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Municipal Technical Advisory Service,
The University of Tennessee, Knoxville, TN 37916
In cooperation with the Tennessee Municipal League



This report was funded, in part, by a grant from the National Science Foundation. The data and opinions presented here are solely those of the authors and do not necessarily represent the official position of the Foundation.

by Donald F. Norris & Vanessa F. Hester

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TECHNICAL REPORT:
STREET AND ROAD MAINTENANCE

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April 1981

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Vanessa F. Hester

INTRODUCTION

This Report addresses an increasingly complex and costly problem facing local governments: namely, street and road maintenance. It was written to provide information and guidance to local public officials and professionals in the field on new and perhaps better materials, methods and equipment for street and road maintenance.

Provided here is an overview of several alternative and innovative methods of street and road maintenance in three areas: pothole repair; pavement cracking and repair; and asphalt recycling. In addition, an annotated bibliography covering general aspects of street and road maintenance, pothole repair, pavement cracking and repair, and asphalt recycling is included.

The authors wish to thank the following persons for their assistance and for their reviews of the initial draft of this Report. They are: A.B. Webb, Jr., District Engineer, The Asphalt Institute; Willis Whitney, Engineering Extension Specialist, Center for Local Government Technology, Oklahoma State University; and Frank E. Kirk and A.C. Lock, Jr., Engineering and Public Works Consultants, Municipal Technical Advisory Service, The University of Tennessee. Even with the expert assistance provided by these persons, any errors remaining in the manuscript are the responsibility of the authors alone.

Support for the development of this Report was provided by a grant from the National Science Foundation, Directorate for Engineering and Applied Science, Division of Intergovernmental Science and Public Technology, as well as by direct and indirect support from the University of Tennessee. Any opinions, findings, or conclusions expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

PROBLEM NO. 1: POTHOLES

Potholes may be described as bowl-shaped failures in a roadway. They are the result of localized pavement disintegration caused by such things as poor drainage or improper street design or construction resulting in base or subbase failure. An important factor in pothole development is the freeze-thaw cycle experienced in many parts of the country during the winter months. Once the pavement surface is broken, deterioration continues at an accelerated rate.

Pothole maintenance is a continuing problem and is often required at a time when it is difficult to make permanent repairs. For example, most potholes appear during cold, wet weather conditions during which most cold-mix patching materials will not adhere satisfactorily to the road bed and when hot mix is either unavailable or it is not feasible to keep it hot from plant to repair site. Under these conditions, traditional methods of repair may not be successful and potholes may require numerous patchings.

For these and other reasons, more effective patching methods are being sought by state and local governments. A limited sample of alternative methods and materials is reported in the pages that follow. These include: U.P.M. High Performance Cold Patch; the Perma Patch Machine; The AMZ machine; foaming asphalt; hot-mix patching; cold-mix patching; and effective training for street and road maintenance crews. Each alternative is treated briefly and sources of additional information including readings, manufacturers and users and, when available, cost and impact data, are provided.

ALTERNATIVE SOLUTIONS

Alternative Number 1:
U.P.M. High Performance Cold Patch

U.P.M. is a high performance bituminous street patching material composed of a specially treated liquid asphalt blend, which is plant mixed with locally available aggregate. Adhesive strength and durability are obtained by the asphalt blend formulation. Application is easily accomplished with hand tools. The material may be used in potholes that have not been cleaned or squared and without a tack coat. It is simply shoveled into the hole and compacted with a hand tamper or truck wheels. U.P.M. Cold Patch has a minimum stockpile life of one year and is produced in various grades, each designed for a different temperature usage range. One such grade enables it to be applied in temperatures as low as -15°F . A street may be opened to traffic immediately upon completion of the patch.

Impact: U.P.M.'s performance under cold, wet weather conditions has been tested in several locations and has consistently been found superior to standard cold patch materials. Further, tests in a variety of locations have shown that if a U.P.M. patch survives the first four months, it appears to become the equivalent of a permanent patch.

At present, U.P.M. has been used by the state Departments of Transportation of and/or by local governments in Colorado, Illinois, Kentucky, Michigan, New York, North Carolina, Tennessee, Virginia, West Virginia, and Wisconsin.

Cost Analysis: The determining factor of whether to use U.P.M. or standard cold mix is the relative performance of the two products. A ton of U.P.M. Cold Patch costs approximately \$55 in Tennessee, compared with an average

price of \$20/ton for standard cold mix. In calculating cost, however, it must be remembered that studies have shown U.P.M. to have a 70 to 92 percent chance of becoming a permanent patch. Thus, especially when labor and equipment costs are added, U.P.M. appears to be a more cost effective alternative than cold patching.

In discussing any "all-weather," permanent patching material however, the following caveat expressed by one expert in the field should be considered. While many users are pleased with the results of these materials, claims such as those indicating that the material can be placed in any conditions without cleaning or preparing the pothole to form a completely permanent patch may be excessively optimistic. Nevertheless, such materials may provide an effective alternative to traditional patching methods and, according to several studies, appear to have done so in a variety of locations.

Availability: U.P.M. Liquid Asphalt Blend is usually sold in bulk to local asphalt plant operators. At the plant, it is mixed with local aggregates under the supervision of representatives from the Sylvax Corporation. After mixing, it is stockpiled and sold to municipalities and other customers. Governmental agencies which operate their own plants may purchase the material directly from Sylvax. U.P.M. Liquid Asphalt Blend is currently available in Tennessee through the Sylvax bulk terminal in Atlanta and is expected to become available from plants in Knoxville and Nashville in coming months.

Selected Readings on U.P.M.:

"Stop the Pothole Dollar Drain", The American City and County, March 1978, p. 55.

Street Patching Operations: Field Test Evaluation Program, Sylvax UPM, Public Technology, Inc., Washington, D.C.

Sylvax UPM Winter Street Patch, Texas Innovation Group, Dispatch 3, Urban Programs Group, Center for Strategic Technology, Texas Engineering Experiment Station, Texas A & M University.

Manufacturer:

Sylvax Chemical Corporation
342 Madison Avenue
New York, New York 10173
(212) 867-5005

Alternative Number 2:
Perma Patch

Perma-Patch represents a new approach to pothole patching. It is the concept of all steps of repair being accomplished by a single machine which is operated by one person. Although this innovative technique remains in an experimental stage, should the Perma-Patch system prove its reliability over time, it appears to have a strong commercially viable future.

Perma-Patch is a mechanized pavement patching machine for year-round use in repairing roadway potholes and other localized failures. The self-contained unit is mounted on a Dodge truck chassis with an operator compartment. It can travel at highway speeds and is capable of transporting enough material to do a day's work. Without leaving the cab, the operator can do the entire patching operation using the electronic control switching panel connected to the hydraulic power system. Material temperatures

can be maintained up to 350°F, and an average 6" to 12" repair requires one to two minutes.

An attached propane heater heats the pothole sufficiently to eliminate the need for squaring and cleaning out the hole. An emulsified asphalt is used as a tack coat, followed by the patching mix material and tamping.

Impact: The Perma-Patch machine is capable of patching under a variety of conditions, making it useful for year-round pothole repair. All phases of the patching process are secured by the use of a single machine in a time-efficient manner which produces a permanent patch. Various types of patching materials may be used including cold or hot mix asphalts and recycled asphalt.

Cost Analysis: At present, the cost of a Perma-Patch machine is estimated at \$40,000 to \$45,000. The State of Colorado has tested and evaluated this machine and preliminary findings indicate an economic savings of approximately 50 percent over conventional patching techniques with the use of the Perma-Patch machine. These savings are realized in reductions of personnel, equipment, and materials costs over more traditional patching methods.

