U.S. Department
of Transportation
**Federal Highway
Administration**

PAVEMENT MAINTENANCE EFFECTIVENESS

INNOVATIVE MATERIALS WORKSHOP

Instructors' Guide

Office of Engineering and
Office of Technology Applications
400 Seventh Street, SW.
Washington, D.C. 20590

NOTICE

Workshop Schedule

SESSION	TITLE	TIME
1	PAVEMENT MAINTENANCE EFFECTIVENESS	8:00 - 8:30
2	CURRENT RESEARCH TRENDS	8:30 - 9:00
	BREAK	9:00 - 9:15
3	PCC JOINT RESEALING	9:15 - 10:45
4	PCC PARTIAL-DEPTH SPALL REPAIR	10:45 -12:30
	LUNCH	12:30 - 1:15
5	AC CRACK TREATMENT	1:15 - 2:45
	BREAK	2:45 - 3:00
6	AC POTHOLE REPAIR	3:00 - 4:30
	DISCUSSION AND CLOSURE	4:30 - 5:00

Preface

This instructor's guide is developed to facilitate a slide presentation on the state of the practice for AC pothole repair and crack treatment operations and PCC partial-depth spall repair and joint-resealing operations. This guide is based primarily on information gathered and evaluated under the Strategic Highway Research Program (SHRP) project H-106 and its successor project, FHWA *Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites*. The target audience for this presentation includes state highway maintenance engineers, managers, and district or area supervisors and foremen.

The Guide is organized into six sessions. The first session provides an introduction to pavement maintenance effectiveness, and the second session presents some of the recent or current research on pavement maintenance. Sessions 3 through 6 are "how to..." sessions that pertain to AC pothole repair and crack treatment operations and PCC spall repair and joint resealing operations.

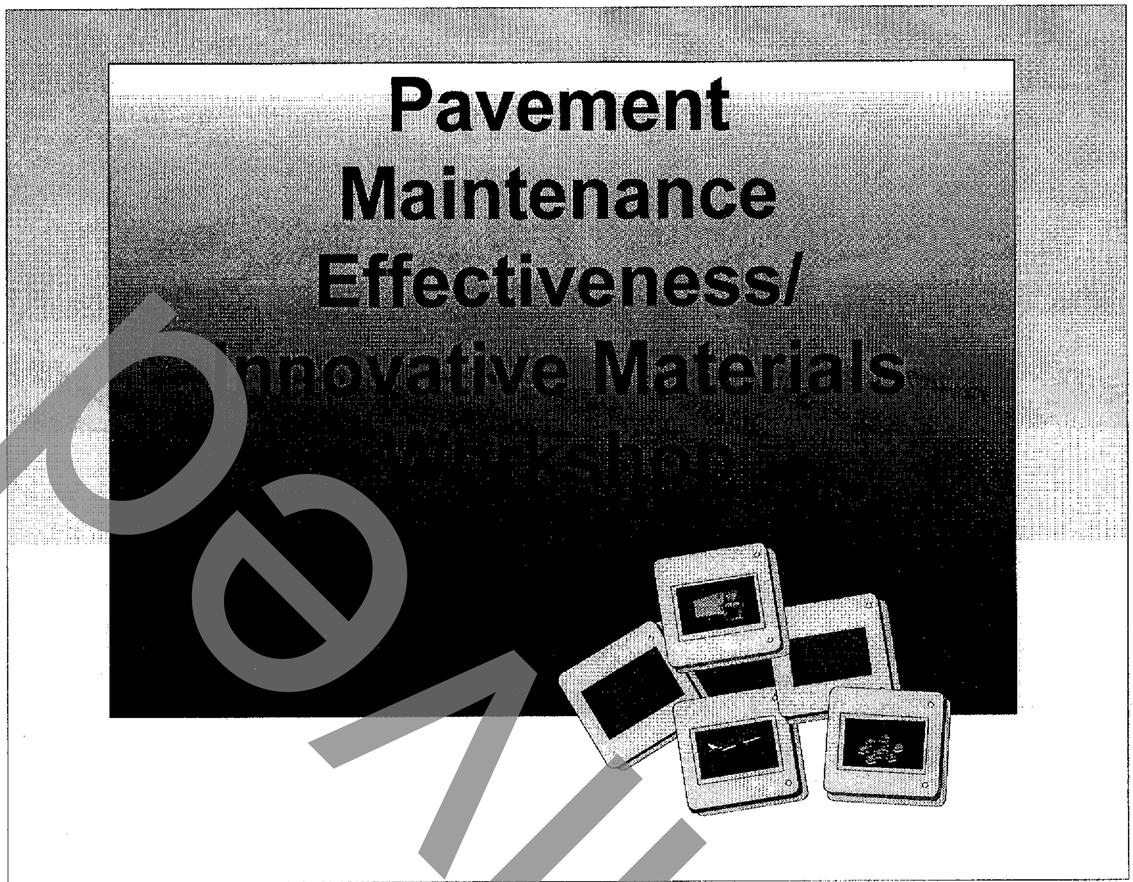
This guide is set up in a traditional script format—with visuals given on the top of a page and the corresponding text listed at the bottom of the page. The text is specifically designed to be a resource to the instructor and attendees.

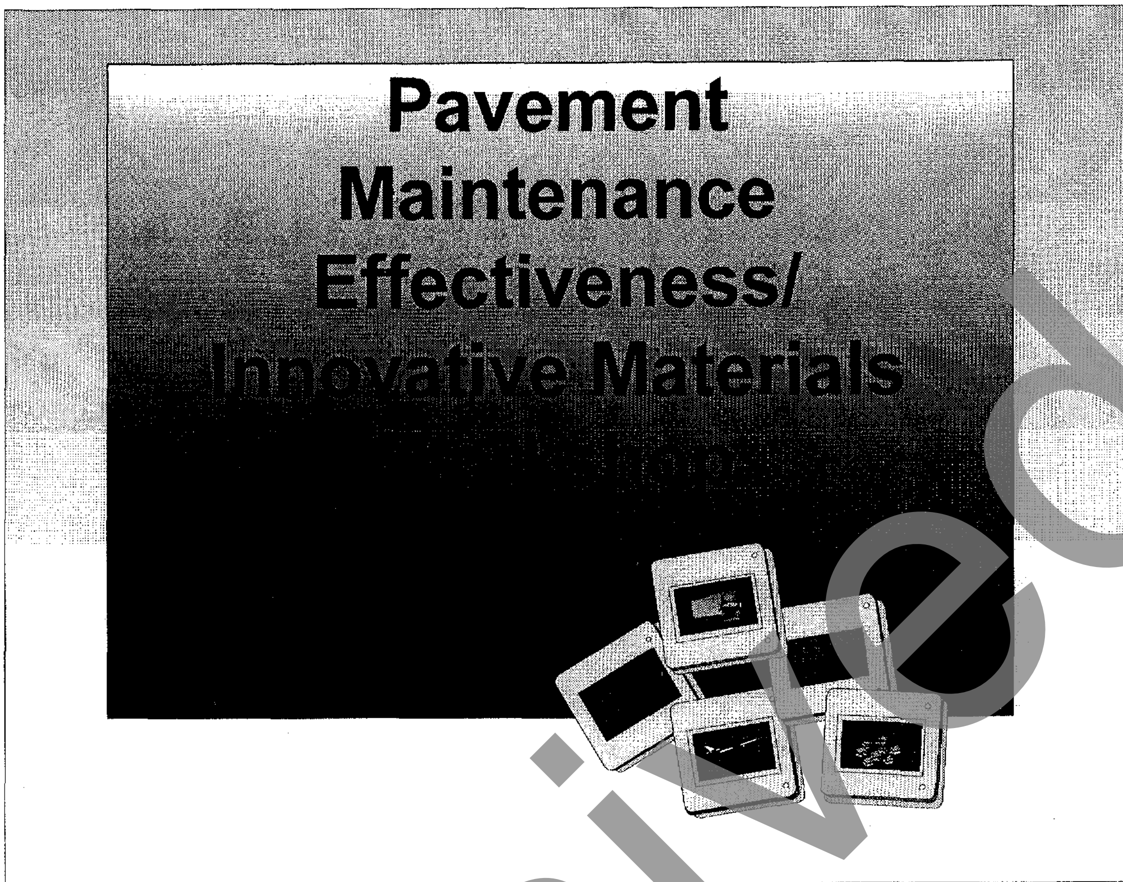
Along with this guide and the slides, the presenter will need the following equipment and materials to complete the presentation:

- Slide Projector.
- Screen.
- Carousel.
- Extension cord (check facilities to see if necessary).
- Sign-in sheet.
- Handouts.

The instructor must handle any preliminary "housekeeping" chores, such as handing out the schedule and instructor's biodata, distributing the necessary handouts, including sign-off sheet, and determining audience interest. The instructor should also briefly introduce himself or herself, and should have the class participants introduce themselves. Ask each participant to give their name, employer, and job responsibilities. Any background information on the participants will also help instructors structure their presentations so that they will be well received.

Table of Contents

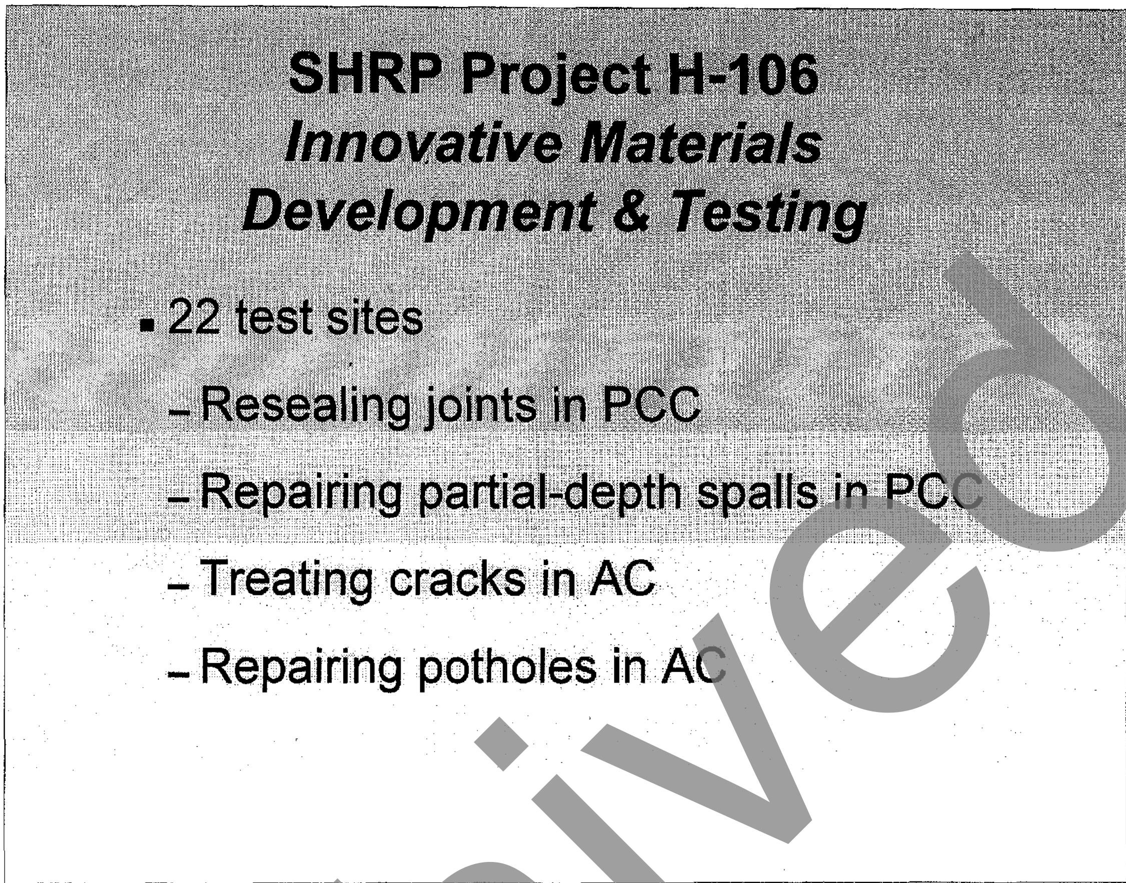

Pavement
Maintenance
Effectiveness/
Innovative Materials
Workshop



Pavement Maintenance Effectiveness/Innovative Materials Workshop
Slide #1

Welcome to the FHWA Workshop on Pavement Maintenance Effectiveness and Innovative Maintenance Materials. I'm Russell Romine, the Principal Instructor for the course. Currently, I'm a Principal Investigator with ERES Consultants, Inc. of Champaign, IL. I've been with ERES since 1990, whence I've been primarily responsible for overseeing the SHRP H-106 experimental maintenance project, which serves as the basis for this course. Prior to joining ERES, I spent 35 years with the Kentucky DOH in varying capacities, the last 11 years of which I served as the Assistant State Highway Operations Engineer. My Co-instructor is Mr. Marshall Stivers. Marshall is also part of the ERES team, having joined the company in early 1995. Before coming to ERES, Marshall had a 36-yr career with the Florida DOT. His last 7 years he served as the State Maintenance Engineer.

This workshop is designed to acquaint highway maintenance workers, supervisors, and engineers with state of the art technologies for performing pavement surface maintenance. It is hoped that this workshop will generate an increased awareness of the need for, and benefits of, effective and timely maintenance.



SHRP Project H-106
Slide #2

The development of this workshop is a direct outgrowth of the research and experimentation conducted under SHRP project H-106 (*Innovative Materials Development and Testing*). That project involved the installation and performance monitoring of 22 test sites covering four of the more common pavement surface maintenance activities:

- PCC joint resealing.
- PCC partial-depth spall repair.
- AC crack treatment, and
- AC pothole repair.

The sites were installed throughout the U.S. and Canada between March 1991 and February 1992. Performance monitoring of the sites began shortly after installation and continued through March 1993, when the SHRP program was terminated.

Page 1-6

FHWA *Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites*

- Resumed monitoring in October 1993
- Annual field inspections
  - AC crack treatment
  - PCC joint resealing
  - PCC partial-depth spall repair
- Semi-annual field inspections
  - AC pothole repair

FHWA *Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites*
Slide #3

Monitoring resumed shortly thereafter under the FHWA project *Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites.*

Under this project, annual inspections are scheduled through 1997 for all intact joint reseal, crack treatment, and spall repair sites, and semi-annual inspections are scheduled for all intact pothole repair sites through 1995.

A final report on the findings and recommendations of each experiment is planned, and interim data analysis reports are being prepared annually, which present the latest performance observations and data analysis findings.

Page 1-6

Workshop Objectives

- Preventive and "Do It Right" maintenance
- Cost-effective technologies

Workshop Objectives
Slide #4

The objectives of this workshop are simple and straightforward.

The first objective is to relate the important concepts of preventive and "Do It Right" maintenance. Too often, maintenance is given inadequate consideration, both in terms of planning for it and actually doing it.

The second objective is to inform and instruct you of the most successful and cost-effective technologies in the maintenance areas of pothole and spall repair, crack treatment, and joint resealing. A large investment was made in the SHRP H-106 project and the information and lessons learned from it were specifically intended to be transferred on to you in the maintenance community.

Workshop Overview

- Session 1 — Pavement Maintenance Effectiveness
- Session 2 — Current Research Trends in Pavement Maintenance
- Session 3 — PCC Joint Resealing
- Session 4 — PCC Partial-Depth Spall Repair
- Session 5 — AC Crack Treatment
- Session 6 — AC Pothole Repair
- General Discussion

Workshop Overview
Slide #5

The complete workshop is composed of six sessions. These sessions include:

- An introductory session on the importance of pavement maintenance, entitled *Pavement Maintenance Effectiveness.*
- The 2nd session, *Current Research Trends*, which discusses some of the recent or current research on pavement maintenance, followed by
- Sessions 3 through 6, which are "how to..." sessions on each of the four types of maintenance studied under SHRP H-106.

This particular workshop has been customized to include sessions _________, as these were the sessions requested by your agency. The schedule that we'll try to adhere to is given at the front of your participant's workbook.

SHRP H-106
Manuals of Practice

References 18, 35, 36 & 39

SHRP H-106 *Manuals of Practice*
Slide #6

Two *Manuals of Practice* were developed under SHRP H-106 and are being made available in this workshop. The first manual, *Asphalt Pavement Repair*, covers materials and procedures for repairing potholes and treating cracks in asphalt pavement. The second manual, *Concrete Pavement Repair*, covers materials and procedures for repairing spalls and resealing joints in concrete pavement. These manuals will be distributed at the end of the workshop to those of you who are interested.

Test and Evaluation Work Plans

- Guides for State agencies interested in evaluating maintenance materials and techniques
- FHWA assistance in planning, conducting, and reporting on field evaluations
- Technical Assistance Application

Test and Evaluation Work Plans
Slide #7
In conjunction with this and other maintenance workshops, the FHWA is sponsoring a technical assistance program for States interested in doing their own field studies of maintenance materials and techniques. Test and Evaluation Work Plans have been developed that serve as guides for planning, conducting, and reporting on field evaluations of selected repairs/treatments. A Work Plan is available for each of the four maintenance activities covered in this workshop. The Work Plans are accompanied by a Technical Assistance Application that can be completed by interested agencies and submitted to the FHWA for consideration. Selection of the States to be given technical assistance will be done once all requests have been received and fully reviewed.

One particular product expected to be evaluated by a State or States is the Iowa DOT's IA-VAC joint seal testing device, which is used to test for failures in concrete joint seals. Several of these devices have been assembled and will be made available to interested States who participate in the Test and Evaluation projects. Further details of the IA-VAC system will be discussed in sessions 2 and 3.

Technical Assistance Application

- Specify type of evaluation desired
- Complete "Agency Request" form
- Complete "Proposed Test Site Information" form
- Submit to FHWA Division Office

Technical Assistance Application
Slide #8

The Technical Assistance Application is fairly easy to fill-out. The interested agency specifies the type of maintenance operation they are interested in studying, with the options being AC pothole repair, AC crack sealing and filling, PCC transverse joint resealing, and PCC partial-depth spall repair.

An "Agency Request" form corresponding to the specified maintenance activity is then completed. This form includes the materials and procedures proposed for evaluation by the interested agency, along with information regarding materials and procedures currently used by the agency. It also is used to indicate the availability of equipment and crews to do the evaluation.

A "Proposed Test Site Information" form is also filled out that details the highway facility on which the evaluation is proposed to be carried out. Information such as pavement location, length, cross-section, current condition, and traffic are asked for in this form.

The completed application forms are then submitted to the FHWA Division Office that represents the interested agency. All requests filed through the division offices will then be forwarded to the headquarters office in Washington, D.C., where selections for technical assistance will be made.

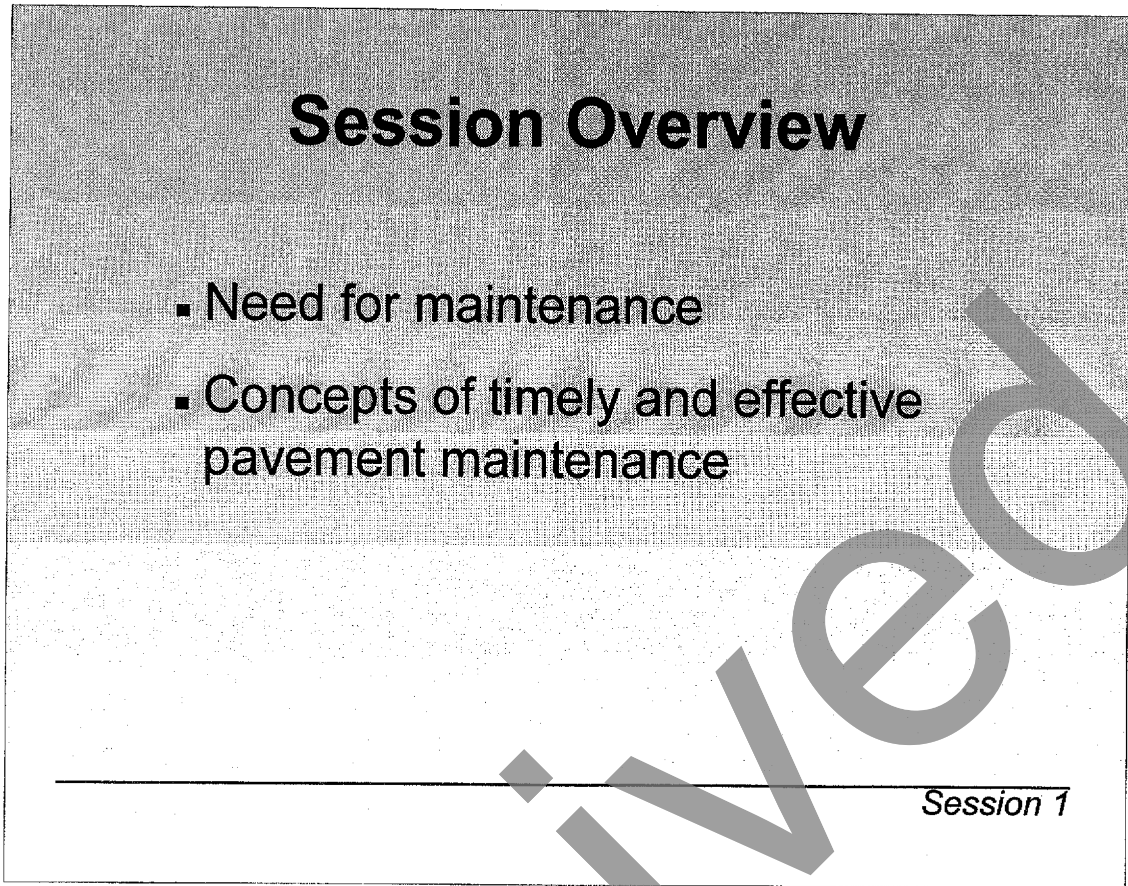

SESSION 1
Pavement Maintenance Effectiveness
Pavement Maintenance Effectiveness/
Innovative Materials Workshop

Pavement Maintenance Effectiveness
Slide #9

Let's go ahead and jump into session 1, *Pavement Maintenance Effectiveness*.

This session is targeted to those of you responsible for making major decisions that affect pavement maintenance performance. Those of you involved in more hands-on maintenance can also benefit by developing a better understanding of the rationale behind the decisions that are passed on to you.

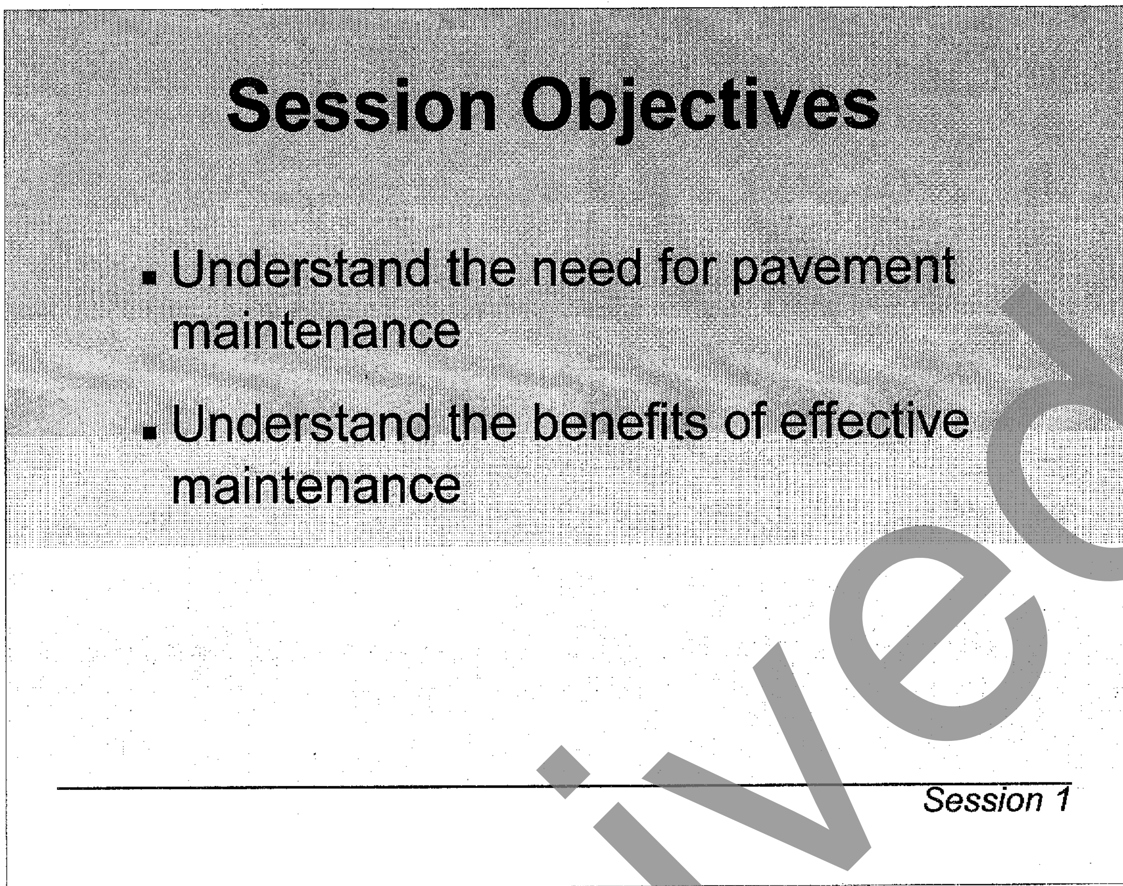
Page 1-1



Session Overview
Slide #10

In this session, we'll discuss the need for pavement maintenance and the concepts of timely and effective maintenance.

Page 1-1



Session Objectives
Slide #11

At the conclusion of this session, you, the participant, should:

- Better understand the need for pavement maintenance, and
- Better understand the benefits of an effective pavement maintenance program.

Now, most people would agree that proper and timely maintenance carried out on any product that deteriorates, will increase the useful life of that product. This is generally the view that highway maintenance officials take with respect to pavements, as most strongly support pavement maintenance as a cost-effective measure.

The actions of many highway agencies seem to contradict this belief, however, as the level of quality of maintenance that is performed on our roads does not always reflect the importance of pavement maintenance.

Page 1-1

Throw-and-Go
Slide #12

Take pothole patching for example. A widely used means of repairing potholes is the throw-and-go procedure, where the patching material is tossed in the hole and left to traffic to compact.

This practice continues, despite the fact that even practitioners of this repair method acknowledge that the patch may not last for more than a few hours.

Page 1-1

Severely Cracked Pavement

Severely Cracked Pavement
Slide #13

Another common practice is to not consider maintenance until the pavement's condition is too deteriorated to benefit from the action. Severely cracked pavements like this one would likely not benefit from crack sealing or filling---it's beyond the point that treatment would be cost-effective.

Page 1-2

"Do It Right"

The Right Procedure

- Higher initial costs, but results in lower life-cycle costs
- Applied in a timely manner, improves pavement performance and safety

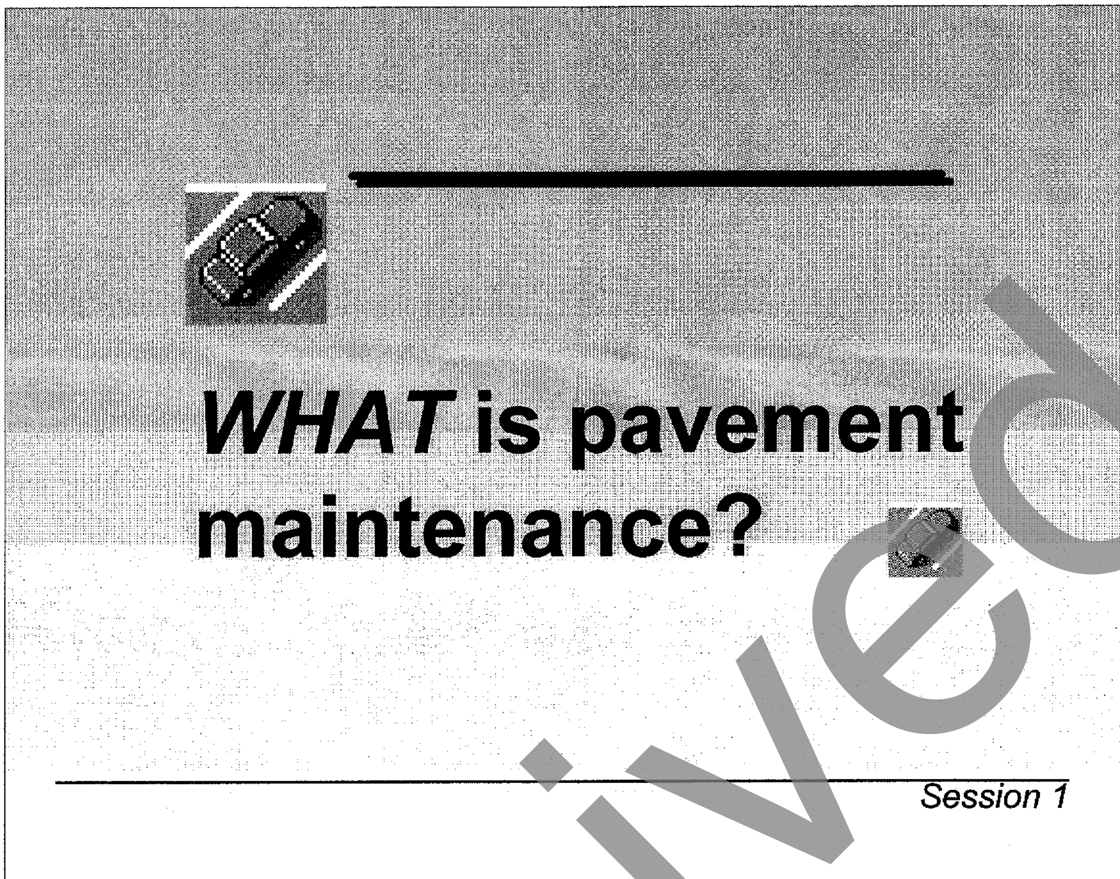
Session 1

"Do It Right"
Slide #14

As you can see here, the right procedure:

- May have higher initial costs, but with much better performance, results in lower life-cycle costs.
- Applied in a timely manner, improves both pavement performance and safety.
- In addition, it often takes only marginally more time than other, less appropriate methods.

Page 1-2



What is Pavement Maintenance?
Slide #15

So, what is pavement maintenance? How is it currently defined or classified?

The current philosophy breaks maintenance out into two categories: routine maintenance and preventive maintenance.

Page 1-3

Routine Maintenance

a program strategy in which minor distresses in a pavement are repaired as they develop

Examples: pothole repair and spall repair

Session 1

Routine Maintenance
Slide #16

Routine maintenance, as you can see, is defined as a program strategy in which minor distresses in a pavement are repaired as they develop.

The repairs are generally made with the intent for them to last as long as possible. However, temporary repairs are occasionally made until more permanent repairs can be produced.

Routine maintenance includes activities such as pothole patching and partial-depth spall repair.

Page 1-3

Preventive Maintenance:

a program strategy intended to arrest light deterioration, retard progressive failures and reduce the need for routine maintenance and service activities

Examples: crack sealing, joint resealing, and surface treatment

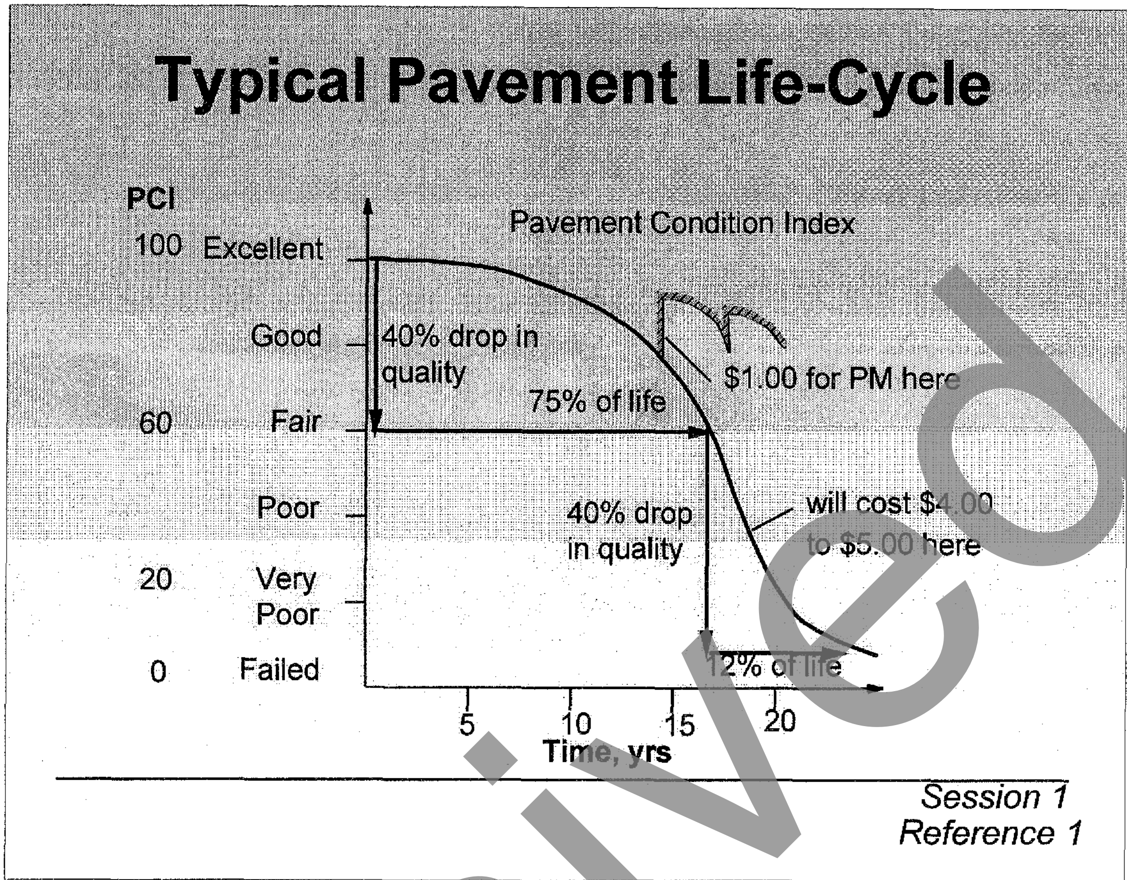
Session 1

Preventive Maintenance
Slide #17

Preventive maintenance, on the other hand, is a program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for routine maintenance activities.

Examples of this type of maintenance include crack sealing, joint resealing, and surface treatments.

Page 1-3



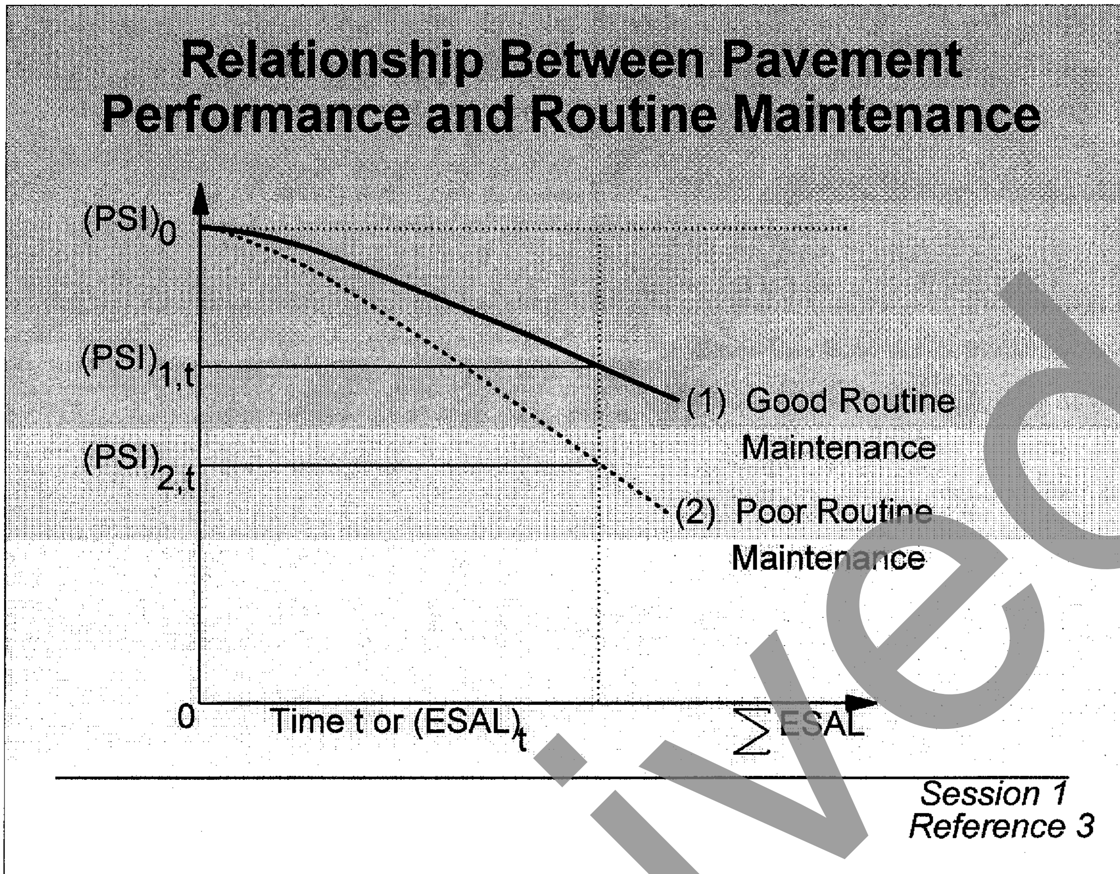
Typical Pavement Life Cycle
Slide #18

Although routine maintenance is more reactive than preventive maintenance, often no distinction between the two is made.

Routine maintenance should be thought of as those activities that allow an agency to obtain the performance originally designed for a pavement. This would be the yellow curve shown in this graph.

Preventive maintenance are those activities that are capable of extending the original design life of the pavement, as illustrated by the green curves in the upper right-hand side.

Page 1-4 Figure 1-1



Relationship Between Pavement Performance & Routine Maintenance
Slide #19

The consequence of effective maintenance can be seen in this figure. The lower curve represents the loss in serviceability with traffic as a result of poor or <u>ineffective</u> routine maintenance. The upper curve represents the loss in serviceability with traffic as a result of <u>effective</u> routine maintenance.

The difference in serviceability at some time, t, is the result of "doing it right" versus "not doing it right." Obviously, by doing it right, a higher serviceability level can be maintained.

Page 1-4 Figure 1-2

Well-Maintained Pavements

- Reduced distress
- Maximized effective service life
- Increased safety
- Protected pavement investment

Session 1

Well-Maintained Pavements
Slide #20

Can anyone tell me why we perform pavement maintenance? Why don't we just let the road take its natural course of deterioration?

The answers to these questions are simple. First, if no maintenance were performed, major rehabilitation would be required much sooner and, quite likely, at a higher serviceability level. At least one study (NCHRP 353) has shown that the pavement damage caused by a dynamic load on a low serviceability pavement is about 50 percent greater than the damage caused by the same dynamic load on a high serviceability pavement. Thus, by keeping serviceability at a fairly high level, the damage potential of vehicle loads are minimized.

The main reason that maintenance must be performed is that it is much more cost-effective than rehabilitation. A large amount of money is invested in the original pavement, and to have a small crew make some intermittent repairs over the length of a highway section is fractional in cost compared to a contractor deploying several crews and much more expensive equipment for the purpose of restoration, resurfacing, or reconstruction.

Page 1-5

Quality Maintenance

Careful Planning

Proper Installation

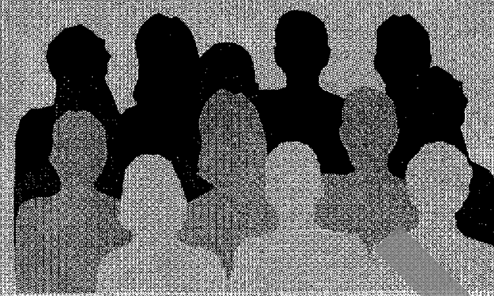
Session 1

Quality Maintenance
Slide #21

In summary, quality maintenance consists of careful planning followed by proper installation. Serious consideration must be given to the availability, costs, and documented performance of materials, equipment, and methods in order to determine the most cost-effective approach. And, once the plan is put into action, "do it right" construction practices must be fully employed.

One aspect of planning that was not previously mentioned is the use of contract maintenance. Occasionally, a backlog of other projects or inadequate in-house resources may warrant consideration of private contractors to perform the desired work. Here, the estimated timelines of both in-house and contracted maintenance must be compared with the "optimal" time, and the overall costs of contracting out must be weighed against the anticipated performance of a contractor's repair/treatment operation.

Savings for Everyone

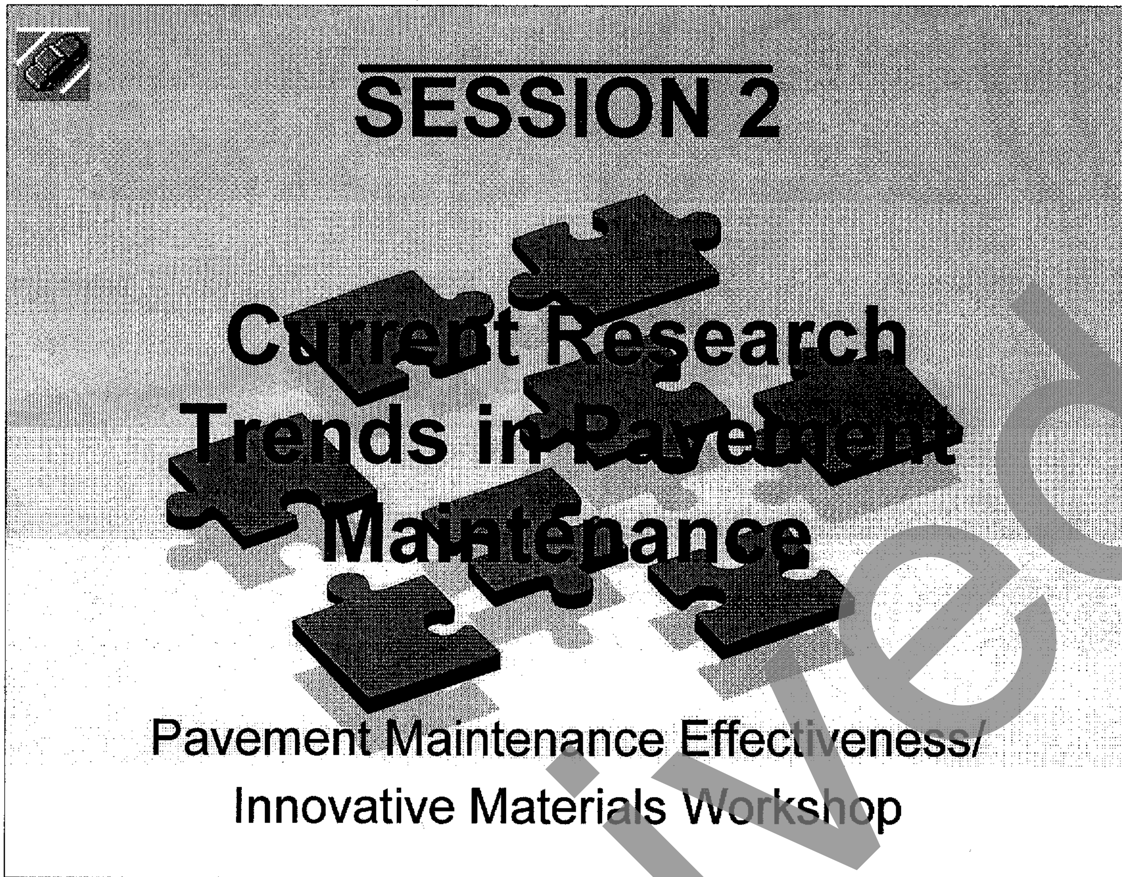


- Less cost for taxpayers
- Less delay and discomfort for drivers
- Safety benefits

Session 1

Savings for Everyone
Slide #22

The result of quality maintenance is usually savings for everyone. Taxpayers will spend less in the long-run for repairs and treatments, as they will last longer and slow pavement deterioration. Less pavement deterioration and fewer road closures will result in reduced delay, discomfort, and accident potential for drivers. And, fewer road closures will mean less exposure to traffic for maintenance workers and contracting crews.


SESSION 2
Current Research Trends in Pavement Maintenance
Pavement Maintenance Effectiveness/ Innovative Materials Workshop

Current Research Trends in Pavement Maintenance
Slide #1

Session 2 of this Pavement Maintenance Workshop is titled *Current Research Trends in Pavement Maintenance* and it provides an overview of the current state of research projects in the maintenance area. These research areas include development of new technologies for determining when preventive maintenance should be performed, new equipment for performing various maintenance activities, and new ways of assessing the performance of various maintenance treatments and their effect on the traveling public.

It is hoped that this session will bring an increased awareness to the benefits of planned, preventive maintenance strategies as opposed to the reactive maintenance strategies currently being employed by many agencies.

Page 2-1

Session Overview

- Introduction
- Maintenance effects on service life
- Timing of maintenance
- New technologies
- Maintenance and the public

Session 2

Session Overview
Slide #2

In this session, we'll introduce you to various maintenance research efforts that help make the case for preventive and effective maintenance.

We'll also discuss some of the emerging technologies for performing various maintenance treatments.

Lastly, we'll present some case studies conducted by various highway agencies that focus on the effectiveness of their maintenance strategies.

Page 2-1

Session Objectives

Become familiar with:

- Recent studies examining the effectiveness of pavement maintenance
- Newest technologies in pavement maintenance
- Effect of preventive maintenance on the traveling public

Session 2

Session Objectives
Slide #3

At the conclusion of this session, you all should become familiar with:

- The current state of research in pavement maintenance.
- The latest technologies for pavement maintenance activities, and
- The effects that pavement maintenance has on the public's perception of pavement performance.

Page 2-1

Introduction

- All pavements require some degree of maintenance
- Maintenance costs and benefits should be included in life-cycle pavement costs
- Routine and preventive maintenance activities have an impact on pavement service life

Session 2

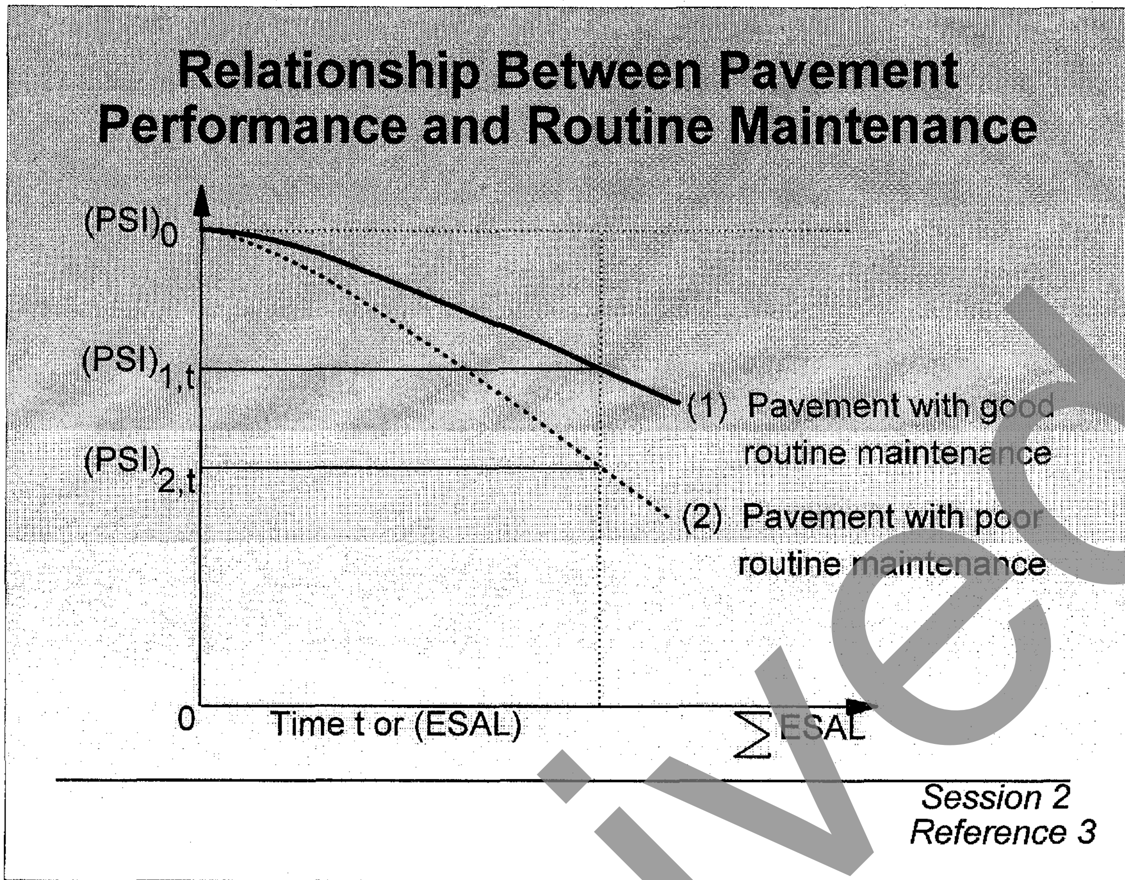
Introduction
Slide #4

Regardless of their design, traffic levels, or climatic region, all pavements will require maintenance at some point in their service life. In many instances, the effect of future maintenance costs in determining the most cost-effective pavement design is not considered.

