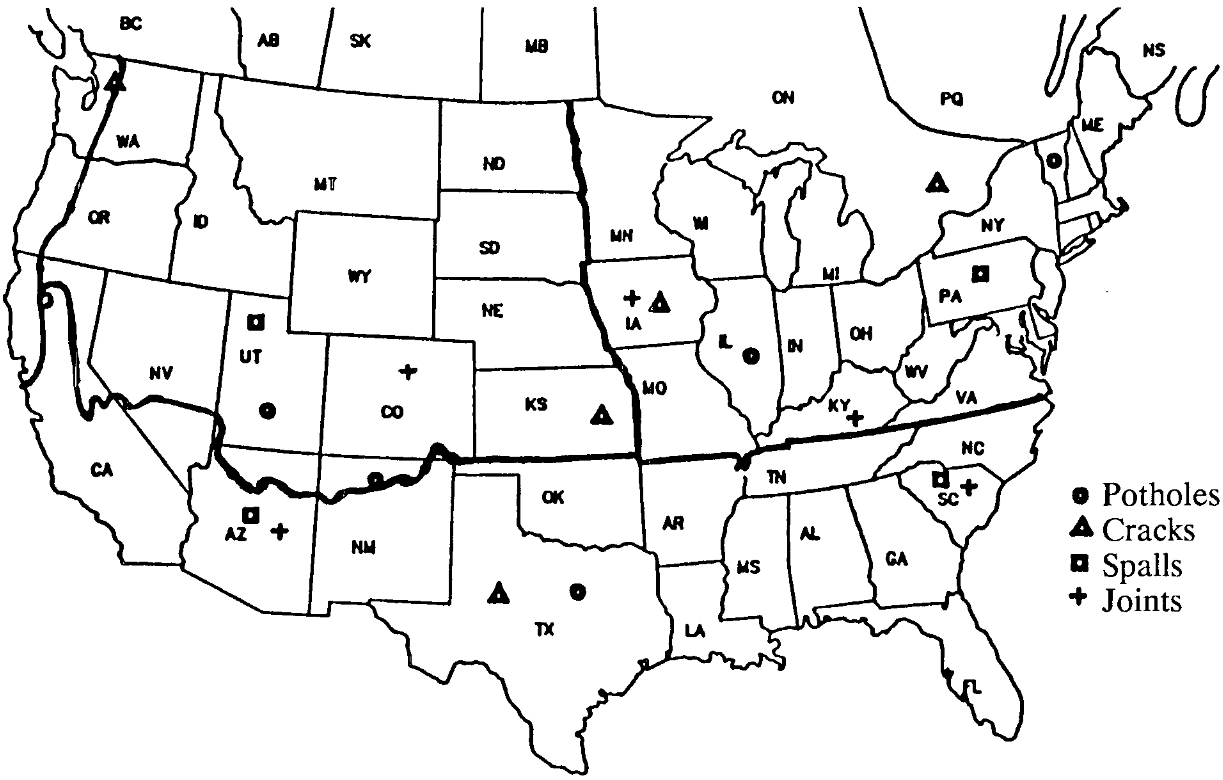


Figure 5. Map of H-106 test sites

Type of Experiment	Highway Number and Location of Test Site	Climatic Regions: Wet/Freeze	Wet/Nonfreeze	Dry/Freeze	Dry/Nonfreeze
Crack	I-35, Des Moines, Iowa	•			
	Route 8, Elma, Washington		•		
	I-20, Abilene, Texas				•
	Route 254, Wichita, Kansas			•	
	Route 7, Perth, Ontario	•			
Joint	I-17, Phoenix, Arizona				•
	I-77, Fairfield, South Carolina		•		
	I-25, Larimar, Colorado			•	
	I-80, Powesheik County, Iowa	•			
	US 127, Frankfort, Kentucky	•			
Pothole	Route 25, Bradford, Vermont	•			
	I-70, Vandalia, Illinois	•			
	SR 1570, Greenville, Texas		•		
	I-15 Frontage, Draper, Utah			•	
	US 395, Alturas, California		•		
	Route 518, Las Vegas, New Mexico			•	
Spall	Route 106, Kittanning, Pennsylvania	•			
	I-15, Ogden, Utah			•	
	I-20, Columbia, South Carolina		•		
	I-17, Phoenix, Arizona				•

Table 7. Test site locations for H-106

For more information about the automated crack-filling robot, contact Principal Investigator Steven Velinsky at the University of California/David, or SHRP Project Manager S.C. Shah. For more information about the pothole patcher, contact Principal Investigators Richard Johnson and James Blaha at Northwestern University/BIRL, or SHRP Project Manager S.C. Shah.

pavements; and pothole repair and crack sealing in asphalt pavements). Based on the survey results, ERES recommended modifications in existing equipment. Three separate areas of equipment development were recommended: automated equipment for pothole repair in asphalt pavements; automated equipment for filling and sealing transverse cracks and joints in asphalt and concrete pavements; and automated equipment for filling and sealing longitudinal cracks and joints in asphalt and concrete pavements. The crack-sealing equipment is being developed by the University of California/Davis and the California Department of Transportation under contract H-107A; and the automated pothole patching equipment is being developed through a joint venture of BIRL/Northwestern University/Crafco under contract H-107B.

Automated Crack-Sealing Equipment: The University of California/Davis and the California Department of Transportation started work in December 1990 on a thirty-month, $1.7 million project to develop automated crack sealing equipment.