Availability: At the time of the research for this Report, the Perma-Patch machine was available only to the Colorado Department of Transportation which was renting the only existing model. The designer indicated that more interest in the prototype machine must be shown before production may begin. The potential of the machine has not been exhausted and it is conceivable that equipment similar to it is being considered by other manufacturers.

Selected Readings on Perma-Patch:

Dennis E. Donnelly, "Experience With A Mechanized Pavement Patching Machine in Colorado", Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April, 1980.

"Potholes: A Simple Problem with Few Simple Solutions", Maintenance Aid Digest, Committee on Maintenance, American Association of State Highway and Transportation Officials, Washington, D.C., July 1978

Manufacturer:

Perma-Patch Company
8198 S. Marshall Street
Littleton, Colorado 80123
(303) 979-6986

Alternative Number 3:AMZ Machine

The AMZ Machine repairs potholes using the proven concept of pressure. The machine is constructed on a twelve foot trailer which can be attached to the rear of a dump truck. The trailer contains a heated tank for emulsion, an air compressor, a funnel-like bin to receive aggregate and dual hoses for emulsion and air or aggregate. The dump truck feeds aggregate into the bin on the trailer for feeding under pressure into the hose. The AMZ machine is plugged into any normal A.C. outlet overnight to heat the asphalt emulsion in the 120 gallon insulated tank.

To patch a pothole, a jet air nozzle blows dirt and water out of the hole and its surrounding edges. Next, asphalt emulsion is sprayed under pressure into the pothole, sealing all openings and fissures. The edges and broken areas are also sprayed. The hole need not be squared. Finally, the aggregate is added and the pothole is filled with aggregate mixed with emulsion under pressure. No rolling is required.

Impact: The AMZ machine eliminates the need for plant mix, tack coat, compaction, or any other additional equipment. One person can easily operate the machine, with another person to drive the truck thus reducing the need for large pothole patching crews. It is a quick, simple method of repair which produces a lasting patch and is especially effective in skin patching alligator cracks.

Cost Analysis: As of the fall of 1980, the AMZ machine cost \$29,000.00. Current prices can be obtained by contacting the manufacturer.

Availability: The manufacturer is based in Nashville and has sold the machine to several Tennessee Municipalities, including Clarksville, Kingsport and Nashville, and to the Tennessee Department of Transportation.

Selected Readings on the AMZ Machine:

"Potholes: A Simple Problem with Few Simple Solutions", Maintenance Aid Digest, Committee on Maintenance, American Association of State Highway and Transportation Officials, Washington, D.C., July 1978.

Manufacturer:

Zimmerman Equipment Corporation
1808 West End Avenue
Nashville, Tennessee 37203
(615) 329-4107

Alternative Number 4:
Foamed Asphalt

Foamed Asphalt consists of asphalt and a foaming additive which when sprinkled with a small amount of water, produces a foaming effect. This is essentially a cold mix method of repair because none of the elements must be heated to the extreme temperatures required for a standard hot mix. The

material is applied over an aggregate mix by squirting it through a specially designed nozzle. When compressed, the combined asphalt and aggregate harden rapidly.

Impact: Foamed asphalt has several advantages. First, it is tolerant of a wide variety of aggregate. Second, a somewhat smaller amount of asphalt is needed for foamed asphalt than is used in regular hot mix. (Some sources contend a savings in asphalt of up to one-half can be achieved with foamed asphalt.) Third, the mixed emulsion and aggregate do not need to be heated to the extreme temperatures of hot mix.

It should be noted that foamed asphalt projects in North Dakota and Oklahoma found the water content of the foamed asphalt mix to be critical to the success of base construction.

Selected Readings on Foamed Asphalt:

UPSIG Newsletter, Issue 80-2, "Pothole Patching Material Being Looked At", Upper Plains States Innovation Group, Box 2755, Bismark, ND 58501.

FHWA, Construction Evaluation Report, "Foamed Asphalt Construction in North Dakota", Project RS-1-804(07)030.

Manufacturer:

Conoco
P.O. Box 2197
Houston, Texas 72001
(713) 965-1576

Alternative Number 5:
Hot Mix Patching

Hot mix asphalt makes long-lasting patches that develop stability rapidly. To make the proper hot-mix patch, the pothole must first be cleaned out. That is, all old material in the area to be removed to the depth necessary to reach dry material. The excavation should extend at

least a foot into the good pavement surrounding the area to be patched. Holes should be "squared up" and the pavement cut should be rectangular or square in shape. The surface of the exposed underlying layer should be cleaned with brooms and/or blown out with compressed air. Once it is cleaned and squared, the hole is then given a light tack coat, backfilled with a dense-graded hot asphalt plant mix which is spread carefully to prevent segregation. The area is then compacted with a vibratory-plate compactor, roller, or the rear wheels of a loaded truck. The finished patch should be compacted to the level of the surrounding pavement.

Impact: The procedure outlined above is an effective method of repairing potholes and creating a permanent patch. Its only limitations are: 1) hot patching is limited in many parts of the country to the warmer months of the year because plant mix may not be available in the winter; and 2) crews must be well trained in proper patching techniques.

Availability: Abundant. Hot mix may be obtained from batch plant operators throughout the country during the warmer months (March through November in Tennessee). In recent years, however, the cost of plant mix has become a concern for many local governments.

Selected Readings on Hot Mix Patching:

"Asphalt Paving Maintenance I - Patching", OSU Extension Facts D-1022, Center for Local Government Technology, Oklahoma State University.

The Asphalt Institute, Asphalt in Pavement Maintenance, Manual MS-16.

"Utilization of Asphalt Emulsions in Highway Construction and Maintenance", Training Workshop Instructors Manual, U.S. Department of Transportation, November 1979.

Suppliers:

Local Hot-Mix Asphalt plants

Alternate Number 6:
Cold-Mix Patching

The cold-mix patch is an alternative currently in wide use around the country, especially in the winter months when hot mix plants are closed. Cold-mix is made with asphalt cement and a liquifier. The liquifier is a petroleum oil such as kerosene or naphtha put into the AC either by the manufacturer or at the hot mix plant.

When designed and installed properly and under the right conditions, cold-mixes can reach the quality of good hot mix, and have ability to be stockpiled for later use. Patching procedures are basically identical to those used with the hot mix patch. In addition, cold-mix traditionally has been the only option available in many parts of the country for winter month patching.

As with some other methods of pothole repair, technically proficient installation of a cold-mix patch is of major importance. This is why many studies have shown that several of the alternatives presented earlier in this report are more cost effective than cold-mix and are receiving increasing attention by local governments around the country.

Alternative Number 7:
Training

Pothole repair may be the most widespread single problem in street and road maintenance. Regardless of the methods, materials or equipment used, effective pothole patching requires skill and close supervision, and it is essential that it be done correctly. Every year local governments spend a great deal of time and money repairing potholes. Often, the lack of technical expertise or supervision, which results in improper pothole repair,

means that the same holes must be filled over and over again--a costly and time consuming process. Training road maintenance crews to install proper lasting patches--that is, to do it right the first time--will reduce call-backs, thus saving materials and labor costs. As simple and straightforward as this sounds, however, it is apparently something that has escaped the attention of many local governments.

A road maintenance training program presented to the road crews and supervisors should train them in proper maintenance and scheduling techniques and should include printed and audio-visual materials and classroom presentations as well as on-the-street "hands-on" instruction. These programs should be oriented to the work on the street and, thus, should not be overly complex or sophisticated.