The choice of maintenance strategies during a pavement's service life impacts the overall life-cycle cost of a particular pavement section. The timing of those maintenance treatments also impacts life-cycle cost. All of these items should be considered when determining what maintenance strategies an agency will adopt.

Question: How does Maintenance in your agency feedback to Design/Construction?

Page 2-2



Relationship Between Pavement Performance and Routine Maintenance
Slide #5

This slide shows the effect of proper routine maintenance on pavement performance. The upper curve shows a section that has received proper routine maintenance throughout its life, whereas the lower curve represents a section that has not. The increase in expected service life for good routine maintenance should be considered when weighing different maintenance alternatives.

As this slide shows, real benefits from pavement maintenance are possible, and should be the goal of all maintenance agencies.

Page 2-3   Figure 2-1

Long-Term Pavement Performance (LTPP) Program

Special Pavement Studies (SPS)

SPS-3 (AC Pavements)

- Slurry seals
- Chip seals
- Thin overlays
- Crack sealing
- Do nothing

SPS-4 (PCC Pavements)

- Joint sealing
- Crack sealing
- Undersealing
- Do nothing

Session 2

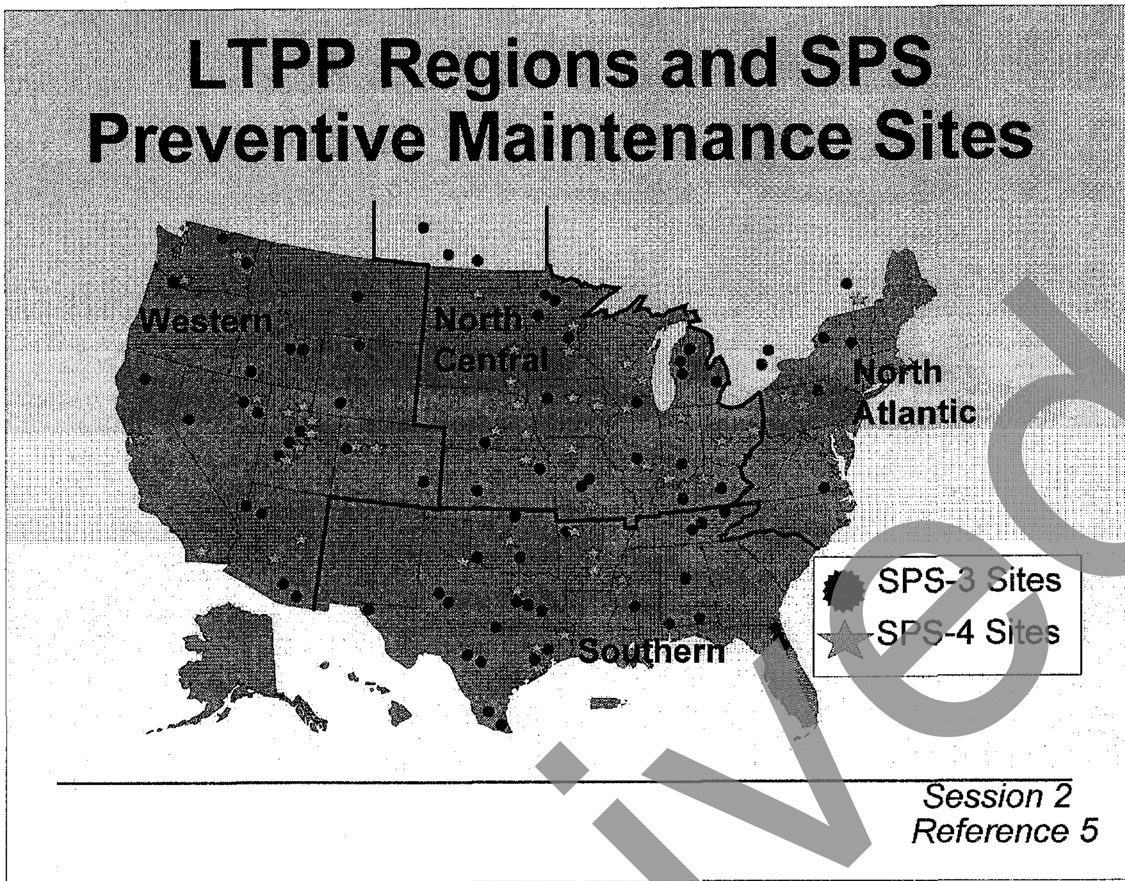
LTPP Special Pavement Studies (SPS)
Slide #6

The Long-Term Pavement Performance (LTPP) program is currently investigating the effectiveness of several different maintenance activities for AC and PCC pavements.

The Special Pavement Studies (SPS)-3 and SPS-4 sites consist of sections of various maintenance treatments and control sections where no treatments were applied. This arrangement allows for comparison of different treatments applied at different times to each other and to a section of pavement where no treatments were applied.

Test sites are being monitored to determine the impact of different maintenance strategies, the timing of maintenance treatments, and the effect of different climatic and traffic conditions on maintenance effectiveness.

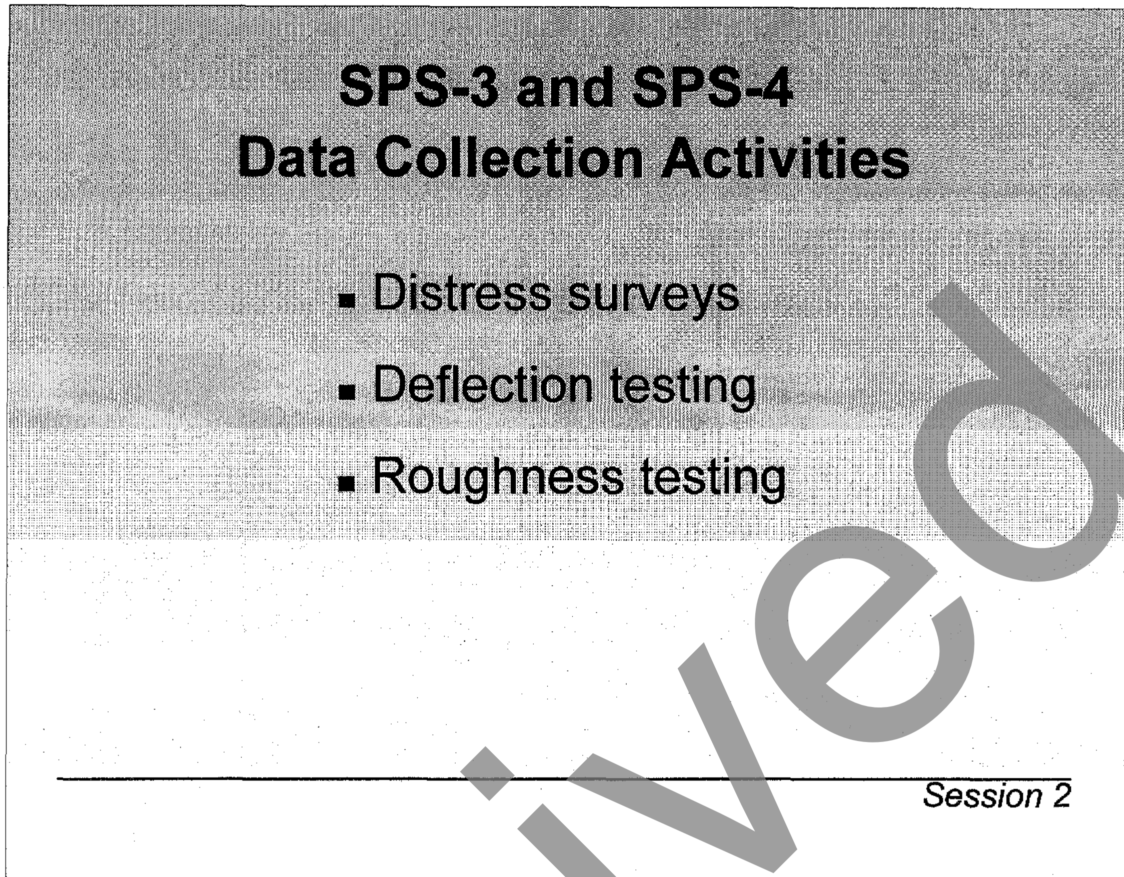
Page 2-3



LTPP Regions and SPS Preventive Maintenance Sites
Slide #7

This map shows the four LTPP regions and the locations of SPS-3 and SPS-4 sites in each region. Currently, there are about 75 SPS-3 sites, containing 553 test sections, and about 50 SPS-4 sites, containing 241 test sections, that are being monitored for performance under the LTPP study.

Map extracted from Reference 3 and updated with SPS-4 joint seal sites.

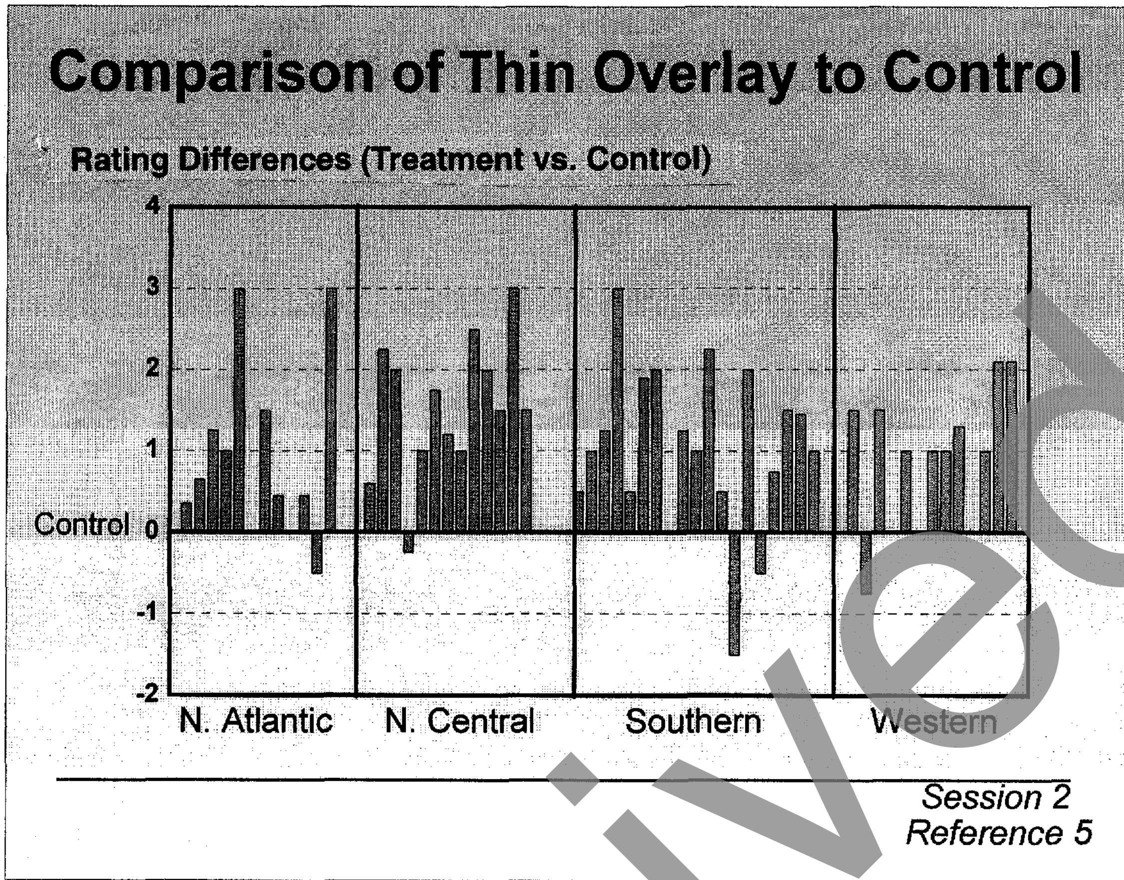


SPS-3 and SPS-4 Data Collection Activities
Slide #8

The primary data collection efforts being performed for the LTPP SPS-3 and SPS-4 sites include distress surveys, deflection testing, and profile testing. This performance data is analyzed to determine which of the test sections is performing the best. The predominant level of comparison to date has been the Pavement Serviceability Index (PSI) of the experimental sections versus the control sections.

There is currently an FHWA contract that will perform a new round of distress surveys this summer, incorporate additional deflection and profile data, and generate a report on the performance of these test sections. The final report should be completed sometime during the summer of 1996.

Page 2-4

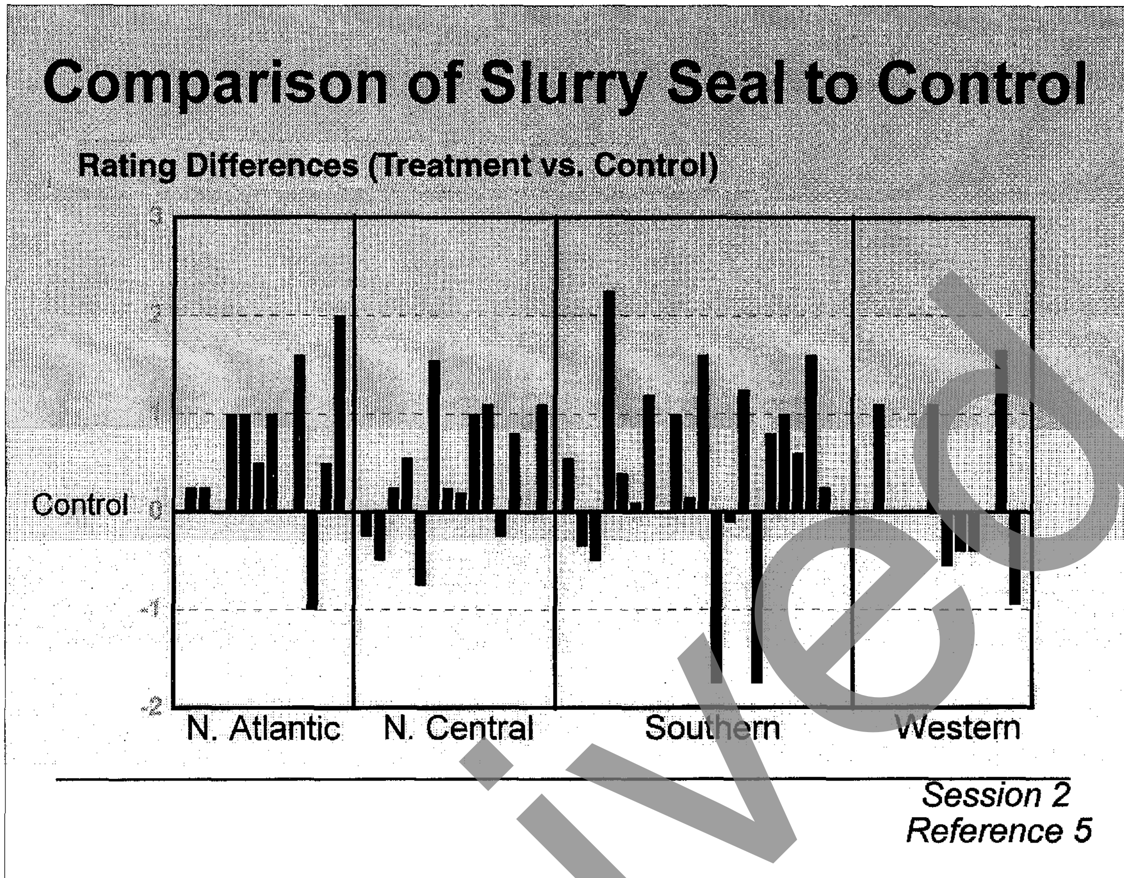


Comparison of Thin Overlay to Control
Slide #9

This slide shows the performance comparisons of SPS-3 thin overlay and corresponding control (do-nothing) sections. Each bar represents the mathematical difference in terms of serviceability points between the thin overlay section and the corresponding control section. Bars greater than zero reflect thin overlays showing better performance than the control. Bars less than zero reflect thin overlays showing worse performance than the control.

As this graph shows, the thin overlays are showing predominantly better pavement performance in all regions. In a few instances, however, the thin overlay sections are performing worse than the control. These observations are primarily the result of treatments placed on unsuitable pavements (i.e., severely aged and/or extensively cracked), and they often appear in the comparisons of the other SPS-3 treatments, as we'll see in the next three slides.

Page 2-5 Figure 2-2

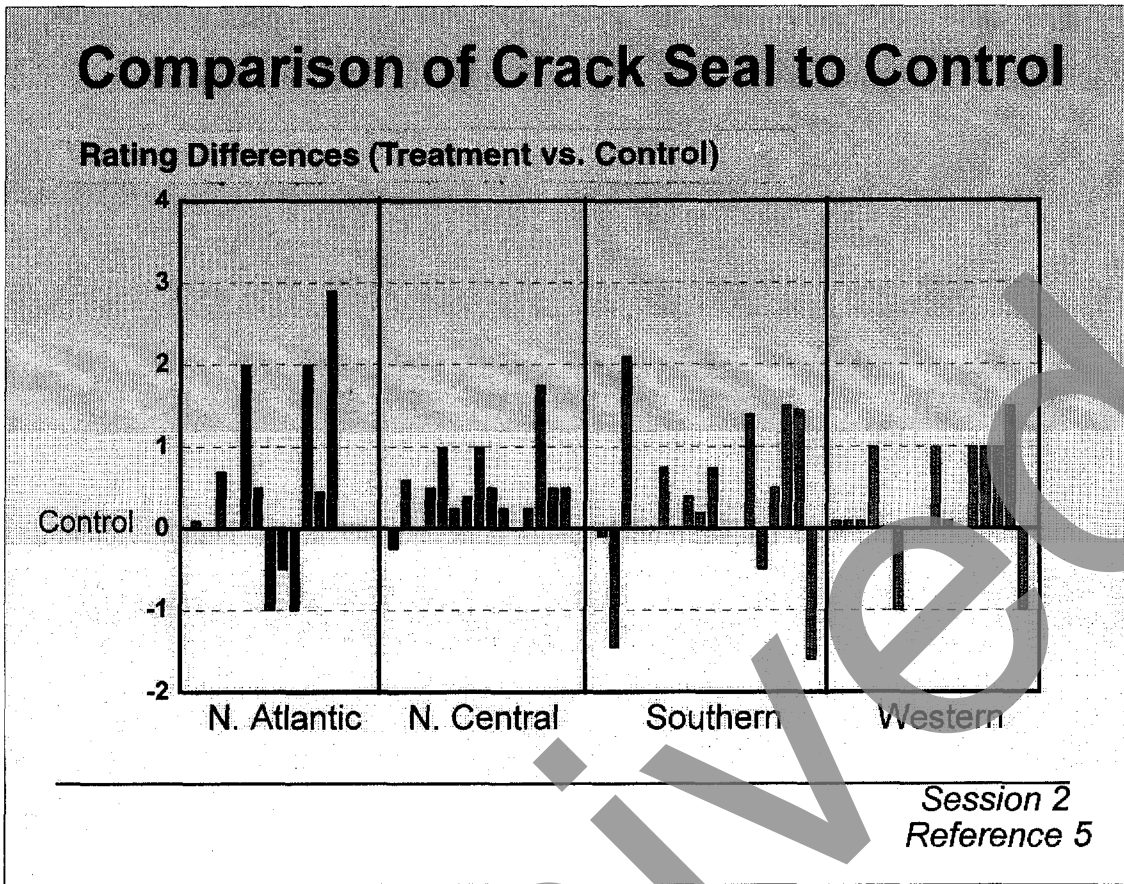


Comparison of Slurry Seal to Control
Slide #10

This slide shows the performance comparisons of SPS-3 slurry seal and corresponding control sections. Although this slide shows improvements in performance for the slurry seal sections, the degree of performance improvement is not the same as that seen in the thin overlay sections.

Here, too, a few of the slurry seal sections show worse performance than the control because of the inappropriateness of the pavement condition. One particular example worth mentioning is a test site in the Western Region whereby the slurry seal and chip seal sections failed shortly after placement. It was found that the severely aged and open pavement accelerated (hydrogenesis) vapor action and stripping, causing the sections to fail.

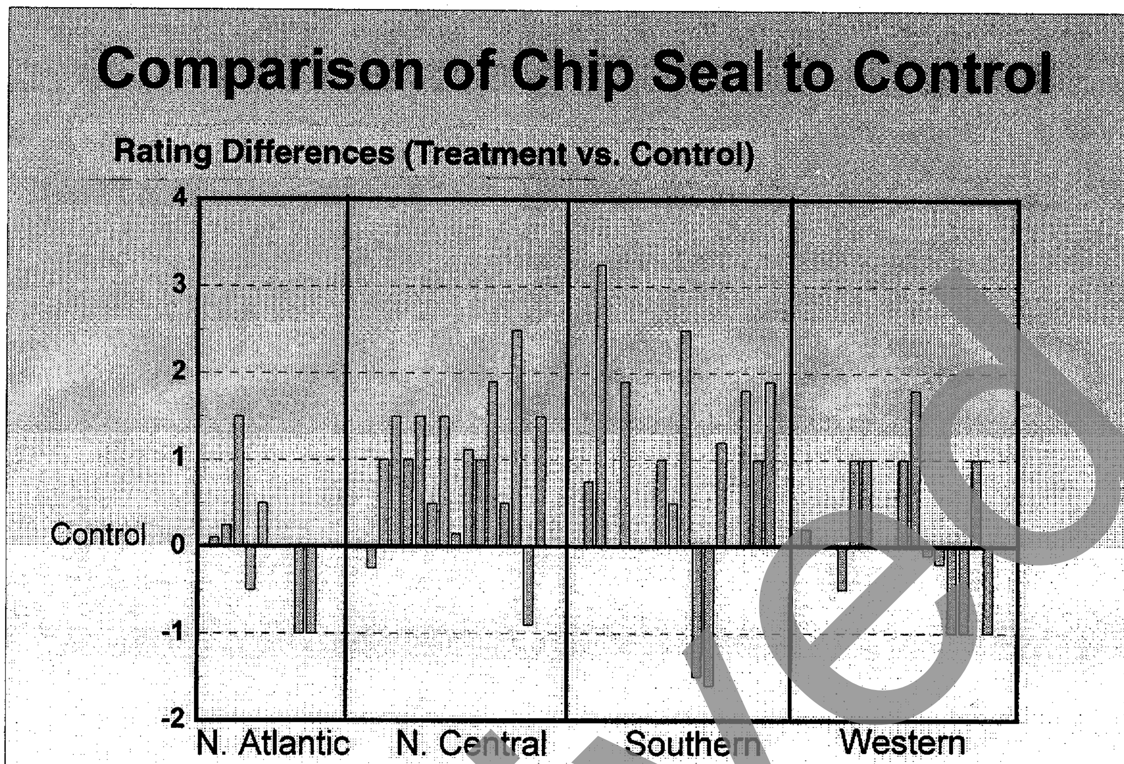
Page 2-5 Figure 2-2



Comparison of Crack Seal to Control
Slide #11

As with the slurry seal sections, the SPS-3 crack seal sections generally show significantly better pavement performance than the control sections, but not to the extent seen in the thin overlay sections.

Page 2-6 Figure 2-2



Session 2
Reference 5

Comparison of Chip Seal to Control
Slide #12

And, finally, with the most of the same exceptions, the SPS-3 chip seal sections also show much better pavement performance than the control sections.

Page 2-6 Figure 2-2

Other SPS-3 Findings to Date

As preventive maintenance treatments:

- Slurry seals perform better when applied to pavements with little cracking
- Chip seals perform better than other treatments on cracked pavements
- Thin asphalt overlays perform better on rough pavements and rutted pavements compared to other SPS-3 treatments

Session 2

Other SPS-3 Findings to Date
Slide #13

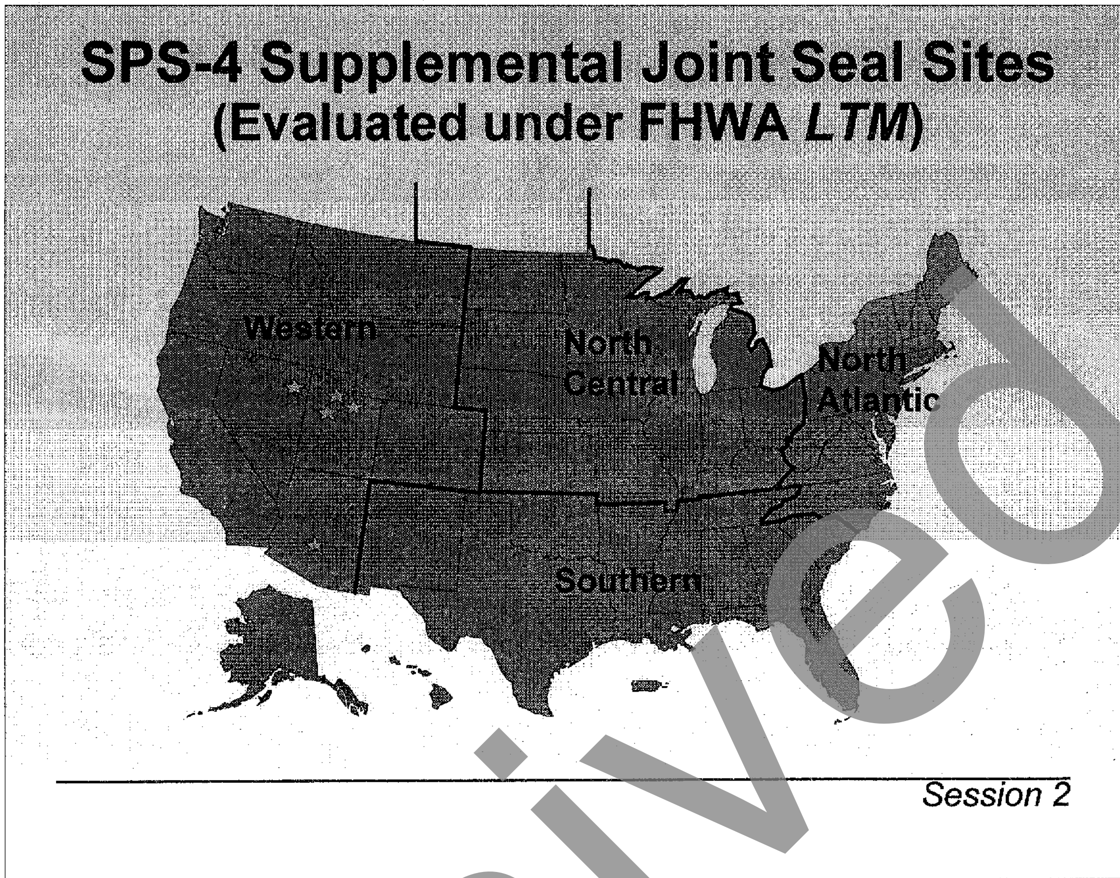
When applied as preventive maintenance treatments:

- slurry seals have been observed to perform better when applied to pavements with little cracking;

- chip seals have been observed to perform better than other treatments on cracked pavements; and

- thin asphalt overlays have been observed to perform better on rough pavements and rutted pavements than the other treatments compared to other SPS-3 treatments used as preventive maintenance.

Page 2-4



SPS-4 Supplemental Joint Seal Sites
Slide #14

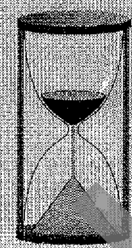
Because of their deep interest in learning more about the performance of several types and brands of joint sealants, Arizona, Utah, and Nevada have established several supplemental joint seal sections as part of their SPS-4 sites. Annual evaluations of these experimental sections are being performed under the FHWA *LTM* contract.

On U.S. 365 in Mesa, the Arizona DOT is studying the performance of hot-applied rubberized asphalts, self-leveling and non-sag silicones, and preformed compression seals, most of which are recessed in 10-mm wide joints.

On I-80 in Wells, the Nevada DOT is testing the performance of self-leveling and non-sag silicones recessed in 10-mm wide joints and a preformed compression seal placed in a 13-mm wide joint.

On I-15 Tremonton, U.S. 40 Heber City, and UT 154 Salt Lake City, the Utah DOT is investigating the performance of hot-applied rubberized asphalts, self-leveling and non-sag silicones, and preformed compression seals. Most of the joint widths are 10 mm; however, some silicone sections are 3-mm "Soff-Cut" sawed joints.

Maintenance Timing



- Response to visible problems or user complaints
- Maintenance performance improves when applications are applied at proper times
- Maintenance needs to be performed on roads that appear to be in good condition

Session 2

Maintenance Timing
Slide #15

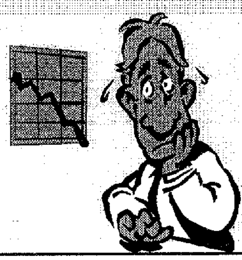
One of the most important aspects of pavement maintenance, and a key objective of SPS-3 and -4 data analysis, is the timing of pavement maintenance. In too many cases, agencies perform pavement maintenance in response to visible distress or complaints from drivers. This type of reactive maintenance does not take advantage of optimum treatment times and also decreases the productivity of the overall maintenance operation.

As has been seen in the SPS-3 test sites, certain applications perform better when fewer cracks are present, which corresponds to a younger pavement. When considering the timing of maintenance operations, the decrease in pavement performance should be considered if maintenance is made to wait beyond the optimum time. One of the hardest things to overcome for many agencies is the desire to wait for distress to be visible before performing maintenance.

Question: Have you worked on a good road and wondered why you were doing so?

Page 2-7

Planned, *PREVENTIVE* maintenance allows for better budget predictions than *REACTIVE* maintenance practices



Session 2

Preventive vs. Reactive Maintenance
Slide #16

Another advantage to preventive maintenance is that the costs required for the maintenance activities can be planned further in advance and included in budget projections. If crack sealing is planned for the third, fourth, or fifth year of an AC pavement, it not only can be budgeted into the overall life-cycle costs, but it will almost certainly perform better than an application performed in the sixth or seventh year when cracks have undergone considerable deterioration.

Allowing cracks to deteriorate too far can also lead to excessive pothole patching, which is a reactive operation that cannot be easily planned for in the budgeting process.

Page 2-8

New Maintenance Technologies

- Devices for determining when maintenance should be performed
- Techniques for performing maintenance operations with more uniformity and higher productivity

Session 2

New Maintenance Technologies
Slide #17

Many new devices and pieces of equipment for pavement maintenance were evaluated under SHRP toward the goal of helping agencies determine when maintenance should be performed and improving the productivity and uniformity of maintenance operations as they are being performed. Some of these technologies continue to be researched and developed, however, on the whole, none have proven very effective.

Pages 2-8 & 2-9

Maintenance Equipment

- SHRP H-107a >>> automated pothole patching device
- SHRP H-107b >>> automated crack sealing device
- Semi-automated pothole repair equipment
- Spot-paving device
- IA-VAC joint seal tester

Session 2

Maintenance Equipment
Slide #18

Two of the projects conducted under SHRP resulted in the development of automated pothole patching and crack sealing devices. These devices were intended to improve safety for maintenance crews and passing motorists, increase productivity of the maintenance operation, and provide more uniformity to the repairs.

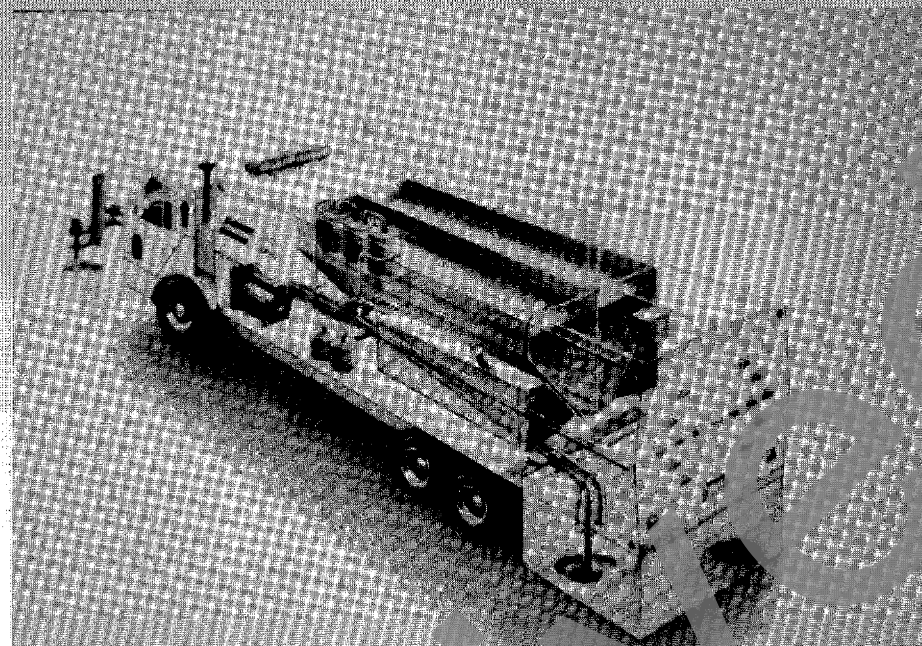
Private development of semi-automated pothole repair equipment includes devices such as the Durapatcher, the AMZ, the Wildcat, and the Roscoe. Although they are 2-man operations, they have generally been noted to provide good patch performance.

Spot paving devices, such as the Leeboy, provide the ability to mill and fill localized deteriorated areas or do partial-width milling and patching.

The Iowa DOT's IA-VAC joint seal tester is a relatively new tool that provides an alternate means of evaluating the effectiveness of joint seals.

Pages 2-9 & 2-10

Automated Pothole Patching Machine



Session 2

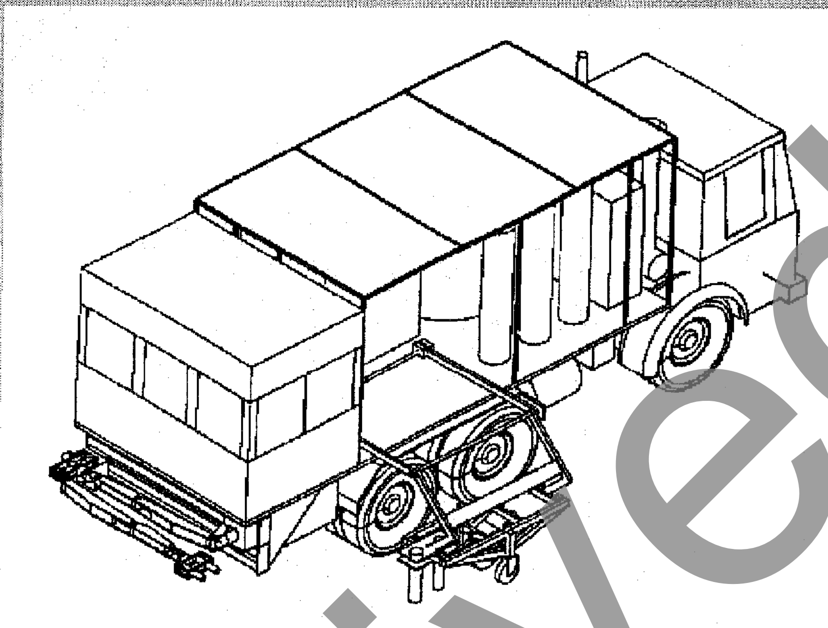
Automated Pothole Patching Machine
Slide #19

The automated pothole patching machine is equipped with devices that can straighten the edges of the pothole, vacuum the debris from the repair area, heat the repair area, and place a spray injection patch into the pothole. Through the use of various sensors and video cameras, the entire operation can be controlled by the vehicle driver from the driver's seat.

At the August 1994 FHWA Highway Operations Technical Working Group (TWG) Meeting, the automated pothole patcher was reported as mechanically complete, but lacking full installation and integration of computer control systems. It is still under development by Northwestern University's Basic Industrial Research Laboratory (BIRL).

Page 2-10

Automated Crack Sealing Machine



Session 2

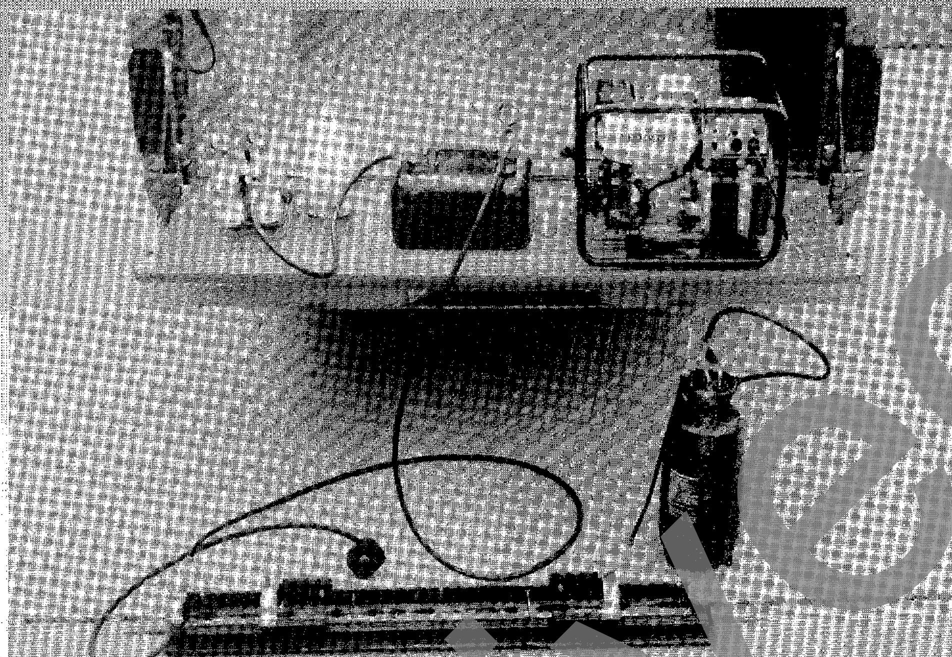
Automated Crack Sealing Machine
Slide #20

The automated crack sealing machine is equipped with video sensors to map the crack to be sealed, rout the crack if necessary, and place the sealant using robotic arms. As with the automated pothole patcher, the entire operation can be controlled by the vehicle driver from the driver's seat.

At the August 1994 FHWA Highway Operations Technical Working Group (TWG) Meeting, it was reported that the longitudinal crack sealing system was functional, but the vision system for transverse crack sealing operations had not been developed. The system is still under development by the University of California---Davis and CALTRANS.

Page 2-11

IA-VAC Joint Seal Tester



Session 2

IA-VAC Joint Seal Tester
Slide #21

The IA-VAC joint seal testing device shown here was developed by the Iowa DOT in the early 1990's as an alternative means of measuring the effectiveness of joint seals. The system is operated by placing the 1.2-m suction chamber lengthwise over a solution-treated joint and then applying a vacuum force to draw up air through any segments of adhesion, cohesion, or spall failure, forming bubbles in the solution atop the joint seal.

The IA-VAC is currently used by the Iowa DOT as a research and special evaluation tool. Under the FHWA *Pavement Maintenance Effectiveness/Innovative Materials* project, several IA-VAC units are being made available to States interested in participating in the Test and Evaluation portion of the project.

We will discuss the IA-VAC in more detail in session 3.

Page 2-9

Maintenance and the Public

- Pavement maintenance should render pavement condition a non-issue to the public
- Goal - best possible pavement condition with least amount of interruption (i.e., minimal lane closure time)
- Inclusion of user-delay costs will necessitate the application of the most cost-effective maintenance option

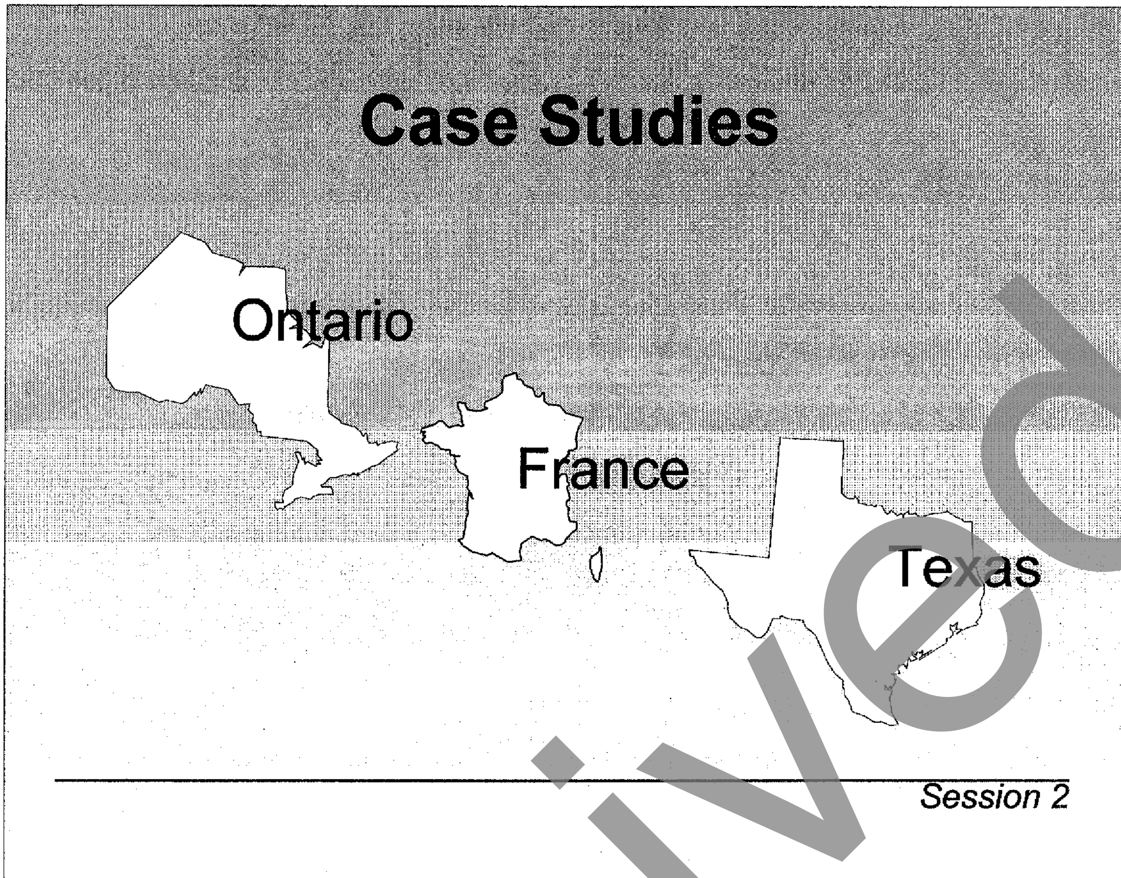
Session 2

Maintenance and the Public
Slide #22

The ultimate objective of most maintenance agencies is to not be noticed by the users. If crews are constantly closely lanes and repeatedly patching potholes or spalls, the public perception of that agency will be negative. On the other hand, an agency that maintains good joint and crack seals, thereby reducing the number of potholes and spalls that develop, and makes long-lasting repairs on those that do develop, they will spend less time on the road and have a more positive public image. Of course staying off the road is only an option for crews where the pavement is performing well. Crews that stay off the road and allow their pavements to deteriorate to a very bad condition will also have a negative image in the eyes of the public.

When considering life-cycle costs for various maintenance strategies, the inclusion of user delay costs will make it difficult to choose any option with significantly shorter life no matter how much lower the initial costs will be. In urban areas where delay costs can approach $1,000,000 per day, the fewer the number of lane closures the more cost-effective the maintenance option.

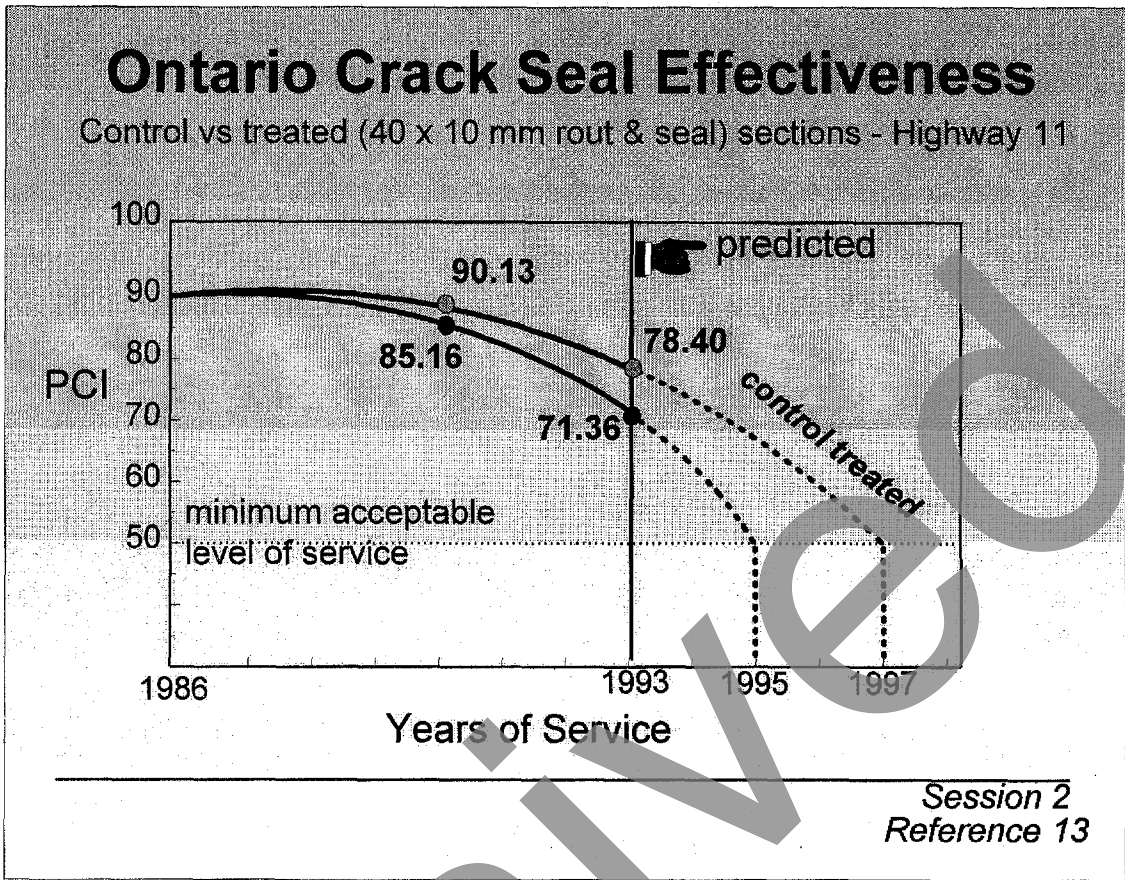
Page 2-12



Case Studies
Slide #23

Several research efforts have been made in the past 10 to 15 years that examine the effectiveness of pavement maintenance. A few particular studies worth discussing are those done in Ontario, France, and Texas.