Fabrication of the first generation prototype began in June 1991 and was scheduled for completion by February 1992. After prototype testing, plans call for development of equipment specifications, operational guidelines, and training manuals.

This project is being monitored in close coordination with SHRP-IDEA Project #17, which is under way at Carnegie Mellon University, and also is developing a crack-filling robot. The Carnegie-Mellon project is narrower in scope and much smaller in budget; it is focused on proving the feasibility of using robotic components for this application. The 107A project has the more ambitious goal of production of a full-scale commercial prototype.

Automated Pothole Patching Equipment: A joint venture of BIRL/Northwestern University/Crafco began a thirty-month, $1.15 million project in December 1990 to develop an automated pothole patcher.

Fabrication of the first generation prototype began in June 1991 and was scheduled for completion by February 1992. After prototype testing, plans call for development of equipment specifications, operational guidelines, and training manuals.

Pavement Condition Measurement: H-103/H-104

Two separate projects are under way to develop equipment that can determine the need for preventive maintenance treatments, and measure their effectiveness. One uses ground-penetrating radar technology and is intended for use on a network basis, operating at or near highway speed. The other uses wave propagation technology, and is intended for use on a project-level basis. The objective is to produce equipment that can be operated by maintenance technicians with only one week of training.

The *ground penetrating radar equipment* is being developed under a contract (H-104A) with Geophysical Survey Systems, Inc. of North Salem, New Hampshire that began in April 1990. The project is planned for three years and budgeted at $1.5 million.

> For more information about the ground-penetrating radar equipment, contact Stanley S. Smith, principal investigator of Geophysical Survey Systems, Inc., or SHRP Program Manager Brian Cox. For more information about the wave propagation equipment, contact Soheil Nazarian, principal investigator for the University of Texas at El Paso, or Brian Cox at SHRP.

The equipment is being designed to measure moisture in the foundation layers and within the asphalt layers of a flexible pavement; moisture and voids under rigid pavement joints; subsurface problems; and overlay delamination. Ground-penetrating radar has previously been applied mostly to locate relatively large objects, such as pipelines and hazardous waste deposits. The challenge in this project is to adapt the technology to detect much smaller phenomena, such as air voids, change in moisture content, or delamination. The technology is available to do this, but it generates read-outs that require expert training to interpret. Consultants are generally employed for this purpose, but data interpretations tend to vary from consultant to consultant, which does not create user confidence in the technology.

A primary objective of the SHRP H-104A project is to develop software to interpret the equipment readings so that highway agency technicians will be able to operate the equipment and interpret results with a minimum of training. Other key design criteria for the equipment include reasonable acquisition and operating costs, ease of use, ease of calibration, reliability and speed of measurements, and ruggedness for field use.

In July 1991, the contractors had made good progress on development of radar hardware and analysis software, and were nearing completion of specifications for a first-generation prototype. Affordability and feasibility were key issues--because the equipment includes complicated electronic components, it is expected to cost in the $100,000 range.

The *wave propagation equipment* is being developed by the University of Texas at El Paso Department of Civil Engineering under a contract (H-104B) that began in April 1990. The device is being designed for maintenance technicians to measure moisture in the foundation layers of a flexible pavement and under rigid pavement joints; fine cracking; voids under rigid pavement joints; overlay delamination; and asphalt aging. The project is planned for three years and budgeted at $700,000.

The equipment will incorporate a seismic testing device to generate and detect stress waves in various levels of the pavement layer. The devices are used in conjunction with various technologies including ultrasonic body waves, ultrasonic surface waves, impulse response, spectral analysis of surface waves, and impact echo.

The feasibility of using wave propagation technologies for pavement diagnosis has been demonstrated previously. The key barrier to implementation has been the time necessary to process the information generated. A major objective of the SHRP work is to use computer-based information processing so that the equipment and operating procedures are suitable for use by state highway departments. Other criteria for equipment design include portability, reasonable acquisition and operating costs, ease of use, ease of calibration, reliability and speed of measurements, and field durability.

In July 1991, the University of Texas at El Paso was making good progress on specifications for a prototype for relatively low-cost ($15,000), portable equipment. If the contractor is successful in producing prototype specifications, a first-generation prototype will be fabricated in late 1991 and tested in two or three states. A near-commercial prototype would then be fabricated and tested in a range of climates (at least six states). The goal is for a commercial prototype, specification detailing, a user manual, and applications guidelines to be available in 1993.

A previous contract with Pennsylvania State University (H-103) for development of pavement maintenance effectiveness measuring equipment was terminated in April 1989 after one year of effort. This action was taken based on the recommendations of the Expert Task Group that reviewed the first interim report, which recommended development of equipment based on electromagnetic and nuclear technology. The consensus of the Expert Task Group members was that the concepts presented in that report were not sufficiently innovative, and that there was too much uncertainty regarding the likelihood of success to justify continuation of the contract.

SHRP retained two consultants to synthesize the information collected under contract H-103 and to make recommendations regarding which (if any) technologies might most effectively be explored for further development under a follow-on contract. The consultants determined that moisture, voids, and delamination are the pavement conditions and damage mechanisms most relevant to pavement effectiveness. They surveyed available technology and determined that radar, mechanical surface waves, mechanical impedance, and electromagnetic conductivity could be used to detect these conditions. They recommended that SHRP issue the Program Announcement for contract H-104 to develop two of the most promising technologies: ground-penetrating radar; and wave propagation technologies. The H-104A and H-104B contracts were the result of that solicitation, which took place January 1, 1989. The consultants' report, *Measuring Systems and Instrumentation for Evaluating the Effectiveness of Pavement Maintenance*, is available on request. (Contact Lisa McNeil at 202-334-1450 and ask for report SHRP-M/UWP-91-513.)