Impact: The effective training of street maintenance crews to perform proper repairs would mean more miles of road maintained for fewer dollars. The savings would be realized in reductions of labor, materials and equipment costs.

Currently, such training programs are offered by the Departments of Transportation in several states, by the American Public Works Association and the Asphalt Institute, and by technical assistance and governmental training agencies in several states. Further, at least a few of these are "packaged" programs with slide-tape, film or videotape presentations and supporting printed materials suitable for use by local street or road maintenance departments.

Selected Readings on Training:

Floyd Burke, Road Maintenance Technical Handbook, Department of Local Government, State of Kentucky, October 1977.

W.W. Baker and Neal McCaleb "Maintenance Crew", The Asphalt Institute Quarterly, April 1961, p.5.

Field Maintenance Manual for Georgia Counties Local Roads and Streets, Department of Transportation, State of Georgia, August 1979.

Contacts for Training:

American Public Works Association
1301 Pennsylvania Avenue NW
Suite 401
Washington, DC 20004
(202) 393-2792

The Asphalt Institute
Asphalt Institute Boulevard
College Park, Maryland 20740
(301) 779-4880

Center for Government Training
The University of Tennessee
P.O. Box 24180
Nashville, Tennessee 37202
(615) 251-1401

Center for Local Government Technology
505 Engineering North
Oklahoma State University
Stillwater, Oklahoma 74074

Municipal Technical Advisory Service
891 20th Street
The University of Tennessee
Knoxville, Tennessee 37916

CONCLUSION

Probably the most widely used methods of pothole repair are hot and cold-mix patching. As we have indicated, however, correct repair technique, proper equipment and proper weather conditions are critical to the successful use of these methods. Because these conditions are not always present, efforts to develop a cost-effective, year-round pothole remedy which can be used in both wet or dry, hot or cold weather has been underway for the past several years. Three of the alternatives presented (U.P.M., Perma-Patch Machine; AMZ Machine) purport to provide the long-awaited answer to the issue of year round patching.

One alternative not explored here which can help to combat the high cost of pothole repair is cooperation between neighboring municipalities and between cities and counties. It seems only reasonable that local governments could reduce the cost of road repairs if they could share costs of the personnel, equipment and materials needed for such maintenance. Although this is not a widespread practice and has clear political implications, as costs continue to escalate it is hoped that cooperation among local governments in street maintenance will begin to occur on an increasingly frequent basis.

This section has covered a few of the more prevalent alternative and innovative methods available for repairing potholes. All prices are based on 1980 data and are subject to change. For further information on these and additional methods of pothole repair, the reader is referred to the readings and sources of technical assistance listed herein as well as to the Annotated Bibliography included in this Report. For additional infor-

mation on the availability, performance and cost-effectiveness of the materials and equipment presented here, the reader is referred to equipment and material manufacturers and suppliers and to the cited state and local government users. Local governments in Tennessee are encouraged to contact MTAS for additional information or technical assistance in pothole patching.

PROBLEM NO. 2: PAVEMENT CRACKING AND REPAIR

Cracks appear in asphalt pavement in a variety of shapes and occur as the result of a number of causes. For example, cracking patterns may be longitudinal, transverse, diagonal or block. Cracks are most commonly caused by movements in the pavement beneath the overlay, often due to temperature or moisture changes. Other causes include traffic, earth movements, loss of moisture in subgrades or asphalt shrinkage.

The cracking pattern is frequently the same for various causes and for various states of distress. Crack filling may be the proper treatment in some cases. In others, complete removal of the affected area and base repair must be completed before effective repair can be made.

For these and other reasons, more effective methods of repairing pavement cracking are being sought by state and local governments. A few of these methods are reported in the pages that follow. They include: the squeegee method for repairing small cracks; slurry seal; geotextiles; asphalt rubber; sulphur asphalt; and sulphur concrete. Each alternative is treated briefly and sources of additional information, including readings, manufacturers and users and, when available, cost and impact data, are provided.

ALTERNATIVE SOLUTIONS

Alternative Number 1:

Squeegee Method for Repairing Small Cracks

If the cracks are less than 1/8 inch wide, a simple squeegee technique may be used for repair. First, the cracks must be thoroughly cleaned and dried by using a compressed air jet to blow out loose material, then brushed with a wire brush to remove more stubborn material. Next, an emulsion slurry or an emulsion mixed with sand should be forced into the

cracks until it is 1/4 inch from the surface. After it has cured, the sealing should be finished by filling the remainder of the crack with emulsified asphalt using a pouring pot and a hand squeegee. Finally, the surface should be sprinkled with sand.

For those cracks over 1/8 inch wide and in pavements which have experienced numerous small cracks, other methods are available for repair. These include slurry seal, geotextiles, asphalt rubber, sulphur asphalt and sulphur concrete. Each is described below.

Alternative Number 2:
Slurry Seal

Slurry seal is a thin asphalt surface treatment applied by a continuous process machine to worn pavements to seal them from water penetration. In the slurry seal, the asphalt is emulsified and as a general recommendation is spread not to exceed 1/2" thick. The slurry consists of emulsified asphalt, aggregate and water which are mixed and placed into a special spreader box which squeegees out the material. A good base is necessary for effective use of slurry seal.

According to various studies, a quick setting emulsion slurry seal will cure quickly enough to support traffic after one hour. Slow setting emulsions cure by drying in the sun and should be used on dry, sunny days. Two hours should be allowed for curing. On cooler and cloudy days or in shaded areas four to six hours may be needed before traffic is allowed. Curing times for both quick and slow setting emulsions will vary due to such factors as temperature and humidity.

Impact: Slurry seal will fill both small and wide cracks and scaled areas and seal the surface to prevent moisture and air intrusion into the pavement. It can be a quick and effective response to many types of pavement cracking problems. Its best use is on high quality surfaces in reasonably good conditions.

Cost Analysis: Material costs will vary according to such factors as availability, transportation cost, and quantity. Typically, a square yard of 1/4-inch thick slurry seal uses approximately 12 pounds of aggregate, 14 gallons of asphalt emulsion and 0.2 pounds of portland cement.

<u>Costs:</u>		<u>Total Per Mile</u>
emulsion	\$0.75/gallon	\$7,920
aggregate	\$8.00 short ton	\$ 451
cement	\$0.55/pound	\$ 744

Equipment costs will also vary. An 8-yard Slurry Seal machine, mounted on a dual rear axle, gasoline-fueled truck will cost about \$50,000 with an average annual maintenance fee of \$1,000.* Concrete mixers can be adapted to this purpose, but are not as effective as a slurry seal machine.

Availability: Slurry seal jobs can be undertaken by city and county road crews or can be contracted along with a variety of other street repair services offered by road contractors. The materials required for slurry seal are usually readily available from local asphalt and aggregate suppliers.

*Contractors, public works equipment suppliers, and asphalt and aggregate suppliers can be contacted for more exact costs for materials and equipment, especially as these costs will change over time and from region to region. The figures provided here were taken from Slurry Seal, Inc., Waco, Texas, Summer 1980.

Selected Readings on Slurry Seal

"Seal Coating: An Engineering Challenge", Public Works, September 1976, p. 90.

"Slurry Seal for Maintenance--Remix for Reconstruction", The American City, July 1971, p. 54.

Phillip G. Manke, "Flexible Pavement Crack Sealing", Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April 1980.

Robert Prince, "Slurry Seal: Questions and Answers", Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April 1980.