Pages 2-12 & 2-13

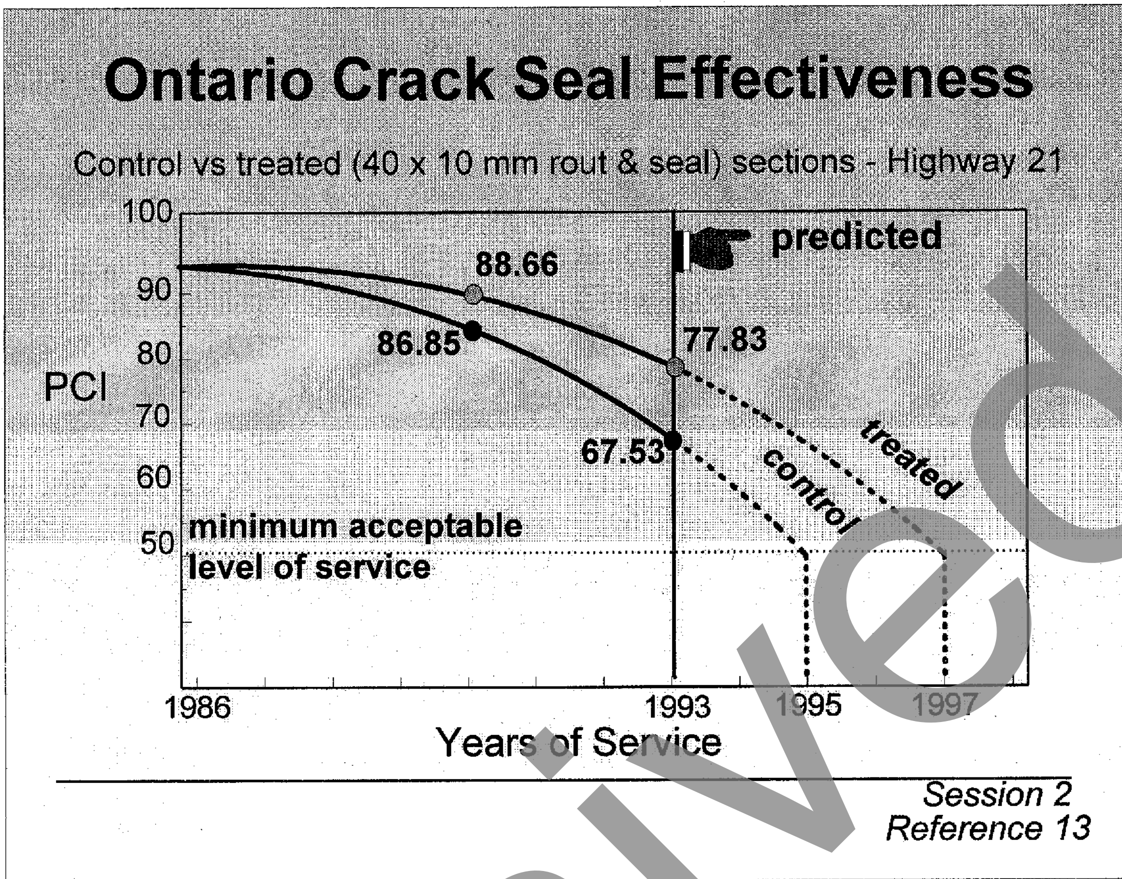


Ontario Crack Seal Effectiveness (Highway 11)
Slide #24

A study initiated in 1986 by the Ministry of Transportation of Ontario (MTO) was designed to look at the cost-effectiveness of routing and sealing cracks in asphalt pavement. Several sets of treated versus untreated sections were constructed and monitored, and the resulting performance curves of those paired sections largely resembled the ones shown in this slide and the next slide.

As you can see for Highway 11 here, 7 years after the crack seal operation, the pavement condition for the rout and seal sections is about 7 points higher than the untreated section.

Page 2-14 Figure 2-4

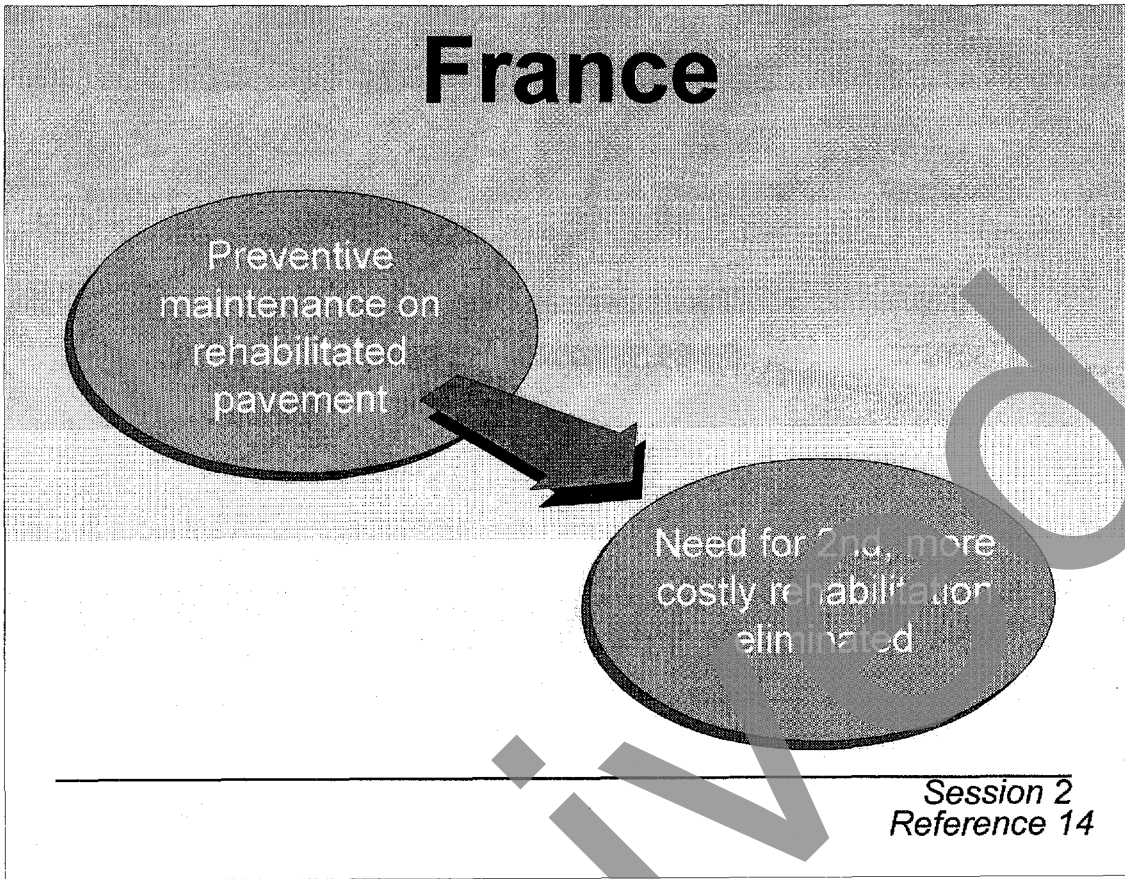


Ontario Crack Seal Effectiveness (Highway 21)
Slide #25

Similarly, for Highway 21 in Ontario, 7 years after the crack seal operation, the pavement condition for the rout and seal sections is about 10 points higher than the untreated section.

The study showed that routing and sealing generally increased pavement service life by about 2 years, and that such a procedure, if applied according to specific guidelines developed by the MTO, was cost-effective.

Page 2-14 Figure 2-3



France
Slide #26

In France, a strategy of preventive maintenance was undertaken for older pavements in need of rehabilitation. This strategy involved carrying out rehabilitation using high quality procedures and then applying seal coats or thin AC overlays as preventive maintenance.

It was found that, although the initial costs of the maintenance were much higher than alternatives, the need for a second more costly rehabilitation was eliminated.

Page 2-13

Texas Supplemental Maintenance Effectiveness Research Program (SMERP)

- Microsurfacing
- Asphalt rubber chip seal
- Polymer-modified emulsion chip seal
- Latex-modified asphalt chip seal
- Asphalt chip seal
- Fog seal

Session 2
Reference 16

Texas
Slide #27

The Texas Department of Highways and Public Transportation (DHPT) initiated a study of maintenance effectiveness through the construction of their own SPS-3 test sites. The study is titled Supplemental Maintenance Effectiveness Research Program (SMERP) and it involves the evaluation of various types of maintenance, including:

- Microsurfacing.
- Asphalt rubber chip seals.
- Polymer-modified emulsion chip seals.
- Latex-modified asphalt chip seals.
- Asphalt chip seals.
- Fog seals.

Control, or untreated, sections are included, and the goal is "to determine the optimum preventive maintenance strategies that prolong pavement life and that demonstrate positive rates of return on preventive maintenance funds."

Pages 2-13 & 2-15

Preliminary Results of SMERP

	Alligator Cracking	Bleeding	Block Cracking	Long/Trans Cracking	Long WP Cracking	Raveling
Asphalt rubber	R	I	R	R	R	I
Micro-surfacing	R	R	R	M	I	R
Polymer-modified emulsion	R	R	R	R	R	R
Latex-modified asphalt	R	I	R	R	R	M
AC	M	I	R	R	R	M
Fog seal	R	I	I	R	M	I
Control	M	I	I	R	I	I

R = reduced   M = mixed   I = increased

Session 2
Reference 17

SMERP Preliminary Results
Slide #28

As seen in this slide, the preliminary results of the SMERP study, based on **6-** and **12-month** inspections, generally show a positive impact on distress occurrence by all treated sections. The control (untreated) sections, on the other hand, have in most instances exhibited increased distress occurrence.

A 2-year inspection of the SMERP sections was slated for this summer, and an update report is expected to be available this fall.

Page 2-15   Table 2-1

Summary

- Pavement maintenance can extend pavement life when applied appropriately
- Current studies should provide additional data as to the effectiveness of properly timed preventive maintenance activities

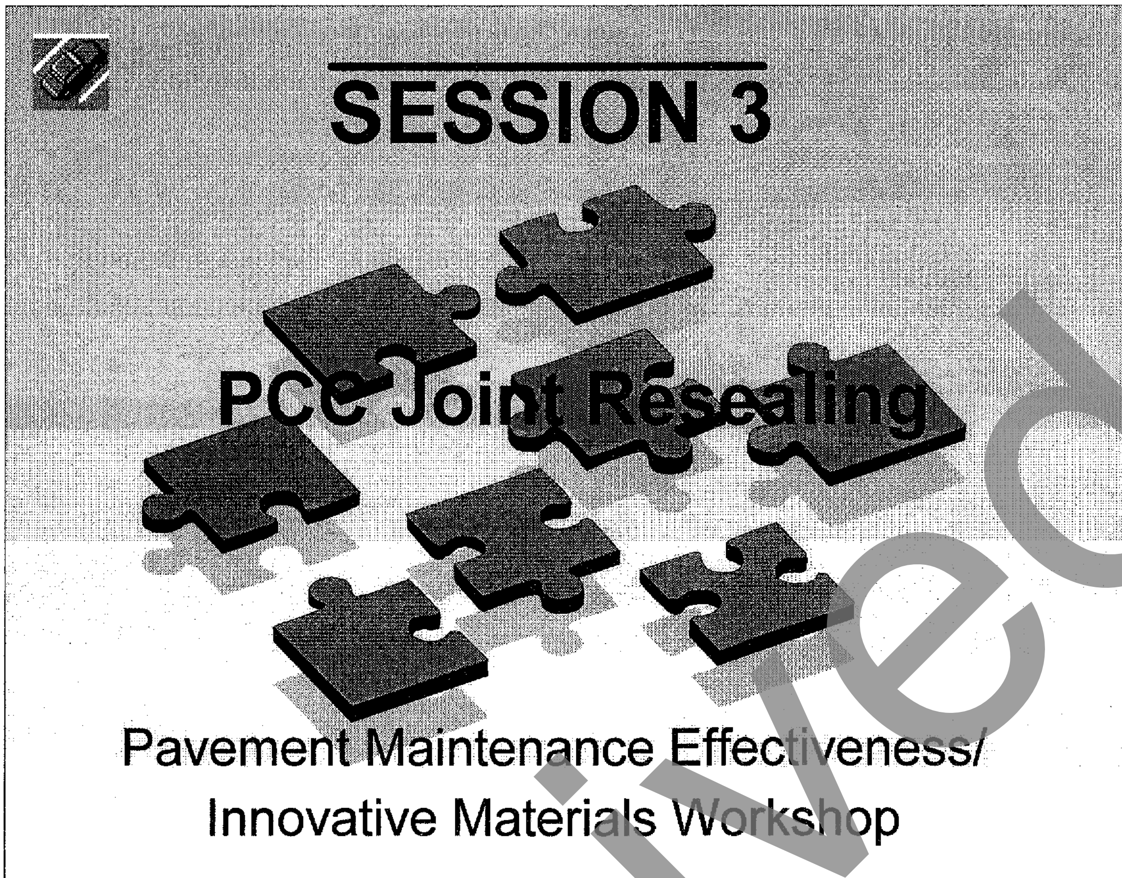
Session 2

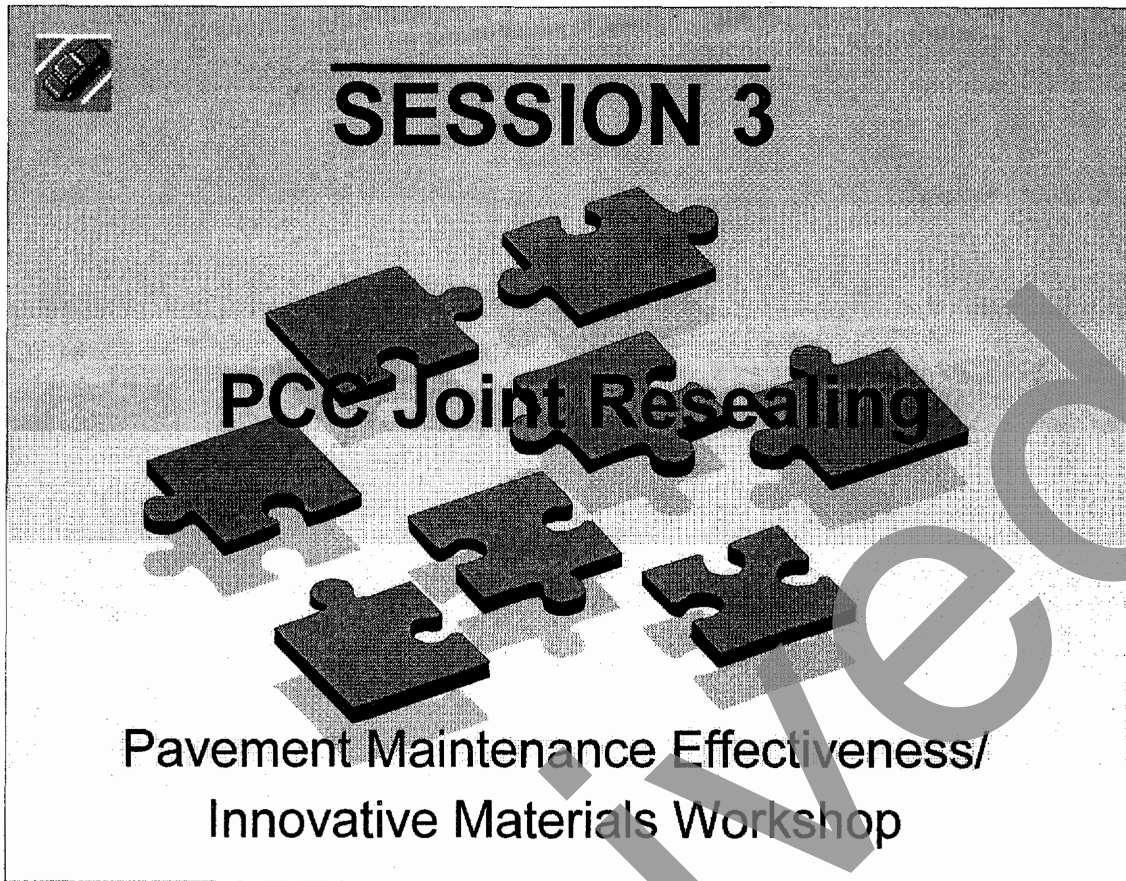
Summary
Slide #29
In summary, considerable research is being and has been performed that indicate and verify the importance of appropriate and timely maintenance in extending pavement life.

The concept of preventive maintenance is perhaps best phrased in reference 1 (NCHRP Synthesis of Highway Practice 153), and is quoted on page 2-16 of the handbook. This quote reads

> *"Cost effective preventive maintenance is largely dependent on the timing of the activity and the quality of the work performed. For a preventive maintenance strategy to be successful, it must be recognized that it is cyclic and requires scheduling. It must be properly funded over a period of years to be effective. Deferring preventive maintenance only increases reactive maintenance and accelerates deterioration."*

Pages 2-15 & 2-16


SESSION 3
PCC Joint Resealing
Pavement Maintenance Effectiveness/
Innovative Materials Workshop



PCC Joint Resealing
Slide #1

- Session 3 of the FHWA Pavement Maintenance Workshop is entitled, "PCC Joint Resealing," and is designed to acquaint highway maintenance workers, supervisors, and engineers with state of the art methods and materials for resealing joints in concrete pavements.
- It is hoped that this session will generate an increased awareness of the need for better designs, materials, and installation procedures, thereby increasing the performance of resealed joints.

Page 3-1

Session Overview

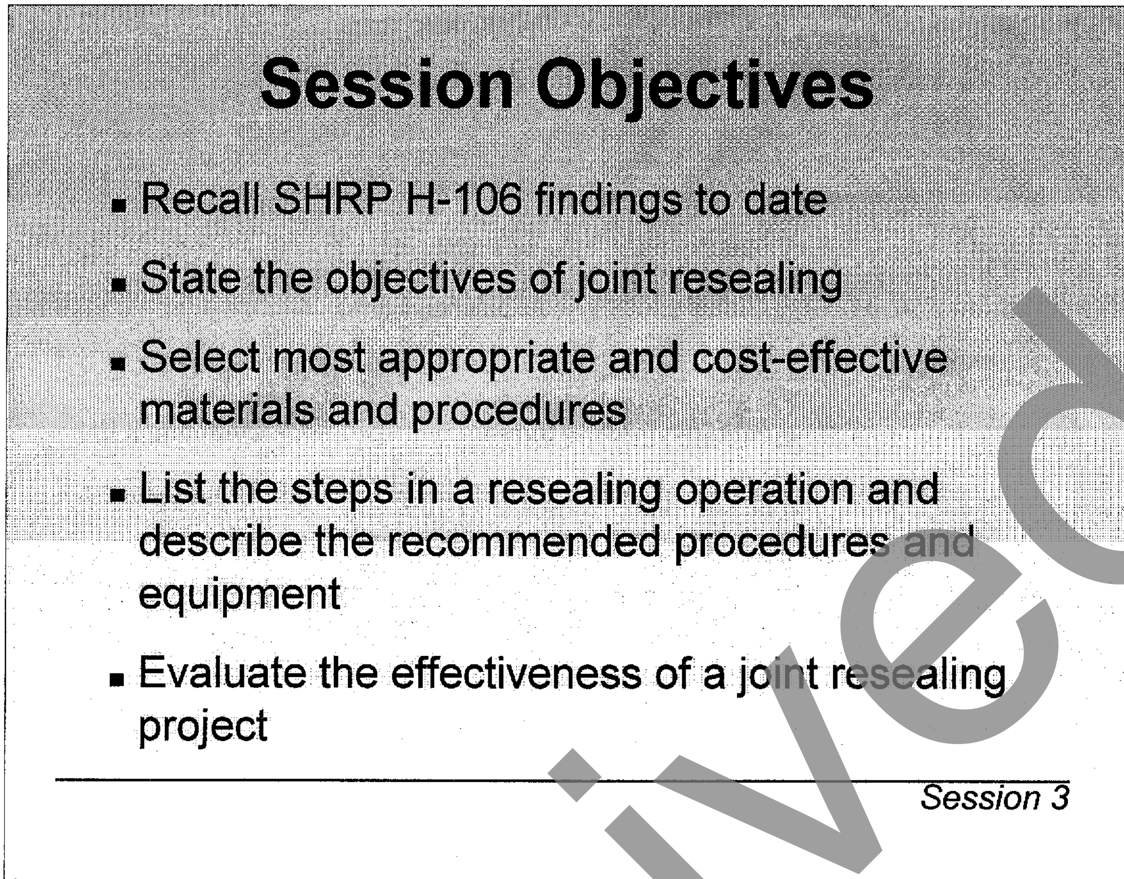
- SHRP H-106 findings
- Resealing objectives
- Planning and design
- Installation
- Evaluation of reseal effectiveness

Session 3

Session Overview
Slide #2

To start the session, we will give a quick overview of the SHRP H-106 joint resealing experiment and tell you what the most recent findings are with respect to performance of materials and methods.

Then, we will proceed into the "how to" portion of the session, discussing first the objectives of resealing and the consequences of late or poor resealing efforts. We will next look at the main items important to the planning of a resealing project, and then discuss the various tasks in a resealing operation and point out the recommended ways of performing those tasks. Lastly, we'll talk about how the effectiveness of resealing operations can be evaluated, so that future maintenance or rehabilitation work can be planned for a facility.



Session Objectives
Slide #3

At the conclusion of this session, you should:

- Be informed of the SHRP H-106 findings to date.
- Be able to state the objectives of joint resealing.
- Be familiarized with the process of selecting the most appropriate and cost-effective materials and procedures.
- List the various steps in a joint resealing operation and describe the recommended procedures and equipment, and
- Be familiarized with the process of evaluating joint seal effectiveness.

Page 3-1

SHRP H-106
Joint Resealing
Experiment Findings

Session 3

SHRP H-106 Joint Resealing Experiment Findings
Slide #4

Let's take a quick look at the SHRP H-106 joint resealing experiment and its latest findings, which stem from test site inspections made in the fall of 1994.

Page 3-1

Test Site Locations

- *I-17* Phoenix, Arizona
- *I-77* Columbia, South Carolina
- *I-25* Ft. Collins, Colorado
- *I-80* Grinnell, Iowa
- *US 127* Frankfort, Kentucky

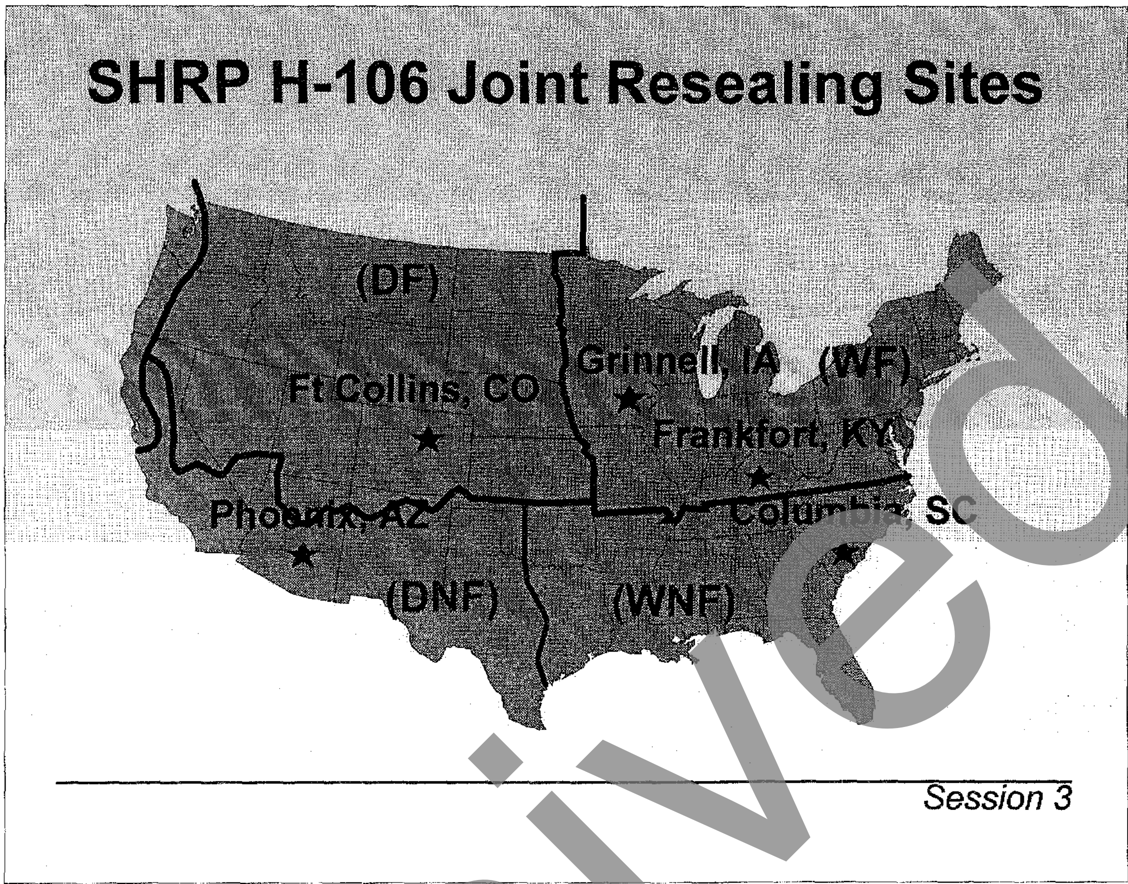
Session 3

Test Site Locations
Slide #5

Very quickly, these are the locations of the five reseal test sites.

I-17 in Phoenix, AZ was installed in April 1991.
I-77 in Columbia, SC was also installed in April 1991.
I-25 in Ft. Collins, CO was put down in April and May 1991
I-80 in Grinnell, IA and *US 127* in Frankfort, KY were installed in the May/June/July 1991 timeframe.

Page 3-2



Test Site Locations
Slide #6

This map shows the locations of the five joint resealing sites with respect to the SHRP-defined climatic zones.

I-17 in Phoenix represents the dry-nonfreeze climate.
I-77 in Columbia is the wet-nonfreeze site.
I-25 in Ft. Collins represents the dry-freeze climate.
I-80 in Grinnell and *US 127* in Frankfort are both wet-freeze test sites. They were specifically selected to examine the effect of joint spacing on sealant performance. The pavement at Grinnell is a short-jointed concrete pavement, whereas the pavement at Frankfort is long-jointed.

Map not in handbook

Experiment Features

- 12 sealant materials
  - rubberized asphalt (standard, low-modulus)
  - silicone (non self-leveling, self-leveling)
  - polysulfide
- 4 installation methods
  - saw-and-recess
  - saw-and-overband
  - plow-and-overband
  - saw-and-flush

See Handbook Table 3-1 *Session 3*

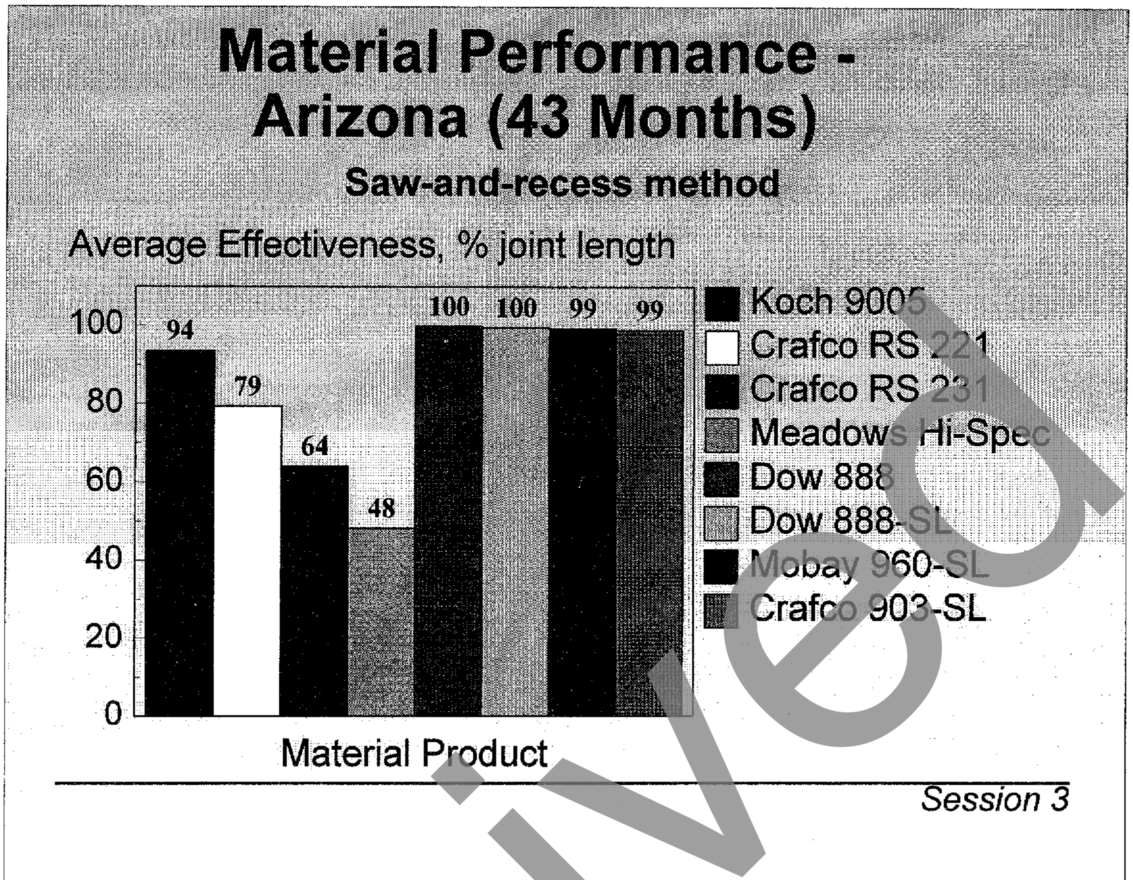
Experiment Features
Slide #7

The experiment included the placement of 12 different sealant materials, consisting of: 3 standard rubberized asphalts, 3 low-modulus rubberized asphalts, 2 nonself-leveling silicones, 3 self-leveling silicones, and 1 polysulfide.

Each of the 12 materials were placed using the saw-and-recess method, and the standard and low-modulus rubberized asphalts were placed using the saw-and-overband, plow-and-overband, and saw-and-flush methods.

Table 3-1 in your handbook shows the specific products included in the experiment and summarizes the combinations of material and method that were used at each site. Also, figure 3-1 in your handbook illustrates the material placement configurations associated with each installation method.

Pages 3-3 & 3-4 Table 3-1 & Figure 3-1



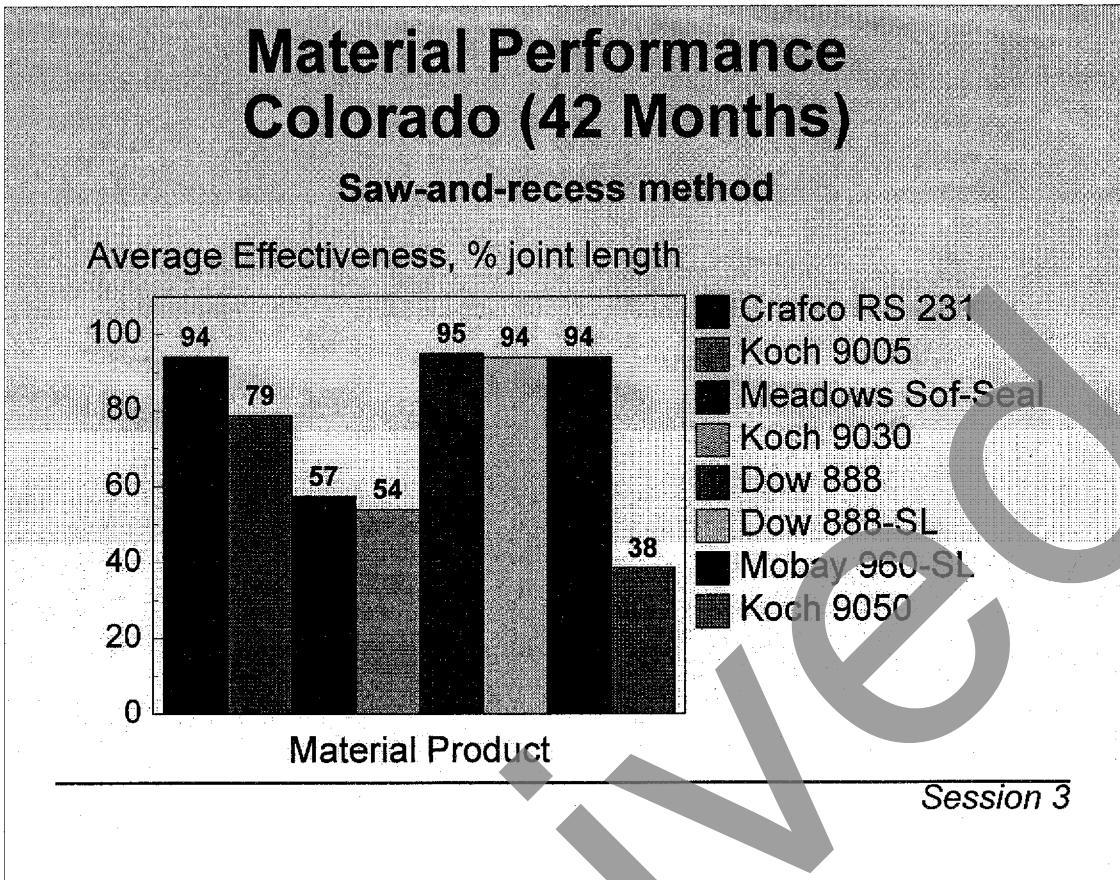
Excellent	> 90% effective
Good	80 - 89% effective
Fair	65 - 79% effective
Poor	50 - 64% effective
Very poor	< 50% effective

Material Performance - Arizona
Slide #8

The next five slides show how each material product placed using the saw-and-recess method is performing at each site. The performance measure illustrated in these slides is average effectiveness, gauged as a percentage of total joint length.

At Arizona, excellent performance is being exhibited by the four silicone products: Dow 888, Dow 888-SL, Mobay 960-SL, and Crafco 903-SL. The standard rubberized asphalt product, Koch 9005, is also showing very good performance. Fair performance has been observed of Crafco RS 221, which is also a standard rubberized sealant. RS 231, a low-modulus rubberized asphalt sealant, is performing poorly, and the standard rubberized asphalt, Meadows Hi-Spec, is showing very poor performance.

Figure not in Handbook
Top to Bottom Legend Order Correponds with Left to Right Chart Order



Material Performance - Colorado
Slide #9

The story at Colorado is fairly similar. The three silicone products placed there are showing excellent performance, as is Crafco RS 231. Koch 9005 is showing fair performance, and Koch 9030 and Meadows Sof-Seal are performing poorly. Koch 9050, a cold-applied polysulfide, is showing very poor performance.

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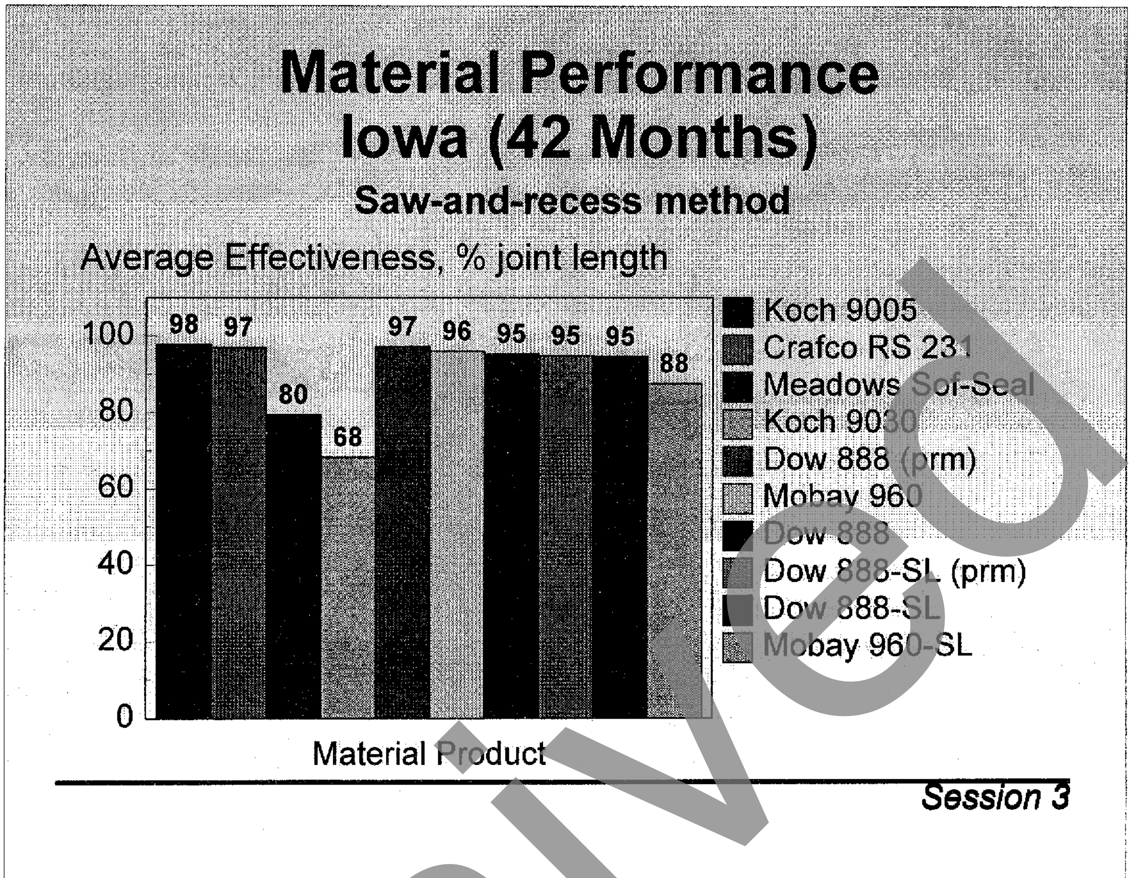

Material Performance - Iowa
Slide #10

This is how performance stacks up at the Iowa site. All but one of the six silicone seals show greater than 90 percent effectiveness; Mobay 960-SL shows 88 percent effectiveness.

Of the four hot-applied sealants, two show excellent performance, those being Crafco RS 231 and Koch 9005, one shows good performance (Meadows Sof-Seal), and the last shows poor performance (Koch 9030)

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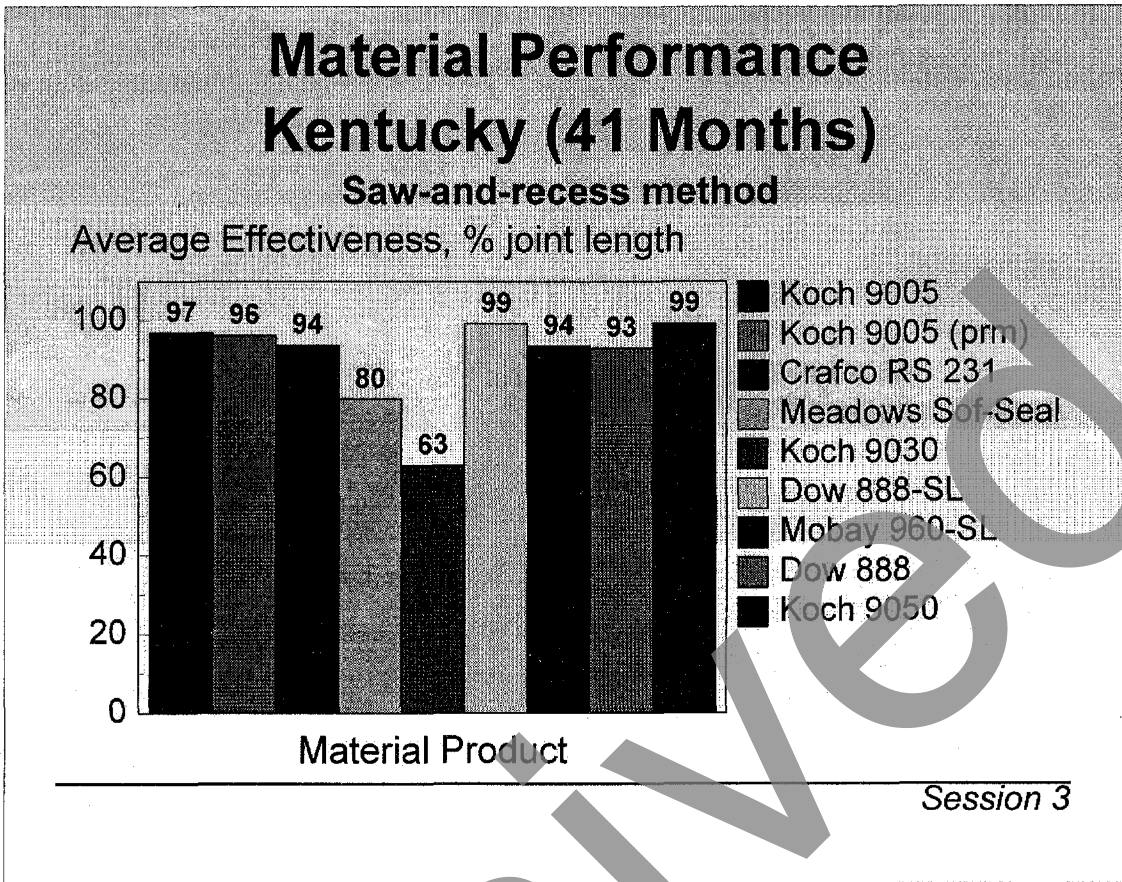

Material Performance - Kentucky
Slide #11

Crafco RS 231 and Koch 9005 are also holding up very well at Kentucky, along with all three silicone seals and the Koch 9050 polysulfide seal. Likewise, Meadows Sof-Seal is showing good performance and Koch 9030 is showing poor performance.

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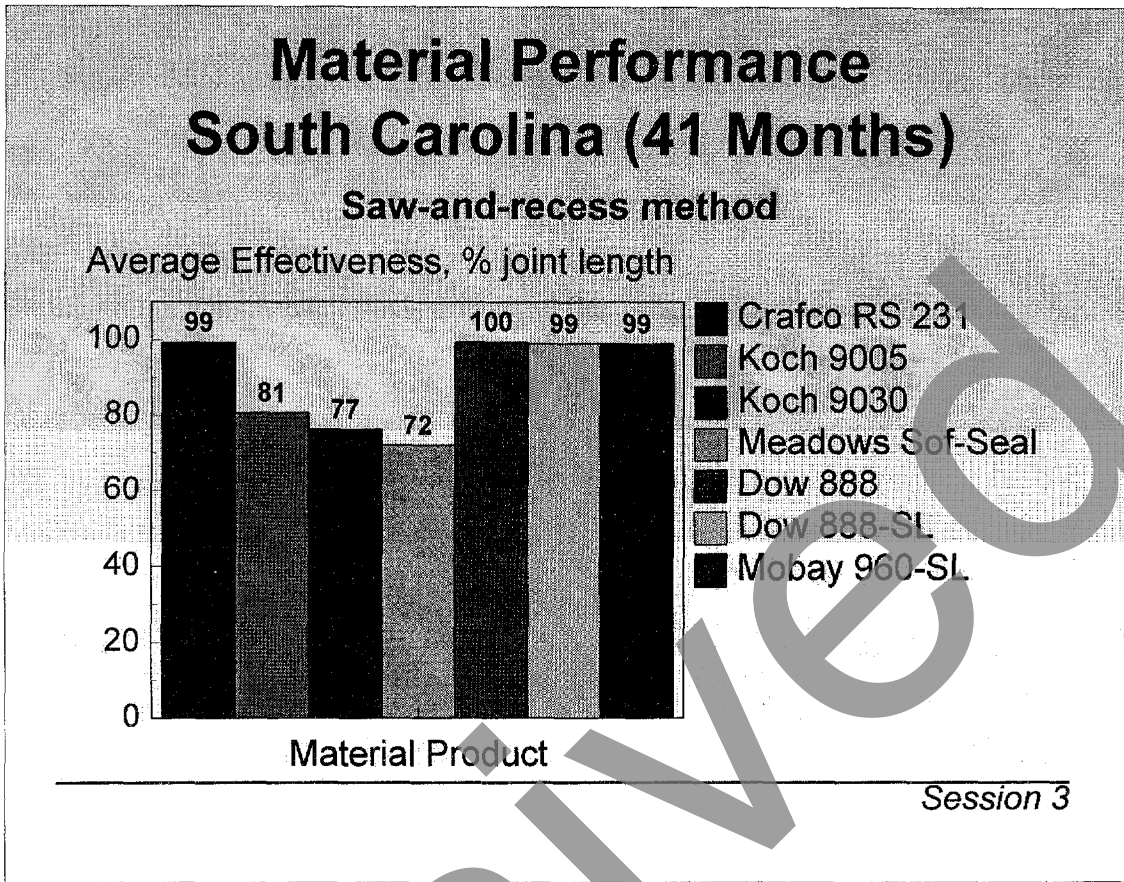
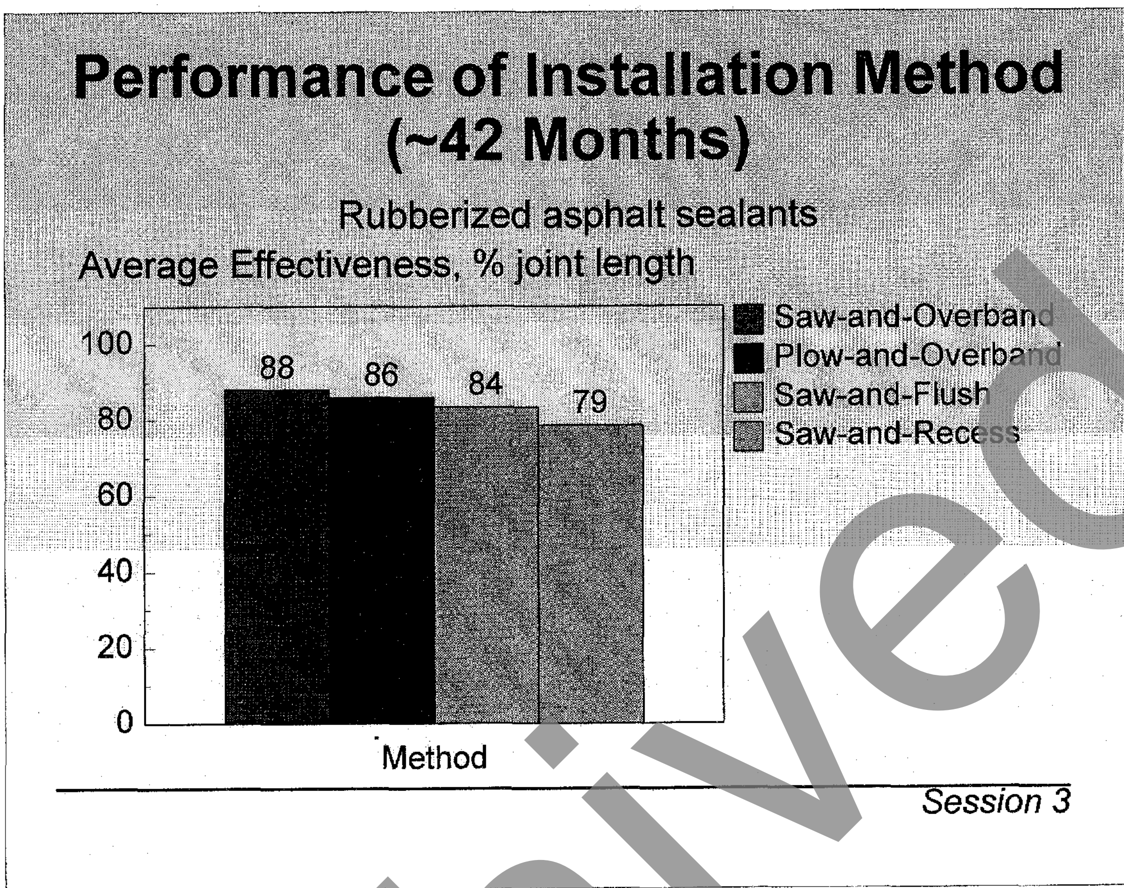


Material Performance - South Carolina
Slide #12

Finally, at South Carolina, Crafco RS 231 and all three silicone seals are showing excellent performance. Koch 9005 is showing good performance, and Koch 9030 and Meadows Sof-Seal are showing fair performance.

Figure not in Handbook
Top to Bottom Legend Order Correponds with Left to Right Chart Order



Performance of Installation Methods
Slide #13

Looking at the performance of installation procedures, we see that the best performance is being provided by the saw-and-overband method, followed closely by the plow-and-overband, and saw-and-flush procedures. The worst performance is being provided by the saw-and-recess configuration, which has averaged about 79 percent effectiveness.

Figure not in Handbook
Top to Bottom Legend Order Correponds with Left to Right Chart Order

Average Annual Cost Comparison (Materials)

Joint Seal Treatment	Service Life, yrs to 90% Effectiveness	Average Annual Cost, $/lane-km
Hi-Spec ($0.64/kg)	1.8	4,345
9005 ($0.51/kg)	5.6	2,208
RS 221 ($0.90/kg)	2.7	3,090
Sof Seal ($1.06/kg)	2.1	3,902
9030 ($0.77/kg)	2.1	4,218
RS 231 ($1.23/kg)	5.5	2,135
888 ($5.47/kg)	6.8	1,633
888-SL ($6.15/kg)	7.4	1,526
960-SL ($6.72/kg)	6.3	1,827

Average of all sites Saw-and-recess method

Session 3

Average Annual Cost Comparison (Materials)
Slide #14

Using a 90 percent effectiveness level, the service life of each joint seal treatment at each site has been estimated. These service life values and the estimated placement costs and user-delay costs associated with each treatment enabled the calculation of average annual costs on a $/lane-km basis.