Worker Protection: H-108/H-109

SHRP is developing new equipment and techniques for protecting maintenance workers in short-term work zones. The objective is to enhance safety through a combined approach including physical protection of the maintenance workers, separation of traffic from the maintenance operation, and enhancing the conspicuousness of the maintenance workers and their equipment.

The first two fully developed work zone safety products--a portable sign and stand, and an interface device for a salt spreader/truck-mounted attenuator--were made available for widespread use by the states in the summer of 1991. Several other innovative devices are being tested by cooperating states on the open highway beginning in May 1991. These devices have completed closed-track testing, and should be available for widespread use in 1992 if the open-highway testing goes well:

- *Intrusion alarms* that tell workers when a vehicle has entered (or is entering) the work zone, giving them four to seven seconds to clear the area. One device uses infrared technology to sense the intruding object; the other uses ultrasonic pulses.

- *Queue Length Detector* uses ultrasonic technology to alert workers to traffic backups so traffic control can be altered to increase traffic flow.

- *Traveled Way Speed Bump* is just like a regular speed bump--except it is mounted on rubber mats and can be moved from work zone to work zone.

- *Direction Indicator Barricade* with a prominent arrow to cue drivers entering work zones to which lane they should use.

- *Flashing Stop/Slow Paddle* that is two signs in one, so the highway worker can change signs with a flick of a wrist. The sign also is equipped with flashing lights.

- *Opposing Traffic Lane Dividers* are delineation devices with directional arrows designed to be used as center-lane dividers to separate opposing traffic when traffic patterns alter from the normal pattern.

- *Lighting Devices Marker* lights for the outer edge of the plow blade to give the operator a better sense of the location of the plow's edges and increase the motorists' awareness of the plow blade.

- A *remote-controlled shadow vehicle* designed to protect maintenance workers from inattentive drivers who run into the back of stopped or slow-moving maintenance vehicles is currently undergoing closed-track testing. The Minnesota Department of Transportation has loaned a dump truck to SHRP to be fitted with radio-control gear, so that the operator can be positioned beside the highway rather than in the drivers' seat of the vulnerable shadow vehicle. Rear-end collisions involving shadow vehicles are one of the most common types of work zone accidents. If all goes well, the truck should be ready for open-highway testing by Minnesota in the Fall of 1992.

When testing is complete, SHRP will provide state highway agencies with plans, drawings, and test results. If enough states are interested in obtaining kits for their own vehicles, SHRP will try to locate a firm willing to manufacture remote-control kits, which are expected to cost in the $25,000 to $35,000 range.

Two additional barrier devices are still in the fabrication stage:

- *Personnel Protection Trailer*: A 50,000 pound, 65-foot-long, adjustable-width trailer towed by a truck-tractor to provide an enclosed, protected area for workers on foot.

- *Portable Crash Cushion*: Equipment that carries a complete sand barrel crash cushion array on a moveable platform. The trailer is used to quickly move the crash cushions into a closed traffic lane upstream of a maintenance operation to block off the traffic lane completely.

The last two devices will be tested in 1992.

Where necessary, the devices are being developed to comply with the *Manual of Uniform Traffic Control Devices*.

For more information on SHRP's work zone safety project, contact Dale Stout, Principal Investigator for ENSCO, Inc., or SHRP Project Manager S.C. Shah. The final report for project H-108, a $528,000, two-year effort, is available on request from SHRP. Contact Lisa McNeil at (202) 334-1450 and request report number SHRP-M/UFR-89-001, *Maintenance Work Zone Safety*. A video on the work zone safety project is planned for completion in the winter of 1991.

The contractors are currently preparing training materials to instruct workers at the cooperating state agencies in use of the devices. SHRP will develop a comprehensive training package later in the program, for release when the majority of the work zone safety devices are ready for full-scale implementation.

The devices were developed from ideas generated through a 1989 Design Competition for Maintenance Work Zone Safety. Graham-Migletz Enterprises of Independence, Missouri, the prime contractor for SHRP's preliminary work zone safety research (contract H-108) evaluated all thirty-seven winning ideas for their potential for cost-effective development, and recommended twenty-four for further evaluation. This evaluation is currently being conducted by ENSCO, Inc. of Springfield, Virginia in a three-year project (H-109) that began January 22, 1990.

As a basis for preparation of the solicitation of entries for the design competition, Graham-Migletz surveyed and evaluated existing work zone safety devices, and evaluated the most common types of accidents in short-term work zones.

III. The Snow and Ice Control Research

Florida and Hawaii are the only states that do not face snow and ice problems at least occasionally. For the northern states, clearing the roads after winter storms accounts for the largest portion of the highway maintenance budget. Efficient snow and ice control operations are essential for economic and social life, but like other essential services do not gain attention except when they fail, which constitutes a crisis.

The use of chemical deicers is a growing concern. Runoff of road salt causes environmental concerns in many areas, and also corrodes highway structures and vehicles. The industry continues to search for inexpensive, effective options to sodium chloride, and ways to reduce the amount of salt used.

Despite the importance of snow and ice control, there has been relatively little technological development in this area. SHRP is conducting much-needed research that is expected to bring progress on several fronts. The Snow and Ice Control Research includes five major initiatives: *Snowplows, Snow Fences, Road Weather Information Systems, Pretreatment, and Deicing Chemicals.* When implemented, the products of SHRP's snow and ice control research have the potential to save highway agencies a tremendous amount of money.