Asphalt Institute Construction Leaflets under the following titles:

Surface Treatment Tips (CL-14)
Preventing Reflection Cracks (CL-16)
Full-Depth Asphalt Patching (CL-19)
Slurry Sealing (CL-22)
Emulsified Asphalt Tack Coat (CL -23)

Alternative Number 3:
Geotextiles

Geotextiles are fabrics composed of filaments derived from synthetic polymers. Woven and nonwoven fabric construction is available. When installed between an old, cracked pavement and a new pavement overlay, the fabrics strengthen the overlay, increase its resistance to cracking and extend pavement life. Most geotextiles are produced in a variety of grades. To repair cracks, for example, a fabric of 4 or 5 oz. per square yard is adequate. These are typical values, however, and weight is not the only criterion for selection.

Before a geotextile is installed, the old surface should be smooth and all potholes and distortions repaired. It should also be free of dirt and dust. A tack coat is used to bond the fabric securely to the existing pavement. A number of tack coats is available, although asphalt cement or

asphalt emulsions have performed best in a number of field tests. The number of gallons per square yard of tack coat depends on the type of grade of fabric used and the type of sealant chosen. The tack coat should be uniform and applied to an area two to six inches wider than the width of the fabric.

The fabric may be placed manually for small jobs or may be mechanically installed for larger ones. If the job requires mechanical means, the manufacturers of the fabric will provide the equipment either as part of the contract or at the then current charge. Approximately 10,000 square yards of fabric per day can be installed mechanically.

Paving operations may start immediately after installation of the fabric (unless asphalt emulsion is used). It is not necessary to place a tack coat on the fabric prior to paving. Standard hot mix, chip seal, slurry seal, or cold overlay may be used as a top coat. For complete resurfacing jobs, standard hot mix is preferred.

Impact: Although evidence supporting the effectiveness of geotextiles is not yet conclusive due to the short time in which they have been in use, preliminary data appear quite supportive. For example, data from a variety of tests indicate that when properly applied a fabric underliner will extend pavement life several years, reduce maintenance costs, and delay reconstruction costs.

In 1978, Dallas, Texas, began a two-year test comparing a hot mix overlay reinforced with nonwoven fabric and an unreinforced hot mix. The test sections were on a road leading to a city landfill which experienced heavy truck traffic. The superintendent of street maintenance, John Murff,

stated that the fabric cost section showed less signs of reflective cracking. He felt that compared to the other test sections, it would be the most durable over a longer period of time.

Other cities which have experimented with geotextiles include Greenville, South Carolina; Laurel, Mississippi; Prairie Village, Kansas; St. Louis, Missouri; and Tulsa, Oklahoma. These cities should be contacted for information concerning their individual projects.

Cost Analysis: The cost of using a geotextile will vary with the grade of fabric needed, the type of material chosen for sealant for the material and method selected for a top coat. Generally, the standard list price of a 4 or 5 oz. fabric is \$0.60/square yard. Manufacturers will comply with individual specifications as to the length, width and amount of fabric on each roll.*

Standard Specifications

<u>Widths</u>	<u>Lengths</u>
148" or 12'4"	984' full roll
166" or 13'10"	493' half roll
209' or 17'5"	328' third roll

Availability: Geotextiles are available from several manufacturers which supply private contractors and local government public works departments. Typically, an order can be filled within seven days. A partial list of manufacturers is provided below.

Selected Readings on Geotextiles

"Experimental Overlays to Minimize Reflection Cracking", U.S. Department of Transportation, Report #FHWA-CA-TL-3167-76-28, September 1976.

*All cost and specification figures were provided in the Summer of 1980 by Monsanto Textiles Company or Phillips Corporation.

"Innovative Road Repair Stretches Tax Dollars", Public Works, May 1980, p. 104.

"Reduction of Reflection Cracking in Bituminous Overlays: Payne's Prairie Experimental Project", Florida Department of Transportation Office of Materials and Research Projects #26260-8426, Report #176-A, June 1977.

"Synthetic Fibers Reduce Reflection Cracking", Public Works, April 1979, p. 55.

Manufacturers of Geotextiles**

E.I. DuPont Textiles
Fibers Department
Old Hickory, Tennessee 37138

Monsanto Textiles Company
Engineering Fabrics Business Group
800 N. Lindbergh Blvd.
St. Louis, Missouri 63166

Phillips Manufacturing Corporation
Box 66
Greenville, South Carolina 29602

Alternative Number 4: Asphalt Rubber

Asphalt rubber consists of relatively heavy concentrations of reclaimed rubber (25 percent rubber, 75 percent asphalt) reacted in hot asphalt. It has a chunky appearance with clearly visible rubber particles. The rubber components are obtained by processing reclaimed waste automotive tires from which metal and cord reinforcement have been removed.

To retard cracks, asphalt rubber is used primarily in two ways. In one, it is used as a surface treatment including chip and seal coats. This process is called "Stress Absorbing Membranes" (SAM). The other common application is the "Stress Absorbing Membranes Interlayers" (SAMI) which

**This is not necessarily an inclusive list and other suppliers or manufacturers should be contacted for comparative data.

consists of a thin layer of asphalt rubber between the existing pavement and an overlay.

The surface to which asphalt rubber is to be applied is first prepared by joint and crack sealing, patching, cleaning, and application of a conventional light tack coat. Other conditions necessary for application include 65°F temperature or above, dry surface, and little or no wind.

The preparation of asphalt rubber will depend on the system being used. If the supplier carries a "devulcanized rubber" (chemically processed), then the rubber and asphalt must react in a nurse tank and then be transferred to a conventional distributor for application. Vulcanized (untreated) rubber uses a special distributor for both reactions and distribution. Typically, field technicians representing the manufacturers of asphalt rubber are present to supervise the mix and offer assistance to the application.

Spraying is the conventional method of application at a rate of 0.6 gallons of asphalt rubber per square yard. Cover aggregate is then applied at approximately 30 lbs. per square yard. The aggregate must be clean and dry and is applied directly behind the distributor.

Pneumatic rollers are recommended for compaction to prevent breakage of particles and should have a minimum weight of two tons per wheel. Four coverages should be adequate for embedment.

A minimum of three hours is required for SAM and to cure fully and to develop full cover aggregate adhesion. For SAMI, a cure period of 48 hours is required to ensure that dilutents, such as kerosene used in the vulcanized system, have evaporated sufficiently to prevent softening of the

asphalt overlay.

Impact: The impact of asphalt rubber is twofold. First, it is an effective method of crack repair. Treated pavements have recorded life expectancy of 13 years. Also, due to the extremely flexible property of rubberized asphalt, it resists cracking in freezing weather.

Second, this method uses scrap auto tires to provide the rubber necessary to obtain the desired properties. Currently, 200 million tires are discarded annually in America. Rather than purchasing new rubber, the manufacturers of asphalt rubber reclaim the old tires, thus saving both energy and natural resources.

Asphalt rubber products have been used by numerous agencies such as the Departments of Transportation in the States of Arkansas, Florida and Georgia, and the cities of Baltimore, Maryland; Cartersville, Georgia; Jackson, Michigan; Milwaukee, Wisconsin; and Phoenix, Arizona.

Cost Analysis: Since 75 percent of the product is asphalt, the cost of asphalt rubber depends a great deal on the price of asphalt. Typically prices are as follows:

SAM (including rubber & chips)	\$1.25/sq. yd.
SAMI - 3/4" overlay	\$2.59/sq. yd.
SAMI - 3/4" w/additional rubber overlay	\$3.10/sq. yd.