As you can see, the most cost-effective seal types are the self-leveling and non-sag silicones, with average annual costs in the $1,500 to $1,800/lane-km range.

Two of the better performing rubberized asphalt sealants are not quite as cost-effective, but the majority of the rubberized asphalt products are not very cost-effective at all, with average annual costs about 2.5 times those of the silicone sealants.

Figure not in Handbook

Average Annual Cost Comparison (Installation Methods)

Joint Seal Installation Method	Service Life, yrs to 90% effectiveness	Average Annual Cost, $/lane-km
Saw-and-recess	5.5	2,135
Saw-and-overband	7.2	1,405
Plow-and-overband	8	1,246
Saw-and-flush	7.3	1,374

Average of all sites   Low-modulus rubberized asphalt

Session 3

Average Annual Cost Comparison (Installation Methods)
Slide #15

Here, we see that the most cost-effective installation method is the plow-and-overband method, followed closely by the saw-and-flush and saw-and-overband methods. The least cost-effective method is the saw-and-recess method.

Figure not in Handbook

Stones and Sand in Joint

Stones and Sand in Joint
Slide #16

With that taste of the H-106 joint resealing experiment, let us change gears now and discuss the recommended ways of planning, conducting, and monitoring joint resealing projects.

As you all know, concrete pavements must function adequately in whatever environment exists locally - including hot, cold, wet, and dirty conditions.

Pavements can be rapidly deteriorated under the effects of these conditions, but joint resealing can significantly counter those effects and thus greatly slow the rate of deterioration.

Page 3-6 Figure 3-3

Function of a Joint Seal

- Keep moisture from reaching base materials
- Stop incompressible sand, stones, and dirt from entering the joint

Session 3

Function of a Joint Seal
Slide #17

There are two major functions of a concrete joint seal. One is to keep moisture from reaching the underlying base material. Especially if the base and subsoil can be softened or pumped under wet conditions, an effective joint seal can reduce these effects.

The other function of a joint seal, particularly in dry climates, is to keep sand and dirt from entering the joint.

Page 3-5

Results of Not Sealing

- Damage resulting from water entrance
  - Softened supporting layers
  - Less resistance to D-cracking

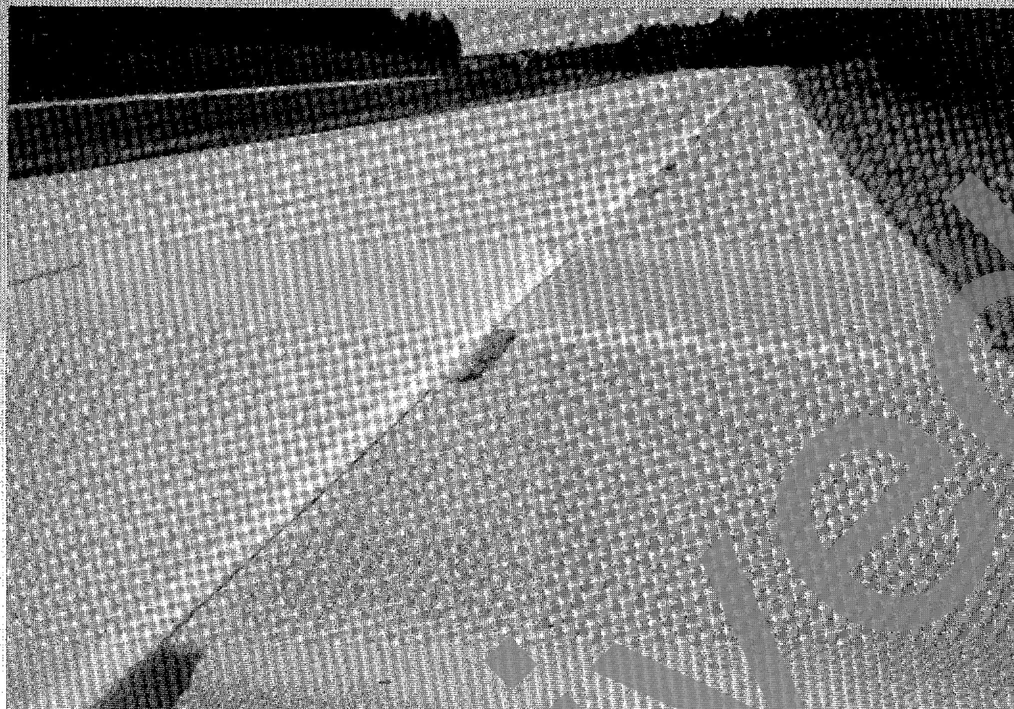
Session 3

Results of Not Sealing
Slide #18

When a joint seal is not present or not effective, water passes through the transverse or longitudinal joints of a concrete pavement, reaching the supporting layers. This, in turn, can lead to softening of the supporting layers and increased D-cracking in susceptible concrete.

Page 3-5

Pumping



Pumping
Slide #19

Over an extended period, softening of the supporting layers can lead to corner breaks, pumping of the fine material from beneath the pavement, as seen here, and . . . .

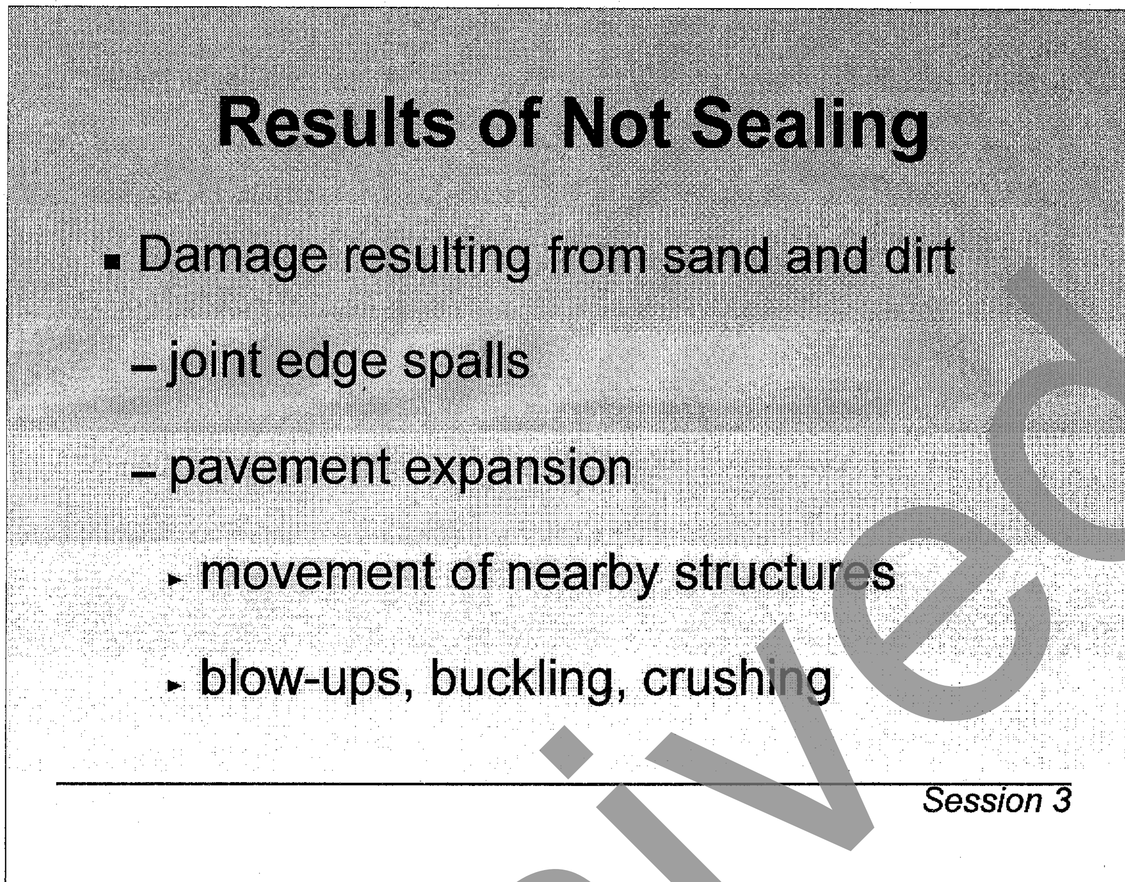
Page 3-6 Figure 3-2

Faulting

Faulting
Slide #20

. . . faulting of the transverse joints.

Figure not in Handbook

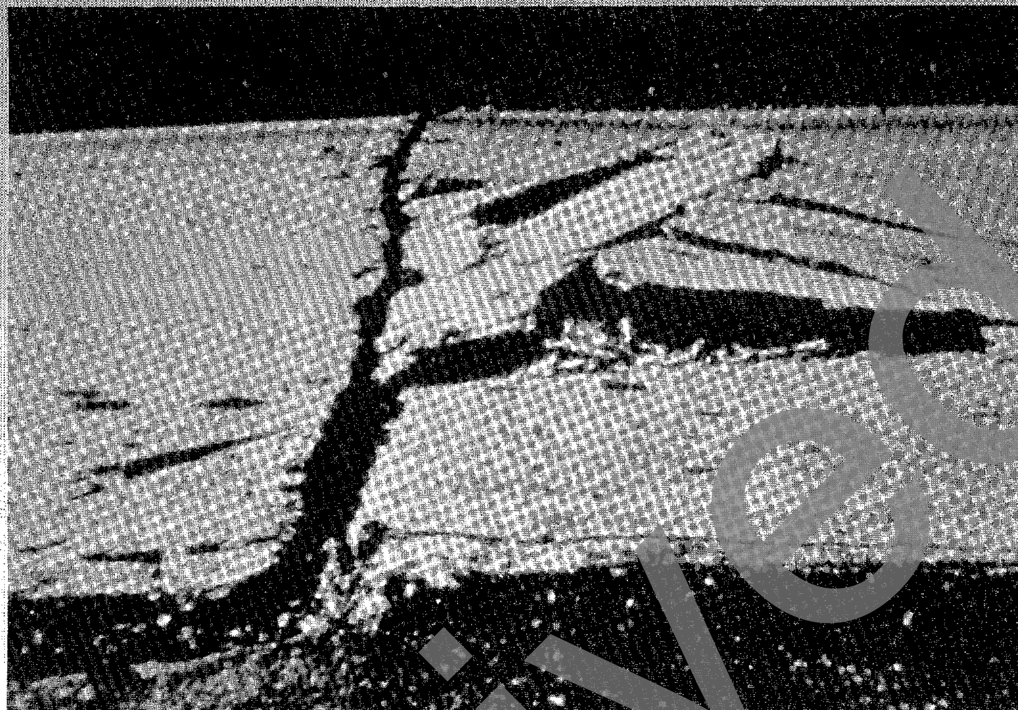


Results of Not Sealing
Slide #21

Sand and dirt entering the joint and becoming lodged between the slabs can result in spalling of joint edges, pavement expansion, movement of nearby bridges, and . . . .

Page 3-5

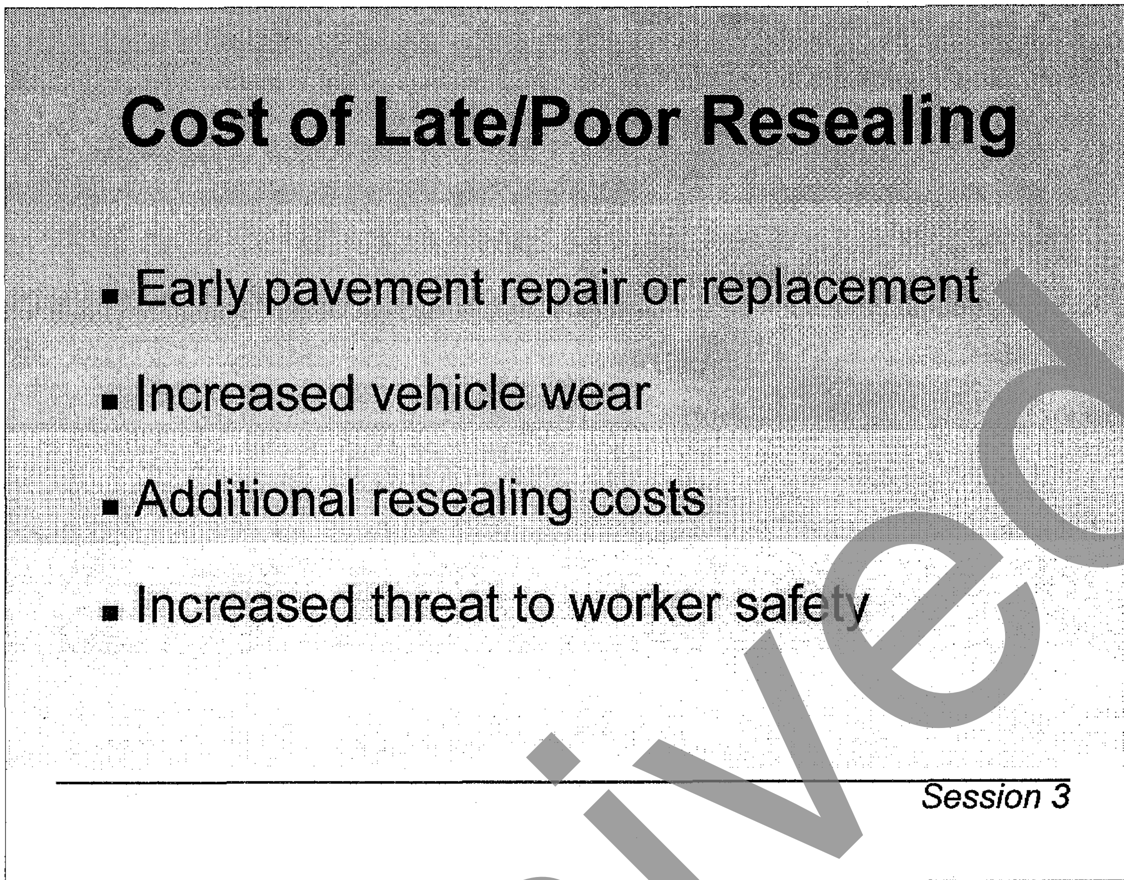
Pavement Buckling



Pavement Buckling
Slide #22

. . . buckling, blow-ups or crushing of concrete slabs.

Figure not in Handbook



Cost of Late/ Poor Resealing
Slide #23

If joints in concrete pavements are not resealed in a timely manner, the pavement may deteriorate rapidly. This can result in increased cost for early repair or replacement. It may also cause additional wear on vehicles traveling the roadway, increasing motorists' cost.

If joint seals do not perform adequately for the planned amount of time, the taxpayer must pay for early resealing. Workers installing the new sealant must also be exposed to traffic conditions more frequently.

Project Planning and Design

- Determine when to reseal
- Choosing materials
- Designing reservoir dimensions
- Selecting installation procedures
- Estimating material, labor, equipment

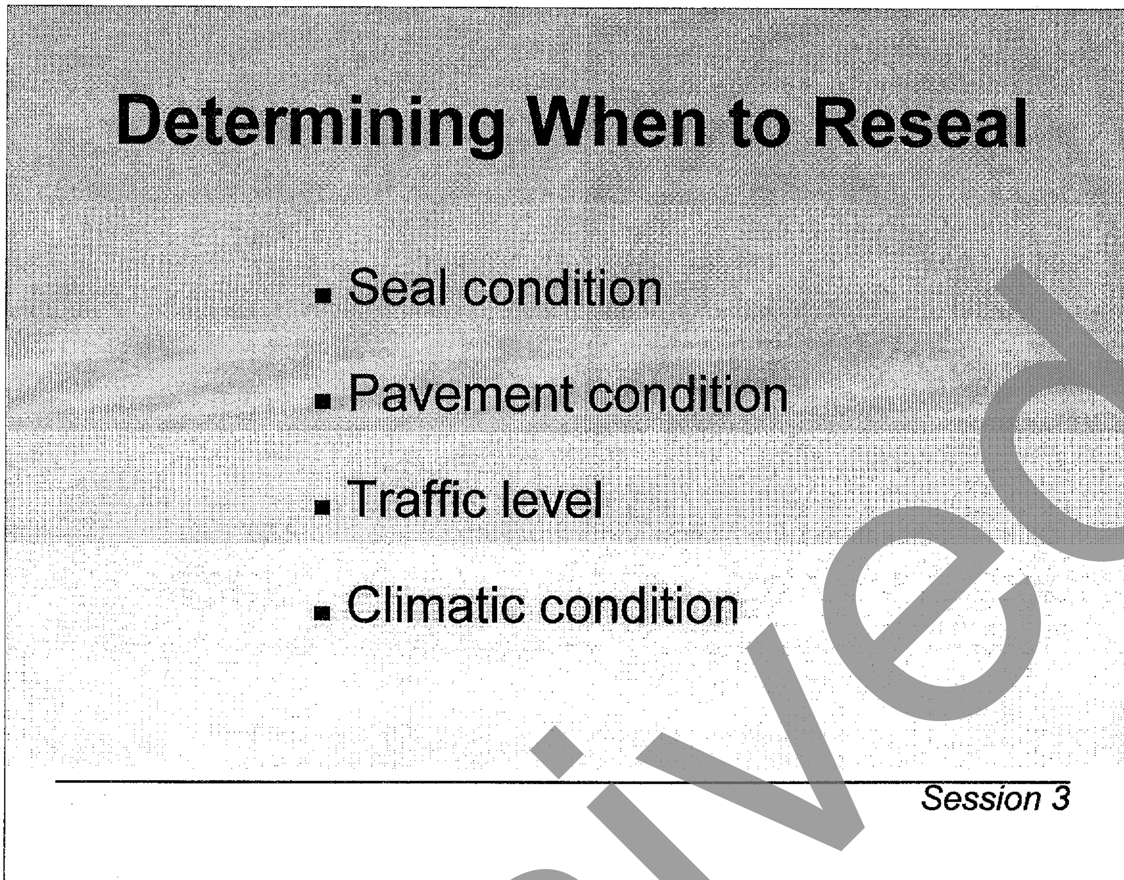
Session 3

Project Planning and Design
Slide #24

To reseal joints in a timely manner, and to achieve satisfactory results, some planning is necessary. Among the items that must be considered are:

- When to schedule the resealing project.
- What materials to use.
- What are the best joint dimensions.
- Which installation methods should be used, and
- How much material, time, and equipment are needed.

Page 3-7



Determining When to Reseal
Slide #25

The decision of when and whether to reseal is many times based on several criteria, not the least of which is the availability of funding. A more technical set of criteria would include:

- The condition of the seal - whether and to what extent it is allowing water and debris to enter the joints.
- The pavement condition - its expected lifetime and if it is showing faulting or pumping.
- The amount of vehicle traffic, and
- The climatic conditions - if it is hot, cold, wet or dry.

The SHRP *Manual of Practice* provides a worksheet and decision table for determining whether to reseal, based on these criteria.

Pages 3-5 & 3-6

Choosing Materials

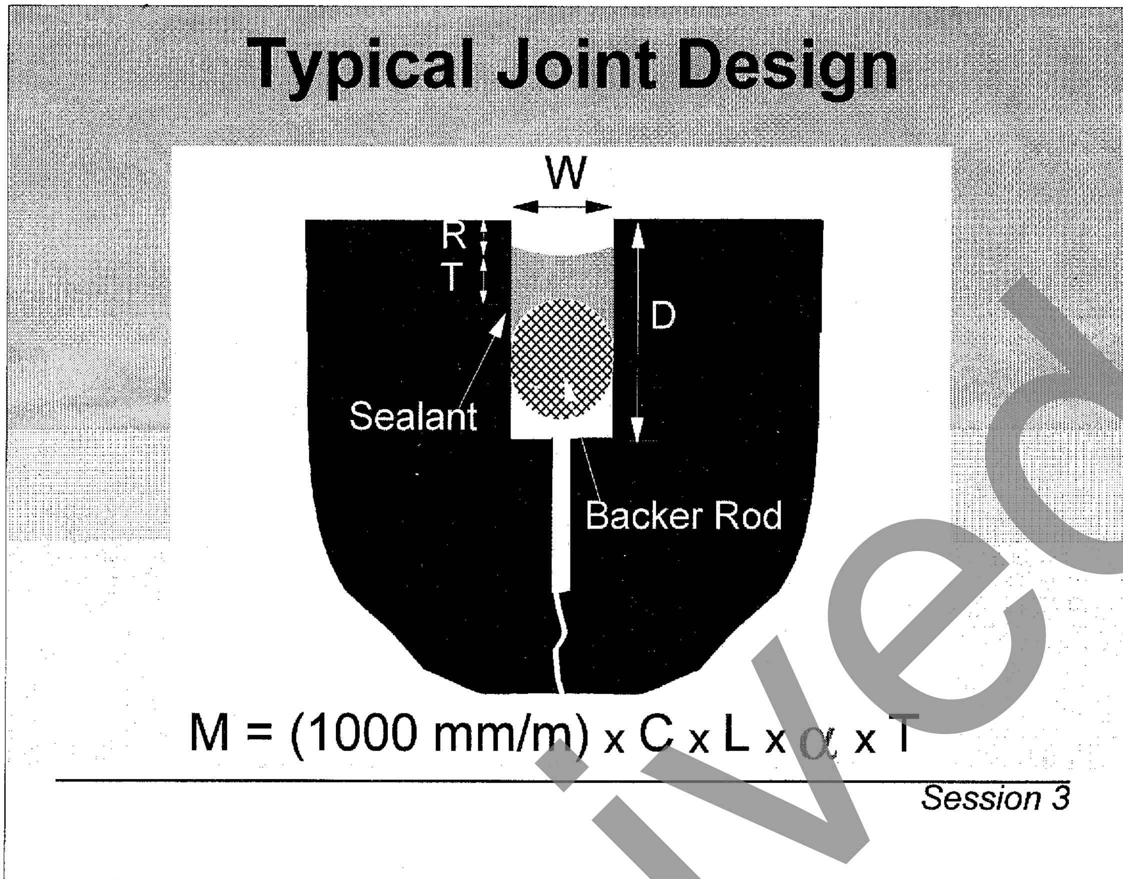
- Sealant material
- Backer rod
- Primer (if needed)

Session 3

Choosing Materials
Slide #26

Sealant material should be chosen to meet the requirements of the project. Backer rod must also be selected, as well as primer, if so desired.

The type of sealant material chosen can significantly affect the performance of a joint seal. Among sealant materials, the elastic and adhesive properties can differ greatly. Also, the properties of some sealants are changed by weathering, extreme temperature, or excess moisture. This, in turn, can result in varying sealant performance.



Typical Joint Design
Slide #27

Here, you are looking at a cross-sectional view of a sealed joint. The sealant is supported by backer rod, shown in hatched green. The shape factor of this sealant is the relation of the width, W, to the sealant thickness, T. If the sealant width is too small, high stresses build at the bonding area between the sealant and the concrete. This can lead to the sealant losing adhesion and pulling away. Excess stress can also build up if the sealant thickness is too great.

Manufacturers of sealant material typically recommend that their sealant surface be recessed (the value R in the figure) below the pavement surface. Many sealants are not resistant to traffic wear, especially silicones. If this recess is not provided, traffic may pull the sealant away from the edge of the joint, causing it to fail.

The equation given in this slide can be used to estimate the amount of horizontal movement a sealant can expect to incur for a given pavement. As you can see on page 3-11 of your handbook, C represents the subbase/slab friction, L the pavement joint spacing, alpha the thermal coefficient of contraction, and T the expected temperature range.

Page 3-10 Figure 3-4
Page 3-11 Equation

Hot-Applied Sealant Materials

Sealant Material	Example Products	Specification
Rubberized asphalt	Crafco RS 221, Koch 9005, Meadows Hi-Spec	ASTM D 3405
Low-modulus rubberized asphalt	Meadows Sof-Seal, Koch 9030, Crafco RS 231	State-modified ASTM D 3405
PVC coal tar	Crafco SS 444	ASTM D 3406

Session 3

Hot-Applied Sealant Materials
Slide #28

Several sealant materials are asphalt based, and must be heated before placing them in the joint reservoir. Rubber and polymers are commonly melted and then mixed with asphalt, creating rubberized asphalt that is more elastic and less sticky than plain asphalt. By using a softer grade of asphalt and additional polymers, low-modulus rubberized asphalt is created, making for a more elastic sealant. PVC coal tar sealant is much less commonly used. It is resistant to spilled fuel, requires a different heating process, and contains some hazardous materials.

Certain physical properties are required of each sealant to meet the ASTM specifications noted. These properties relate to the elasticity, adhesive ability, and weathering resistance of the sealant.

Page 3-8 Table 3-2

Cold-Applied Sealant Materials

Sealant Material	Example Products	Specification
Self-leveling silicone	Dow 890-SL, Crafco 903	State Specs
Nonself-leveling silicone	Dow 888, Bayer Baysilone 960, Crafco 902	State Specs
Polysulfide & Polyurethane	Mameco Vulkem 300 SSL, Sikaflex, Burke U-Seal	Fed SS-S-200-E

Session 3

Cold-Applied Sealant Material
Slide #29

Several cold-applied sealants are on the market today for resealing joints in concrete pavement. These include silicones, polysulfides, and polyurethanes. The most commonly used cold-applied sealants are silicone based. Some silicones are fluid enough to flow into and fill the joint, whereas other nonself-leveling silicone sealants must be formed into the joint using a tooling device.

There is one other type of material that is available for resealing joints, and that is preformed neoprene compression seal. Although this type of seal was not evaluated in the SHRP H-106 study, there are some experimental compression seals being tested at the SPS-4 supplemental joint seal test sites which we discussed in session 2. Some examples of these seals are provided in table 3-2 of your handbook. The important item about the use of compression seals in resealing operations is that the recipient pavement have joints with consistent widths and very few spalls.

Question: What are the types of sealants used in your State? What specific products are used?

Page 3-8 Table 3-2

Backer Rod Materials

Backer Material	Compatibility
Cross-linked, extruded, closed-cell polyethylene	Most hot- and cold-applied sealants
Extruded, closed-cell polyethylene	Most cold-applied sealants
Extruded polyolefin	Most cold-applied sealants

Session 3

Backer Rod Materials
Slide #30

Backer rod is typically inserted into a joint prior to resealing to maintain the sealant at the required thickness and depth, and to keep it from sinking into the reservoir. Three types of backer rod are commonly used.

Cross-linked, extruded, closed-cell polyethylene rod is heat resistant, and is generally used to support sealants that are hot-applied.

Extruded, closed-cell polyethylene foam rod is not heat resistant. It is used to support cold-applied sealants.

Extruded polyolefin foam rod fills irregular joints well, and should be used when joint walls are slightly spalled, or the joints are irregular in width.

Page 3-9 Table 3-3

Designing Reservoir Dimensions

- Shape factor
- Joint width
- Joint depth

Session 3

Designing Reservoir Dimensions
Slide #31

The dimensions of the sealant and the sealant reservoir can greatly affect the performance of a sealant material. These critical dimensions include the joint width and depth, and the sealant width and thickness. The ratio of the sealant width to the sealant thickness, (W:T) is called the "shape factor."

Recommended Shape Factors

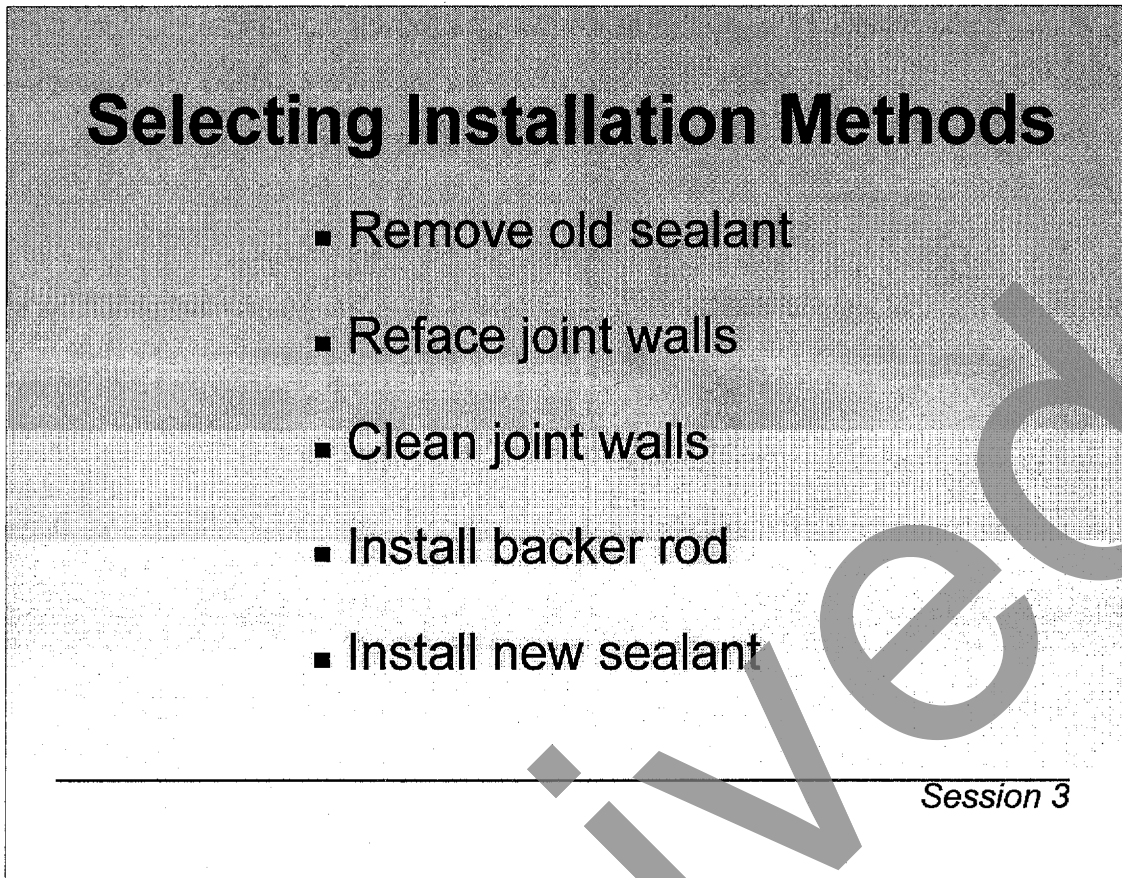
Material Type	Shape Factor (W:T)
Rubberized asphalt	1:1
Silicone	2:1
PVC coal tar	1:2
Polysulfide	1:1
Polyurethane	1:1

Session 3

Recommended Shape Factors
Slide #32

In this slide, we see recommended shape factors for various field-molded sealants. For rubberized asphalt, polysulfide, and polyurethane sealants, the recommended shape factor is 1:1. For silicone, it is 2:1, and for PVC coal tar, it is 1:2.

Page 3-11



Selecting Installation Methods

Slide #33

In addition to materials and joint dimensions, the methods for installation must be chosen during the planning process. The performance of a resealing job is as much a function of the preparation and installation procedures as it is of materials and joint design. Procedures must be selected for the following operations:

- Removing old sealant from the joint.
- Refacing or resawing the joint walls.
- Cleaning the joint walls.
- Inserting backer rod.
- Installing the new sealant.

Because there are various ways of accomplishing each of these tasks, there are many comprehensive installation methods available. Some common methods are described on pages 3-13 and 3-14, and are illustrated in table 3-5. Among these are the four methods studied in the H-106 experiment:

- Saw-and-recess.
- Saw-and-overband.
- Plow-and-overband.
- Saw-and-flush.

Pages 3-13 & 3-14   Table 3-5

Cost-Effectiveness

- Best use of available funds
  - Materials
  - Equipment
  - Installation procedures

Session 3

Cost-Effectiveness
Slide #34

It is critical that the cost-effectiveness of each material and procedure be considered in the selection process. Cost-effective resealing means that the materials and methods chosen will provide the best use of available funds for the particular project.

One material may be inexpensive, but may not last very long. Another material may perform well for more than 10 years, but the pavement may be scheduled for replacement in 5 years. One installation procedure will be quick and easy, but its use may cause the seal to fail quickly. These are some of the factors that must be considered when determining cost-effectiveness.

Cost-Effectiveness Example
Pages 3-15 thru 3-18

Installation

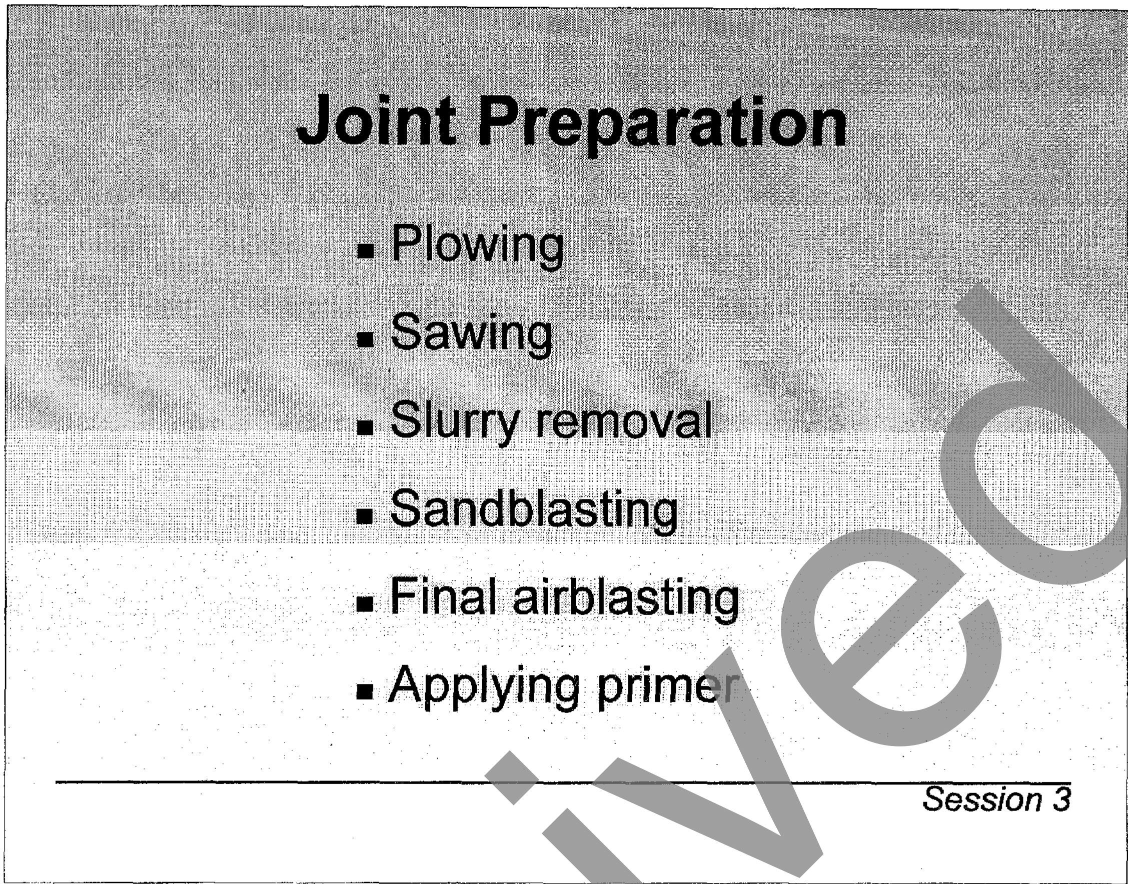
- Joint preparation
- Material preparation and application

Session 3

Installation
Slide #35

Now, let's continue on to a discussion of the steps involved in resealing joints in concrete pavements. The resealing operation involves two processes: preparing the joints and preparing and applying the sealant material. Sealant installation must be completed immediately after the joints have been prepared to achieve good results.

Page 3-19



Joint Preparation
Slide #36

To prepare joints for sealant installation, several processes must be completed. These include:

- Plowing the old sealant from the joint.
- Resawing the joint edges.
- Removing slurry from the sawing operation.
- Sandblasting the joint walls.
- Airblasting sand and debris from the joint, and
- Applying primer to the joint sidewalls, if necessary.

Question: What are the current practices in this State and the surrounding areas?

Page 3-19

Rear Mounted Plow Blade

Rear-Mounted Plow Blade
Slide #37

Joint plowing removes old sealant from joints so that the sealant doesn't "gum-up" the saw blades. In recent usage, plow blades have been attached to the front of skid loaders, at the middle of tractors, and at the rear of tractors, as shown here.

The blades used should be rectangular, non-tapered, and tipped with carbide, similar to what's shown here. The blade width should either be smaller than the narrowest joint width at the time of plowing, or blades of many widths should be kept available.

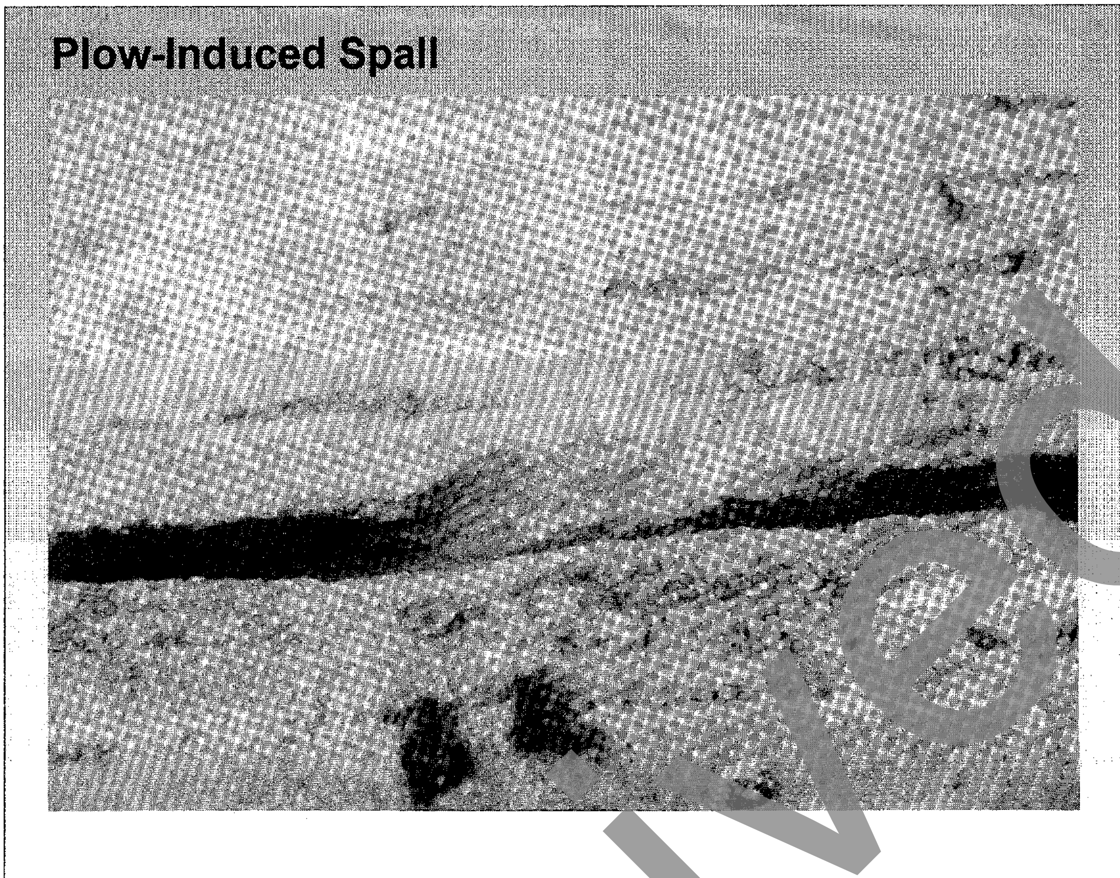
To ensure good results, the plowing equipment must be able to force the blade against each joint sidewall and the blade's height must be controllable.

Page 3-20 Figure 3-5 (similar photo)

Removal of Old Sealant Using Hooks and Knives

Removal of Old Sealant Using Hooks and Knives
Slide #38

If plowing does not precede the sawing operation, hooks and knives may be needed to clear large debris from the sawed joints prior to airblasting or waterblasting.



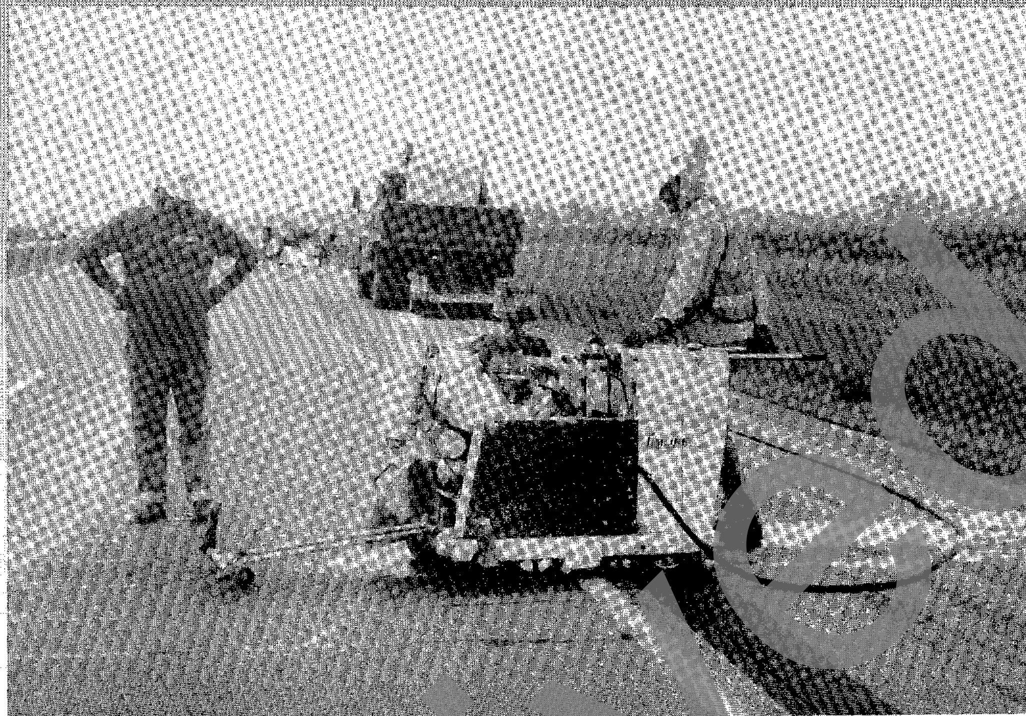
Plow-Induced Spall
Slide #39

When done prior to sawing operations, it is important that joint plowing removes enough sealant (95 percent or more) to allow sawing to progress smoothly. When joint plowing is done solely, without sawing operations, it is important that plows remove enough sealant and that sandblasting operations completely remove any sealant that remains.

In both cases, the plow must not spall or damage the sidewalls of the joints, or this may lead to premature sealant failure. Shown here is an example of a spall created by plowing out old sealant. Such spalls can result from plow blades that are too wide, excess force on the sidewall, or plow blades that are not deep enough in the joint.

Page 3-21

Concrete Saw

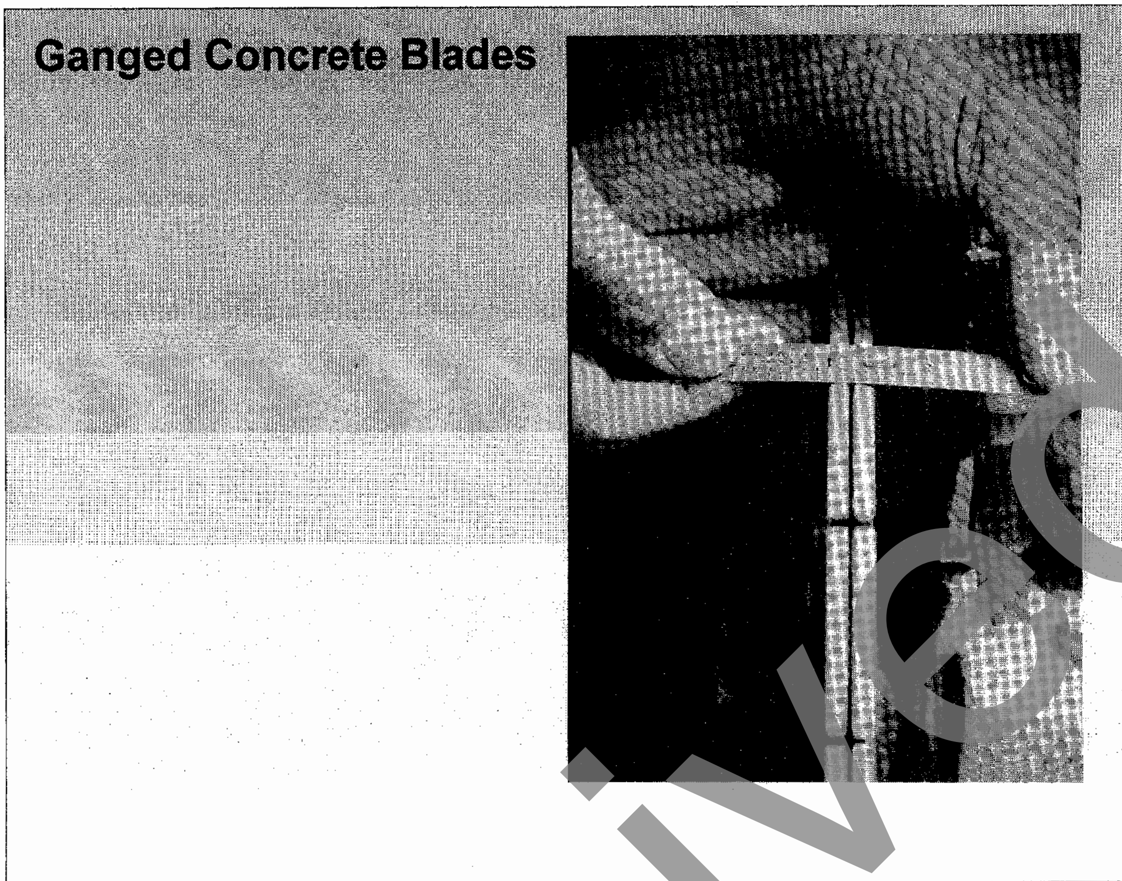


Concrete Saw
Slide #40

The purpose of resawing a sealant reservoir is to provide a freshly-sawed surface to which sealant can bond. Unless the joint width is too narrow, a minimum amount of concrete should be removed (about 1 to 2 mm on both sides).

The equipment used for resawing sealant reservoirs should be water-cooled 25- to 50-kW saws. The saw in this slide is a 50-kW concrete saw. Notice the guide on the front of the saw to assist in following the joint.

Page 3-22 thru 3-24



Ganged Concrete Blades
Slide #41

Time and expense can be saved by making one sawing pass for each joint, so full-width or "ganged" diamond-tipped blades designed for cutting hardened concrete are recommended. The saw in the previous slide used diamond-tipped blades 305 mm in diameter and 5 mm thick, as seen here. A spacer was inserted between the blades to achieve a 13-mm cutting width.

Page 3-22 thru 3-24

Joint Resawing Results

- Uniform width and depth
- Old sealant completely removed
- Freshly exposed concrete
- No new spalling or microcracking

Session 3

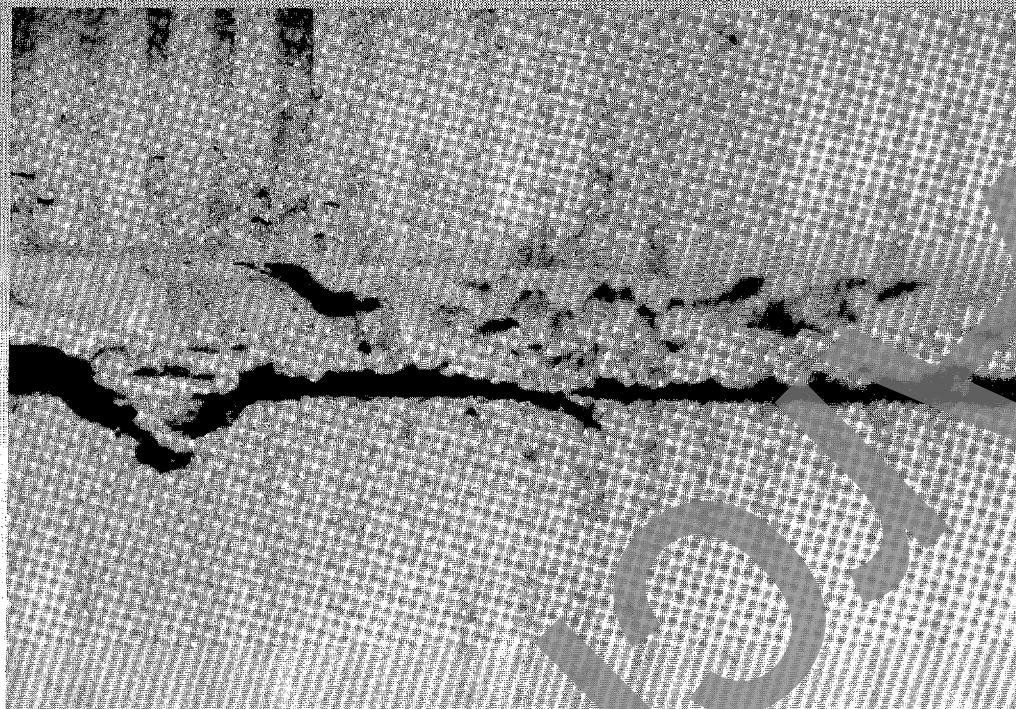
Joint Resawing Results
Slide #42

Results of the resawing operation should include:

- The reservoir width and depth should be uniform and within the specified range.
- Old sealant should be completely removed, leaving freshly exposed concrete on the joint walls.
- The saw should not produce any new spalls along the joint edges.