SHRP's Snow and Ice Control Research includes five major initiatives: *Snowplows, Snow Fences, Road Weather Information Systems, Pretreatment, and Deicing Chemicals.*

Snowplows

SHRP is developing an advanced snowplow blade, cutting edge, and snowscoop attachment. The goal is a 20 percent increase in plowing efficiency.

Snow Fences

Snow fences control blowing snow to make road surfaces and safer, to improve driver visibility, and to reduce the costs of snow removal. But to be effective, snow fences have to be used properly, and the information needed to do this has not been available to most users. SHRP has studied exactly how snow fences work and has developed a *Snow Fence Guide* and accompanying video for use by engineers and maintenance superintendents. A *Drift Control Handbook* is scheduled for completion in 1992. In addition to more detailed information on snow fence design, the 1992 publication will include design guidelines for improving highway geometries to reduce the need for snow fences.

Road Weather Information Systems

Better weather prediction and communication systems will make it easier to decide which roads to treat first, and in what manner. Plenty of monitoring and communications equipment components are already commercially available, and the quality of weather data is steadily improving. SHRP is developing much-needed guidelines for development of monitoring and communications systems for highway agencies. These systems include pavement condition sensors, meteorological instrumentation, and connecting hardware and software.

Pretreatment

Improved weather prediction and pavement condition data make it more feasible to apply chemical treatment before a storm hits, so less chemical is needed to do the job, and roads stay safer. SHRP is evaluating the effectiveness of pretreatment (anti-icing). Included are investigations of innovative application methods and alternative chemicals.

Deicing Chemicals

New products for road deicing continually enter the market. Highway agencies need a uniform, reliable method for evaluating these chemicals. SHRP is developing a suite of tests for evaluation of the performance and safety of deicing chemicals.

Each of these projects is discussed in more detail on the following pages.

Snowplows: H-206

The University of Wyoming Department of Mechanical Engineering is developing an improved snowplow blade. The objective is to develop a plow that minimizes the energy needed to throw snow clear of the roadway.

The $1.2 million project (H-206), which began in October 1988 and is scheduled to terminate in March 1993, has produced an experimental plow that shows a twenty percent improvement in efficiency over conventional plows. The plow underwent testing in West Yellowstone, Montana during the 1990-1991 winter.

The first step in the development of the improved snowplow was computer simulation of the flow characteristics of snow over various plow geometries. The plow was designed

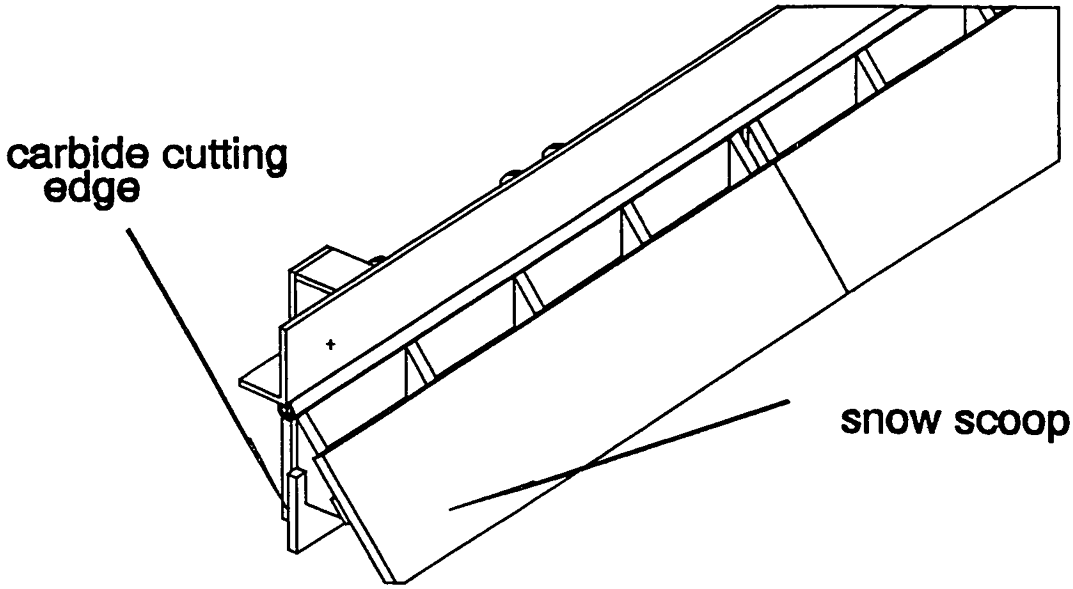


Figure 6. Dual Cutting Edge Plow Design

based on analytical models for the flow of snow, and on laboratory-scale experiments. A full-size experimental plow was fabricated in the fall of 1990. It was designed to investigate a range of geometries and was based on the variable geometry moldboard concept developed by Frink America, a Clayton, New York snowplow manufacturer and subcontractor on the H-206 project. The plow has an ultra-high molecular weight polyethylene moldboard that can be shaped by adjusting turnbuckles attached to the positioning arms, and by turnbuckles that control the geometry of both the tripping edge and the top of the moldboard. The plow incorporates a tripping edge rather than a full tripping moldboard because the design team felt that the truck's stability and control during tripping could be improved with this design.