These prices are comparable to standard hot mix overlays while improving on performance. For example, studies have shown that a 3/4" SAMI overlay can achieve strength equal to that of a 2" standard asphalt overlay at considerably less cost (\$3.10 per square yard for SAMI versus up to \$10.00 per square yard for asphalt).

Availability: The manufacturers of asphalt rubber have distributors available around the country to serve specific regions. For Tennessee, the distribution point is Atlanta, Georgia.

Selected Readings on Asphalt Rubber:

"Cost Benefit Factors of Natural Rubber", American City, October 1971, p. 30.

"Ground Tires Reduce Pavement Cracking", American City and County, March 1974, p. 43.

"How To Make Asphalt Streets Last Longer", American City and County, March 1974, p. 43.

R.D. Pavlovich, "Asphalt Rubber for Street and Road Maintenance", Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April 1980.

Manufacturers of Asphalt Rubber*

Arizona Refining Company
P. O. Box 1453
Phoenix, Arizona 85001

Crafco, Inc.
P. O. Box 20133
Phoenix, Arizona 85036

Genstar Conservation Systems, Inc.
2621 Camelback Road
Bldg. D. Suite 146
Phoenix, Arizona 85016

Sahuaro Petroleum and Asphalt Co.
731 North 19th Avenue
P. O. Box 4378
Pheonix, Arizona 85005

Additional Information:

Engineers Testing Laboratories, Inc.
P. O. Box 4378
Pheonix, Arizona 85036

*This is not necessarily an inclusive list and other suppliers or manufacturers should be contacted for comparative data.

Alternative Number 5:

Sulphur-Asphalt

Sulphur-extended asphalt (SEA) is a hot mix in which a portion of the asphalt binder has been replaced by sulphur. At the time of mixing, approximately 20 percent of the sulphur by weight is dissolved in the asphalt. The remaining sulphur crystalizes and acts as a binder and a mineral filler. Sulphur adds strength to the asphalt, but strict guidelines must be followed in the mixing to acquire the desired properties. Thirty-five percent sulphur by volume is the maximum in order to avoid brittleness.

The operation and equipment used for asphalt concrete are essentially the same for SEA, with the exception of mixing. The hauling, spreading and compacting equipment need no modifications to handle SEA. The hot mix plant, however, requires modification to accommodate SEA--the sulphur has to be fed into the mix. This can be accomplished through one of two basic methods, direct feed and in-line blending. In the direct feed method, the molten sulphur is pumped directly into the weight bucket after the asphalt and then both are fed into the pugmill, where blending and mixing occur. In the in-line blending method, the asphalt and sulphur are preblended in a static in-line blender before being fed into the weight bucket of a batch plant or into a drum mixer. The recommended mixing range for either of these methods is between 265° F to 285° F.

Impact: SEA has been in use for such short time, that conclusive test data are not available. It is believed from available results, however, that SEA reduces the occurrence of cracking, thereby increasing the service life of the pavement. The addition of sulphur stiffens the pavement during hot

months, adds flexibility to the asphalt for cold months, and shows improved resistance to solvents, such as gasoline, or diesel fuel. To date, SEA projects are performing as well as, and in some cases superior to, control asphalt concrete sections in tests.

Several cities which have experimented with SEA, include: College Station, Texas; Gainesville, Florida; Henderson, Nevada; Lee Creek, North Carolina, Midland, Michigan; and Wateska, Illinois.

Availability: At present, sulphur producers in the U.S. estimate there will be a surplus of sulphur by 1985. The principle producer of sulphur is Canada, although the southwestern region of the U.S. recently has begun extracting large amounts of sulphur.*

Little modification is needed in order to adapt a hot mix plant to produce sulphur asphalt. Therefore, nearly any plant may be converted to sulphur asphalt production.

Selected Readings on Sulphur-Asphalt:

"Sulphur-Asphalt Pavements: The Minnesota DOT Projects", Rural and Urban Roads, November 1979, p. 34.

"Sulphur-Asphalt Pavements: The Delaware DOT Projects", Rural and Urban Roads, April 1980, p. 32.

"Sulphur/Asphalt Roads Performing Well", American City and County, April 1980, p. 13.

"Sulphur: Triple Threat Pavement Binder Material", Public Works, January 1980, p. 62.

*Information supplied by the U.S. Department of the Interior Bureau of Mines.

Manufacturers

The Sulphur Institute has prepared a booklet entitled "Sulphur Sources for Pavement Projects" which lists the companies, individuals, and telephone numbers to contact to obtain further information:

The Sulphur Institute
1725 K Street, NW
Washington, D.C. 20006
(202) 331-9660

Alternative Number 6: Sulphur-Concrete

All of the material and methods discussed for the repair of cracks to this point have involved to a greater or lesser degree the use of asphalt cement. The following material, sulphur-concrete, is a type of concrete in which portland cement and water are replaced by a chemically modified sulphur which adds strength and resistance to the pavement. Although it is classified as a concrete and can be pre-cast, sulphur-concrete has its own unique qualities which distinguish it from portland cement.

Sulphur-concrete contains no portland cement and requires no water in its manufacture. It is produced by a dry process similar to that used for making asphaltic concrete in which the sulphur, aggregate and SRX (a proprietary fire resistant additive) are batched into a heated mixer. Conventional asphalt plants and concrete batch plants equipped with an aggregate dryer may be used for the production of sulphur-concrete.

The hot mix is transported in heated or insulated trucks for field-poured applications by conventional asphalt pavers or concrete slip-formers or extruders. The mix should be maintained in the heated condition (between 250°F to 300°F). The setting time for sulphur-concrete ranges

from a few minutes to several hours depending on temperature of site, with full strength developing almost immediately upon cooling.

Impact: Sulphur-concrete is well suited to both cold weather and hot weather concreting. It reduces the occurrence of thermal cracking and stiffens the pavement during the hot summer months. Sulphur-concrete can be poured at -40°F without freezing problems and sets very rapidly, reaching 50% strength in a few hours and virtually 100% in two to three days. In addition, it shows water impermeability, corrosion resistance and high elasticity properties. It may also be recycled.

Sulphur-concrete is energy efficient in that it takes one-third as much energy as required to produce a portland cement concrete.

Cost Analysis: Sulphur can be purchased in liquid form (hot), as crushed bulk, as flakes, and more recently as granules. The price from Canadian plants, where it is most abundant is \$22.00/ton, plus shipping. Currently, in the U.S. sulphur costs approximately \$41.00/ton.

Availability: At present, sulphur producers in the U.S. estimate there will be a surplus by 1985. The principal producer of sulphur is Canada, although the southwestern region of the U.S. recently has begun extracting large amounts of sulphur.*

Selected Readings on Sulphur-Concrete

"Sulphur: Triple Threat Pavement Binder Material", Public Works, January 1980.

"Sulphurcrete -- A new Type of Concrete", APWA Reporter, August 1978, p.16.

Alan Vroom, "Sulfurcrete -- A Technical Brief", Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April 1980.

*Information supplied by the U.S. Bureau of Mines.

Manufacturers of Sulphur Concrete**

Sulphur Innovations, Ltd.
3015 58th Avenue S.E.
Calgary, Alberta
Canada

For Further Information:

The Sulphur Institute
1725 K Street, NW
Washington, D.C. 20006
(202) 331-9660

CONCLUSION

This Report has presented an overview of several alternative methods and materials for the repair of pavement cracking. Although no method can attest to complete effectiveness, the best possible results for each can be achieved by carefully following the procedures set forth for its application. In addition, careful analysis and planning should be undertaken to determine which method of repair is best suited for a particular situation.