Pages 3-22 & 3-23

Slurry from Sawing Operation



Slurry From Sawing Operation
Slide #43

The wet-sawing operation leaves behind a slurry of old sealant, concrete dust, debris, and water. If this slurry is allowed to dry in the joint, it becomes difficult to remove, and any dust that remains on the joint walls will prevent the new sealant from sticking. Therefore, this sawing slurry must be removed immediately after sawing.

Page 3-24

Initial Joint Cleaning Equipment

- Oil- and moisture-free compressed air
- Minimum 620 kPa at 4.3 m^3/min
- Balanced nozzle with shut-off valve
- Face shield, ear protectors

Session 3

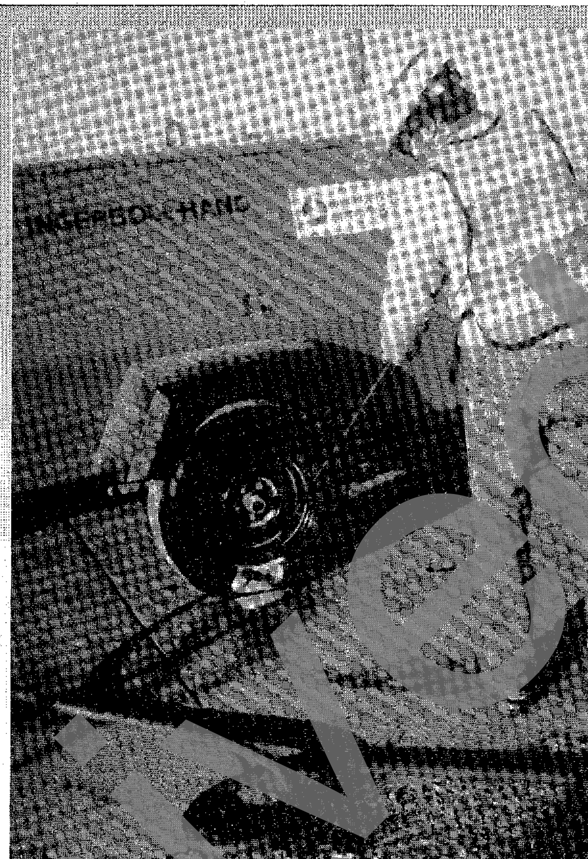
Initial Joint Cleaning Equipment
Slide #44

Methods used for removing this slurry include flushing with water, waterblasting, airblasting, and removing large debris by hand. Good success has been achieved using airblasting or waterblasting equipment to remove the slurry, if it is done immediately after sawing.

Airblasting equipment must supply oil-free and moisture-free air at a minimum pressure of 620 kPa. A balance nozzle with a shut-off valve is useful and a face-shield and ear protectors are recommended.

Pages 3-24 thru 3-26

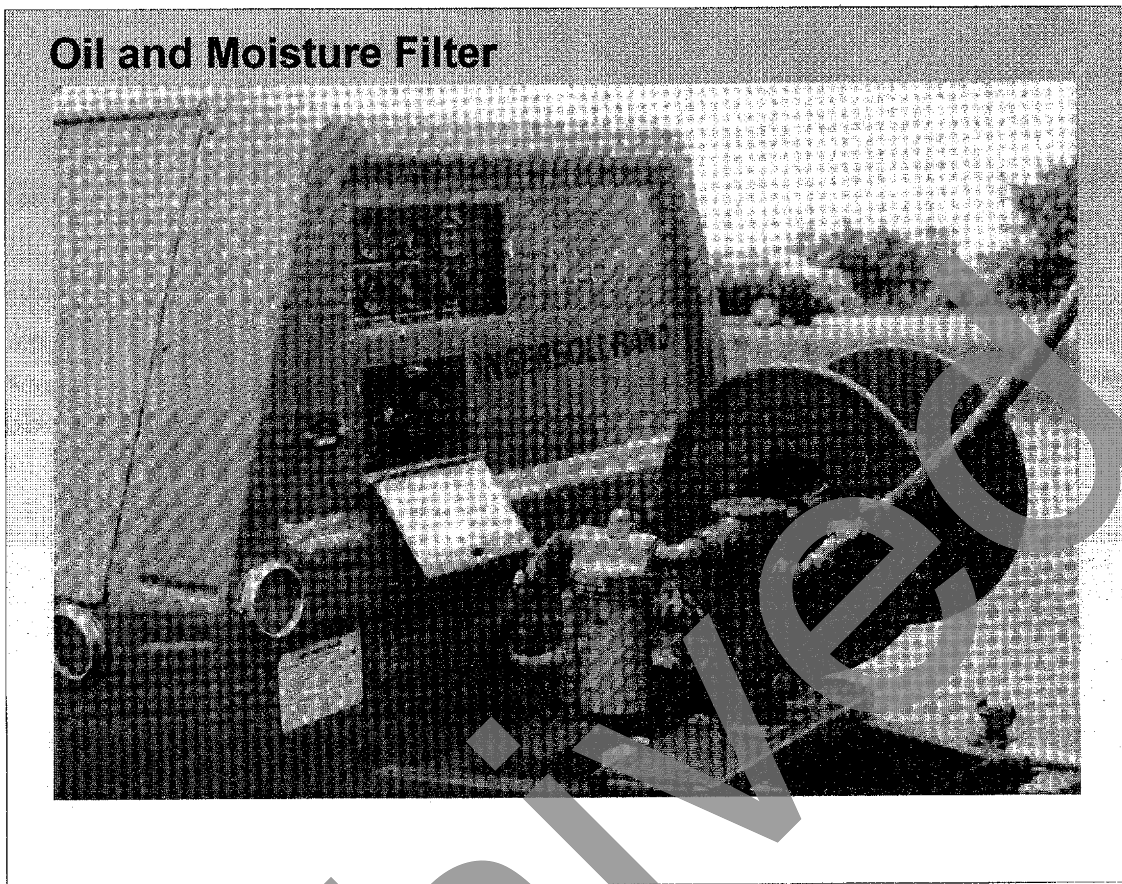
Oil in Airstream



Oil in Airstream
Slide #45

Most modern compressors used by maintenance crews add oil to the airstream to help lubricate pneumatic equipment. Such compressors must be modified to remove the oil, or the concrete joints will be severely contaminated. This slide shows the oil distributed on a tire after a few seconds of exposure to a stream of unfiltered compressed air.

Page 3-26



Oil and Moisture Filter
Slide #46

Even with the oil supply shut off, oil and moisture filters are required to remove the oil and water from the airstream of most compressors. These filters, like the blue filter shown in this slide, can trap a fair amount of contaminants. Sometimes the inside of air hoses becomes coated with oil and the hoses must be cleaned or replaced before cleaning joints in concrete pavements.

Question: Have any of you experienced air contamination problems?

Page 3-26

Initial Joint Cleaning Results

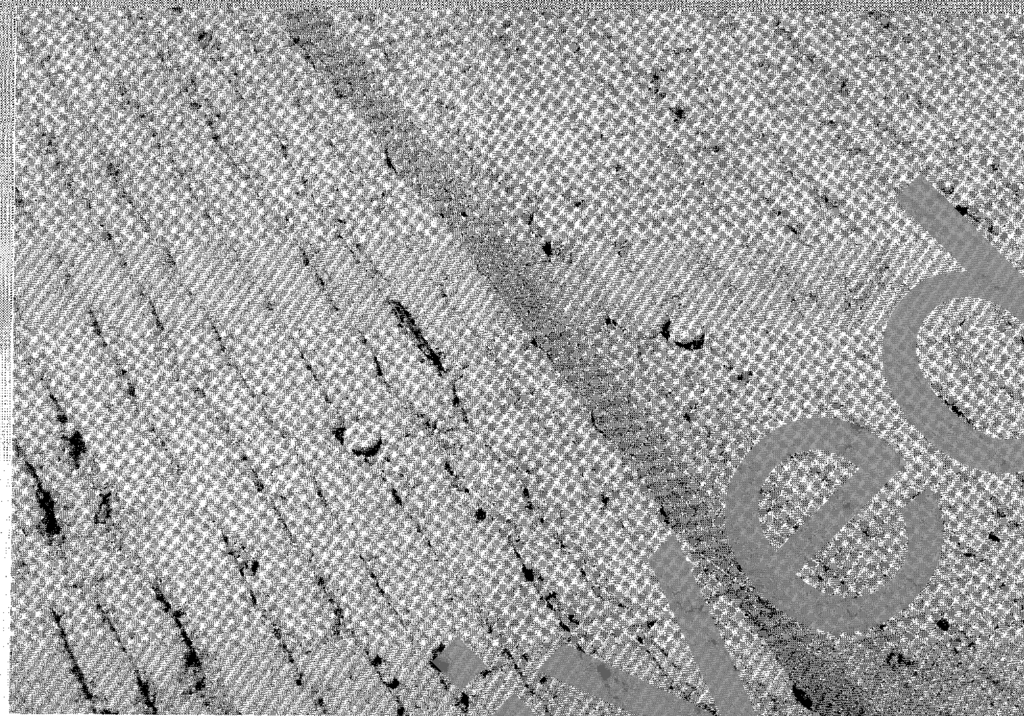
- Loose sealant and slurry removed from joint reservoir
- Debris removed from surrounding pavement surface

Session 3

Initial Joint Cleaning Results
Slide #47

Following initial joint cleaning, no loose sealant or slurry should remain in the joint reservoir. Also, to keep from recontaminating the joints, sawing and cleaning debris should be removed from the surrounding pavement surface by a vacuum or by blowing it to the pavement edge with compressed air.

Joint After Sawing & Initial Cleaning



Joint After Sawing and Initial Cleaning
Slide #48

After sawing and initial cleaning using compressed air, joint reservoirs should look similar to this one. The slurry has been removed, and the joint walls and pavement surface are nearly clean and ready for abrasive blasting.

Abrasive Blasting Equipment

- Sand, slag, or other abrasive
- Compressed air $\geq$ 620 kPa at 4.3 m^3/min
- Venturi nozzle $\leq$ 6 mm
- Continuous loading unit
- Remote shut-off valves, protective helmets, fresh-air supply, and protective clothing

Session 3

Abrasive Blasting Equipment
Slide #49

Abrasive blasting equipment is used to force a stream of air and abrasive particles against the concrete joint walls, removing all slurry dust, old sealant, and other contaminants, and leaving a roughened surface to which sealant can bond. Typically sand or slag are used as abrasive particles.

The air supply for the equipment must supply air with more than 620 kPa at 4.3 m^3/min. A 5- to 6-mm diameter opening, tungsten carbide or ceramic venturi nozzle works well for cleaning joint walls. Equipment that can continue operation while loading abrasive will save time. Several safety items are available with blasting units, including remote shut-off switches, protective helmets, fresh air supplies and protective clothing.

Pages 3-24 & 3-25

Abrasive Blasting Equipment and Accessories

Abrasive Blasting Equipment and Accessories
Slide #50

This slide shows an "alien" with an abrasive blasting unit and accessory equipment, including protective clothing, an air-fed helmet, and a remote shut-off switch. Silicosis is known to occur in workers overexposed to sandblasting dust. Therefore, all protective devices must be present and functional to increase worker safety.

Abrasive Blasting Procedures

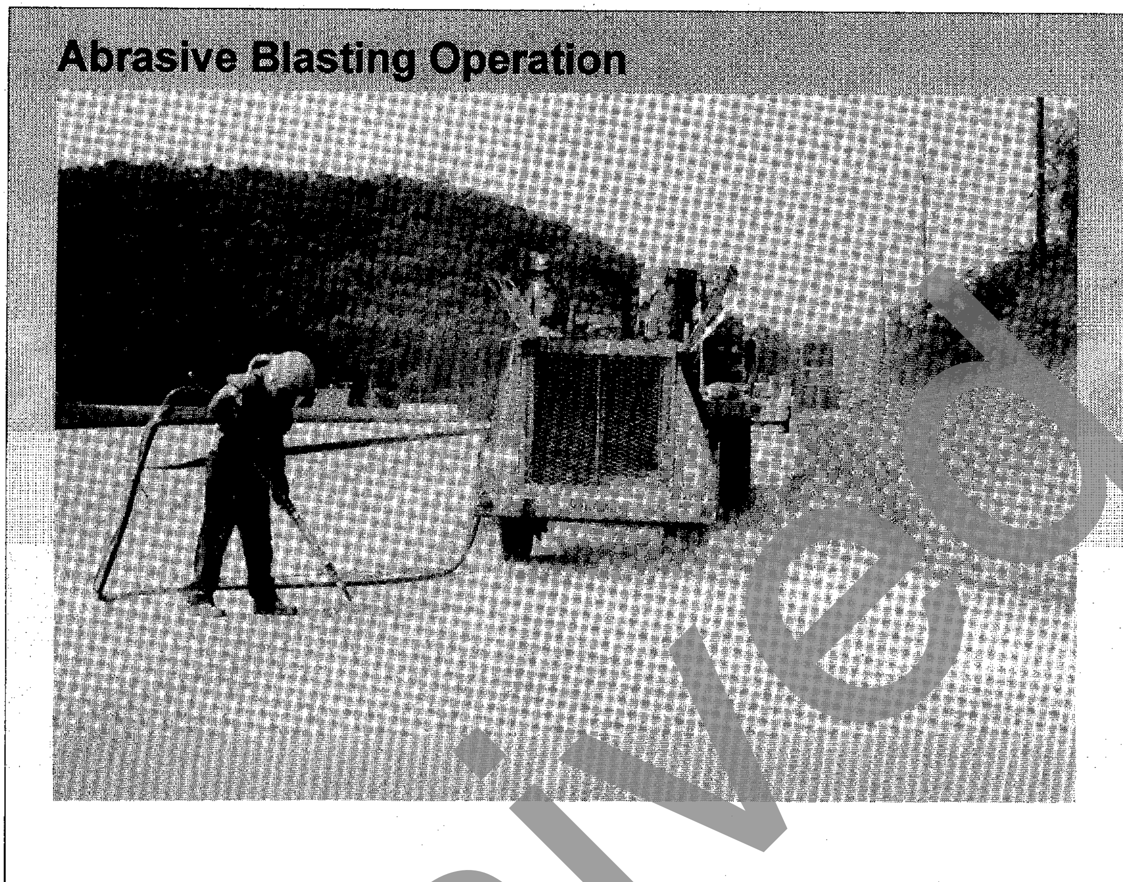
- Hold nozzle $\leq$ 50 mm from surface
- At least one pass for each joint face
- Clean the entire length uniformly
- Remove old sealant with repeat passes

Session 3

Abrasive Blasting Procedures
Slide #51

To achieve adequate results, the abrasive blasting nozzle must be held no more than 50 mm from the pavement surface. At least one pass must be made over each joint wall holding the nozzle at a 60 degree angle with the pavement surface. The entire length of the joint must be cleaned uniformly, and any remaining sealant or contaminants must be removed with repeated passes.

Page 3-25

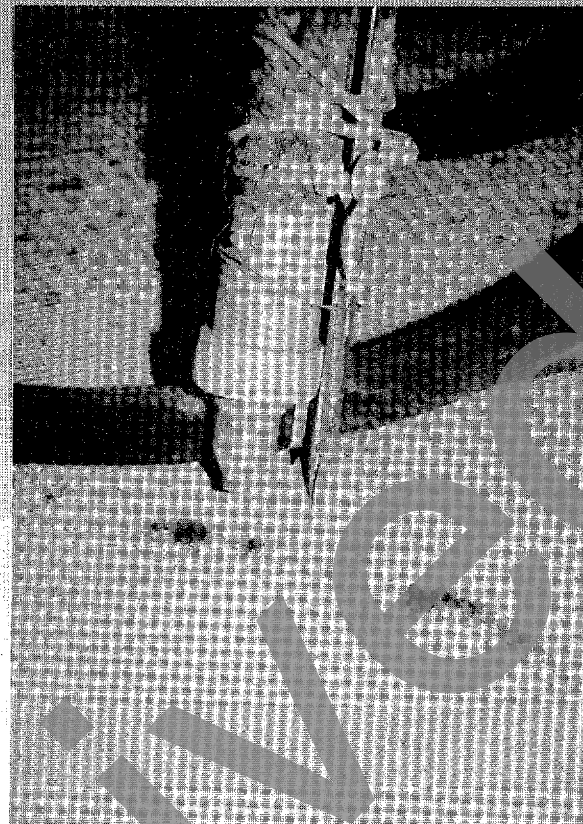


Abrasive Blasting Operation
Slide #52

To reduce operator fatigue, a piece of wood or angle iron can be attached to the blasting hose, allowing the operator to stand erect while blasting the joints. Even with this attachment it is difficult to keep the nozzle at the proper angle and height and directed at the joint wall.

Pages 3-24 & 3-25   Figure 3-6

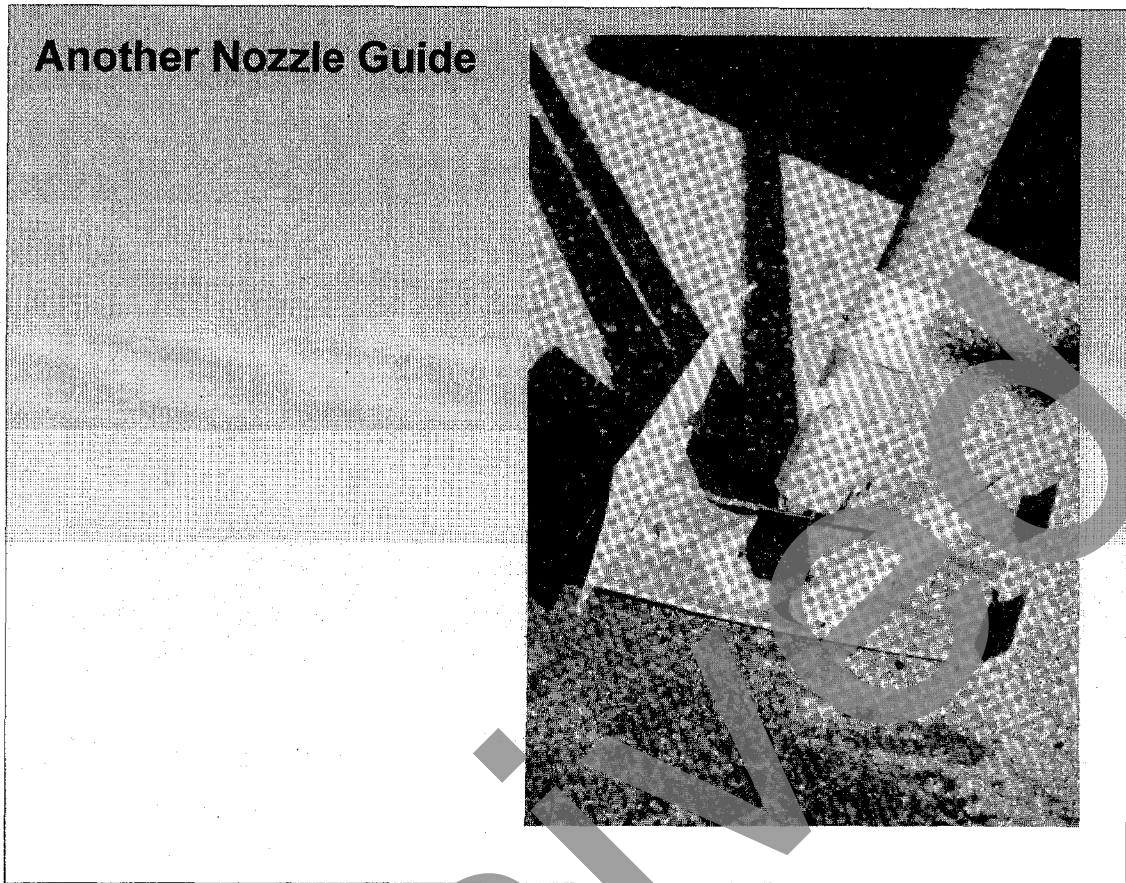
Guide for Nozzle



Guide for Nozzle
Slide #53

Extending a piece of sharpened angle iron past the nozzle tip can help keep the nozzle directed at the joint wall and elevated 50 mm above the pavement surface.

Page 3-25

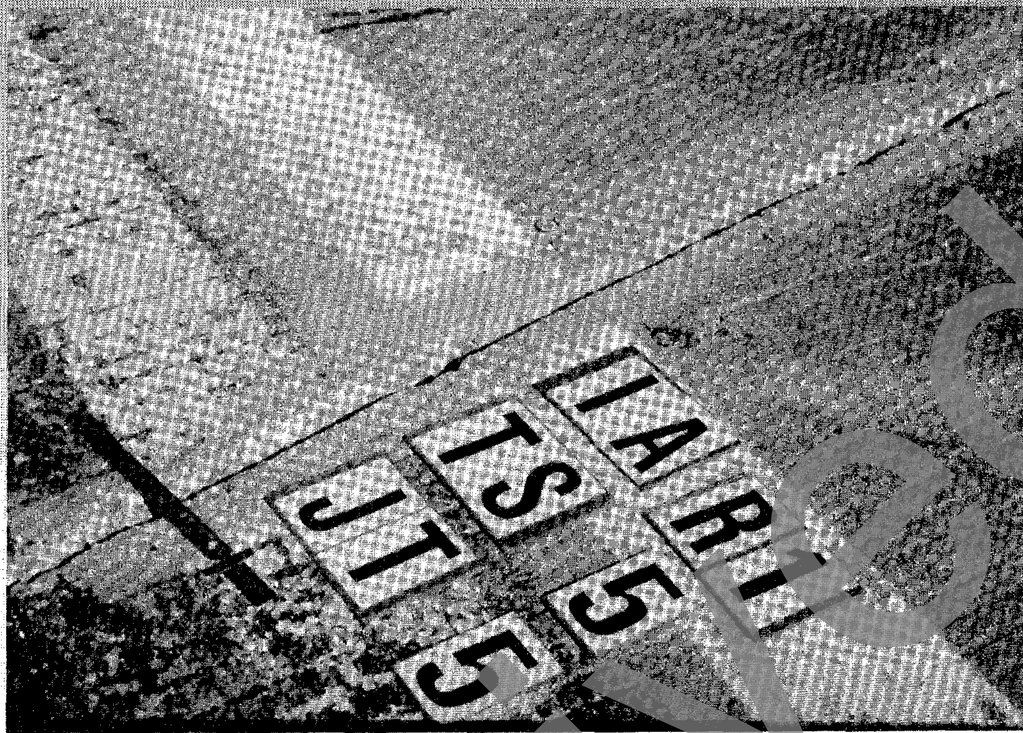


Another Nozzle Guide
Slide #54

Another type of guide, shown here, gives control of the angle of the nozzle as well as nozzle height and position. A bolt through the plate keeps the plate centered over the joint, and a shield is attached to the plate to protect workers and passing vehicles. Roller guides with dual nozzles have also been used successfully on large contract projects.

Page 3-25

Joint After Abrasive Blasting



Joint After Abrasive Blasting
Slide #55

Here, we see a joint immediately after abrasive blasting. Notice the freshly exposed concrete in the joint and on the pavement surface near the joint.

Abrasive blasting is only for areas that are to be in contact with sealant. For recessed sealant, abrasive blasting is only needed along the top 40 mm of the joint reservoir. Since this joint was to receive an overbanded seal, the pavement surface was also abrasive blasted to a width of about 100 mm.

Abrasive blasting must completely remove all dried sawing slurry, dirt, old sealant, and other contaminants, leaving freshly exposed concrete along both joint walls. Until this is achieved, the joint must receive additional abrasive blasting, otherwise seal failure may result.

Page 3-24

Airblasting Equipment

- Oil- and moisture-free compressed air
- Minimum 620 kPa at 4.3 m^3/min
- Minimum 20 mm ID hose
- Balanced nozzle with shut-off valve
- Face shield, ear protectors

Session 3

Airblasting Equipment
Slide #56

After joints have been cleaned with abrasive, the sand and dust must be completely removed from the joints and surrounding pavement. An air compressor should be used for this operation that has the same characteristics as that used for initial slurry removal. It is even more critical that this air supply be completely free from oil and moisture, and that the volume and velocity of the air stream be at least 620 kPa at 4.3 m^3/min.

Page 3-26

Example of Airblasting Procedures

Example of Airblasting Procedures
Slide #57

Here we see a highway worker removing debris from a joint using compressed air. He is keeping the nozzle 25 to 50 mm from the pavement surface, and is blowing debris in front of him so as to not recontaminate the joints.

Additional passes may be necessary to completely remove all dust, dirt and sand. As each joint is cleaned, debris on the surrounding pavement must also be vacuumed or blown away, taking care not to recontaminate the joints.

Notice that for eye and ear protection, he is wearing a face mask and ear plugs.

Page 3-27

Final Airblasting Results

- Removes all dust, dirt, and sand
- Clears debris from adjacent pavement
- Does not introduce oil or moisture
- Following airblasting the joint is clean and dry

Session 3

Final Airblasting Results
Slide #58

Because airblasting is the final cleaning procedure prior to installing joint sealant, the result of this operation will greatly influence how well a sealant bonds to the concrete. After airblasting, all dust, dirt, and sand must be completely removed from the joint and from the surrounding pavement surface. Oil or moisture, which can keep sealant from bonding well, must not be introduced to the joints by the airstream. Following airblasting, the joint must be completely clean and dry.

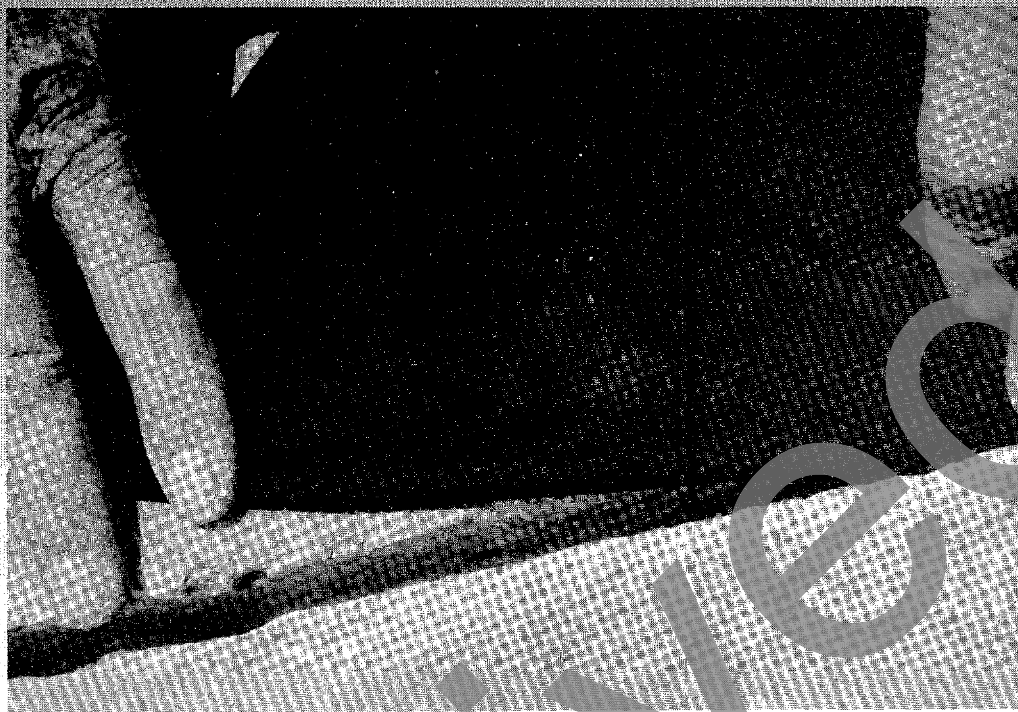
Page 3-26

Black-Cloth Test Procedure

Black-Cloth Test Procedure
Slide #59

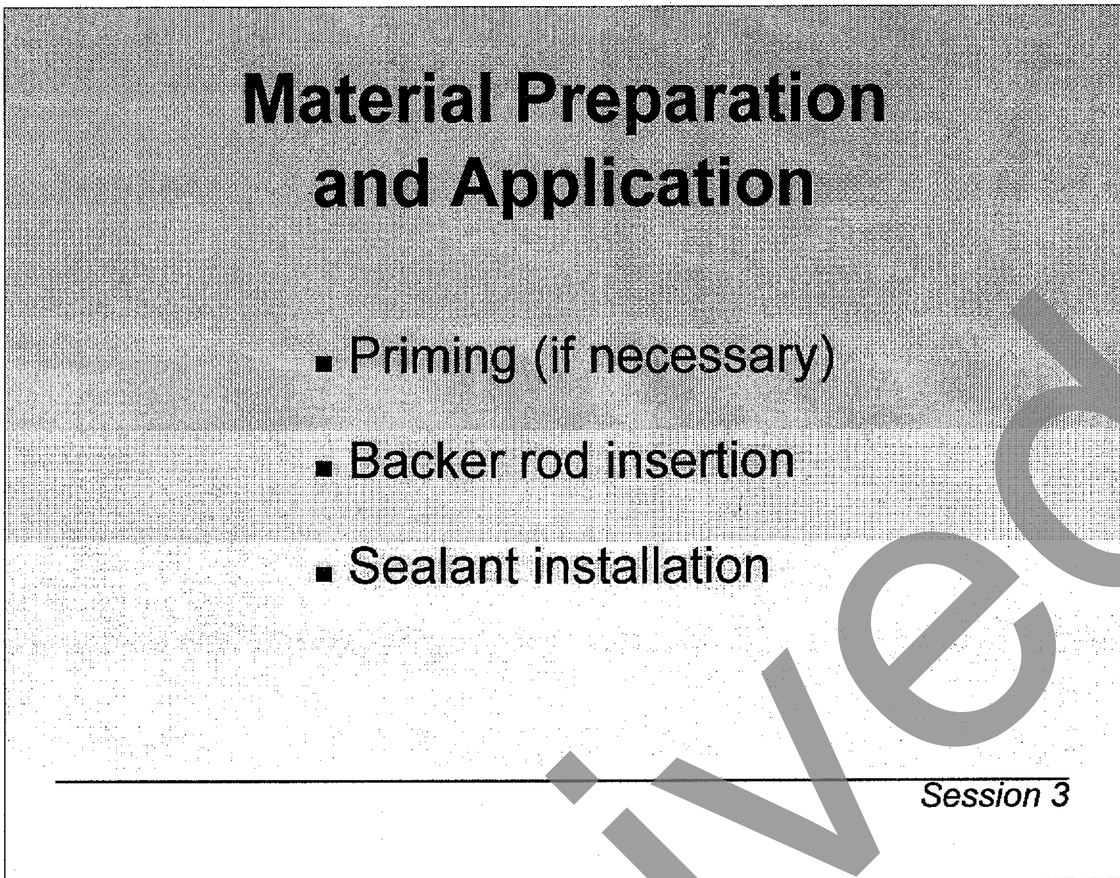
Visual inspection is the only way to ensure that each joint is clean and dry. Old sealant can generally be seen fairly well during inspection, but dust on the joint walls is difficult to detect. One method of detecting this dust is to run one's finger along the joint wall and observe if any dust particles stuck to it. Another procedure is to wrap a piece of black cloth around a piece of backer rod or a finger, and run it through the joint.

Black-Cloth Test Results



Black-Cloth Test Result
Slide #60

Any dust that is picked up is more easily observed with this method.



Material Preparation and Application
Slide #61

After final airblasting and before any backer rod or sealant is placed, it may be recommended by the sealant manufacturer that primer material be applied to the joint sidewalls. Primer acts as an adhesive interface between the joint sidewall and the sealant, and may be applied using a brush or spray equipment.

Generally, the material preparation and application phase consists of backer rod insertion, followed by cold- or hot-applied sealant installation. In all resealing operations, it is critical that airblasting, priming, backer rod insertion, and sealant installation follow the abrasive blasting operation as quickly as possible.

Page 3-28

Adjustable Insertion Tool

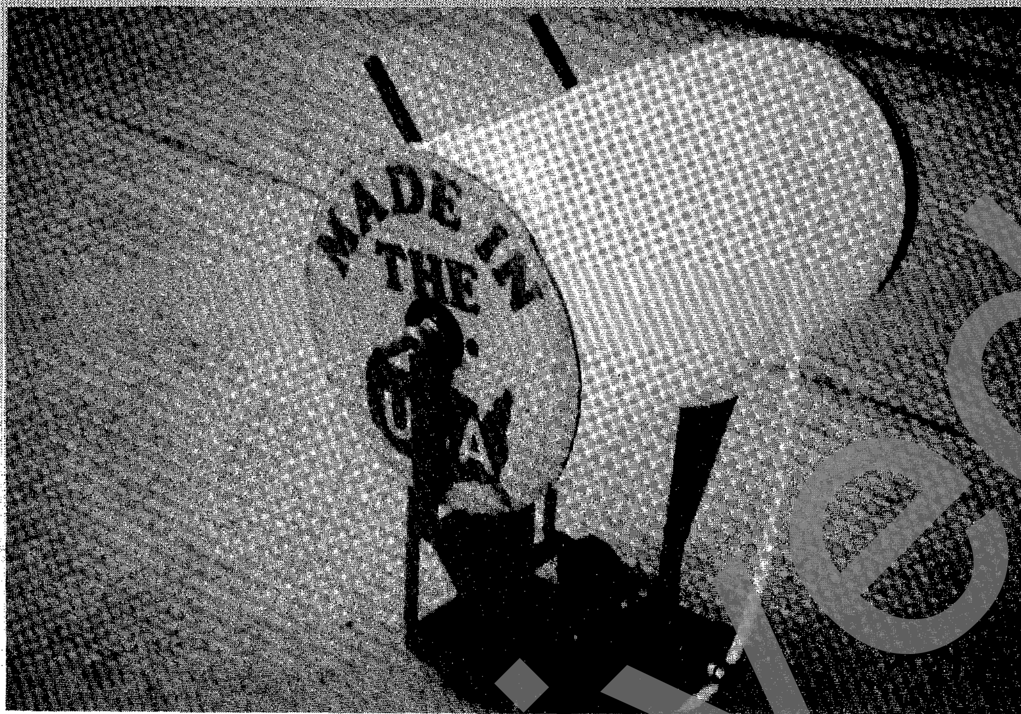
Adjustable Insertion Tool
Slide #62

Backer rod must be inserted into the joint reservoir to keep the sealant at the correct thickness and depth. Several tools are used for inserting backer rod. Most are fabricated by maintenance crews or sealing contractors.

The insertion tools are generally discs with rounded edges that insert easily into a joint reservoir. Support wheels are used to maintain the correct backer rod depth. Lightweight, adjustable tools, like this one, make insertion quick and easy.

Page 3-29 Figure 3-7

Automated, Self-Guided Insertion Tool



Automated, Self-Guided Insertion Tool
Slide #63

In addition to manual insertion tools, there are automated, self-guided insertion devices available that are most suitable for use in continuous, uniformly sized joints. This is one such device.

Page 3-29

Inserting Backer Rod Into Joint

Inserting Backer Rod Into Joint
Slide #64

Since joint widths vary, depending on sawing accuracy and the presence of spalls, a variety of diameters of backer rod should be available to meet the needs of the project.

When installing backer rod, one end of the rod is typically inserted into a joint at the pavement edge and the rod is laid across the length of the joint to be resealed, as seen in this slide. The insertion tool is rolled across the rod, pushing it into the joint. If the correct depth is not achieved in the first pass, a second pass with the insertion tool will be required. Then, if necessary, the rod is trimmed at each end to produce a tight seal.

Upon completion, the top of the backer rod should be at the design depth, with less than 2 mm variation. Rod must be large enough in diameter so that gaps are not formed between it and the joint sidewalls. It must be tight enough in the joint that the rod cannot slip down into the joint when sealant is placed on it, yet it cannot be so tight that the rod is torn during rod insertion. No gaps should be allowed between rod segments or at joint intersections. If the rod is stretched during insertion, it may shrink before sealant installation, causing sealant to leak through the gaps and resulting in seal failure.

Pages 3-28 thru 3-30

Hot-Applied Sealant Equipment

- Raises sealant temperature without overheating
- Gives exact temperature control
- Inserts sealant from the bottom of the joint

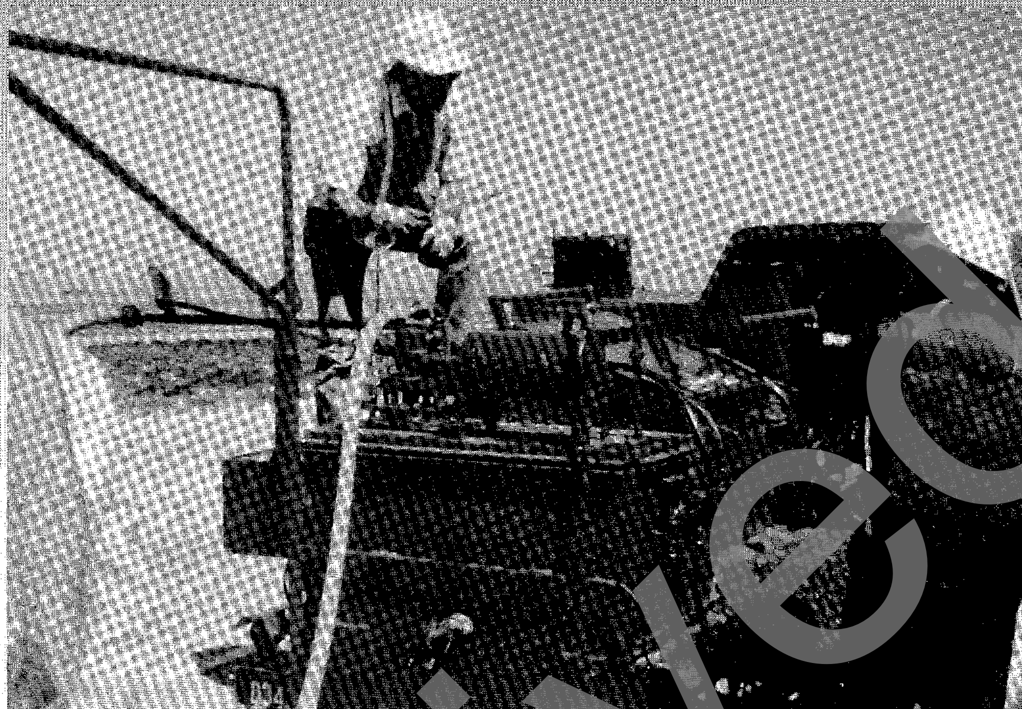
Session 3

Hot-Applied Sealant Equipment
Slide #65

Special equipment is used to install sealant that must be hot when applied. Typically these D-3405 sealants must be 180° to 200° C when applied. The equipment for installation of hot-applied sealants must be able to raise the sealant temperature quickly, without overheating the sealant. It must give exact control of the sealant temperature, and it must allow the operator to insert sealant from the bottom of the sealant reservoir.

Pages 3-31 & 3-32

Example Hot-Applied Sealant Installation Equipment

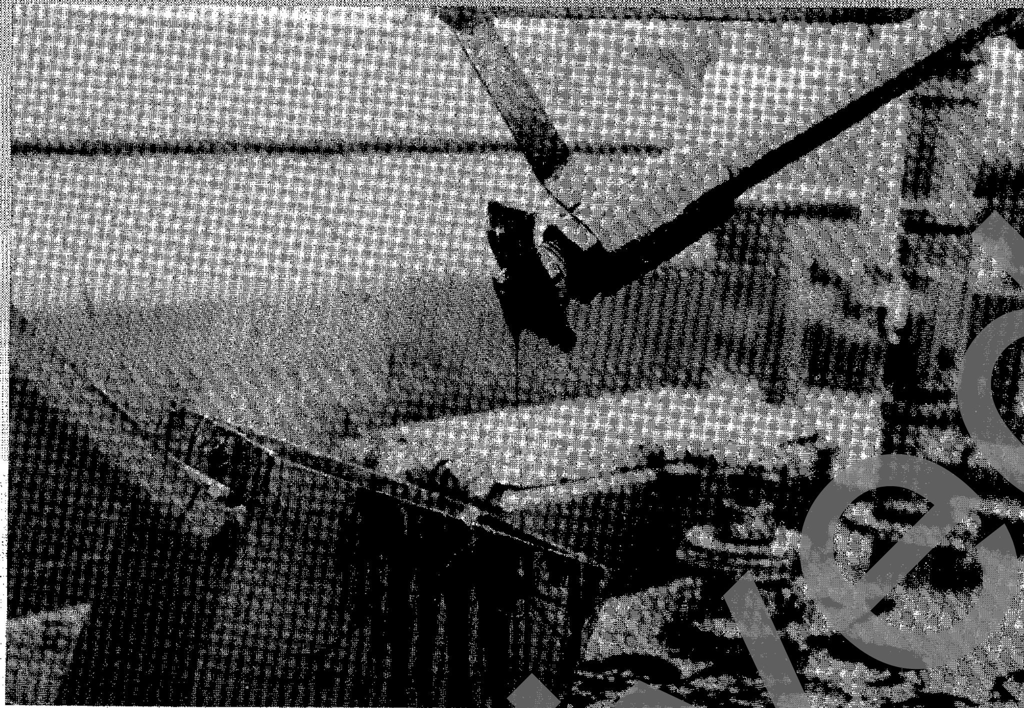


Example Hot-Applied Sealant Installation Equipment
Slide #66

This is a melter/applicator for hot-applied sealants made by one of many manufacturers. The sealant container is surrounded by a second container filled with heated oil. As the oil is heated, so is the sealant. During heating, the sealant is also stirred so that sealant near the container walls is not overheated. Sealant is then pumped through a hose and wand into the joint sealant reservoirs.

The proper equipment must be used for hot-applied sealant installation since overheating a rubberized asphalt sealant can cause the material to break down, changing its flow and adhesive properties.

Page 3-32



Nozzle for Inserting Sealant at Bottom of Reservoir

Nozzle for Inserting Sealant at Bottom of Reservoir
Slide #67

If sealant is poured into a joint reservoir, bubbles can be trapped in the sealant, resulting in possible seal failure. Nozzles have been designed to reduce this bubbling by inserting the sealant into the bottom of the reservoir. If problems with bubbling occur, this type of nozzle may be necessary.

Page 3-33

Installing Hot-Applied Sealant

Installing Hot-Applied Sealant
Slide #68

Applying the sealant at the correct temperature and thickness is critical to its peformance. Also, if the pavement is too cold, the sealant may cool before it can bond well with the joint walls. Therefore, during installation of hot-applied sealants, the pavement must be dry and the air temperature should be above 5° C. Sealant should be installed to the correct thickness and proper depth below the pavement surface.

As illustrated in this slide, sealant should be applied from the bottom up, progressing in a backward motion. Bubbles, sunken sealant, and sealant that remains tacky after the normal setting time must be constantly watched for, and corrected as soon as they are detected.

Sealant temperatures must be within the limits recommended by the manufacturer. Prolonged heating of the sealant (4 to 6 hours) can result in material breakdown and should be avoided.

Page 3-34   Figure 3-8

Silicone Sealant Installation Equipment

- Air-powered pumping system
- Dispensing wand
- Surface tooling equipment

Session 3

Installing Hot-Applied Sealant
Slide #69

Now let's take a look at silicone sealant installation. Preparation procedures for silicone sealant is generally the same as for hot-applied sealants. Unheated silicone sealant is typically pumped into joints by an air-operated pump attached to 208-L drums or to 19-L pails.

A dispensing wand should be used that allows the operator to accurately control the sealant application. If the silicone is not self-leveling, small trowels, pieces of backer rod, or sections of tubing should be used to strike off the sealant surface.

Pages 3-36 thru 3-38

Installation of Silicone Sealant

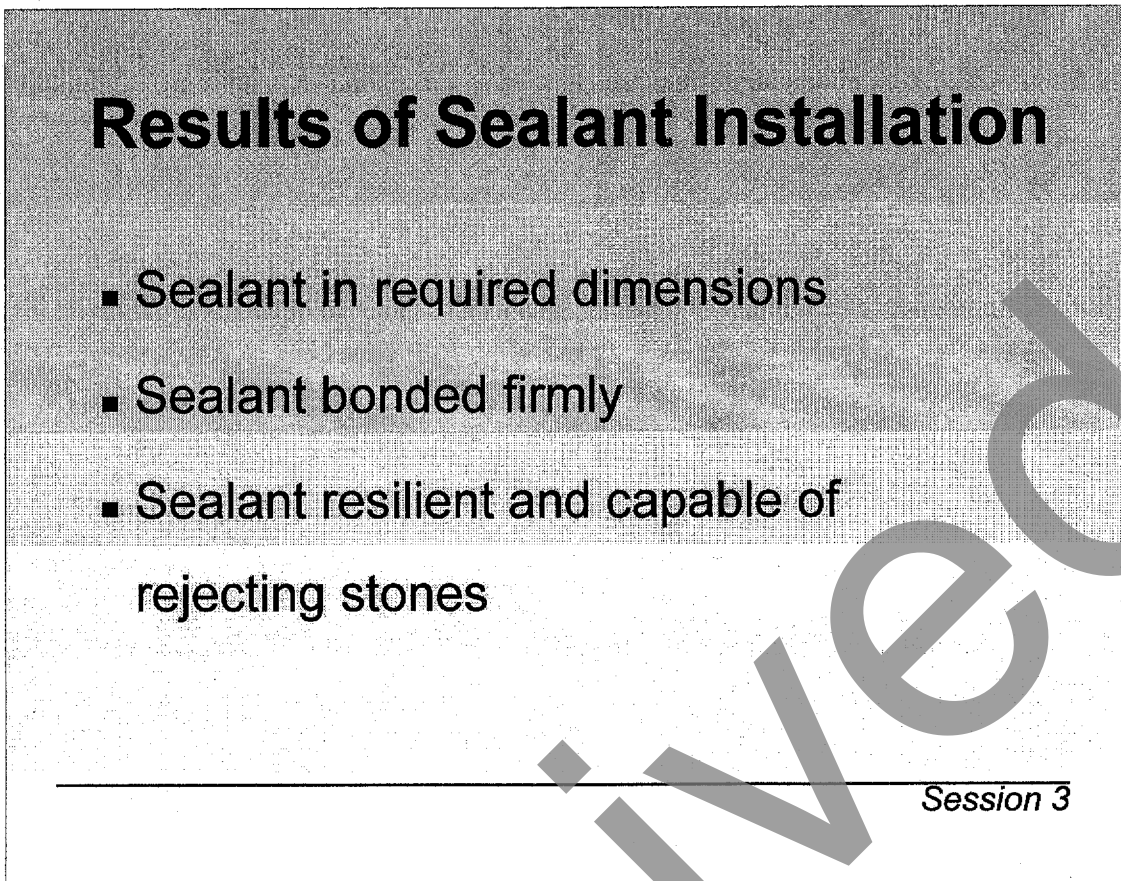
Installation of Silicone Sealant
Slide #70

As with hot-applied sealants, manufacturers of silicone sealant recommend that the air temperature be 5 C and rising. When installing silicone sealant, fill the reservoir from the bottom, keeping the sealant at the proper thickness and recessed at least 5 mm below the pavement surface.

If the sealant requires tooling, use a trowel, backer rod, or other appropriate object to force the sealant around the backer rod, leaving a half-round surface, recessed about 5 mm at the middle. Remove all sealant from the pavement surface before it cures.

The operator in this slide is sealing joints with silicone from a 208-L drum. Many operators use plates or balls on the ends of their applicators to help insert the sealant properly. If the operator walks backwards and the applicator nozzle is angled slightly back toward the operator, he can see the sealant leaving the nozzle and better control the amount of sealant filling the joint.

Page 3-37 Figure 3-9



Results of Sealant Installation
Slide #71

Whether hot-applied sealants or silicone sealants are installed, several results of installation are required of each. First, the sealant must be in the specified dimensions with respect to width and thickness, and recessment or overbanding, whichever the case may be.