The tripping edge has three, four-foot-long segments of mild steel hinged along the top edge. AASHTO standard carbide blades are attached in a conventional manner for the mild steel blade, and these blades are designed to operate perpendicular to the road surface in order to shear ice most effectively (Figure 6).

The plow also has a snowscoop made from one-inch, ultra-high molecular-weight polyethylene mounted at an angle of forty-five degrees to the road surface, and mounted immediately in front of the steel blade to leave a two-inch gap for discharge of cuttings. Previous analytical and experimental studies have indicated that the snowscoop would be dramatically effective in decreasing the energy consumed in snowplowing, and the field tests bore this out.

For more information on the snowplow work, contact Principal Investigator Kynric Pell at the University of Wyoming, or SHRP Project Manager David Minsk.

The snowscoop is being designed for retrofit to plows with cutting edges that are perpendicular to the road. Consideration of the tripping action will be important in retrofit. Detailed drawings of the snowscoop have been provided to several agencies that want to try it, including the California Department of Transportation, the North Dakota Department of Transportation, and the Port Authority of New York and New Jersey.

During the second half of 1991, the University of Wyoming research team plans to fabricate a second experimental plow. The second experimental plow also will be adjustable.

A related project at the University of Iowa Institute of Hydraulic Research is developing improved cutting edges for the plow blades based on studies of the mechanics of ice cutting. The project (H-204A) is funded at $183,000 and began in October 1990. It is scheduled for completion in August 1992.

Snow Fences: H-206

Although actual costs vary widely, mechanical snow removal typically costs about $3 per ton. The cost of storing snow with snow fences averages about 1/100th of the cost of snow removal, or $0.03 per ton, over the twenty-five year life of a fence. Snow fences also have important safety benefits. They intercept snow and thus improve visibility and road surface traction.

To be effective, snow fences have to be used properly, and the information needed to do this has not been available to most users.

As a subcontractor under contract H-206, Tabler and Associates of Niwot, Colorado is developing practical guidance for snow fence design. Using computer simulation techniques similar to those used by the University of Wyoming for the snowplow project, Tabler investigated the physics of blowing snow and developed equations to predict snowdrift development. These relationships are useful for determining optimum snow fence placement and height.

New York State and Minnesota held workshops on the principles of snow drift control during the winter of 1990-1991, and New York installed an experimental snow fence. Minnesota plans to install experimental fences in the 1991-1992 winter.

SHRP's *Snow Fence Guide* was released in July 1991. The guide is intended for use by maintenance supervisors and engineers. It is organized according to the following "Steps for Designing Effective Snow Fences:"

1. Obtain support for a snow fence program.
2. Understand how fences work.

3. Understand the problem.
4. Determine the wind direction and the snow transport.
5. Determine the fence height and the number of rows.
6. Determine fence placement.
7. Design the fence.
8. Meet with landowners.

> For more information on snow fences, contact Ron Tabler at Tabler and Associates, Niwot, Colorado, or SHRP Project Manager David Minsk. The *Snow Fence Guide* and the video "Effective Snow Fences" may be ordered through the Transportation Research Board.

A twenty-one minute video on snow fences was released simultaneously with the *Guide*. It explains the economic benefits of snow fences and gives the basics regarding how to design and install them.

An engineering design manual giving full details on how to predict snow drifts, how to plan, design, and construct snow fences, and how to design drift-free highways is scheduled for release in 1992.

Road Weather Information Systems: H-207

The United States and Canada spend over $2 billion each year on snow and ice control. SHRP estimates that ten percent of that cost--$200 million--could be saved through more extensive use of road weather information and communication systems.

Under contract H-207, Matrix Management Group of Seattle, Washington has surveyed technologies that can assist highway departments in making timely responses to snow and ice conditions, and identified those with the greatest potential for saving money. Some of the greatest savings can be obtained by elimination of unnecessary call-outs and better scheduling of crews based on knowledge of the probable extent and severity of winter storms. Pavement temperature sensors and ice detectors, atmospheric sensors that measure various meteorological conditions, detailed weather and pavement condition forecasts, and pavement thermography are technologies identified as of greatest value in accomplishing the objective of achieving timely and effective snow and ice control.

Pavement Temperature and Atmospheric Sensors

Three manufacturers currently offer pavement temperature sensors in the U.S. market. Pavement temperature, rather than air temperature, is the critical factor in the formation of ice and frost and the bonding of snow to the pavement, and its measurement is the key to prediction of ice formation as well as to selection of the appropriate chemical or non-chemical treatment. Sensors also indicate how much chemical remains on the pavement from previous applications. Atmospheric sensors provide information on wind speed and direction, and the presence and amount of precipitation.

For more information about SHRP's Road Weather Information Systems work, contact Principal Investigator Edward Boselly of the Matrix Management Group, Seattle, Washington, or SHRP Project Manager David Minsk.

Studies in England showed pavement temperature forecasts to be accurate within 1 degree Celsius 90 percent of the time. The sensor manufacturers provide data analysis services that use computer models to predict temperatures 18 hours in advance. The prediction models are based on observed conditions, including amount of cloud cover, wind speed, air temperature, and precipitation. Some highway agencies contract with sensor manufacturers to provide the forecasts. Others sell the forecasting software, and highway agencies must contract with professional meteorological services to obtain accurate input data on observed conditions.

The National Weather Service provides forecasts that are usually too general to be of great value to maintenance managers. More detailed, precise, and timely local weather information is available from private services. SHRP's research to date shows that use of such forecasts, in association with pavement sensors, may be one of the most cost-effective actions that highway agencies can take because it assists making more reliable decisions regarding the timing and amount of chemical treatments.