The reader should be aware that this Report has discussed only a limited number of alternatives. Additional sources of information in the area of pavement cracking repair are listed below. Tennessee officials should feel free to contact MTAS for either assistance or additional information.

**This is not necessarily an inclusive list and manufacturers or suppliers of the product should be contacted for comparative data.

Additional Sources of Assistance

The Sulphur Institute
1725 K Street, N.W.
Washington, D.C. 20006
(202) 331-9660

The Asphalt Institute
Asphalt Institute Blvd.
College Park, Maryland 20740
(301) 779-4880

Engineers Testing Laboratories, Inc.
P.O. Box 21387
Phoenix, Arizona 85036
(602) 268-1381

Municipal Technical Advisory Service
The University of Tennessee
891 20th Street
Knoxville, Tennessee 37916
(615) 974-5301

PROBLEM NO. 3: ASPHALT PAVEMENT RECYCLING

Street and road maintenance costs continue to increase while the purchasing power of tax revenues for both construction and maintenance declines. It is more important than ever therefore, that the most cost-effective methods are employed both for construction and maintenance.

Pavement recycling has become an increasingly viable technology for street and road maintenance. Recycling involves the removal of in-place pavement and the reprocessing of pavement materials for use in resurfacing. There are several methods available for both pavement removal and recycling, each of which is applicable to differing pavement conditions and desired improvements.

Asphalt pavement recycling has proved to be cost effective for both urban and rural road systems. Recycling helps to conserve national resources, save money and reduce air pollution. Even if pavement recycling is not contemplated, pavement removal often has several advantages. Pavement removal, generally in preparation for installation of a new surface treatment, allows for the retention of existing grades, and existing curb, gutter and manhole heights and does not alter clearances from the roadway to overhead structures such as bridges or over-passes.

Provided here is an overview of several alternative methods for asphalt pavement recycling. These include: hot-mix recycling; cold in-place recycling; the use of heater-planters and heater-scarifiers; and pavement ripping, planning, scarifying, and grinding. Each alternative is treated briefly and sources of additional information, including readings, manufacturers and users and, when available, cost and impact data, are provided.

BASIC RECYCLING TECHNOLOGIES

The most prevalent methods of asphalt pavement recycling are hot-mix recycling and cold in-place recycling. (Cold recycling can also be done at a central plant.) These are discussed below and are followed by consideration of heated and cold removal technologies which are commonly used for pavement removal preparatory to asphalt pavement recycling.

Alternative Number 1: Hot-Mix Recycling

Asphalt pavement recycling begins with the removal of existing in-place pavement. With hot-mix recycling, the existing pavement is removed, sized and mixed with from 25% to 40% new asphalt and a rejuvenation agent. Mixing can occur either at a hot-mix plant or on-site.

Removal is achieved by ripping up the asphalt surface using one of the several methods discussed later in this section. The removed pavement is reprocessed on-site or is removed to a hot-mix plant or central cold-mix plant where it is crushed and processed. The recycled material is then returned to the roadway and placed with a conventional paving machine and compacted. The section of roadway which is to be recycled must be closed for several days for removal of the old surface and the replacement of recycled material.

Impact: The major advantage with hot mix recycling, as with any type of recycling, is that it decreases the amount of new asphalt and aggregate necessary for the construction or reconstruction. This can represent a significant savings in dollars as well as natural resources, especially in a period of increasing asphalt prices.

Recycling will provide a new pavement surface without changing existing clearances and will save curb, gutter and manhole heights. Recycling is also a major energy saver. For example, a 15,000 ton project recently completed saved the equivalent of over 9000 gallons of gasoline.*

Hot mix recycling has been used in several states including Colorado, Florida, Louisiana, Michigan, Mississippi, Texas, and Wisconsin.

Cost Analysis: Because hot mix recycling is a relatively new technique to many contractors, bid prices may be somewhat higher than if standard hot-mix were specified for a job. Bid prices in such cases appear to be inflated due to uncertainties, such as the contractor's ability to recover the cost of necessary equipment and minor plant modifications. After several projects, however, it is assumed that prices will stabilize.

At present, states have reported prices ranging from \$5.00 to \$15.00 per ton for hot-mix recycled asphalt. These prices vary for several reasons. For example, different percentages of existing pavement to the virgin mix were used; some figures include fuel costs, others do not; and the varying costs of asphalt, aggregate and labor. Generally, however, an estimated \$2.50 to \$3.00/ton of asphalt can be saved using a recycled mix over standard hot-mix.

Availability: Recycling may be undertaken by any contractor with the necessary equipment or one willing to make the initial investment either to buy new equipment or modify existing equipment. Essentially, all the necessary materials are provided by the old pavement, adding only small

*Information provided by the Federal Highway Administration.

quantities of asphalt, aggregate and rejuvenation agent. Further, only limited modification is required to a conventional batch plant to enable it to produce recycled asphalt.

Alternative Number 2:
Cold In-Place Recycling

With cold in-place recycling, surface materials are first removed to the base. Often, cold milling machines are used to scrape the existing pavement and break it into chunks. A rejuvenating agent is added to soften the asphalt and to restore some of its physical properties. The milled material is then wind-rowed and recovered by an asphalt paver, relaid and rolled. (Several other methods are available for cold in-place recycling, but for the sake of brevity only one is reported here. Readers are referred to the literature on recycling for additional information.)

Availability: Cold in-place recycling is accomplished by utilizing common equipment and by using materials from the old in-place pavement. What may complicate a cold in-place recycling project is that the method is relatively new, and consequently few contractors have employed it or have the knowledge necessary to perform a proper job. Thus, while the equipment and technology is available for high quality cold in-place recycling at economical costs, experienced contractors may be difficult to find.

PAVEMENT REMOVAL TECHNOLOGIES

The following technologies are commonly used to remove asphalt pavement preparatory to recycling.

Alternative Number 1:
Heater-Planer

The heater-planer is a machine which uses intense heat to soften an asphalt pavement surface preparatory to planing. Two types of heater-planers are available. With one (the integral method) the existing asphalt overlay is heated, removed, recycled and spread by a single integrated piece of equipment. It is compacted immediately thereafter with separate equipment. The second (the paving train method) heats and planes the existing overlay, but recycling, spreading and compacting occur after the heater-planer passes through. In both cases, additional virgin asphalt and a rejuvenation agent are mixed with the old pavement before the recycled material is replaced.

Cost estimates show a range of \$.70 to \$.90 per square yard per inch of depth for removal of asphalt pavement by heater-planer.

Alternative Number 2:
The Heater-Scarifier

The heater-scarifier is similar to the heater-planer except that carbide teeth are used to loosen the pavement after heating. Cost estimates show a range of \$.15 to \$.60 per square yard per 3/4 inch of depth for removal of asphalt pavement by heater-scarifier.

In all hot-mix recycling methods, the pavement must first be removed, crushed, mixed with virgin materials (such as asphalt or asphalt and aggregate), sometimes also a rejuvenation agent, and then spread and compacted. Hot-mix recycling can occur on-site, as with the integral method heater-planer or using portable hot-mix recycling equipment. The removed asphalt can also be trucked to a recycling plant (often a modified

conventional hot-mix plant) for reprocessing and returned to the site for spreading.

Asphalt pavement removed by either a heater-planer or heater-scarifier cannot ~~be~~ stockpiled. In order to be recycled, it must be used immediately or upon cooling it forms into a hardened mass.