The sealant must also be bonded firmly with the joint walls, and it must be flexible, yet resistant to penetration by stones and debris.

If the proper sealant is correctly installed, the pavement will be protected from the entrance of moisture and debris for years to come.

Performance Evaluation

- Visual inspection once a year
- Locate sample section
- Examine seals for failure distresses
  - full-depth adhesion loss
  - full-depth cohesion loss
  - full-depth spalls

Session 3

Performance Evaluation
Slide #72

Upon completion of the installation process, it is useful to periodically examine how the joint seals are performing. A visual inspection at least once a year, not only indicates how the seals are performing, but can be used to project how long they might last. This can be a valuable planning tool.

Evaluations can be performed fairly quickly and accurately by locating a small representative sample section, say 150 m long. The seals within that sample section can be visually examined for segments of failure distress such as:

- full-depth adhesion loss.
- full-depth cohesion loss, and
- full-depth spalls.

Question: Does your State make an effort to regularly monitor joint seal performance?

Pages 3-39 & 3-40

Performance Criteria

- Determine percentage of joint length failed
  - failure>>>allowance of water through joint sealant system
    - excellent (0 - 10% failure)
    - good (11 - 20%)
    - fair (21 - 35%)
    - poor (36 - 50%)
    - very poor or failed (> 50%)
- Compute percentage of joint seal effectiveness
  - %Eff = 100 - %Fail

Session 3

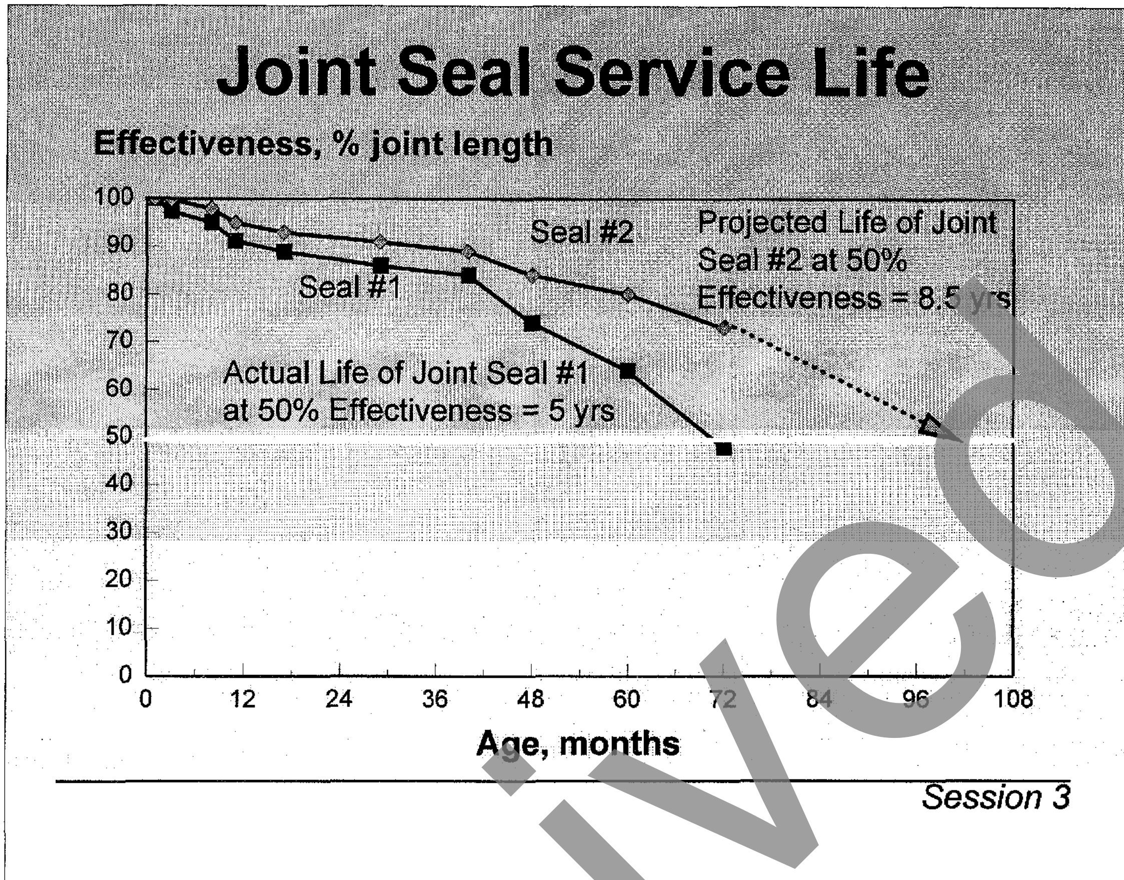
Performance Criteria
Slide #73

The assessment of joint seal performance is typically made on the basis of percentage of joint length failed, with failure meaning that the sealant is letting water enter into the pavement system. The percentage of joint length failed is simply determined by summing the lengths of failed joint seal segments and dividing by the total length of joint seal examined, and then multiplying by 100.

A common guideline for rating joint seal performance is shown here. If the percentage of failure is below 10, then the seal is providing excellent performance. Between 11 and 20 percent, the seal is giving very good performance. Between 21 and 35 percent, the seal is providing fair performance. Between 36 and 50 percent, the seal is giving poor performance. And, above 50 percent, the seal is considered failed.

The effectiveness of a joint seal is simply the opposite of joint seal failure, and is computed by subtracting the percentage of failure from 100 percent. So, if a seal shows 25 percent failure, it is considered to be 75 percent effective.

Page 3-40



Joint Seal Service Life
Slide #74

To estimate how long a particular joint seal treatment will last and subsequently determine it's cost-effectiveness, the performance of the treatment can be plotted over time, as shown in this slide.

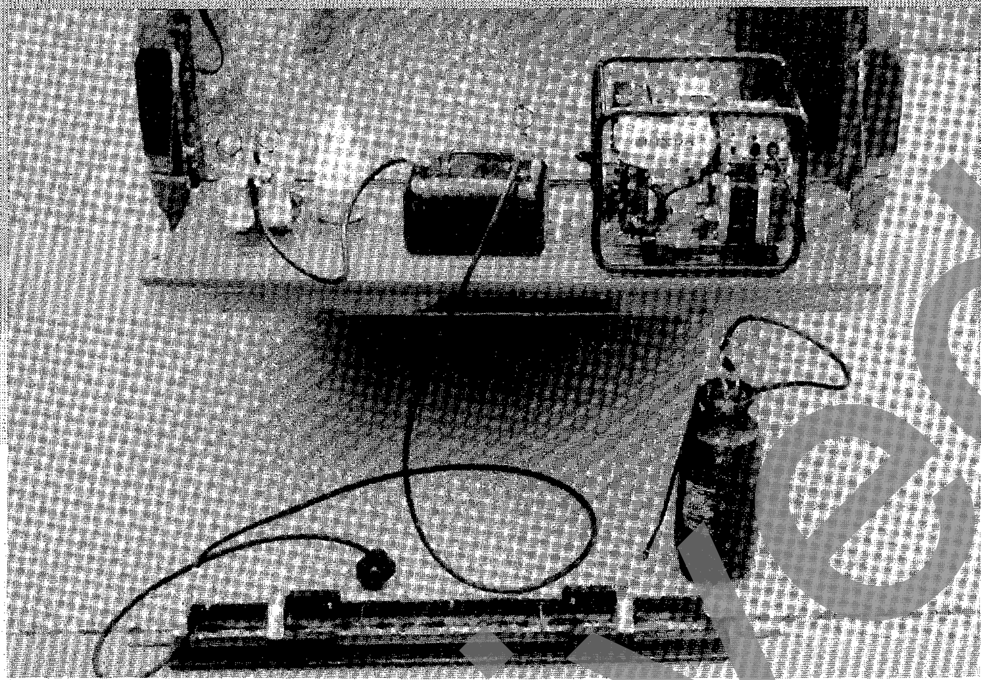
Here, the percent effectiveness of two different seals have been tracked out to 6 yrs (72 months). After 6 yrs, seal # 2 shows about 74 percent effectiveness, whereas seal #1 shows about 49 percent effectiveness.

By designating a minimum effectiveness level, which might serve as a trigger for doing resealing or other maintenance or rehabilitation work, the service life of a seal can be determined or even estimated. In this example, at 50 percent effectiveness, seal #1 has about a 6-yr service life, whereas seal #2 is projected to have an 8.5-yr service life.

Question: Does your State have a nominal effectiveness (or failure) level by which future maintenance is planned?

Page 3-40 Figure 3-10

IA-VAC Joint Seal Tester



IA-VAC Joint Seal Tester
Slide #75

An alternative method of evaluating joint seal effectiveness is the innovative leak test method that can be done using the IA-VAC joint seal tester shown here. This device, as we mentioned earlier, is used to draw up air beneath a solution-wetted joint seal, so as to produce bubbles where there are leaks.

The system consists of a suction chamber (pavement forefront) connected to a vacuum reservoir tank (tailgate center) and vacuum pump (tailgate left). It is powered by a portable generator (tailgate right), and it comes with a sprayer (pavement right) for applying solution to the joint seal prior to testing.

The FHWA is making available this device to selected States interested in tyring it out as a joint seal evaluation tool.

Question: Would your State be interested?

Page 3-41 Figure 3-11

Test and Evaluation
Joint Resealing

1. Identify material-procedure combinations
2. Identify test site location
3. Lay out site
4. Install experimental seals
5. Monitor seal performance
6. Analyze and report performance data

Session 3

Test and Evaluation (Joint Resealing)
Slide #76

As mentioned in session 1, the FHWA is sponsoring a technical assistance program for States interested in doing their own field studies of maintenance materials and techniques. One area of pavement maintenance that States can receive technical assistance on is joint resealing in concrete pavements.

There are essentially six steps associated with performing a test and evaluation study in this area, with assistance being available for each step. The steps are:

1. Identifying the combinations of materials and procedures you wish to evaluate.
2. Identifying a suitable location for conducting the study.
3. Laying out the site (i.e., marking the joints to be resealed).
4. Installing the experimental seals.
5. Periodically inspecting the seals for performance, and
6. Analyzing and reporting the performance data.

The Test and Evaluation Work Plans describe in more detail the work associated with each step. Again, if your agency is interested in this kind of study, the Technical Assistance Application must be filled out and submitted to the FHWA for consideration.

SESSION 4

PCC Partial-Depth Spall Repair

Pavement Maintenance Effectiveness/
Innovative Materials Workshop

PCC Partial-Depth Spall Repair
Slide #1

Session 4 of this Workshop is entitled, "PCC partial-depth spall repair," and is designed to inform highway maintenance workers, supervisors, and engineers of the state of the practice in spall repair. The session material is based primarily on the experiences of the SHRP H-106 spall repair experiment, which tested different types of repair materials and procedures via test sites located throughout the U.S.

It is hoped that this session will generate an increased awareness of the need for better materials and placement procedures, thereby increasing the performance of spall repairs.

Page 4-1

Session Overview

- SHRP H-106 findings
- Repair objectives
- Planning and design
- Installation
- Evaluation of repair effectiveness

Session 4

Session Overview
Slide #2

We'll begin this session with a quick overview of the SHRP H-106 spall repair experiment and tell you what the latest findings are with respect to performance of materials and methods.

Then, we will proceed into the "how to" portion of the session, discussing the objectives and applications of partial-depth spall repair, followed by a detailed discussion of both the project planning process and the installation process.

Lastly, we will look at how to evaluate the performance of repairs, so that future maintenance or rehabilitation work can be planned and so performance histories of materials and procedures can be kept.

Session Objectives

- Recall SHRP H-106 findings to date
- State the objective of partial-depth spall repair operations
- Select most appropriate and cost-effective materials and procedures
- List the tasks in a repair operation and describe the recommended procedures and equipment
- Evaluate the effectiveness of a repair project

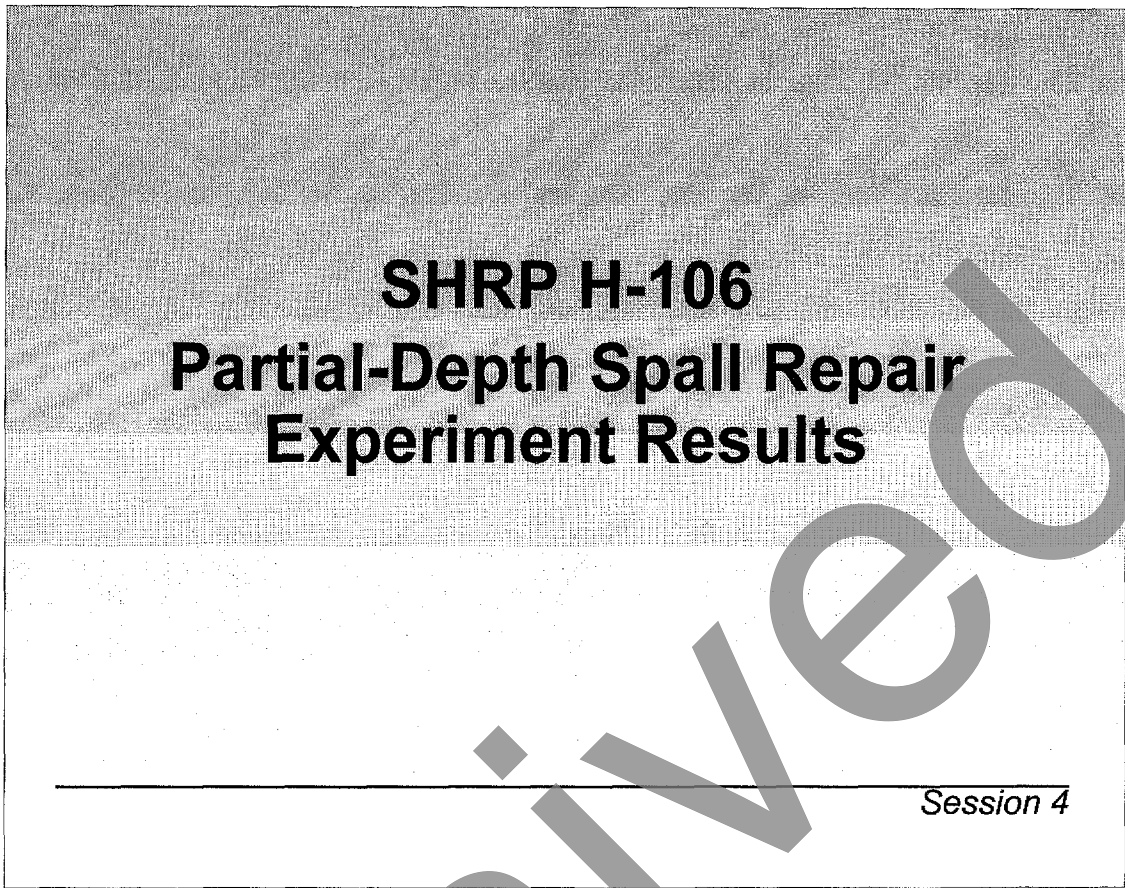
Session 4

Session Objectives
Slide #3

At the conclusion of this session, you should:

- Be informed of the SHRP H-106 findings to date.
- Be able to state the objective of partial-depth spall repair operations.
- Be familiarized with the process of selecting the most appropriate and cost-effective materials and procedures.
- Be able to list the various tasks in a repair operation and describe the recommended procedures and equipment for those tasks, and
- Be familiarized with the process of evaluating repair effectiveness.

Page 4-1



SHRP H-106 Partial-Depth Spall Repair Experiment Results
Slide #4

Let's take a quick look at the SHRP H-106 spall repair experiment and its latest findings, which stem from test site inspections made in the winter (January/February) of 1995.

Page 4-1

Test Site Locations

- *PA 28* Kittanning, Pennsylvania
- *I-15* Ogden, Utah
- *I-20* Columbia, South Carolina
- *I-17* Phoenix, Arizona

Session 4

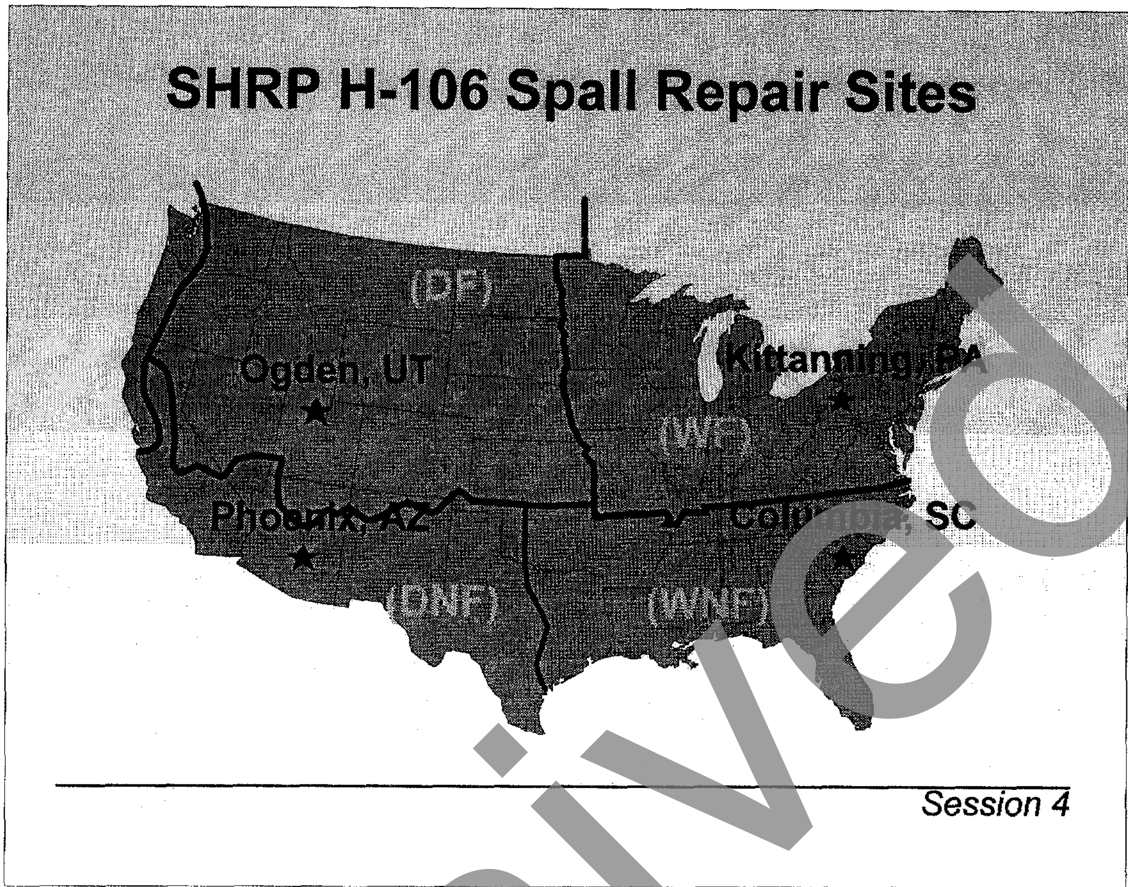
Test Site Locations
Slide #5

As you can see, this experiment consists of four test sites located in the U.S. These sites are:

- *PA 28* in Kittanning, Pennsylvania.
- *I-15* in Ogden, Utah.
- *I-20* in Columbia, South Carolina, and
- *I-17* in Phoenix, Arizona.

Each site was put down in the April/May/June 1991 time frame, with the exception of several adverse-condition patches placed at Pennsylvania in March 1991.

Page 4-12



SHRP H-106 Spall Repair Sites
Slide #6

This map shows the locations of the four spall repair sites with respect to the SHRP climatic zones. As you can see, there is one site located in each region.

PA 28 in Kittanning represents the wet-freeze site.
I 15 in Ogden is the dry-freeze site.
I-20 in Columbia is the wet-nonfreeze site, and
I-17 in Phoenix represents the dry-nonfreeze site.

In the fall of 1995, the Phoenix site was lost to rehabilitation, but not before one final inspection, which was conducted in September.

Map not in handbook

Experiment Features

- 11 repair materials
  - cementitious
  - polymer
  - bituminous
- 5 repair procedures
  - saw-and-patch
  - chip-and-patch
  - mill-and-patch
  - waterblast-and-patch
  - clean-and-patch

Session 4

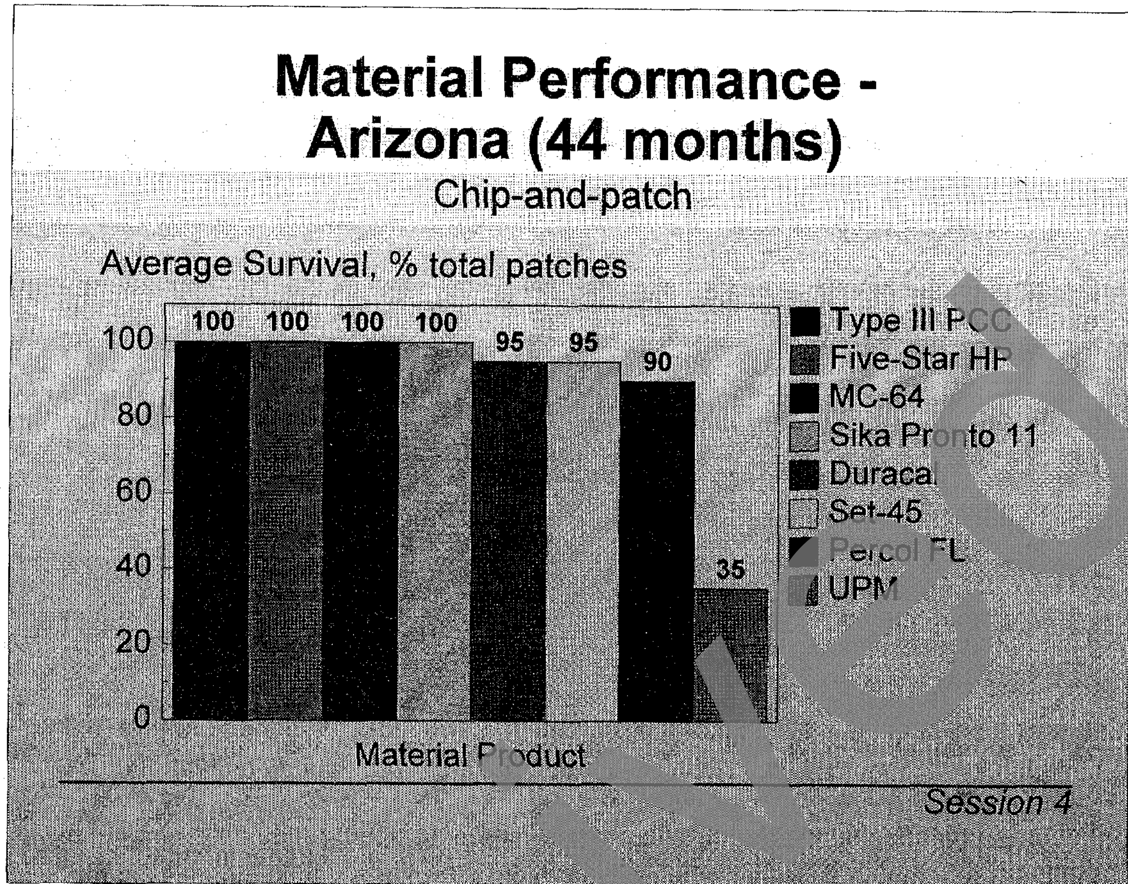
Experiment Features
Slide #7

The spall repair experiment included the placement of 11 different patching materials. Four of these materials were cementitious including type III PCC, 5 were polymeric, and 2 were bituminous, including a spray-injection mix.

Most of these materials were placed using the saw-and-patch, chip-and-patch, and mill-and-patch procedures. In addition, three materials were placed using the clean-and-patch procedure and one material was placed using the waterblast-and-patch procedure.

Table 4-1 on page 4-3 of your handbook shows the specific products included in the experiment and summarizes the combinations of material and method that were used at each site. Table 4-2 on page 4-4 describes each installation method in detail.

Pages 4-3 & 4-4   Tables 4-1 & 4-2



Material Performance - Arizona (Chip-and-patch)
Slide #8

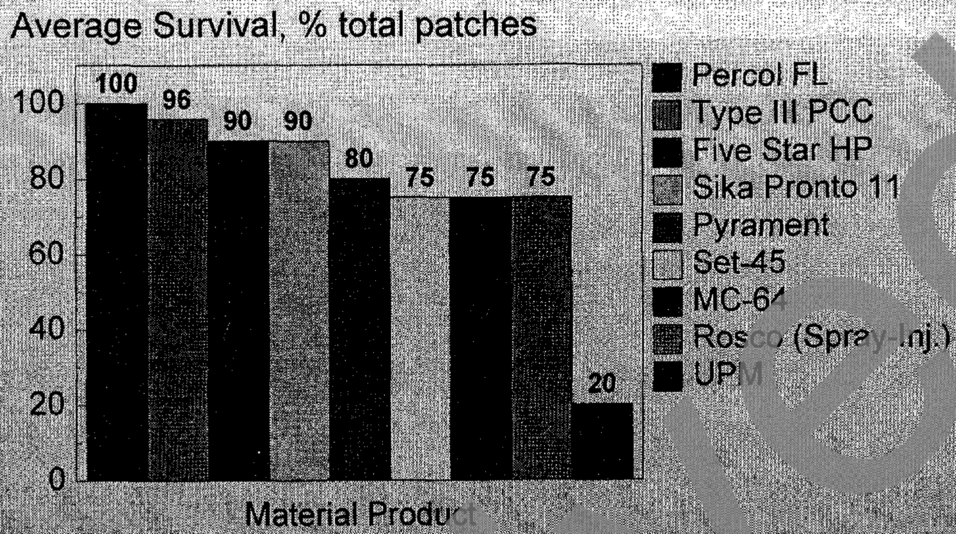
The next three slides show how each material product placed using the chip-and-patch procedure is performing at each site. The performance measure illustrated in these slides is average survival, gauged as a percentage of the total number of experimental patches.

At Arizona, all seven cementitious and polymeric materials are performing very well (> 90 percent survival). The bituminous cold-mix, UPM, however, is performing very poorly, with only 7 of the 20 patches holding up after 44 months.

Figure not in Handbook
Top to Bottom Legend Order Correponds with Left to Right Chart Order

Material Performance - Pennsylvania (47 months)

Chip-and-patch



Material Performance - Pennsylvania (Chip-and-patch)
Slide #9

At Pennsylvania, there are significantly more patch failures. Four (Percol, Type III PCC, Five Star, and Sika Pronto) of the eight cementitious and polymeric materials are performing very well and one (Pyrament) is performing well. The remaining two (Set 45 and MC-64) show fair performance, along with the Rosco spray-injection bituminous patches. UPM High-Performance Cold-Mix again is showing very poor performance.

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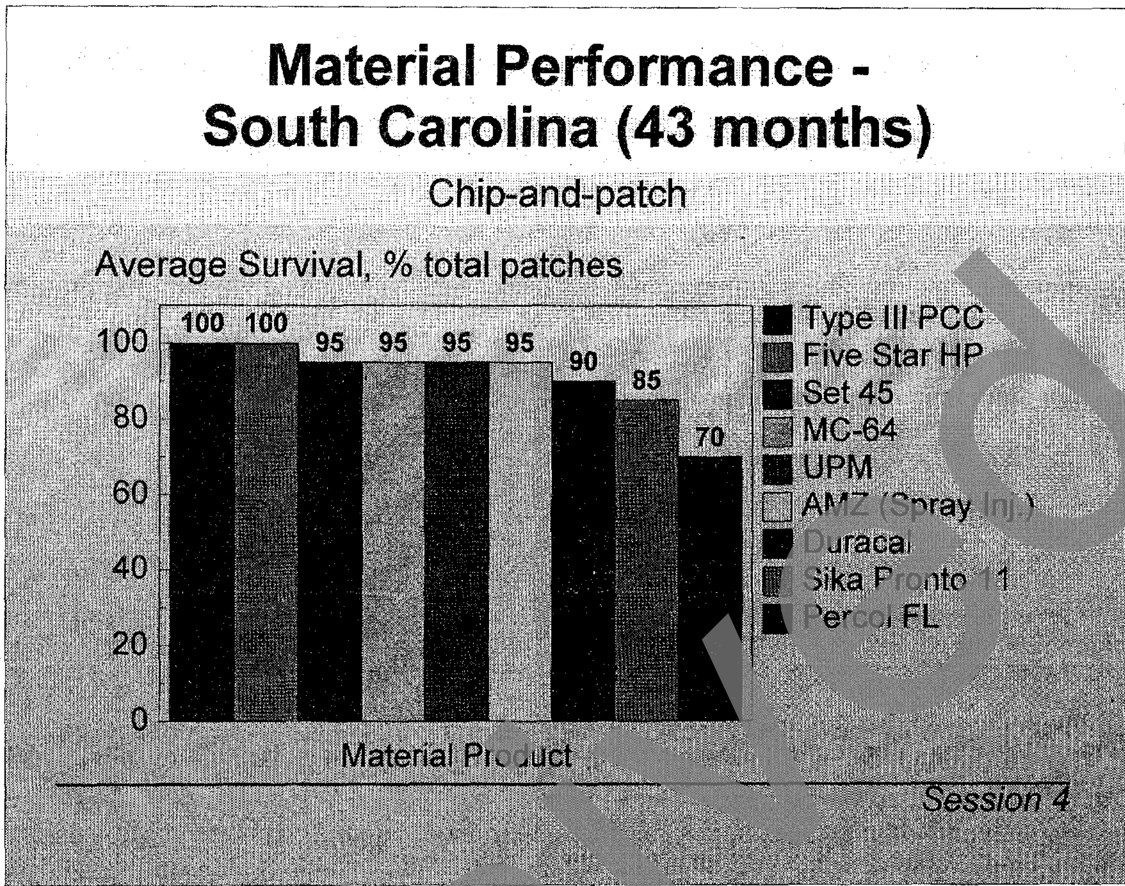
Top to Bottom Legend Order Correponds with Left to Right Chart Order

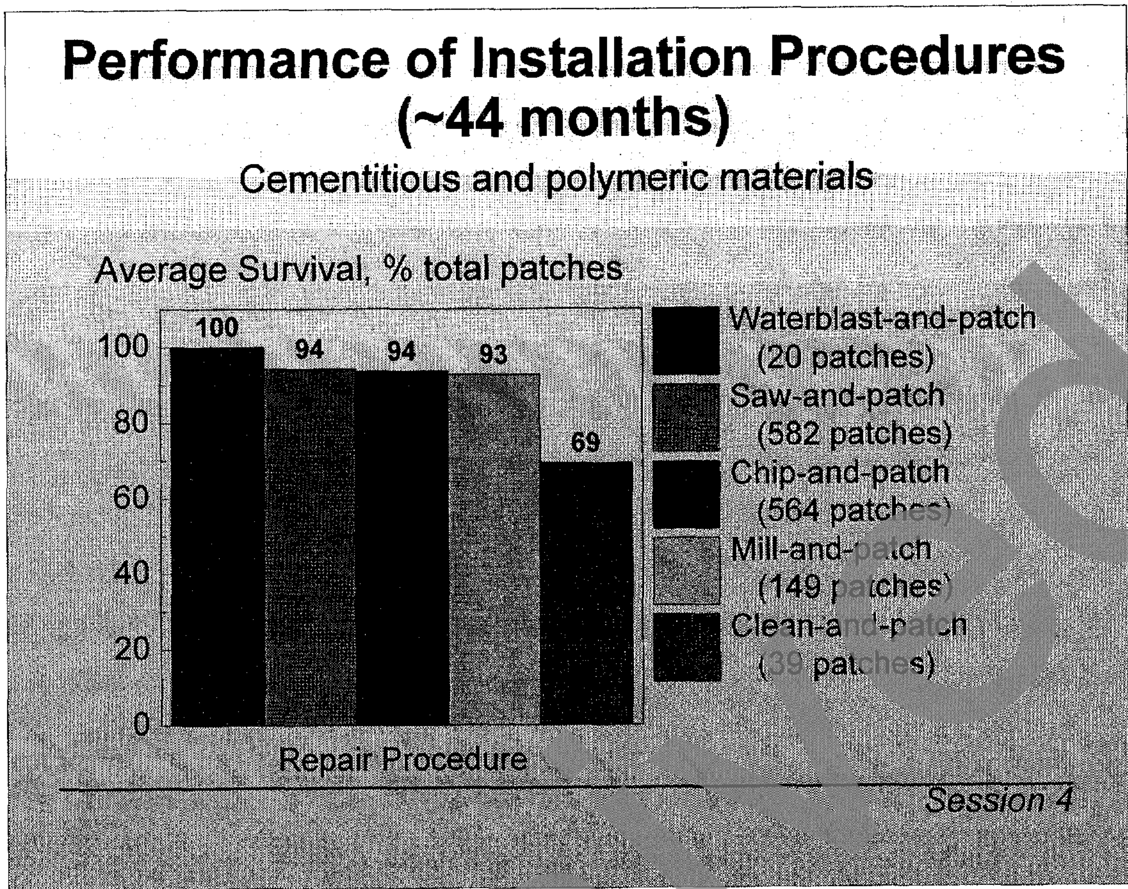


Material Performance - South Carolina (Chip-and-patch)
Slide #10

At South Carolina, most of the materials are showing very good performance. Each of the two bituminous patch types (UPM and AMZ spray-injection) show only 1 failed patch out of 20. Sika Pronto is showing good performance and Percol is showing fair performance.

We don't have a performance slide for the Utah site because all of the repair types placed there are performing very well.

Figure not in Handbook
Top to Bottom Legend Order Correponds with Left to Right Chart Order



Performance of Installation Procedures
Slide #11

This slide shows a performance comparison of patching procedures. Although it is not an accurate comparison (the number of patches for a specific repair procedure vary greatly from 20 to 582), it does convey the observation that not much difference exists yet between the survial characteristics of saw-and-patch, chip-and-patch, and mill-and-patch procedures.

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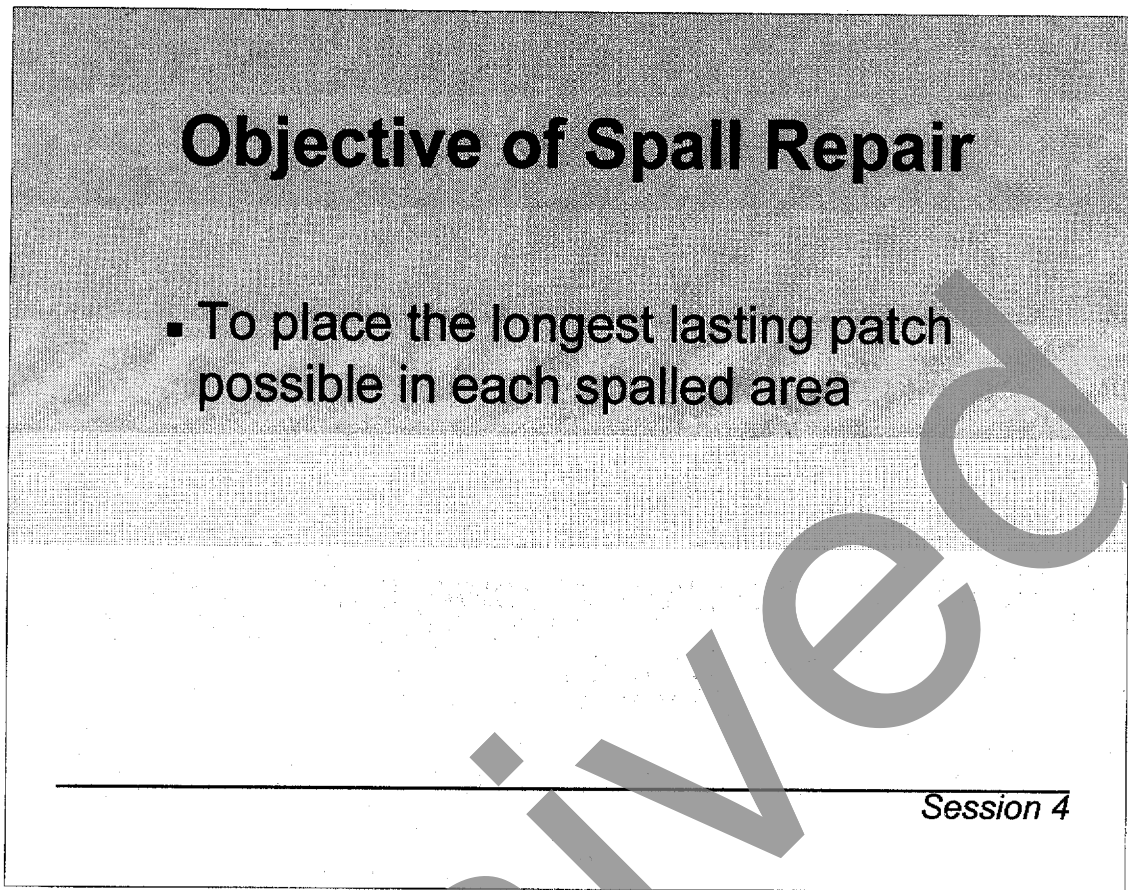


Objective of Spall Repair
Slide #12

The objective of partial-depth spall repair is simple. It is to place the longest lasting patch possible in each spalled area. Repairs that must be made repeatedly increase crew exposure to traffic, and result in additional agency costs <u>and</u> user costs.

Page 4-5

Applications of Partial-Depth Spall Repair

- Limited to spalls in the top one-third of slab thickness
  - cores
- Other restrictions
  - no misaligned dowel bars
  - no D-cracking

Session 4

Applications of Partial-Depth Spall Repair
Slide #13

Partial-depth spall repair is removing an area of deteriorated concrete that is generally limited to the top one-third of the concrete slab thickness, and replacing it with a patch. Cores can be taken at joints to find out how deep the spalls are.

Spalling deeper than the top third of the slab, or spalling that is caused by misaligned dowel bars or D-cracking should not be repaired with a partial-depth patch.

Page 4-5

Project Planning and Design

- Objectives
- Materials
- Patch dimensions
- Repair procedures
- Estimating resources
- Cost-effectiveness

Session 4

Project Planning and Design
Slide #14

Let's take a brief look at the planning and design process. Materials, patch dimensions, and repair procedures are chosen during the design phase. The highway agency must choose the most cost-effective materials and procedures that meet the objectives of the project.

The objectives of the project depend on climatic conditions, the urgency of the repairs, and future rehabilitation schedules. The highway agency must also estimate the materials, equipment and labor needed for the job.

Page 4-5

Repair Materials

- Rapid-setting patching materials
  - cementitious concrete
  - polymer concrete
  - bituminous material
- Accessory materials

Session 4

Repair Materials
Slide #15

There are many types of materials used in repairing partial-depth spalls. Patching materials include cementitious and polymer concretes, and bituminous materials.

Accessory materials include bonding agents, joint bond breakers, curing compounds, and joint sealants. The highway agency can select appropriate materials by comparing their physical properties and working tolerances, such as installation temperatures, time to traffic, whether the material can be mixed with moist aggregate, whether the material can be placed on a moist repair surface, and so on.

Page 4-7

Example Materials

Material Type	Products
Cementitious	Type III PCC, Duracal, Set-45, Five Star HP
Polymeric	Sika Pronto 11, MC-64, Penatron R/M-3003, Pyrament 505, Percol FL
Bituminous	UPM High Performance Cold-Mix, Spray-Injection

Session 4

Example Materials
Slide #16

There are many rapid-setting patching materials on the market today. Some examples of cementitious materials include Type III PCC, Duracal, Set-45, and Five Star Highway Patch (HP). Polymer concrete products include MC-64, SikaPronto 11, Penatron R/M-3003, Pyrament 505, and Percol FL. Bituminous materials include UPM High Performance Cold-Mix and spray-injection mixes.

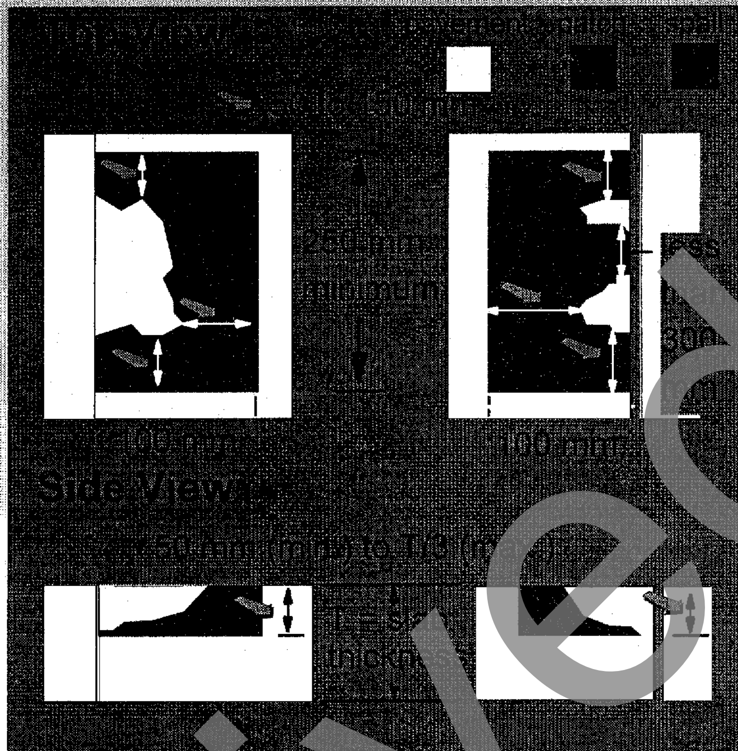
The working time for these materials range from 1 to 30 minutes; the installation temperature ranges from about -25°to 45°C; and the time to traffic at 20°C ranges from immediately to 6 hours. Some materials are moisture sensitive, and cost, labor needs, equipment needs, and expected life of the repair varies widely.

Question: What are the types of materials used in your State? What specific products are used?

Page 4-8   Table 4-3

Patch Dimensions

- Make one patch for small spalls < 300 mm apart
- Don't patch:
  - spalls < 150 mm long
  - spalls < 40 mm wide



Session 4

Patch Dimensions
Slide #17

Before constructing a patch, its dimensions must be determined and its boundaries must be marked on the pavement. Patch boundaries must include all weak concrete. Partial-depth patches should be at least 50 mm deep, but no deeper than one-third of the pavement slab thickness.

The patch should extend 50 to 150 mm beyond the spalled area and the patch should be at least 100 mm wide. If a spall is less than 150 mm long or less than 40 mm wide, it should not be patched. Instead it should be filled with a joint sealant or a grout.

Repair Procedures

- Saw-and-patch
- Chip-and-patch
- Mill-and-patch
- Waterblast-and-patch
- Clean-and-patch

Session 4

Repair Procedures
Slide #18

The five repair procedures that we'll focus on in this session are those that were studied in the H-106 experiment. These include the saw-and-patch, chip-and-patch, mill-and-patch, waterblast-and-patch, and clean-and-patch procedures. The primary difference between these procedures is the way in which the deteriorated and weak concrete is removed.

A full-depth repair must be used if the deterioration is found to be deeper than the top third of the pavement slab, or if reinforcing bars or mesh are reached.

Page 4-13

Saw-and-Patch

Advantages

- Vertical edge face
- Forces isolated in patch
- No edge spalling
- Easy to remove concrete
- Most crews familiar with method

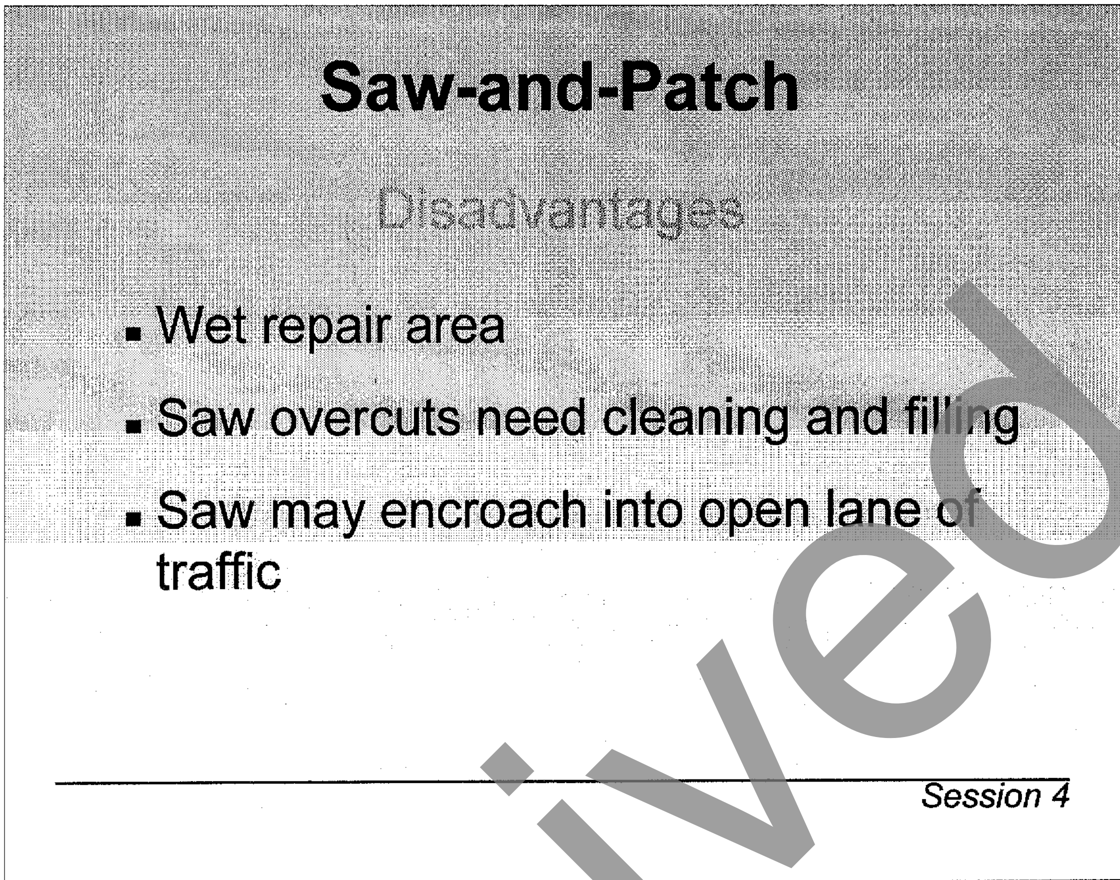
Session 4

Saw-and-Patch Advantages
Slide #19

When done properly, the advantages of the saw-and-patch procedure are that:

- the saw leaves vertical edges faces.
- the force of the jackhammer stays inside the patch boundaries.
- there is little or no edge spalling.
- removal of weak concrete within the sawed boundaries is usually easier and faster when the boundaries are sawed than when they are not sawed, and
- most crews are familiar with the method.

Pages 4-14 & 4-15

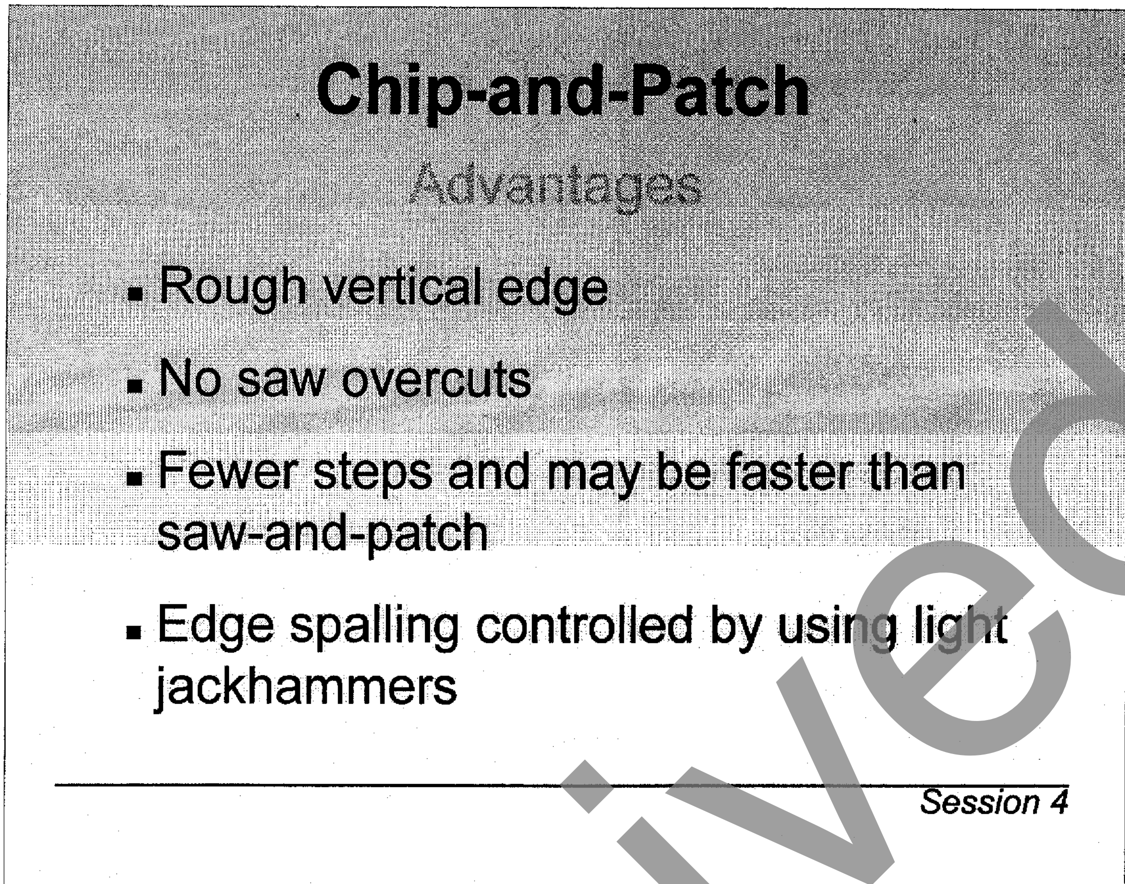


Saw-and-Patch Disadvantages
Slide #20

The disadvantages of the saw-and-patch procedure are that:

- since water is used when sawing, the repair area is saturated for some time, possibly delaying the repair (though this problem can be avoided by sawing a day or so ahead of jackhammering and patching).
- saw overcuts weaken the repair area and must be cleaned and sealed, and
- the saw may encroach into the open lane of traffic.