SHRP is developing a suggested format for contracting for professional weather services, which will be published in January 1992 in a publication entitled *Guidelines for Utilizing Road Weather Information System Technology.*

SHRP conducted field observations in seven states during the 1990-1991 winter (see map, Figure 7) to help determine whether pavement sensors accurately reflect pavement surface temperature, to determine how many are needed in a road weather information system, and where they should be placed. The conclusions will be published in January 1992 as *Guidelines for Locating and Placing Road Weather Information System Sensors.*

The lack of communication compatibility among sensor systems has been a problem for highway agencies. SHRP is recommending standard communications protocols and data format standards that would permit sensors from any source to be used on a network. The results will be published in *Guidelines for Road Weather Information System Communications* in January 1992. In addition to the communications protocols and data format standards, this document will include a model system for communication of weather information to highway agencies; and communication of highway information to other government agencies and the public.

Thermal Mapping

Some spots along a road tend to stay warmer than the nearby roadway; other areas are consistently colder. Thermal maps are generated using an infrared radiometer to take a

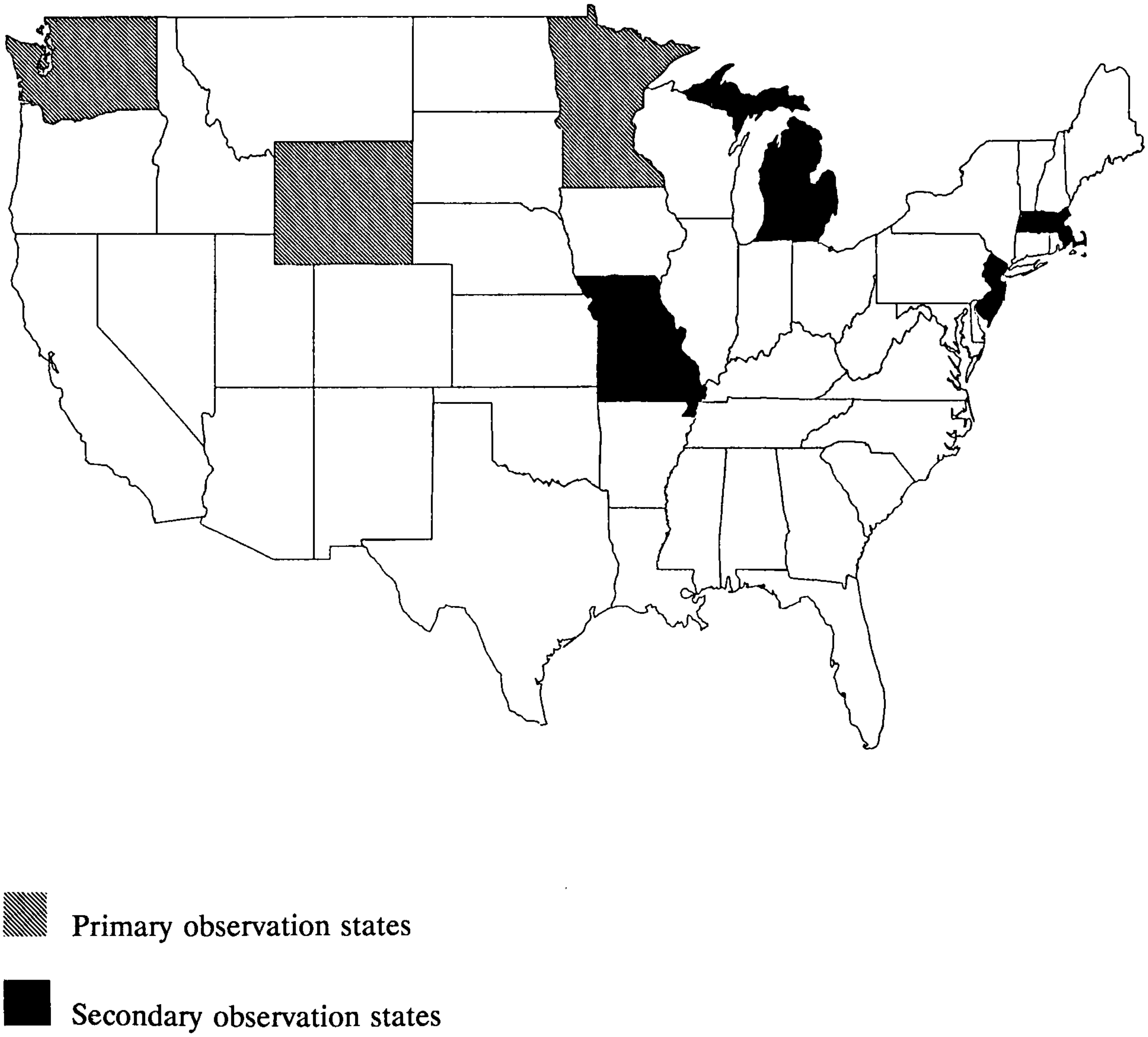


Figure 7. Colorado, Massachusetts, Michigan, Minnesota, Missouri, New Jersey and Washington field tested pavement sensors during the 1990-91 winter.

series of pavement temperature measurements along a roadway under different atmospheric conditions. The maps are color-keyed to display, for example, the warmer areas in red and the cooler areas in blue.