Alternatives 1 and 2, the heater-planer and heater-scarifier can be employed only if a hot mix recycling method is to be used. Alternatives 3 through 6, ripping, planing, grinding or milling and scarifying, can be used with either hot-mix or cold-in place recycling methods. In addition, the materials removed with the latter four methods may be removed and stockpiled for later use or for use at another site.

Alternative Number 3:

Ripping

Ripping pavement using a specially equipped bulldozer or road grader is the first step in one of the several methods available to prepare a road surface for either hot-mix and cold in-place recycling. With cold in-place recycling the removed asphalt is crushed, mixed in-place with virgin materials and a rejuvenation agent, spread and compacted. As an alternative, the removed asphalt can be added to a portable hot-mix recycler or trucked to a hot-mix plant for recycling. In either case, virgin materials and a rejuvenation agent are added, the recycled material is returned to the roadway and is spread and compacted.

Alternative Number 4:
Planing

Planing for cold in-place recycling involves essentially the same process as with the heater-planer except that the planing is accomplished without high intensity heat to soften the pavement. Processing the removed asphalt for replacement may be done in the same way as with ripping.

Alternative Number 5:
Grinding or Milling

Grinding or milling is accomplished by a machine with high tensile carbide teeth on a rotating drum. Pavement can be milled up to 6" in depth. The removed pavement is windrowed for reprocessing and replacement on-site or is removed to a recycling plant and reprocessed much the same as with ripping or planing.

Grinding is frequently undertaken on a surface in order to maintain existing clearances and curb and manhole heights. When combined with recycling, it can provide an economical method of pavement replacement.

Cost estimates for cold milling show a range of \$.30 to \$1.20 per square yard per inch of depth with \$.60 being an average cost.

Alternative Number 6:
Scarifying

Scarifying is another method of asphalt pavement removal which lends itself to recycling technology. Scarifying is especially useful for reduction of cracking patterns and for improved bonding between the old surface and the new overlay, and for reconstruction of chip and seal surfaces prior to installing a new overlay. Scarifying is often done with a specially equipped motor grader which will rip up to the top six inches of surface.

The removed material is then blended, bladed back into place, compacted and a final surface treatment is added. Alternatively, the removed pavement can be recycled using either cold in-place or hot mix recycling methods.

PORTABLE ASPHALT RECYCLING EQUIPMENT

Pavement materials which have been removed with one of the techniques discussed here can be recycled either on-site or they can be removed and stockpiled for later use or for use in a different location. One of the advantages of stockpiling asphalt pavement is that it can be used year-round by a variety of portable asphalt recycling equipment.

There are several portable asphalt recycling systems on the market. Two examples are the "Porta Patcher" portable pothole patcher and the "BOMAG AR 5" mobile asphalt recycler. These are essentially drum-type mixers equipped with propane burners capable of achieving the 300°F or greater temperatures required for heating and recycling either finely graded pieces or larger chunks of asphalt pavement. These recyclers are drawn behind a truck which also carries the additional equipment and materials necessary for on-site pavement recycling.

Savings of up to \$15.00 per ton have been achieved in some areas using portable recyclers. The City of Maryville, Tennessee (pop. 17,000) reports that it was able to recover the purchase price of a portable recycler in 14 weeks (70 working days) of on-the-street use. Maryville's total cost (capital and labor) for installation of asphalt was \$20.00 per ton using the portable recycler compared with the \$21.50 per ton the City had been paying for asphalt alone. These figures are based on operating data from the first quarter of 1981.

CONCLUSION

This section has presented a brief overview of several alternative technologies involved in hot-mix and cold in-place asphalt pavement recycling, together with commonly used asphalt pavement removal technologies. Asphalt pavement recycling is another of the many solutions to the growing and costly problem of street and road repair. In many cases, asphalt recycling can provide a cost-effective alternative to new asphalt overlays.

Sources which examine the different methods of recycling and provide additional information are listed below. For cost data from actual recycling projects, the Departments of Transportation and local governments in states which have conducted recycling projects should be contacted. Of course, local governments in Tennessee are encouraged to contact MTAS for technical assistance or additional information on pavement recycling.

For Additional Information

The Asphalt Institute
Asphalt Institute Building
College Park, Maryland 20740
(301) 779-4880

Asphalt Recycling and Reclaiming Association
1000 Vermont Avenue, NW
Washington, DC 20005
(202) 628-4634

For Equipment Manufacturers (Portable Recyclers)*

Porta Patcher

Brown Equipment Company
10222 13th Street, Baerfield
P.O. Box 9036
Fort Wayne, IN 46899
(219) 747-2312

BOMAG AR 5

Koehring Compaction and General Equipment Company
400 Wayne Avenue
Dayton, OH 45410
(513) 461-4860

*Only two of several manufacturers are listed here. Interested parties should consult standard equipment manufacturers guides for further information on the names of other manufacturers.

Selected Readings:

Asphalt Recycling and Reclaiming Association, "Recommended Specifications for Surface Recycling", October 1980.

E.R. Brown, "Pavement Recycling", Engineering and Research at WES/US Army Corps of Engineers Information Exchange Bulletin, Vol. 0-80-2, July 1980.

E.D. Crockett, "Cold Recycling-A Viable Alternative", Public Works, February 1980, p. 58.

Roger W. Gose, "Recycling Asphalt Pavement", OSU Extension Facts, D-1207, Center for Local Government Technology, Oklahoma State University.

Gary Holland, "A Discussion of Selected Asphalt Pavement Recycling Alternatives", monograph, CTIP Program, Public Technology, Inc., and cooperative Oklahoma Extension Service, Oklahoma State University, 1980.

Dallas Little, "Cold Recycling: Design and Materials Testing", Rural and Urban Roads, March 1980, p. 44.

John O'Connor, "Plain Facts About Asphalt Recycling", The American City and County, August 1979, p. 35.

Robert Simanski, "Asphalt Recycling Is Here To Stay", The Asphalt Institute, March 1979, p. 35.

"Special Issue-Recycling", Rural and Urban Roads, July 1980.

Gordon Whitney, "America's Recycling Future: ARBA's View", Rural and Urban Roads, March 1980, p. 50.

Ellis Williams, "Asphalt Recycling: A Dollar Stretching Way to Improve Pavement", The Asphalt Institute, May 1978, #MISC-78-2.

In Process

Asphalt Institute, Manual on Asphalt Recycling. As this Report goes to Press, the Asphalt Institute is in the process of developing a manual on asphalt recycling for publication in late 1981. Interested parties should contact the Asphalt Institute for further information and for copies of this manual.

ANNOTATED BIBLIOGRAPHY:
STREET AND ROAD MAINTENANCE

INTRODUCTION

This annotated bibliography on street and road maintenance is divided into four sections: materials of General Interest; and materials on Pavement Cracking; Pothole Repair; and Asphalt Pavement Recycling. In almost every case, the bibliographical entry is followed by a brief description of the contents of the entry.

This is a selected bibliography. No attempt was made, nor within the scope of this effort could it have been made, to identify, catalogue and describe all of the materials which have been published on street and road maintenance in recent years. Instead, representative materials which the authors believe will be of interest and value to local public officials and to professionals in the field of street and road maintenance have been included.

Copies of the materials contained in this bibliography may be obtained from the listed publishers or authors. Please do not contact MTAS for copies of these materials.

GENERAL

Ross Anderson, "Pavement Study Stretches Rehabilitation Budget", Public Works, September 1977, p. 129. Tips on more practical methods of pavement.

The Asphalt Institute, Asphalt in Pavement Maintenance, MS-16, December 1967. Provides information on methods and equipment associated with the use of asphalt maintenance.