Page 4-15

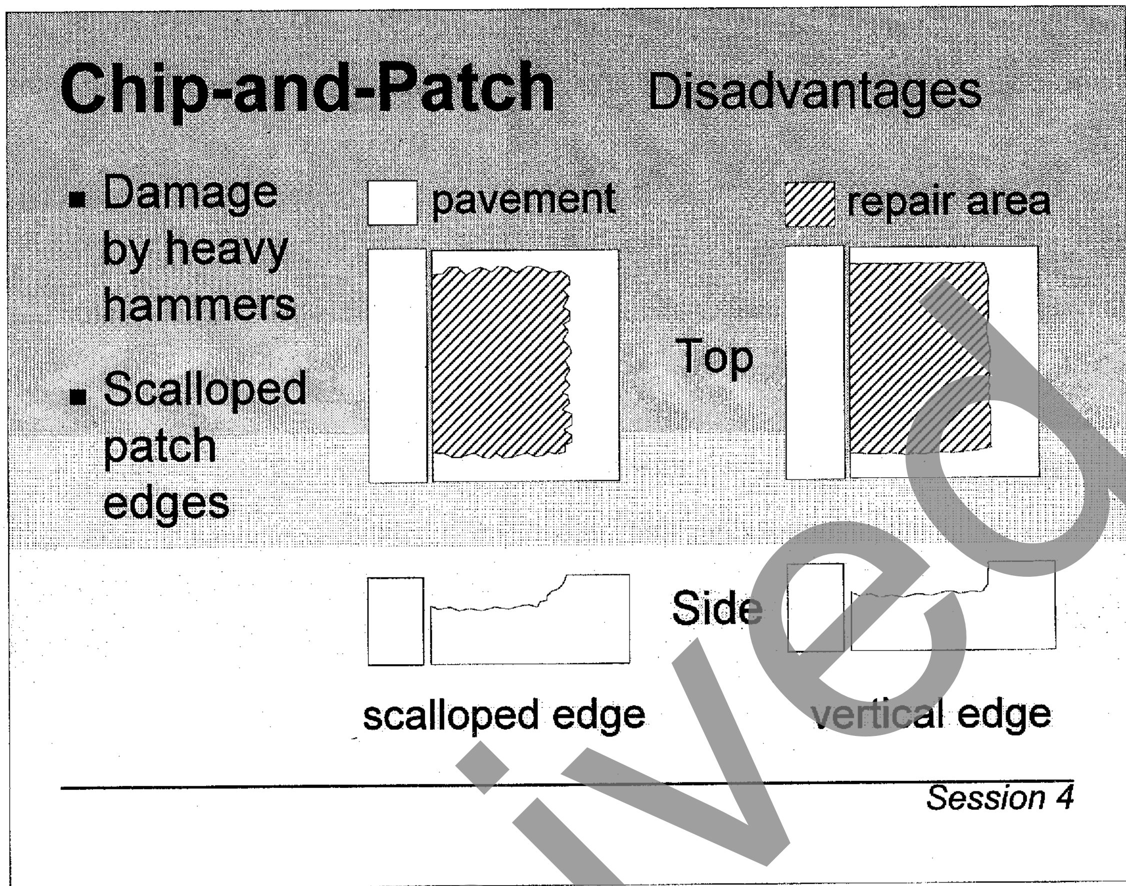


Chip-and-Patch Advantages
Slide #21

The advantages of the chip-and-patch procedure are that:

- the rough, vertical edges of the repair area help the patch bond well to the pavement.
- there are no saw overcuts to clean and seal.
- it has fewer steps than the saw-and-patch method.
- spalling is controlled by using light hammers at the edges, and
- it may be quicker than the saw-and-patch method.

Page 4-16



Chip-and-Patch Disadvantages
Slide #22

The disadvantages of the chip-and-patch procedure are that:

- good concrete may be damaged by heavy hammers, and
- jackhammers can cause scalloped patch edges into which the repair material must be feathered.

Pages 4-16 & 4-17 Figures 4-4 & 4-5

Mill-and-Patch

Advantages

- Efficient and economical when patching large areas
- Rough, irregular patch surface promotes bonding

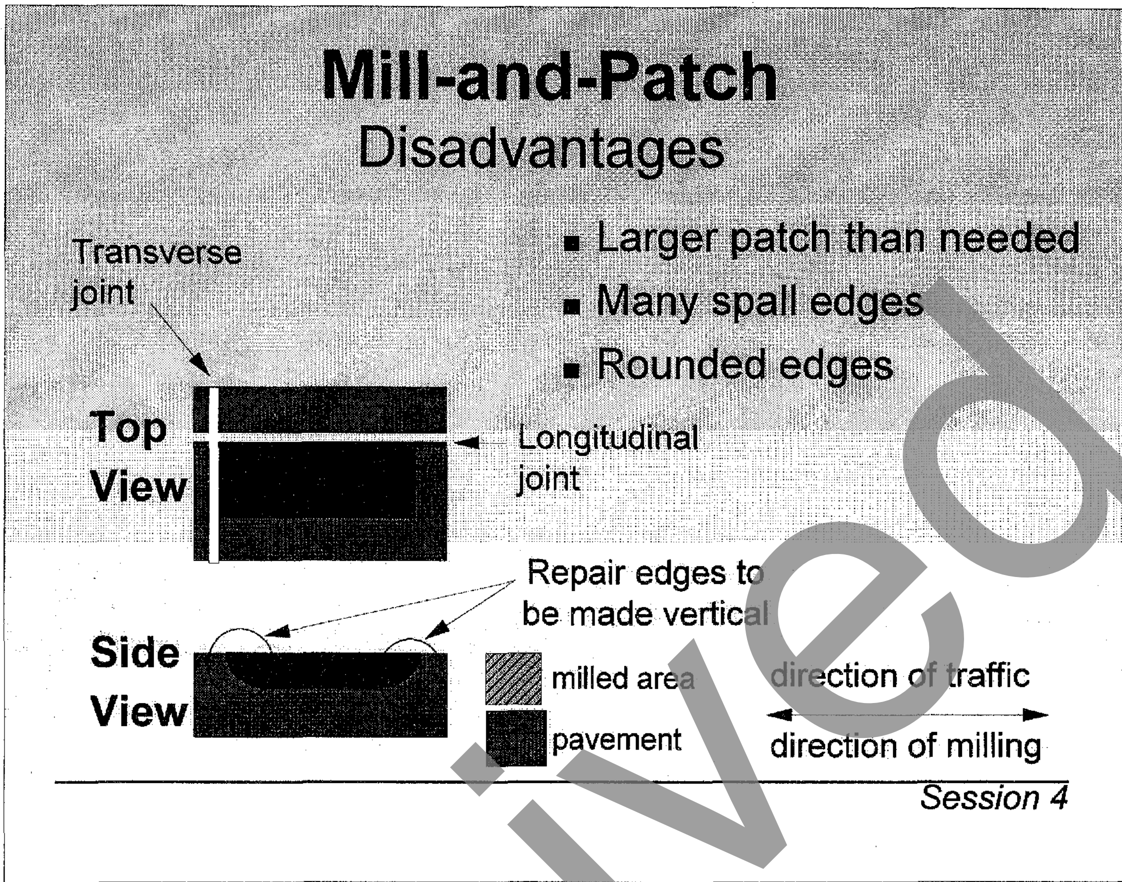
Session 4

Mill-and-Patch Advantages
Slide #23

The advantages of the mill-and-patch procedure are that:

- it is efficient and economical when repairing large areas, and
- it leaves a rough, irregular surface that helps the patch bond well to the pavement.

Page 4-18



Mill-and-Patch Disadvantages
Slide #24

The disadvantages of the mill-and-patch procedure are that:

- if the spalled area is less than 300 by 300 mm, the patch may be larger than needed, because the smallest milling head currently available provides a 300 by 300 mm cut.
- the milling operation may cause edge spalling of good pavement, and
- the milling machine makes a hole with two rounded edges that may need to be made vertical by chiseling if they are perpendicular to the direction of traffic.

Page 4-18 Figure 4-6

Waterblast-and-Patch

Advantages

- Only weak concrete is removed
- Rough, irregular patch surface promotes bonding

Session 4

Waterblast-and-Patch Advantages
Slide #25

The advantages of waterblasting are that:

- once an experienced operator adjusts the waterblasting parameters, only weak concrete is removed, and
- it leaves a rough, irregular surface that helps the patch bond well to the pavement.

Page 4-20

Waterblast-and-Patch

Disadvantages

- Wet repair area/extra drying time
- Hard to control depth
- Expensive
- Hard to get good production rate
- Variable performance
- Danger of operation

Session 4

Waterblast-and-Patch Disadvantages
Slide #26

The disadvantages of waterblasting are that:

- the repair area is wet for some time following the operation, thus delaying patch placement until it is dry.
- it can be hard to control the depth of removal.
- equipment rental can be expensive.
- it can be hard to obtain a good production rate.
- overall performance is highly variable, and
- the operation can be dangerous (a shield must be built around the repair to protect traffic if the patch is next to a lane carrying traffic).

Page 4-20

Clean-and-Patch

Advantages

- Can use under adverse conditions
  - air temperature below 5°C
  - repair area saturated with surface moisture

Session 4

Clean-and-Patch Advantages
Slide #27

The advantage of the clean-and-patch procedure is that it can be used under adverse conditions - when the air temperature is below 5°C, and the repair area is saturated with surface moisture.

Page 4-20

Clean-and-Patch

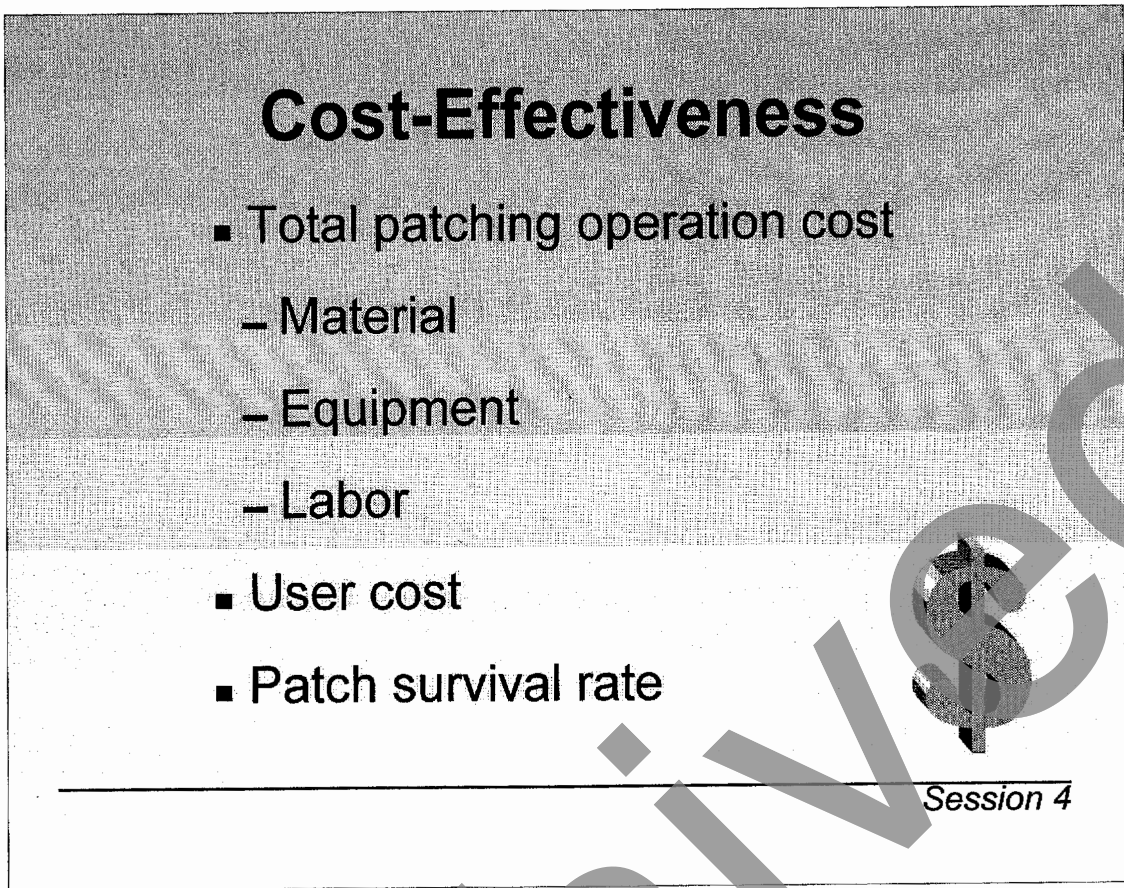
Disadvantages

- May need to repeat repair using more rigorous procedure during better condition

Session 4

Clean-and-Patch Disadvantages
Slide #28

The main disadvantage of the clean-and-patch procedure is that the patch may fail earlier than patches placed under more favorable weather conditions, and the repair may therefore need to be repeated.



Cost-Effectiveness
Slide #29

Cost-effectiveness is affected by:

- the cost of the materials and equipment.
- the crew size.
- the amount of time it takes to construct the patch.
- how fast the patch can be opened to traffic, and
- the life of the patch.

Page 4-12

Installation

- Sounding
- Preparing the spalled area
- Mixing materials
- Placement
- Preparing the patch for traffic

Session 4

Installation
Slide #30

When the planning and design process has been completed and the timing is right, installation can begin. The first step in the installation process is to define and mark the patch boundaries. This is achieved by "sounding" the spalled concrete area using a hammer, chain, or steel rod.

Next, the adjacent joints must be carefully prepared and the deteriorated concrete must be removed. The repair area is then cleaned to make way for the patch material, which is usually mixed while the repair area is being prepared. Once the material has been properly placed in the repair area, it must be vibrated or rolled, finished, and then allowed to cure before opening to traffic.

Page 4-26

Sounding

- Determines extent of deterioration
- Strike concrete with:
  - Solid steel rod
  - Ball peen hammer
  - Chain
- Clear ringing sound>>>sound concrete
- Dull sound>>>unsound concrete

Session 4

Sounding
Slide #31

Because weak concrete cannot always be seen at the pavement surface, sounding is the only way to be sure that the patch boundaries include all the weak concrete. The concrete around the visible spall should be struck with a solid steel rod, a ball peen hammer, or a steel chain.

If the concrete gives a clear ringing sound, the concrete is good. If the concrete gives a dull sound, the concrete is weak and should be included inside the patch boundaries. Sounding is more of an art than a science, and should always be done by someone with experience.

Preparing the Spalled Area

- Initial joint preparation
- Removing deteriorated concrete
- Cleaning repair area
- Installing joint bond breaker
- Pre-placement inspection

Session 4

Preparing the Spalled Area
Slide #32

Once the boundaries of the deteriorated area have been marked, patch preparation can begin. Patch preparation includes preparing the joints, removing deteriorated and weak concrete, cleaning the repair area, installing a joint bond breaker if needed, and inspecting the patch before placement begins.

Page 4-26

Joint Preparation

- Remove old sealant
- Resaw the joint
  - For nonflexible patch materials, resaw at least 25 mm deeper than the repair area and 50 to 75 mm beyond the repair area
- Saw out joint inserts

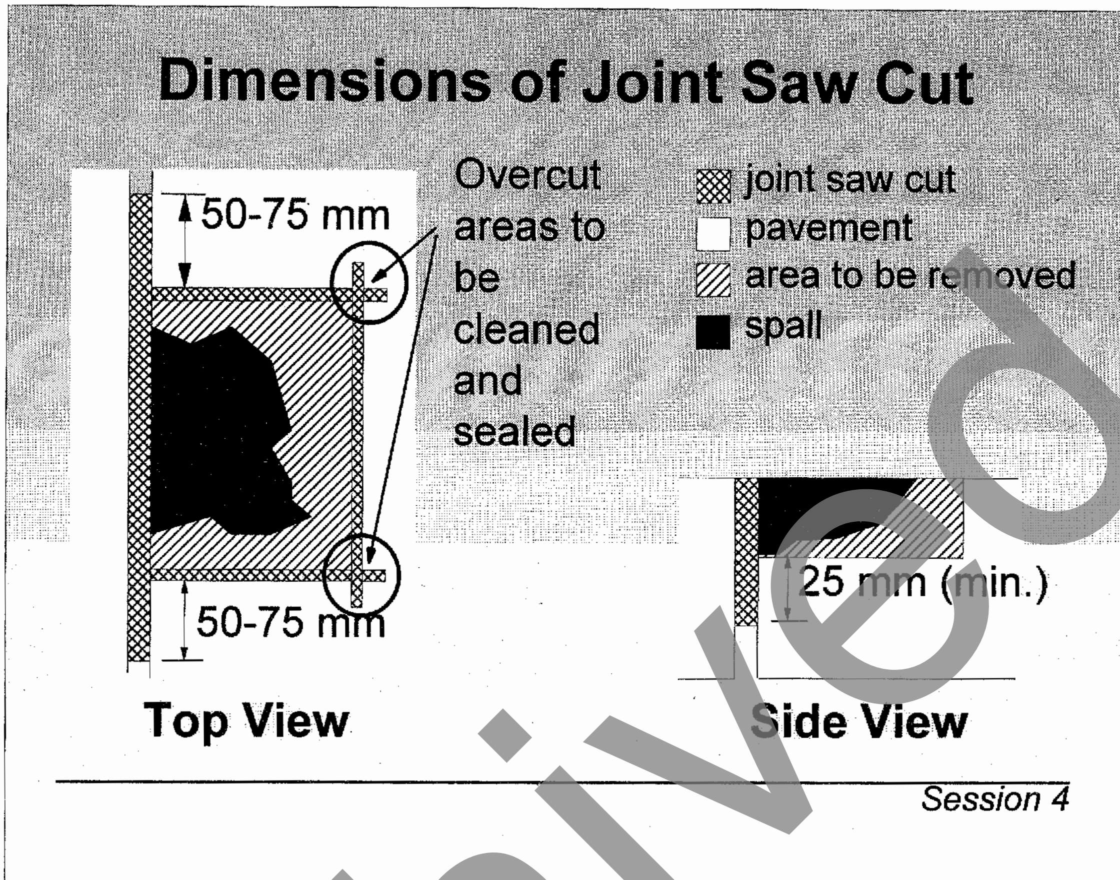
Session 4

Joint Preparation
Slide #33

Pavements expand and contract during warming and cooling. Nonflexible patches can be crushed if the joints next to them are not prepared properly. This is the most common cause of partial-depth patch failure.

If a nonflexible material is used, old sealant in the adjacent joint and 75 to 100 mm beyond the patch must be removed, and the joint must be resawn. If a flexible material is used, the old sealant should still be removed, through sawing may not be needed. If there are metal or plastic inserts in the joint, they must be sawn out. Joints are not sawn when weather conditions are adverse.

Page 4-27



Dimensions of Joint Saw Cut
Slide #34

When using nonflexible materials, the joints next to the repair should be resawn using a double-bladed concrete saw. The cut should be at least 25 mm deeper than the repair and should extend 50 to 75 mm beyond the repair in each direction. All sawing slurry should be washed from the repair area before it dries.

Page 4-15 Figure 4-3

Saw-and-Patch

- Saw patch boundaries at least 25 mm below spall area
- Remove concrete with jackhammer
  - Use 7 kg hammer at patch edges
  - Prefer 7 kg hammer at patch center, but 14 kg hammer acceptable
- Start at center, work toward edges

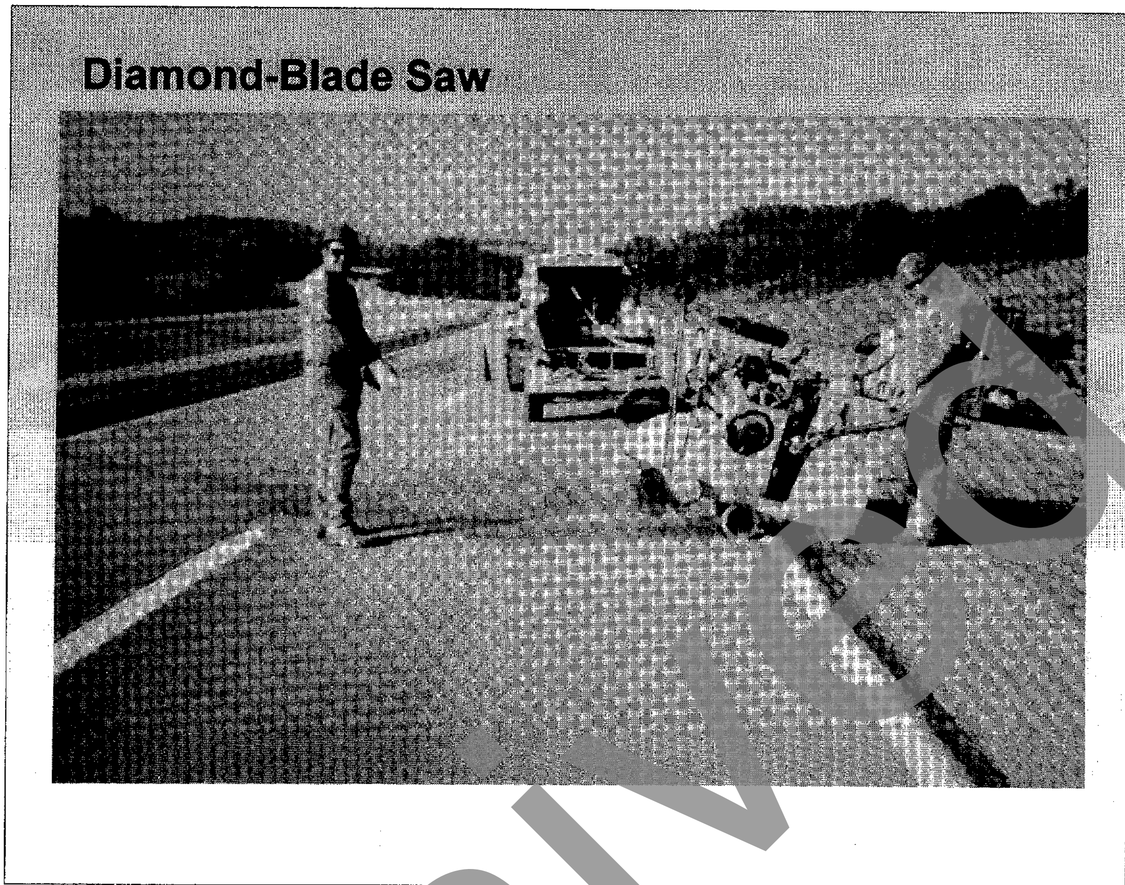
Session 4

Saw-and-Patch
Slide #35

In the saw-and-patch procedure, the patch boundaries are cut at least 25 mm below the spall bottom using a diamond-blade saw. The cut usually extends 50 to 75 mm beyond the patch boundaries to obtain that depth. Sawing slurry should be washed away before it dries.

Weak and deteriorated concrete is removed with jackhammers. Hammers weighing less than 7 kg pounds are preferred, but hammers weighing up to 14 kg may be allowed. Removal must begin near the center of the spall and move toward (but not to) the patch boundaries. Only 7-kg hammers may be used at the boundaries.

Pages 4-14 thru 4-16



Diamond Blade Saw
Slide #36

This slide shows a diamond-blade saw being used to cut a joint.

Chip-and-Patch

- Patch boundaries are not sawed
- Remove concrete with jackhammer
  - use 7 kg at patch edges
  - prefer 7 kg at patch center, but 14 kg permitted
- Start at center, work toward edges
- Specify minimum vertical edge

Session 4

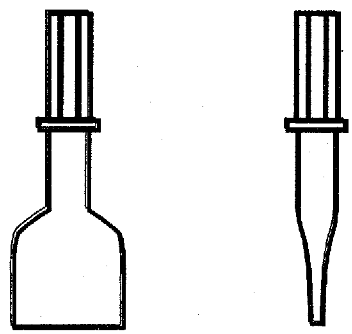
Chip-and-Patch
Slide #37

The chip-and-patch procedure is the same as the saw-and-patch procedure, except the patch boundaries are not sawed. Weak and deteriorated concrete is removed with jackhammers. Hammers weighing less than 7 kg are preferred, but hammers weighing up to 14 kg may be allowed. Removal must begin near the center of the spall and move toward (but not to) the patch boundaries. Only 7 kg hammers may be used at the patch boundaries.

If the selected repair material is not to be feathered, a minimum vertical face on all sides of the repair area is required. Often, this minimum is 25 mm, but it can be greater.

Page 4-16

Spade Bits



Front View   Side View

- Use spade bits only
- Never use gouge bits

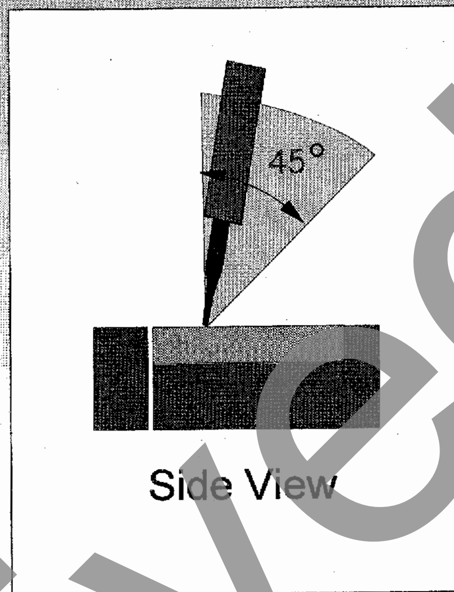
Session 4

Spade Bits
Slide #38

Jackhammers should always be fitted with spade bits, as gouge bits can damage good concrete.

Using Jackhammers

- Jackhammers
- Mechanical chipping tools
- Operate jackhammer at < 45 degrees from the vertical



Session 4

Using Jackhammers
Slide #39

Jackhammers and mechanical chipping tools should be operated at an angle less than 45 degrees, as measured from the vertical.

Page 4-14 Figure 4-2

Jackhammer In Use

Jackhammer in Use
Slide #40

Here, we see a jackhammer being used to remove the deteriorated concrete and to straighten the sides of the repair area.

Mill-and-Patch

- Remove concrete with milling machine
  - 300 mm wide cutting head
  - Drum diameter of 900 mm or less
- Two rounded patch edges
  - Orient parallel to direction of traffic
  - Chip to make vertical

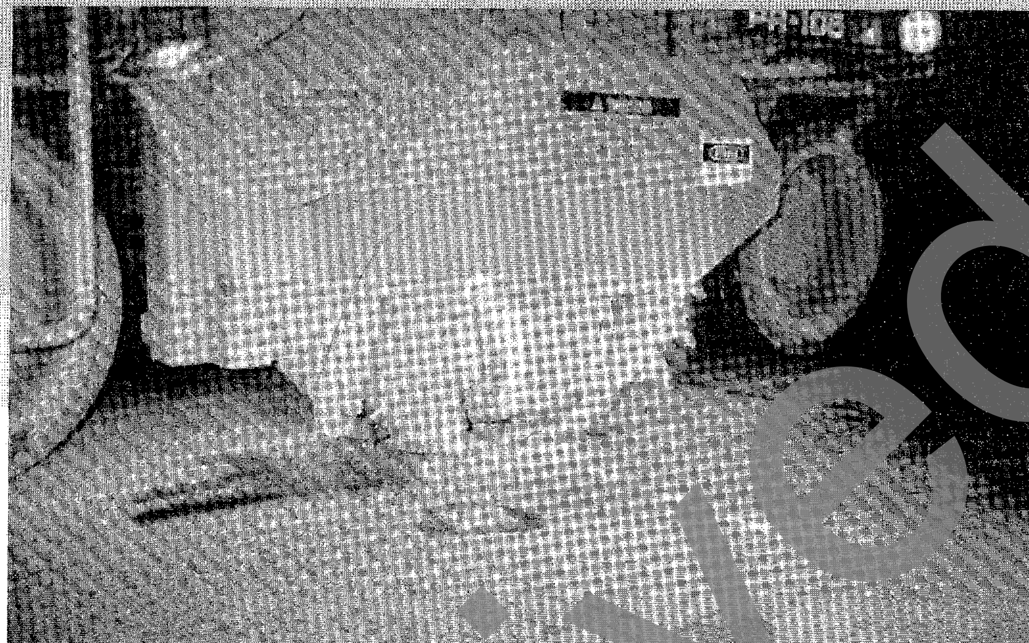
Session 4

Mill-and-Patch
Slide #41

In the mill-and-patch procedure, all deteriorated and weak concrete is removed using a carbide-tipped milling machine that makes a 300 mm wide cut or narrower, and has a drum diameter of 900 mm or less. The small amount of material that remains at the patch corners must be removed by light jackhammering or sawing. Whenever possible, the milling machine should be oriented such that the rounded edges of the hole it produces are parallel to the direction of traffic. If this orientation is not possible, the rounded edges should be made vertical using a light jackhammer.

Page 4-18

Carbide-Tipped Milling Machine



Carbide-Tipped Milling Machine
Slide #42

This slide shows a carbide-tipped milling machine.

Waterblast-and-Patch

- Remove concrete using waterblaster
  - 100,000 to 200,000 kPa
  - Mobile robot
- Set parameters in test areas
- Don't change parameters unless concrete changes
- Protective shield

Session 4

Waterblast-and-Patch
Slide #43

The waterblast-and-patch procedure uses a high-pressure water jet to remove the deteriorated concrete. The waterblasting equipment should be able to produce a stream of water at 100,000 to 200,000 kPa, and should be controlled by a mobile robot.

The first step is to build a shield around the repair area if there is any traffic passing in the next lane. Then, two trial areas, one of good concrete and one of deteriorated concrete, are used to determine the proper speed, pressure, and number of overlapping passes. These parameters should not be changed unless the concrete changes.

Page 4-19

Waterblasting Operation

Waterblasting Operations
Slide #44

Here is a slide showing the barrier that has been built around a waterblasting operation.

Page 4-19   Figure 4-7

Clean-and-Patch

- Remove concrete with hand tools
- Jackhammer allowed if needed
- Clean by sweeping

Session 4

Clean-and-Patch
Slide #45

Under adverse conditions, hand-picks and shovels should be used to remove loose materials. Sometimes a light jackhammer may be used for large areas or if the deteriorated concrete is held tightly in place. The loose materials should be swept away using stiff brooms.

Page 4-20

Cleaning

- Sandblasting
- Airblasting
- Sweeping
- Oil and moisture filters

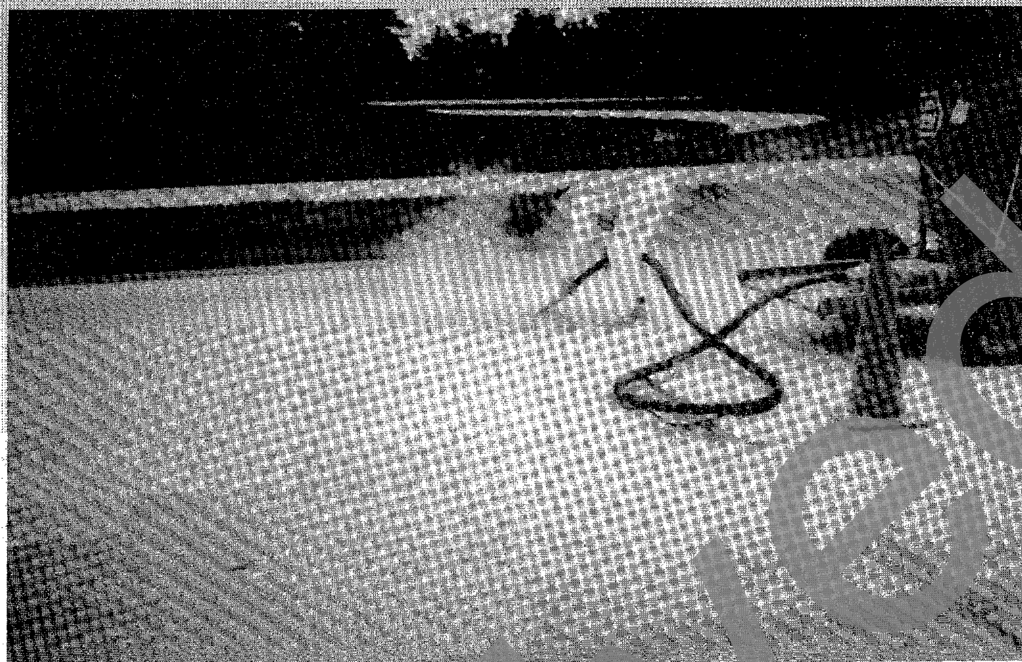
Session 4

Cleaning
Slide #46

After all weak and deteriorated concrete has been removed, the surface of the repair area must be cleaned. Sandblasting, airblasting, and sweeping normally provide a clean, rough surface that helps the patch bond to the pavement. Sandblasting is highly recommended for cleaning the surface of the repair area. After sandblasting, high-pressure airblasting should be used to remove any remaining dust, debris, and loosened concrete fragments. Compressed air units should have oil and moisture filters. Under adverse conditions, the repair area is cleaned only be sweeping.

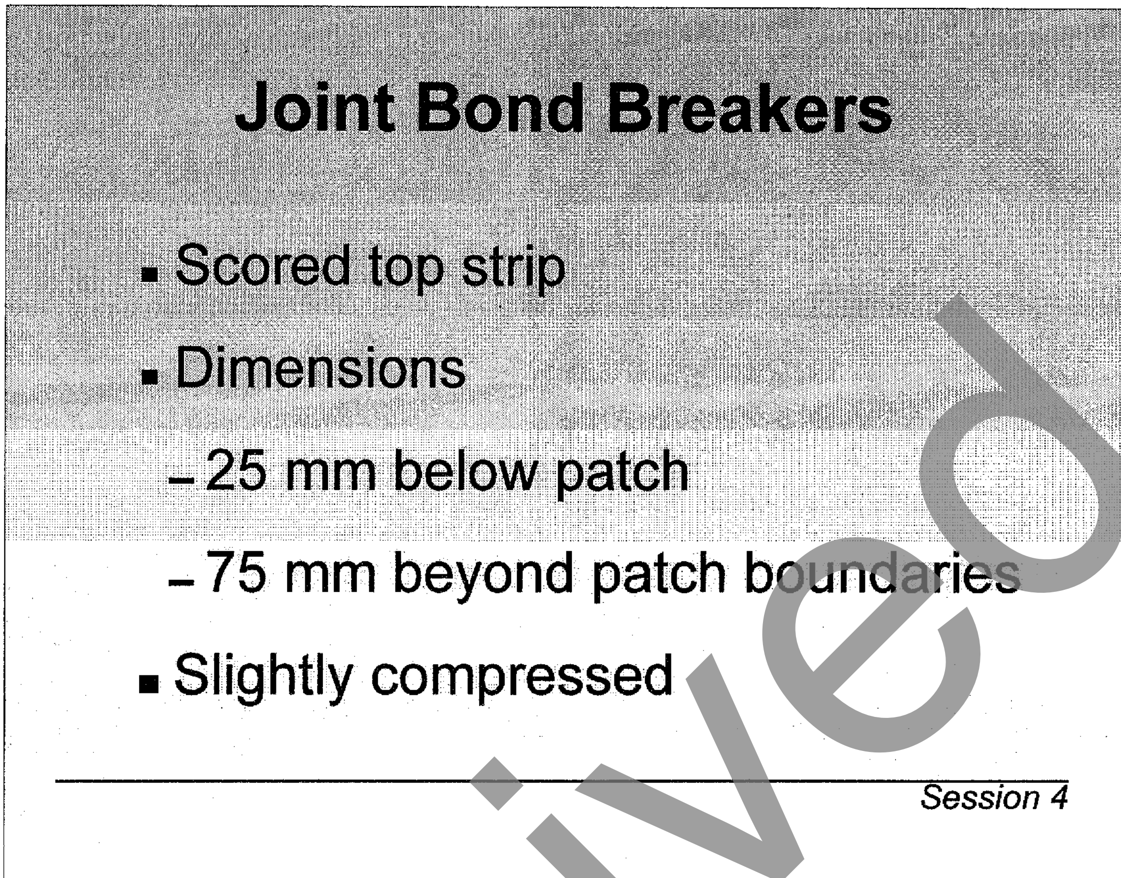
Pages 4-31 & 4-32

Sandblaster In Use



Sandblaster in Use
Slide #47

This slide shows a sandblaster being used to clean a repair area before material placement.



Joint Bond Breakers
Slide #48

When using nonflexible patching materials, a bond breaker must then be installed in any joints that are next to the patch. Joint bond breakers with a scored top strip should be used because the strip can later be torn away to make a reservoir for the joint sealant.

The bond breaker should extend 25 mm below and 75 mm beyond the patch boundaries to keep the repair material out of the joint. The bond breaker should be slightly wider than the joint so that it is slightly compressed. A rigid fiberboard should be used at the lane-shoulder joint where more support is needed.

Pages 4-28 & 4-29

Mixing Materials

- Materials
  - Bonding agents
  - Patching materials
- Methods
  - Drum mixers
  - Paddle mixers
  - Jiffy mixers

Session 4

Mixing Materials
Slide #49

Once the repair area has been cleaned, and a bond breaker has been installed (if it was needed), the mixing of bonding agents and patching materials can begin. The volume of material needed for a partial-depth patch is usually small. Small drum or paddle-type mixers with capacities of 0.15 to 0.25 m^3, and Jiffy mixers are often used. Bituminous cold-mixes are generally mixed at a local plant using the manufacturer's mix design. A spray-injection machine mixes a heated asphalt emulsion with aggregate. An experienced operator should carefully control the volume of each component.

Page 4-33

Mixing Precautions

- Manufacturer's recommendations
- Carefully observe
  - Mixing sequence
  - Component amounts
  - Mixing times
  - Water content

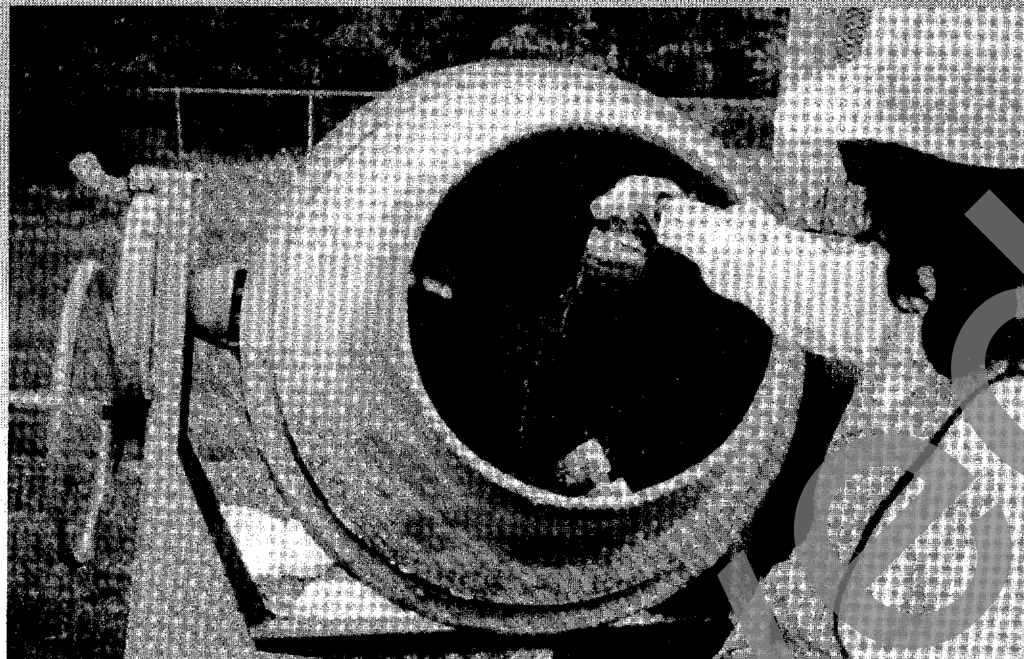
Session 4

Mixing Precautions
Slide #50

All repair materials should be mixed carefully according of the manufacturer's instructions. Mixing sequences, component amounts, mixing times, and water content must be carefully observed. Mixing longer than needed for good blending reduces the already short time available for placing and finishing rapid-setting materials. Additional water may significantly reduce the strength of the patch.

Page 4-33

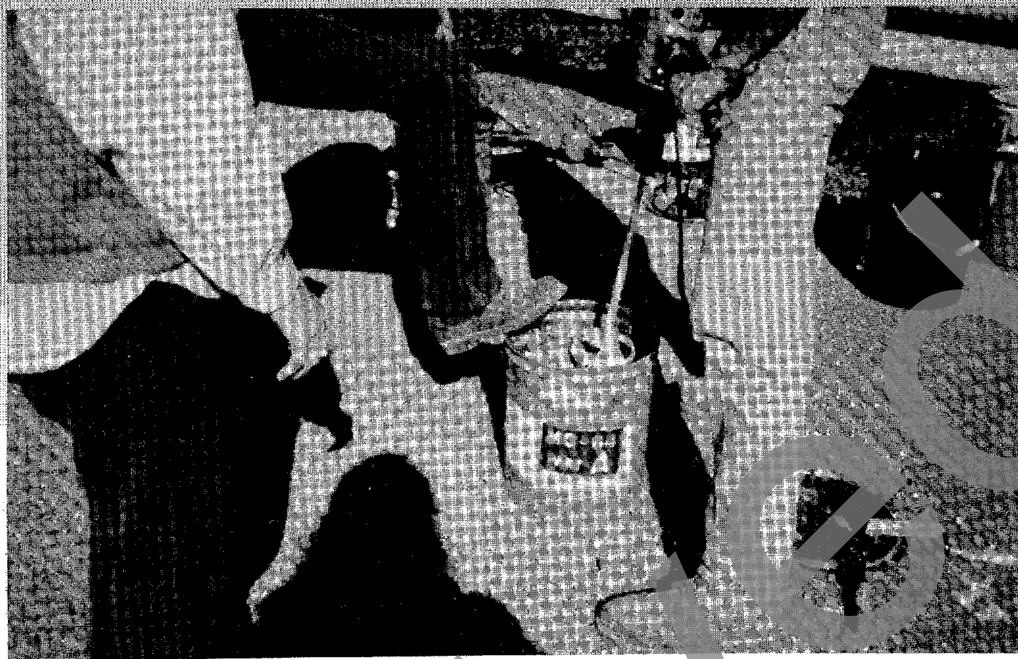
Mixing Operation



Mixing Operation
Slide #51

This slide shows carefully measured components being added to a small drum mixer.

Jiffy Mixer



Jiffy Mixer
Slide #52

In this slide, a Jiffy mixer is being used to mix a small amount of repair material.

Material Placement

- Bonding agent
- Patching material placement method
  - Shovel
  - Pour or pump
  - Spray-injection

Session 4

Material Placement
Slide #53

When needed, bonding agents are applied just before placing the patch. They should be tacky when the patch is placed. The repair area must be thoroughly coated in order to promote good bonding of the repair materials repair area.

Pages 4-32 & 4-33

Material Placement

Material Placement
Slide #54

This slide shows a cementitious material being placed with a shovel.

Polymeric Material Placement

Polymeric Material Placement
Slide #55

In this slide, a polymeric material is being placed by pumping over preplaced aggregate.

Vibrating and Rolling

- Vibrate cementitious materials
  - small internal vibrator
  - vibrating screed
  - rod or tamp with hand tools
- Compact bituminous materials
  - vibratory roller
  - vibratory plate

Session 4

Vibrating and Rolling
Slide #56

Vibration and rolling are two ways to release trapped air from fresh mix. Cementitious and some polymeric materials may be vibrated using a small internal vibrator, a vibrating screed (if the patch is very large), or by rodding or tamping with hand tools (if the patch is very small). Small pencil vibrators are recommended for most patches. Rolling may be done using a vibratory roller or plate. Bituminous patching materials should be compacted with 3 to 8 passes until they are level with the pavement.

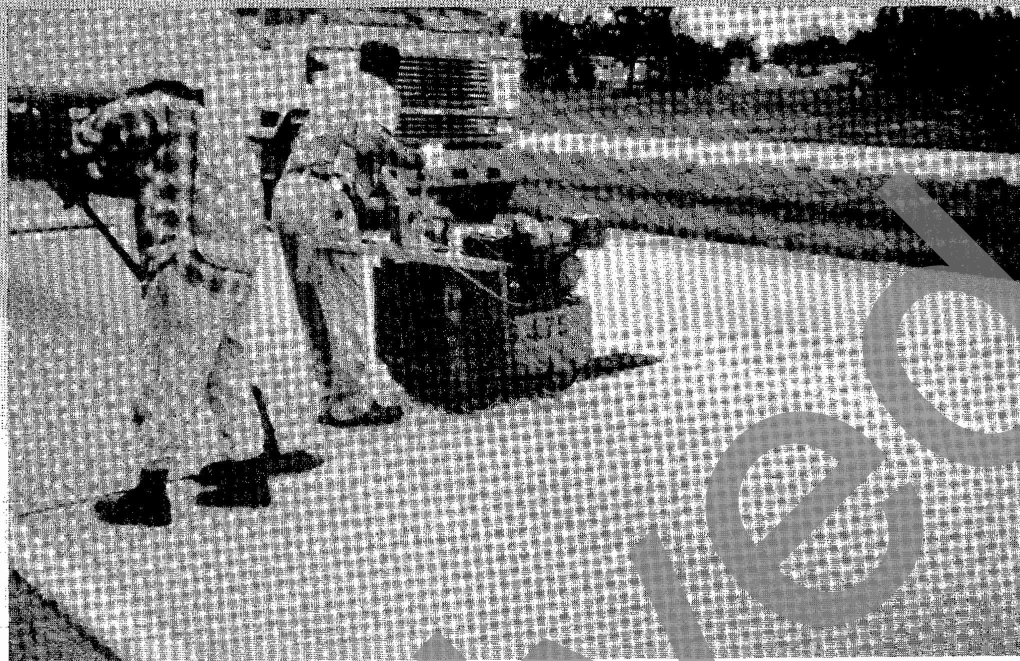
Pages 4-34 & 4-35

Consolidation of a Cementitious Patch

Consolidation of a Cementitious Patch
Slide #57

This slide shows an internal vibrator being used of consolidate a freshly placed patch.

Consolidation of a Cold-Mix Patch

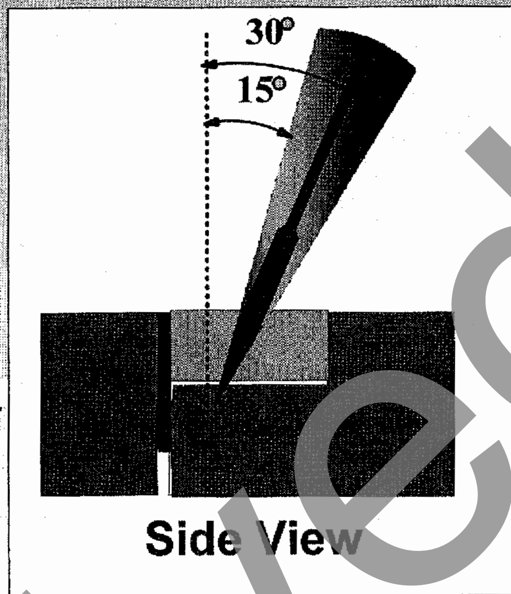


Consolidation of a Cold-Mix Patch
Slide #58

In this slide, a vibratory roller is being used to compact a bituminous cold-mix patch.