The identification of habitually warmer or colder pavement areas makes it easier to site pavement sensors so that they will provide the best information. The information obtained from thermal mapping also may be applied for snowplow route design. Plowing the coldest roads first will reduce the likelihood that a strong bond will form between the ice and the pavement, which makes ice removal more difficult. Thermal mapping has been used in two states; its cost-effectiveness for wider application is being assessed.

Encouraging State-Wide Data Systems

Questionnaire surveys conducted by SHRP have revealed that much could be gained by encouraging development of state-wide meteorological sensor systems for use by a variety of state agencies. At present, highway agencies are not always aware of, or are not always benefitting from, sensor networks installed for aviation, agricultural, meteorological, stream gauging, or air pollution control purposes.

The H-207 project is funded at $999,700. It began in October 1988 and is scheduled to terminate in January 1992.

For more information about Artificial Intelligence-Supported Weather Prediction for Highway Operations, contact Principal Investigator Elmar Reiter at Wels Research Corporation in Boulder, Colorado, or SHRP Project Manager David Minsk.

Artificial Intelligence-Supported Weather Prediction for Highway Operations: SHRP-IDEA 018

SHRP has a special program called "SHRP-IDEA" that funds small projects that are related to the technical research areas SHRP is investigating, and that offer highly innovative approaches. A SHRP-IDEA project being conducted by Wels Research Corp. is closely related to the work being conducted under contract H-207. Wels is developing a computer program that will provide an easily-interpreted display of local weather conditions up to 24 hours before a winter storm. The graphical interface displays topographic elevations, road information, and weather, using mouse-driven menus. The system uses a condensed numerical prediction model supplemented by local terrain data and artificial intelligence elements, processed on a desktop computer. The Colorado Department of Highways is cooperating in development of this system, which will be tested early in the 1991-1992 winter.

Pretreatment: H-208

Technological improvements in weather forecasting and in assessment of pavement surface condition (see "Road Weather Information Systems" above) offer the potential for successful implementation of anti-icing treatments.

"Anti-icing" or "pretreatment" refers to the application of a chemical freezing-point depressant on a pavement prior to, or very quickly after, the start of an ice or snow storm. This inhibits the formation of an ice-pavement bond and makes snow removal easier, and reduces the amount of chemicals needed. Benefits include lower cost and increased safety.

State highway agencies in the United States generally do not pretreat pavement due to uncertainty about how anti-icing should be conducted. In the past, agencies have not attempted anti-icing treatments because of imprecision in prediction of icing, uncertainty about the condition of the pavement surface, and concerns about public objections should a pretreatment later prove to have been unnecessary.

SHRP is conducting tests on in-service highways to determine the conditions under which anti-icing will be effective, and to learn which application techniques work best under various conditions. The tests will be conducted in a number of different locations so that the many variables influencing the effectiveness of chemicals used for anti-icing may be considered. Several state highway agencies will cooperate in these tests as part of contract H-208A with Midwest Research Institute. The Minnesota Department of Transportation is a subcontractor. Minnesota DOT is assisting in the multi-state field study and also is evaluating chemical application equipment designed or modified for the necessary low spread rates.

Because determination of the optimum (minimum effective) application rates of salt and other chemicals will involve use of amounts that could endanger drivers, tests will also be conducted on an unused airport runway in Houghton, Michigan by Michigan Technological University under contract H-208B. A Saab friction tester will be used to measure the change in friction coefficient with time after chemical application.

A cost-benefit comparison of pretreatment versus deicing will be made. The study will also investigate the influence of pretreatment on accident rates, in addition to the determination of appropriate application rates for a range of traffic and environmental conditions, and the evaluation of equipment capabilities to provided the desired low application rates. The project will investigate the effectiveness and costs of both salt and nonchloride chemicals, in both solid and liquid form.

Products from these contracts will include:

- A report on the effectiveness of anti-icing treatments in maintaining an acceptable friction coefficient and in reducing the total amount of chemical applied during a winter storm;

- A report on a survey of equipment sources and evaluation of equipment used for anti-icing treatments;

- A manual of practice for use by state highway agencies to use in implementing an anti-icing treatment program.

The project began in April 1991 and is planned to extend through March 1993. All of the reports listed above are expected to be available in 1993. Midwest Research Institute is funded at $625,000 and Michigan Technological University at $170,000.

Deicing Chemicals: H-205

This project (H-205), also being conducted by Midwest Research Institute, is divided into two phases. The first deals with development of procedures for evaluation of deicing chemicals; the second, with improving the performance and characteristics of sodium chloride as a deicer.

For more information about the deicing chemicals work, contact SHRP Project Manager David Minsk.

Maintenance organizations need a uniform procedure by which they can test and monitor deicing chemicals. The freezing point depressants that are currently in use exhibit a wide variation in properties, many of which affect their usefulness as deicing chemicals. The objective of the first phase is to establish criteria for the evaluation of deicing chemical effectiveness, characteristics, and impacts, and to develop standard procedures for monitoring and testing. The objective of the second phase is to investigate ways to improve the ice-melting properties of salt.

This project was funded at $570,000 and runs from April 1988 to September 1991. The final report will be published in late 1991.

IV. Research Implementation: H-110

The highway personnel who will implement the results of SHRP's research are a particularly numerous, diverse and dispersed group. In recognition of the extra effort needed to implement research in this area, the SHRP Highway Operations program has provided for a three year, $1 million project to produce training and implementation products (H-110).

> For more information about implementation, contact Project Manager John Hibbs at SHRP.