The Asphalt Institute, Asphalt Overlays and Pavement Rehabilitation, MS-17, November 1969. Presents economical ways to salvage and strengthen roads with asphalt overlays.

The Asphalt Institute, The Asphalt Paving Manual, MS-8, April 1978. Provides guidance and instruction to those actively engaged in paving.

The Asphalt Institute, A Basic Asphalt Emulsion Manual, MS-19, March 1979. A guide to the use of asphalt emulsions, including their chemistry, storage, handling and correct selection and use.

The Asphalt Institute, Full Depth Asphalt Paving for Municipal Streets. MISC-75-6. Provides examples and design information for full-depth paving (photos and drawings).

- The Asphalt Institute, How to Design Full-Depth Asphalt Pavements for Streets, IS-96. Design information from a variety of road tests and studies (illustrations, drawings).
- The Asphalt Institute, A Pavement Rating System for Low-Volume Asphalt Roads, IS-169. Provides a rating method for maintenance of low traffic roads (numerical values; rating forms photographic illustrations).
- The Asphalt Institute, A Simplified Method for the Design of Asphalt Overlays for Light-to-Medium Traffic Pavements, IS-139. Guidelines for asphalt overlays for deteriorated surfaces on low traffic roads.
- The Asphalt Institute, Surface Treatment Tips, CL-14. Discusses methods, equipment, etc., for asphalt surface treatments, usually less than one inch thick, applicable to almost any kind of roadway surface.
- Stephen Biles, A Training Manual For Setting Street Maintenance Priorities, Texas Innovation Group, Urban Programs Group, Center for Strategic Technology, Texas A & M University, August, 1979. Guidance for road maintenance officials in judging the relative condition of streets and ranking them in their order of priority for maintenance.
- Floyd Burke, Road Maintenance Training Workshop, Kentucky Department for Local Government, September 1977. A training package designed to instruct proper road maintenance procedure.
- "Determining Thickness of Asphalt Overlays", APWA Reporter, April 1977, p. 12. The article outlines the overlay procedure for small community or rural roads with less than 100 heavy trucks per day.
- Georgia Institute of Technology, A Manual on Implementation of a Maintenance Management System for Streets and Roads in Small to Medium Sized Local Governments, April 1976. The manual outlines a step-by-step procedure for implementing a maintenance management system in small-to-medium-sized local governments.
- R.G. Hicks, Field Maintenance Manual for Georgia Counties Local Roads and Streets, Georgia Institute of Technology, 1979. The manual is designed to give assistance to Georgia counties to identify road failures and determine the best method of repair.
- ICMA, The Pavement Maintenance and Improvement Program, Management Information Service, #261, October 1965. Presents a method which city officials can use to determine street failures and develop a program of maintenance and improvement on a priority basis.
- Roger E. Kempel, "Economics of Timely Street Maintenance," APWA Reporter, January 1981, p. 14.

W.B. Ledbetter, "Incinerated Trash Tested As Asphaltic Base Aggregate", Rural and Urban Roads, March 1979, p. 53. Houston has undertaken an experimental project of using incinerated trash to replace aggregate in bituminous mixture.

Thomas J. McLean, "Asphalt Paving Materials", OSU Extension Facts, College of Engineering, Oklahoma State University, 1975. A discussion of the components of asphalt and how it is best mixed to meet special road problems.

Proceedings of the National Road and Street Maintenance Conference, Center for Local Government Technology, Oklahoma State University, April 1980. Contains presentations by several noted specialists in various areas of road and street maintenance at a 1980 Conference. (Many of the papers presented at this Conference are listed under "Selected Readings" for the alternative maintenance technologies presented earlier in this Report.)

"Rehabilitating Streets", APWA Reporter, April 1978, p. 12. Elkhart County's success with the Central Chemical Claveda Process plus SA-1, an accelerated reduction-oxidation process chemical.

Ralph Speer, "New Technologies For Maintaining Streets", APWA Reporter, August 1976, p. 15. A synopsis of Norman, Oklahoma's street maintenance plan which provides a high level of service in an economical manner.

Tennessee Municipal League, Asphalt Pricing: Summary of Survey Data, May 1979. A summary of asphalt prices in Tennessee in the Spring of 1979.

U.S. Department of Transportation, A Users Manual for a Management Control System for Street Maintenance, November 1977. The results of a study of the problems associated with managing street maintenance functions in small municipalities.

POTHOLE REPAIR

American Association of State Highway and Transportation Officials, "Potholes: A Simple Problem With Few Simple Solutions", Maintenance Aid Digest, Washington, D.C., July 1978. Publication of AASHTO's limited survey to determine the degree of usage of new products, associated costs and obtained success.

George Asbury, "Mystery Cold Patch Works, But Specs Are Hard to Develop", Rural and Urban Roads, February 1978, p. 46. A new cold patch mix is being used in Kentucky which provides fast and satisfactory patches on heavy traffic roads.

The Asphalt Institute, Full Depth Asphalt Patching, CL-19. Discusses the "full-depth" asphalt patch and its uses to repair localized pavement distress extending well below the roadway surface.

The Asphalt Institute, Asphalt Cold-Mix Manual, MS-14. Manual for use in design, control, etc., of asphalt cold-mix construction (photos, illustrations).

Center for Local Government Technology, A Users Manual for a Management Control System For Street Maintenance, Oklahoma State University, September 1978. A manual for scheduling street maintenance and measuring the results of maintenance.

Charles A. Connell, "Maritime Province Solves Winter Patching Problem", Public Works, August 1979, p. 63. New Brunswick DOT district uses portable asphalt mixer to provide hot mix when commercial plants are closed.

Colorado Department of Highways, Experience with a Mechanized Pavement Patching Machine In Colorado, December 1979. An evaluation of a mechanized pavement patching machine for use in repairing roadway potholes and other localized failures.

Colorado Innovation Center Newsletter, "Road Patching Materials Evaluation", September 1979. A discussion with conclusions of road patching material tests.

William S. Foster, "How To Make Asphalt Streets Last Longer", The American City, March 1974, p. 43. The article addresses the causes of street deterioration how to classify failures and recommends repair procedures for cracks and potholes.

Bill Johnson, "Expediting Asphalt Patching", Public Works, September 1979, p. 83. Unconventional use of a catchbasin cleaner puts machine into pothole patching trains.

- Victor A. Krouse, Sr., "Economics of Pothole Patching," APWA Reporter, January 1981, p. 18.
- Thomas J. McLean, "Asphalt Paving Maintenance I-Patching", OSU Extension Facts, College of Engineering, Oklahoma State University. A general introduction to maintenance procedures and specific information on patching.
- L.A. Maciula, "Patching Potholes", Asphalt in Pavement Maintenance, Manual No. 16 (MS-16), The Asphalt Institute. Illustrates an effective method of pothole repair.
- Louis O'Brien, "Value Engineering In Pothole Patching", Rural and Urban Roads, February 1978, p. 46. A new cold patch mix is being used in Kentucky which provides fast and satisfactory patches on heavy traffic roads.
- "Potholes: New Materials and Techniques for Effective Road Repair", Public Technology Newsletter, June 1978. A summary of pothole repair materials tested by local governments and Public Technology Incorporated.
- "Pothole Patching: A Better Way", Public Works, September 1977, p. 129. Tips on more practical methods of pothole repair.
- "Preventive Maintenance Beats Pothole Patching", American City and County, September 1970, p. 111. A good preventive maintenance program keeps equipment operating efficiently.
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