Maintenance operations can be characterized as one of two types--policy and programming activities that typically are the responsibility of head office personnel, and implementation activities that are carried out by district and field personnel. Figure x shows the titles and functions of maintenance personnel in a typical agency. Traffic engineering personnel also are identified because they are involved in work zone safety and, in some cases, in pavement condition analysis.

The contractor, Roy Jorgensen Associates of Buckeystown, Md., is developing implementation and training products to reach these diverse audiences--including videos, training courses, user manuals, Product Alerts, and other means.

As of July 1991, three videos had been produced:

- *Technical Advancements for Maintenance Workers (for Chief Administrative Officers)* Sept. 1990, 12 min.

  Describes progress in SHRP's maintenance and snow and ice research, with emphasis on economic benefits. A summary brochure is available with the video. Order from Kathryn Bine Brosseau, 202/334-1470.

- *Technical Advancements for Maintenance Workers (for Maintenance Managers and Work Crews)* Sept. 1990, 15 min.

Describes progress in SHRP's maintenance and snow and ice research, with emphasis on technological details. A summary brochure is available with the video. Order from Kathryn Bine Brosseau, 202/334-1470.

- *Efficient Snow Fences*, July 1991, 21 min.

  Explains principals of snow fence design. Order from Transportation Research Board.

Videos about the Work Zone Safety Devices and the Storm Monitoring Systems are planned for production later in 1991.

The contract is administered on a task-order basis. As the research nears completion, more products will be planned and produced.

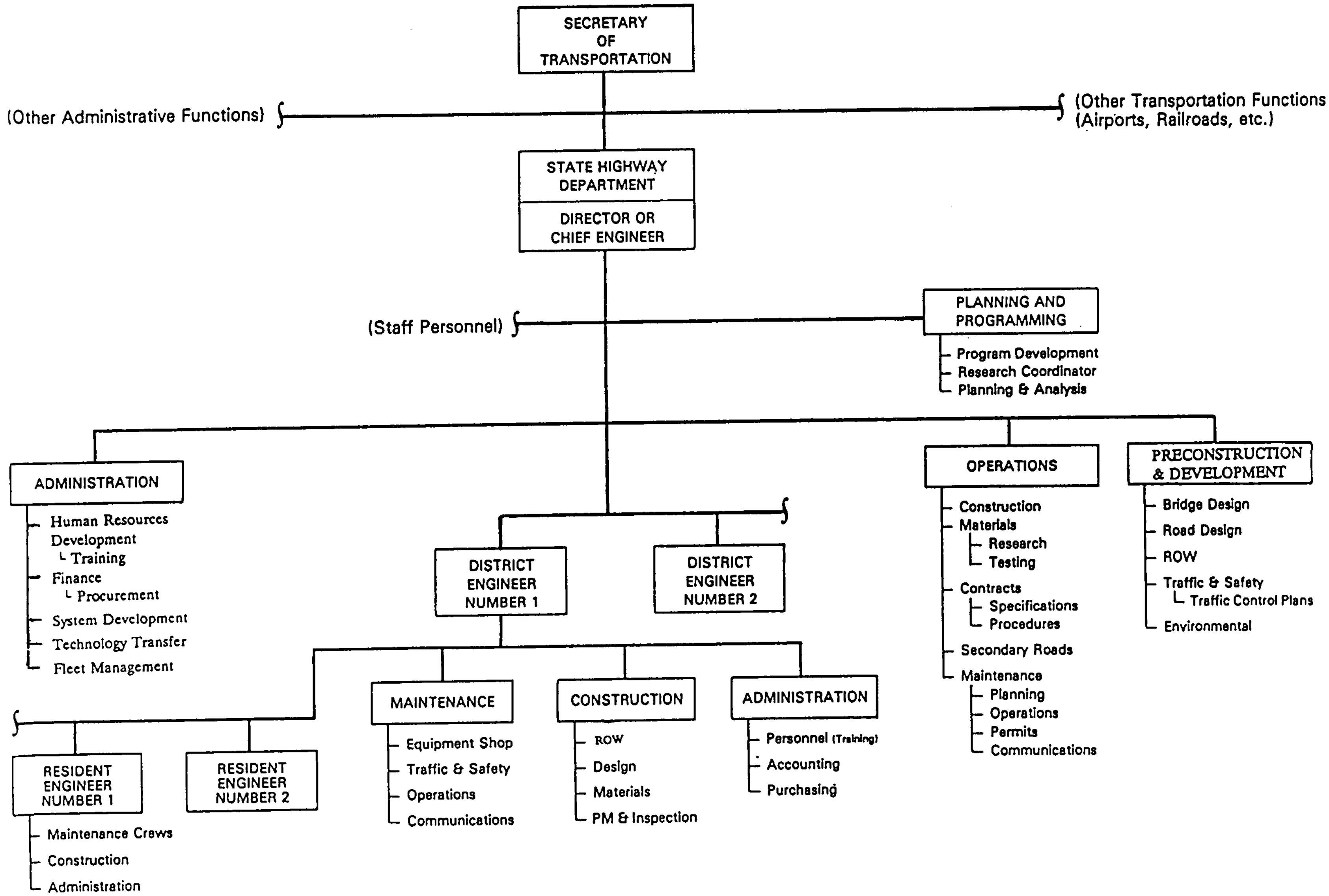


Figure 8. Organization of a typical highway agency

Appendix

SHRP Highway Operations Contractors and Principal Investigators

SHRP Highway Operations Contractors and Principal Investigators

July 1991

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