Using an Internal Vibrator

- Lift up and down
- Don't move horizontally
- Enough vibration when
  - mix stops settling
  - no more air bubbles
  - smooth layer of mortar



Session 4

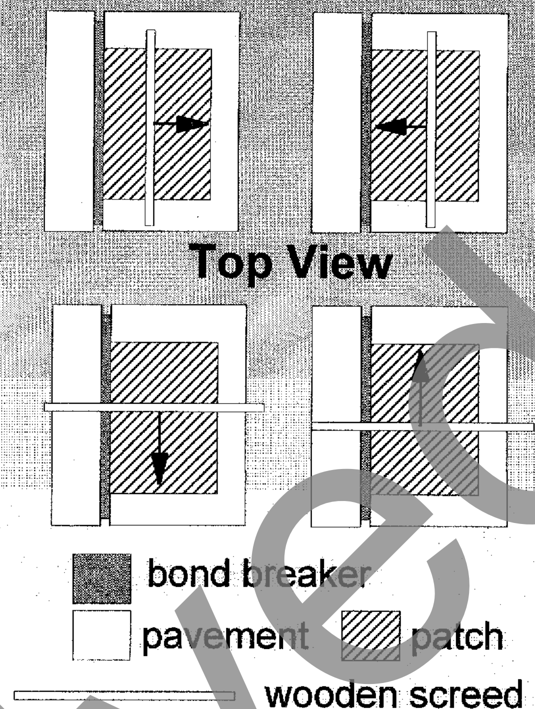
Using an Internal Vibrator
Slide #59

The vibrator should be held at an angle of 15 to 30 degrees from the vertical, and be moved through the patch until the entire repair has been vibrated. It should be lifted up and down, but not moved horizontally in the patch. The mix has been vibrated enough when it stops settling, air bubbles no longer appear, and a smooth layer of mortar appears at the surface of the patch.

Page 4-34 Figure 4-13

Screeding and Finishing

- Trowel level
- Vibrate
- Screed with stiff board
- Work toward edge of patch
- Match surface



Session 4

Screeding and Finishing
Slide #60

The surface of patches made from cementitious and some polymeric materials should be troweled level with the pavement. Vibration may be needed to finish the patch if the mix is stiff. Partial-depth patches are usually small enough to be screeded with a stiff board resting on the pavement. The material should be worked toward the patch edges using at least two passes. The patch surface must be troweled to remove any remaining irregularities. Extra mortar from troweling can be used to fill saw overcuts. If the patch is large, it should be finished to match the pavement surface.

Page 4-35

Curing

- Water curing
  - Continuous water spraying
  - Saturated coverings
- Sealed curing
  - Plastic sheeting
  - Curing compounds

Session 4

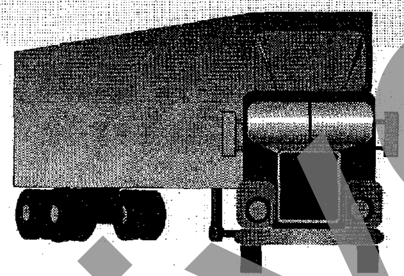
Curing
Slide #61

Improper curing can cause shrinkage cracks and early failure of the patch. The manufacturer's recommendations should be followed for patches that require curing. There are several ways that patches can be cured. Patches may be water cured by continuously spraying them with water or by covering them with moist burlap. Sealed curing prevents moisture loss but does not add moisture to the patch. Patches may be covered with polyethylene sheeting or a curing compound can be applied to their surfaces. Pigmented curing compounds work well with PCC-based patches.

Page 4-35

Opening to Traffic

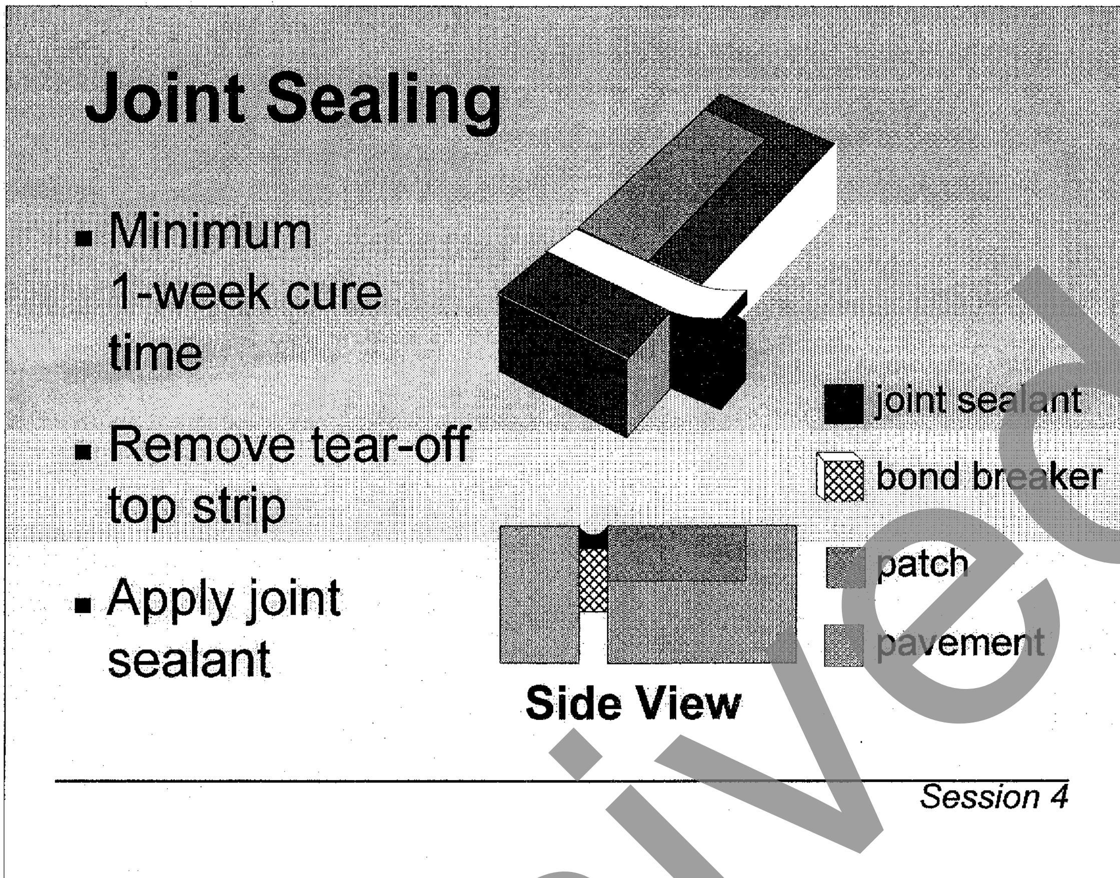
- Temperature during curing period
- Manufacturer's recommendations
- Test cylinders or beams for strength



Session 4

Opening to Traffic
Slide #62

The time for opening to traffic will depend on air temperature during the curing period. The specifications of rapid-setting mixes should be checked for recommended opening times. Cylinders or beams can also be tested for strength to determine what opening time will allow the repair material to develop enough strength to carry traffic.



Joint Sealing
Slide #63

The final step in the partial-depth spall repair process is restoring the joints around the patch. A minimum 1-week cure time should be allowed before joints sealing. If a scored bond breaker has been used, the tear-off top strip should be removed, and the selected joint sealant applied.

Page 4-28 Figure 4-9

Repair Quality

- Materials, procedures, and work
- Long-term performance
- Long-term cost-effectiveness

Session 4

Repair Quality
Slide #64

Partial-depth patches that are placed with poorly chosen materials, improper construction procedures, or poor work quality will perform poorly and will require additional patching in a short period.

However, patches that are placed with appropriate materials, proper procedures, and good work quality will perform well for several years, thereby disrupting traffic less and reducing worker's risk.

Doing the job right the first time will save time, money, and labor.

Safety

- Materials safety data sheets
- Equipment safety guidelines
  - waterblasters
  - pavement saws
  - jackhammers
- Traffic control
- Material disposal

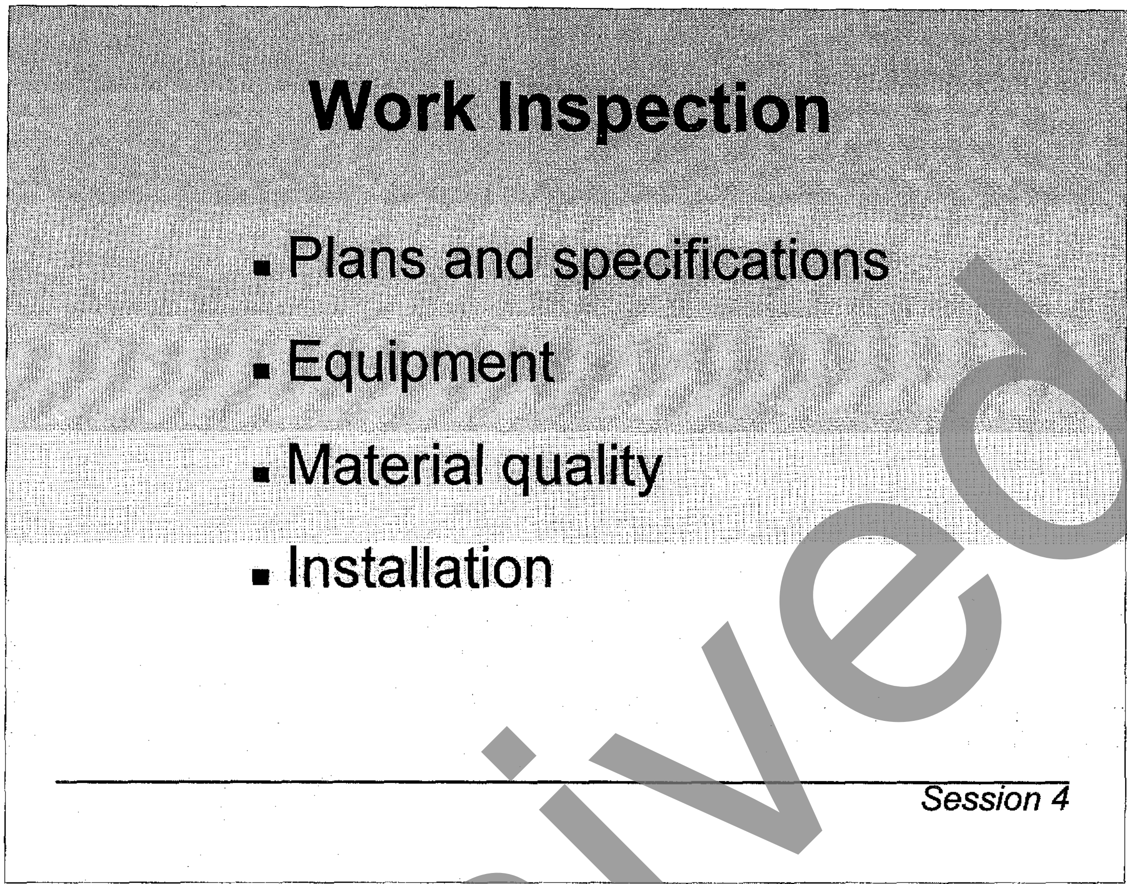
Session 4

Safety
Slide #65

Safety must be an important goal of every member of the maintenance crew.

Material safety data sheets (MSDS) and equipment safety guidelines must be followed to ensure safe handling of materials and equipment. Good traffic control should be used at all times to protect the maintenance crew from traffic hazards, and to protect motorists from construction hazards. Wasted materials should be disposed of using the manufacturer's guidelines and in accordance with State and local laws.

Page 4-26



Work Inspection
Slide #66

The maintenance project is a team effort. A supervisor or inspector must make sure that plans and specifications are being followed, equipment is performing well and is being used properly, quality materials are being used, and the patch is installed using good practices and good work quality. If something does go wrong, the maintenance team must work together to fix the problem.

Causes of Patch Failure

- Lack of bond
- Compression failure
- Variability of materials
- Improper use of materials
- Insufficient consolidation
- Incompatible thermal expansion
- Feathering of materials

Session 4

Causes of Patch Failures
Slide #67

Without quality control and inspection, the patch is likely to fail. Some common causes of patch failure are lack of bond between the patch and pavement, crushing of the patch because joints were not prepared properly, variability of materials, improper use of materials, insufficient vibration or rolling of the patch, choosing a patching material that expands and contracts with temperature changes differently than the pavement, and feathering of the patching material into a repair area with scalloped edges.

Page 4-36

Performance Evaluation

- Periodic visual inspections
- Sample day's or week's worth of patching
- Report number of failed patches
- Calculate patch survival rate (use table 4-10 in handbook)

Session 4

Performance Evaluation
Slide #68

To monitor the performance of specific types of patches that have been placed, periodic inspections of a sampling of those patches is necessary. Typically, annual inspections are sufficient, so long as they are done during key times of the year (e.g., in the spring after possible freeze/thaw damage).

Depending on how many patches were placed as part of a project, between 5 and 10 percent of the total number of patches should be examined for failure. Failure is perhaps best defined by the need for repatching. During each inspection, the number of failed patches should be reported, along with the age of the patches at the time of the inspection.

Using table 4-10 on page 4-38 of your handbook, the survival rate of a specific patch type can be calculated and compared with other types of patches that are being used.

Pages 4-37 & 4-38   Figure 4-10

Test and Evaluation
Partial-Depth Spall Repair

1. Identify material-procedure combinations
2. Identify test site location
3. Lay out site
4. Install experimental repairs
5. Monitor repair performance
6. Analyze and report performance data

Session 4

Test and Evaluation (Partial-Depth Spall Repair)
Slide #69

As mentioned in session 1, the FHWA is sponsoring a technical assistance program for States interested in doing their own field studies of maintenance materials and techniques. One area of pavement maintenance that States can receive technical assistance on is partial-depth spall repair in concrete pavements.

There are essentially six steps associated with performing a test and evaluation study in this area, with assistance being available for each step. The steps are:

1. Identifying the combinations of materials and procedures you wish to evaluate.
2. Identifying a suitable location for conducting the study.
3. Laying out the site (i.e., marking the locations to be patched).
4. Installing the experimental repairs.
5. Periodically inspecting the repairs for performance, and
6. Analyzing and reporting the performance data.

The Test and Evaluation Work Plans describe in more detail the work associated with each step. Again, if your agency is interested in this kind of study, the Technical Assistance Application must be filled out and submitted to the FHWA for consideration.


SESSION 5
AC Crack Treatment
Pavement Maintenance Effectiveness/
Innovative Materials Workshop

Session 5 AC Crack Treatment
Slide #1

Session 5 of the FHWA Pavement Maintenance Workshop is entitled, "AC Crack Treatment," and is designed to acquaint highway maintenance workers, supervisors, and engineers with state-of-the-art methods and materials for sealing and filling cracks in asphalt pavements.

It is hoped that this session will generate an increased awareness of the need for better designs, materials, and installation procedures, thereby increasing the performance of crack treatments.

Page 5-1

Session Overview

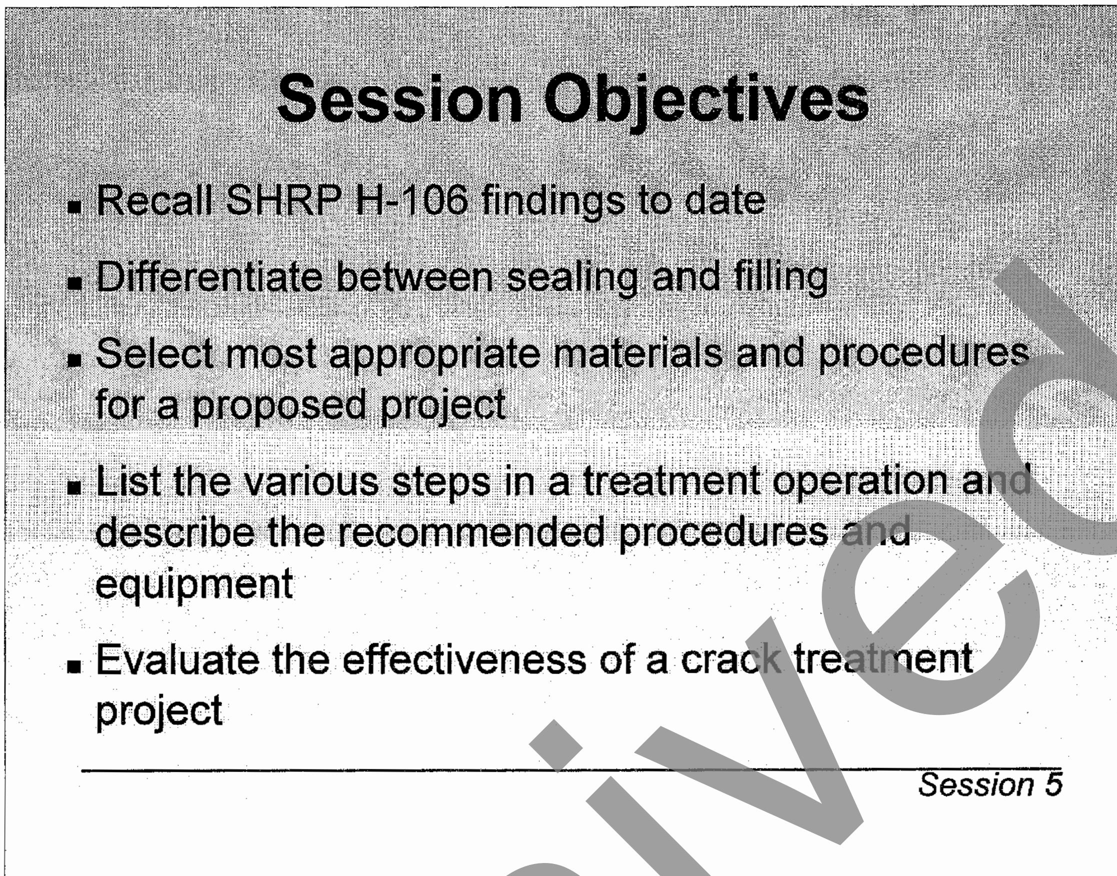
- SHRP H-106 findings
- Treatment objectives
- Project planning and design
- Installation
- Evaluation of treatment performance

Session 5

Session Overview
Slide #2

First, we will give a quick overview of the SHRP H-106 crack treatment experiment and tell you what the most recent findings are with respect to performance of materials and methods.

Then, we will proceed into the "how to" portion of the session, discussing first the objectives of crack treatment and the appropriate situations for performing it. We will then discuss the various aspects associated with planning crack sealing and crack filling operations, and then focus on the recommended installation procedures and practices. Lastly, we'll talk about how the effectiveness of resealing operations can be evaluated.



Session Objectives
Slide #3

At the conclusion of this session, you should:

- Be informed of the SHRP H-106 findings to date.
- Be able to differentiate between crack sealing and filling.
- Be familiarized with the process of selecting the most appropriate materials and procedures.
- List the various steps in a crack treatment operation and describe the recommended procedures and equipment, and
- Be familiarized with the process of evaluating treatment effectiveness.

Page 5-1

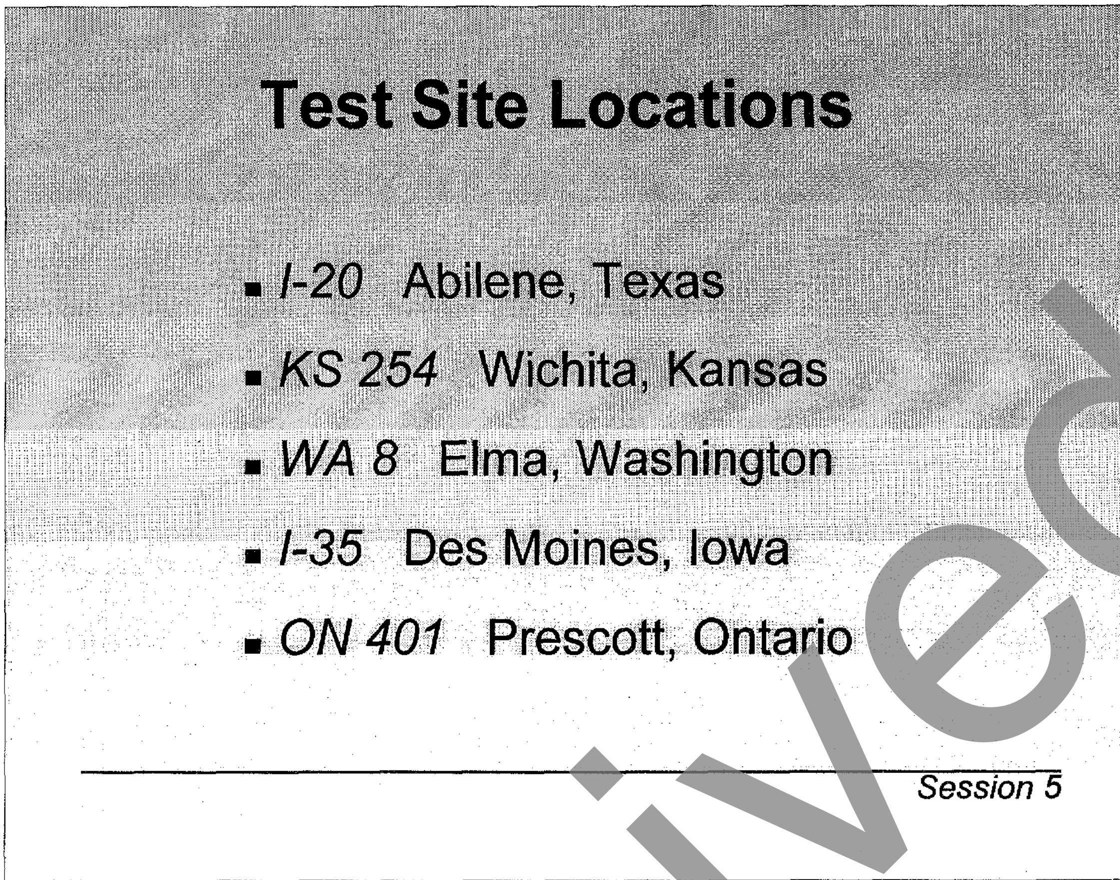
SHRP H-106
Crack Treatment
Experiment Findings

Session 5

SHRP H-106 Crack Treatment Experiment Findings
Slide #4

Let's take a quick look at the SHRP H-106 crack treatment experiment and its latest findings, which stem from test site inspections made in the fall of 1994.

Page 5-1



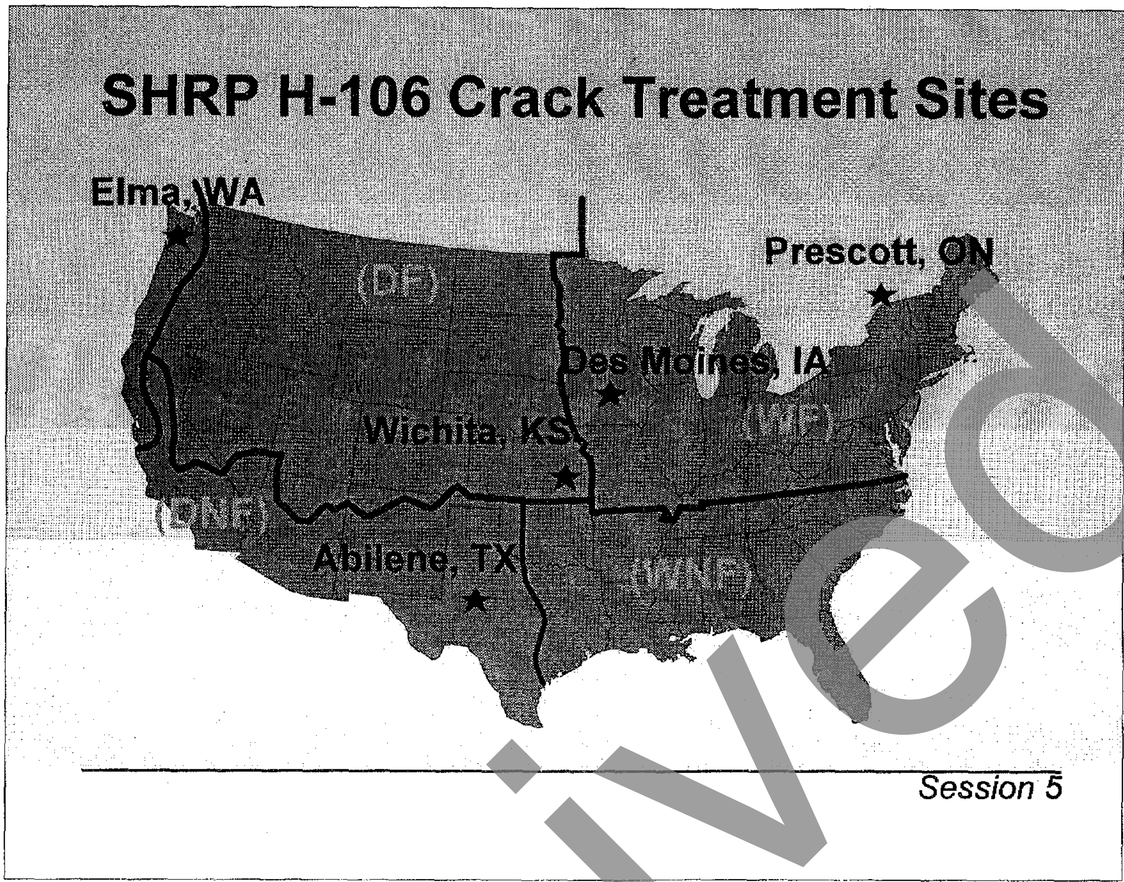
Test Site Locations
Slide #5

Very quickly, these are the locations of the five crack treatment test sites.

I-20 in Abilene, TX was installed in March 1991.
KS 254 in Wichita, KS was installed in April and May 1991.
WA 8 in Elma, WA was put down in April 1991.
I-35 in Des Moines, IA was installed in June 1991, and
ON 401 in Prescott, ON was done in August, 1991.

The first four sites here are transverse crack seal sites, whereas the Ontario site is a longitudinal crack fill site. Unfortunately, in the summer of 1995, the Washington crack seal site was lost to an overlay, the effect of which is considerably less performance data to observe and analyze.

Page 5-2



SHRP H-106 Crack Treatment Sites
Slide #6

This map shows the locations of the five crack treatment sites with respect to the SHRP-defined climatic zones.

I-20 in Abilene represents the dry-nonfreeze climatic region.
KS 254 in Wichita represents the dry-freeze climate.
WA 8 in Elma is the wet-nonfreeze site, and
I-35 in Des Moines and *ON 401* in Prescott are both wet-freeze sites.

Map not in handbook

Experiment Features (Crack Seal)

- 10 sealant products
  - Rubberized asphalt
  - Low-modulus rubberized asphalt
  - Fiberized asphalt
  - Self-leveling silicone
- 4 crack cleaning procedures
  - Compressed air
  - Wirebrush and compressed air
  - Hot compressed air (heat lance)
  - Sandblast and compressed air

Session 5

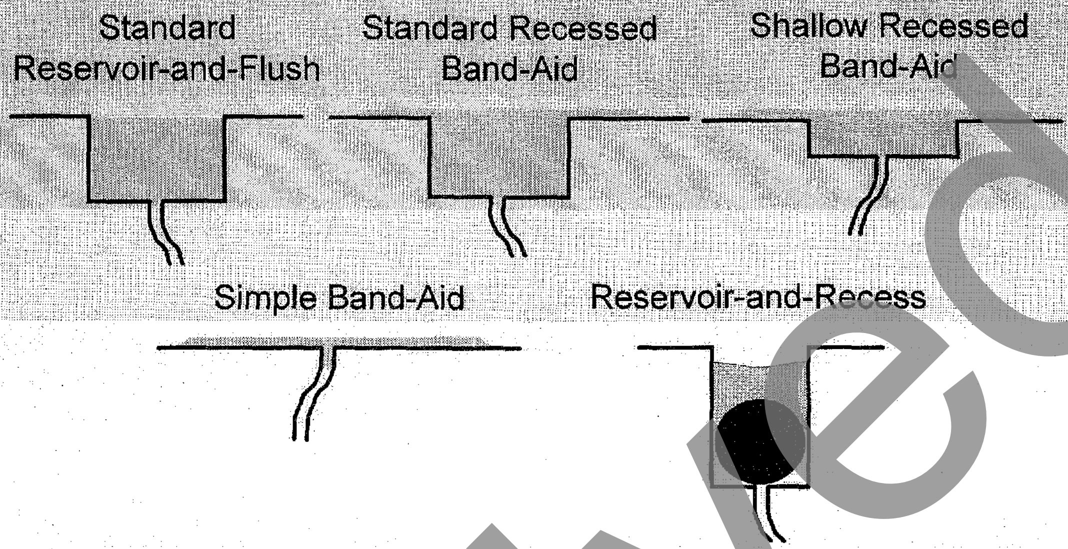
Experiment Features (Crack Seal)
Slide #7

The crack seal portion of the crack treatment experiment included the placement of 10 different sealant products, consisting of 6 standard rubberized asphalt sealants, 2 low-modulus rubberized asphalt sealants, 1 fiberized asphalt sealant, and 1 self-leveling silicone sealant.

In most of the hot-applied test sections, the cracks were cleaned using hot compressed air supplied by a heat lance. High-pressure air was used to clean the cracks in a few hot-applied sections, and at one section in Iowa, a wirebrush and compressed air was employed. For the cold-applied, self-leveling silicone sections, the crack reservoirs were sandblasted and then hit with compressed air.

Page 5-3   Table 5-1

Material Placement Configurations (Crack Seal)



Session 5

Material Placement Configurations (Crack Seal)
Slide #8

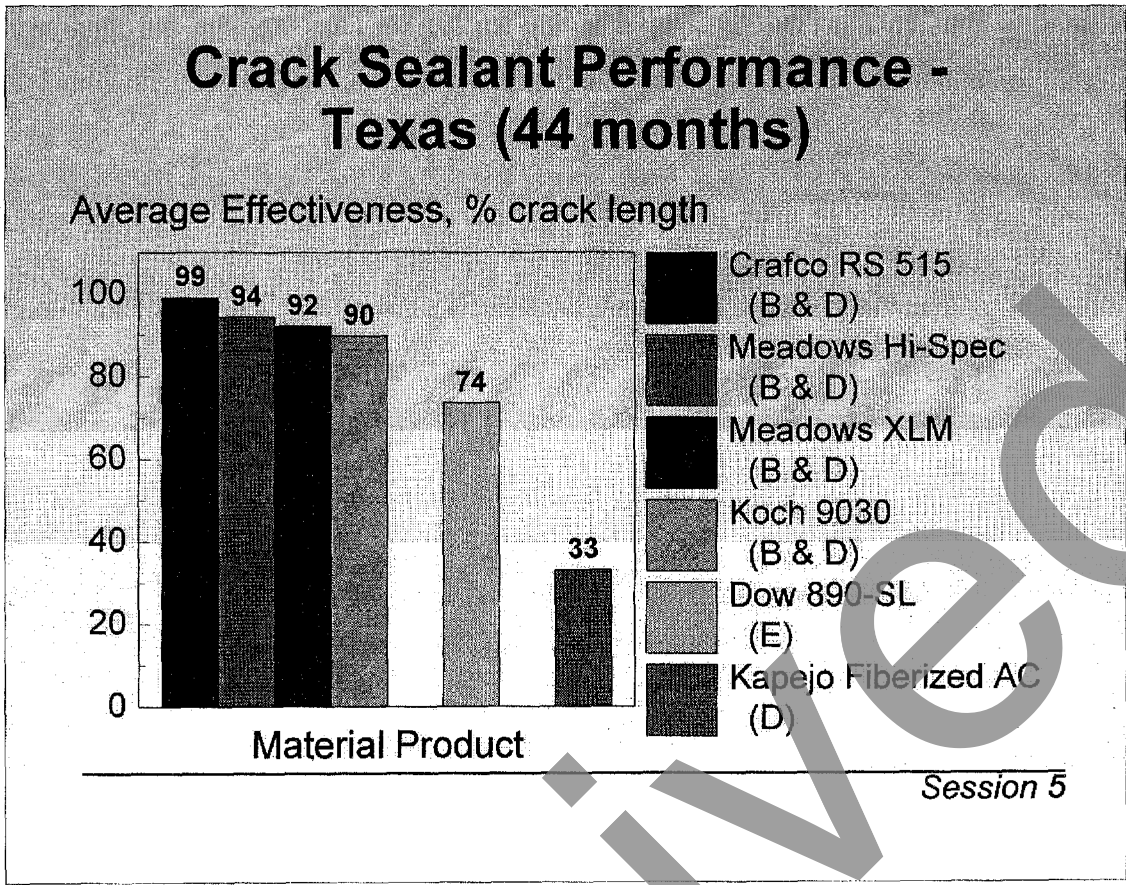
This slide shows the primary configurations in which the experimental transverse crack sealants were placed. The rubberized asphalt products were placed in the first four configurations, those being the reservoir-and-flush, standard recessed band-aid, shallow recessed band-aid, and the simple band-aid. The fiberized asphalt was placed only in the simple band-aid configuration, and the silicone was placed in the reservoir-and-recess configuration.

The dimensions associated with each configuration are given in figure 5-1 of your handbook. However, very quickly, the routed reservoir in the first two configurations are about 15 mm wide by 20 mm deep, whereas the routed reservoir in the shallow recessed band-aid is about 40 mm wide by 5 mm deep. A saw was typically used to create the reservoir in the last configuration. The cut here was 15 mm wide by 40 mm deep.

The band-aid dimension is about 75 mm wide by 3 mm thick.

Table 5-1 in your handbook shows the specific materials used in the study and summarizes the combinations of material and method that were placed at each site.

Page 5-4 Figure 5-1



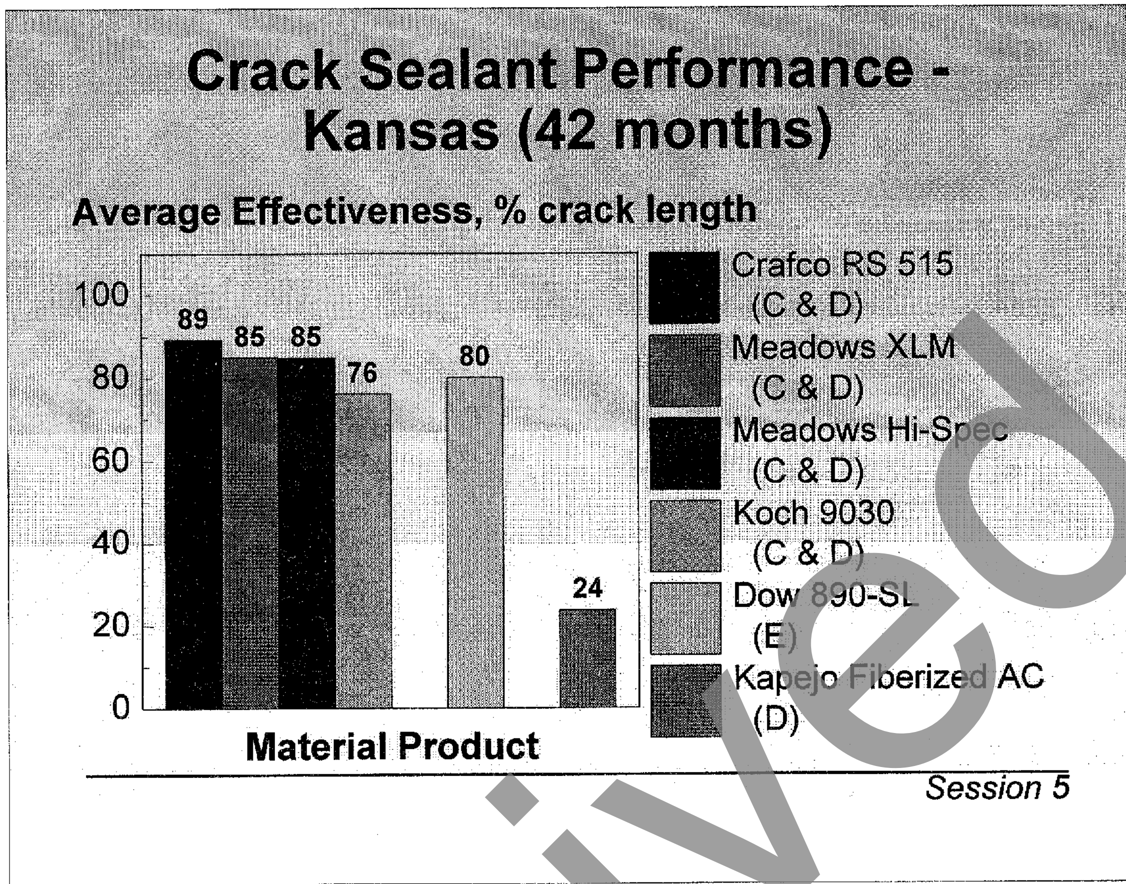
Crack Sealant Performance - Texas
Slide #9

The next four slides show how the experimental crack seal materials are performing at each test site. The performance measure illustrated in these slides is average effectiveness, gauged as a percentage of total crack treatment length. The slides show comparisons of four rubberized asphalt sealants placed in common configurations. Also included are the fiberized asphalt material that was placed in the simple band-aid configuration and the self-leveling silicone that was placed in the reservoir-and-recess configuration.

As you can see in this slide, the most effective crack seal at the Texas site is Crafco RS 515, which is a standard rubberized asphalt. Another standard rubberized asphalt, Meadows Hi-Spec, has been slightly less effective, but is still performing very well. The two low-modulus rubberized asphalts, Meadows XLM and Koch 9030, are also performing very well. The performance of Dow 890-SL self-leveling silicone has been fair, primarily because it was placed too high in some places and was consequently pulled out by traffic. Very poor performance has been observed of the Kapejo Bonifiberized asphalt.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order



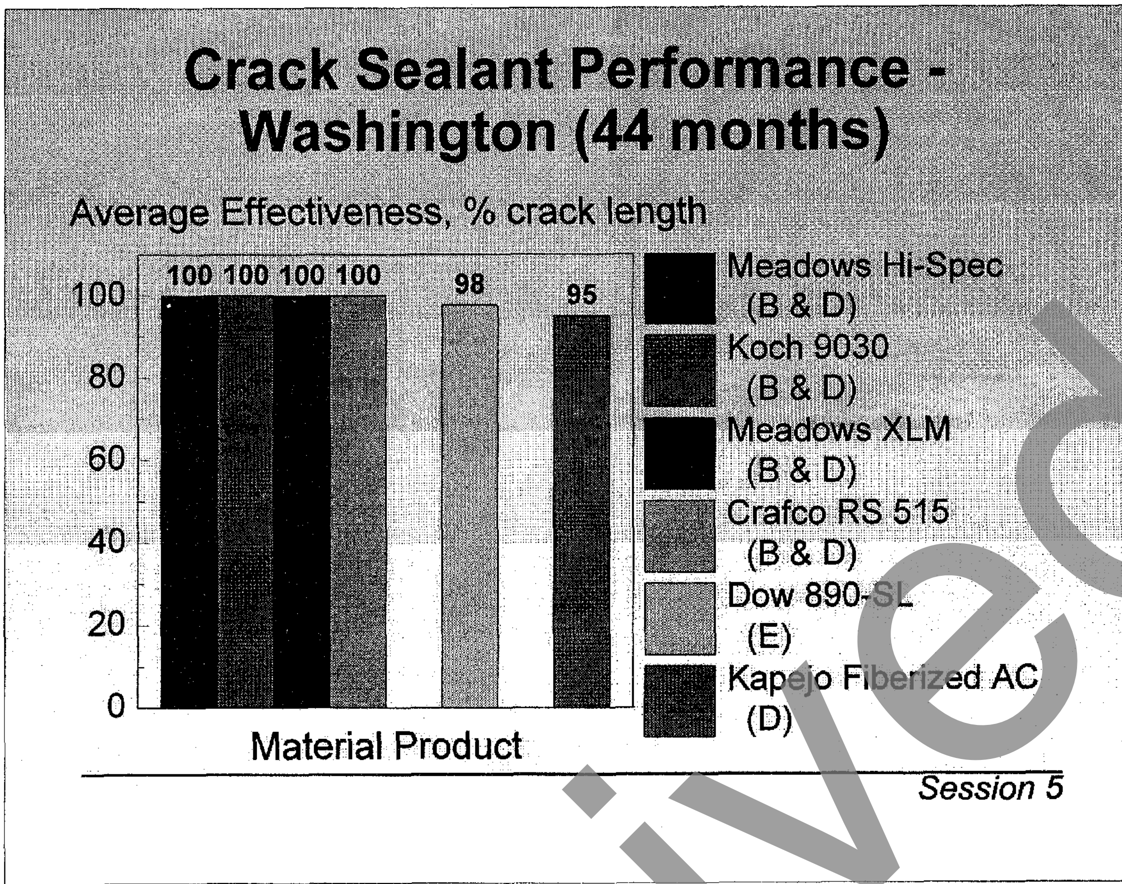
Crack Sealant Performance - Kansas

Slide #10

At the Kansas ideal-conditions site, three of the four rubberized asphalt sealants---Crafco RS 515, Meadows XLM, and Meadows Hi-Spec---along with the Dow 890-SL self-leveling silicone, show good performance. Koch 9030 is showing fair performance and the Kapejo Bonifiberized asphalt is largely ineffective.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order

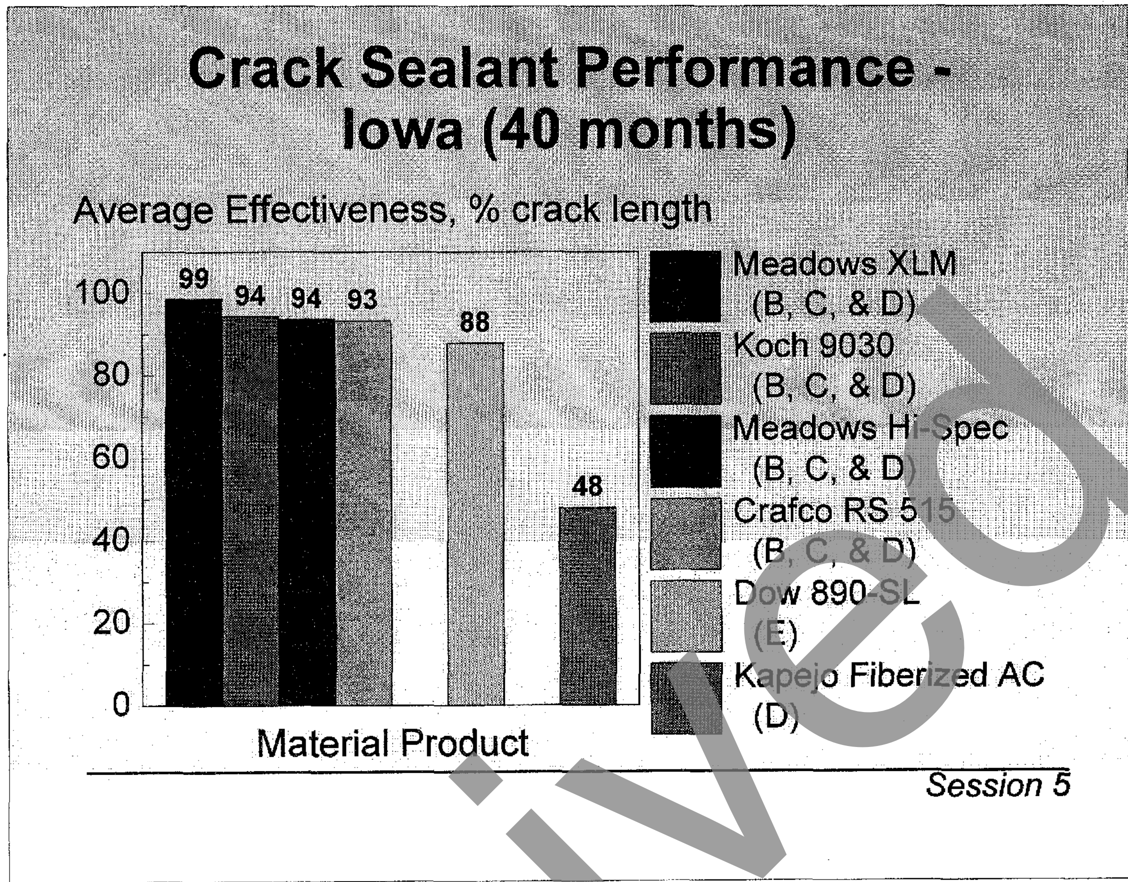


Crack Sealant Performance - Washington
Slide #11

The best overall sealant performance has been at the Washington site, which is located in a moderate climate and has low-volume traffic. At the time of the final inspection (the site was overlaid in the fall of 1995), all six products were showing excellent performance.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order

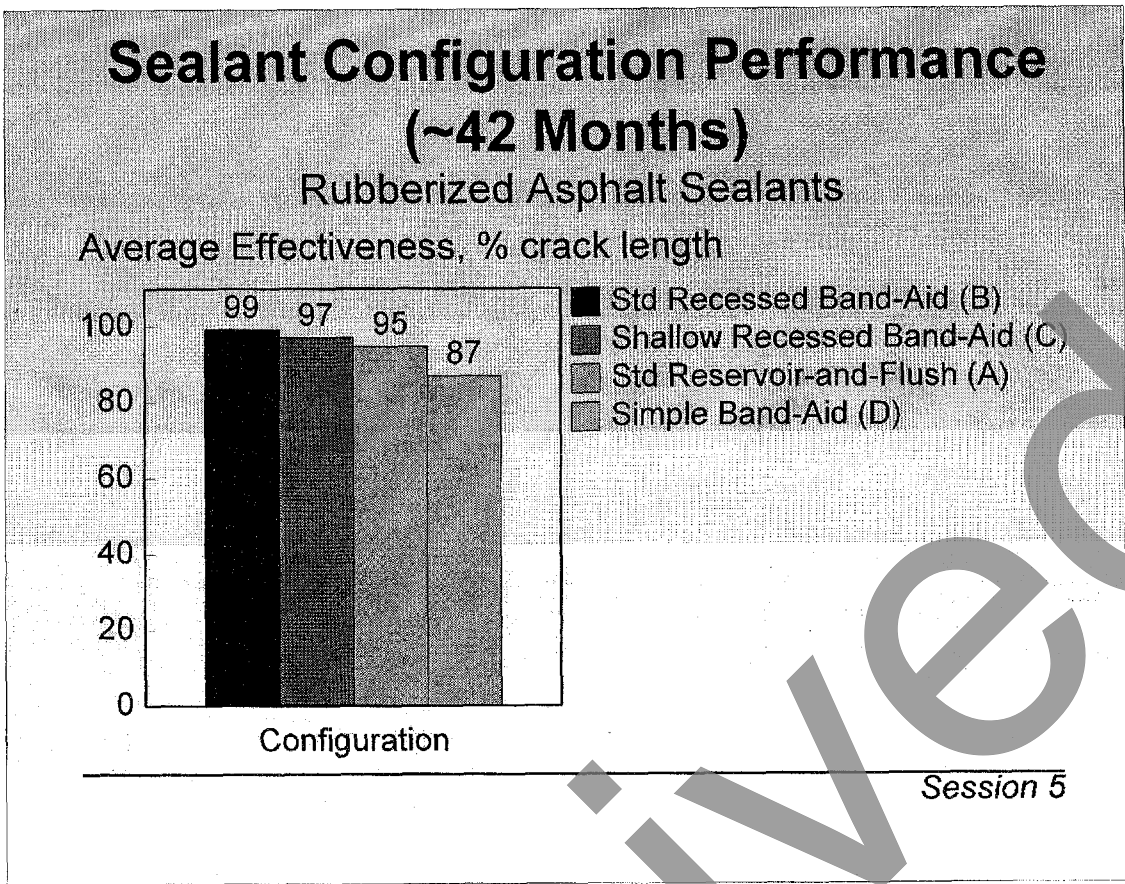


Crack Sealant Performance - Iowa
Slide #12

At the Iowa site, all four rubberized asphalt sealants are performing very well and Dow 890-SL is showing slightly worse performance, but is still in good condition. The Kapejo Bonifiberized asphalt is showing less than 50 percent effectiveness, and is thus performing very poorly.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order



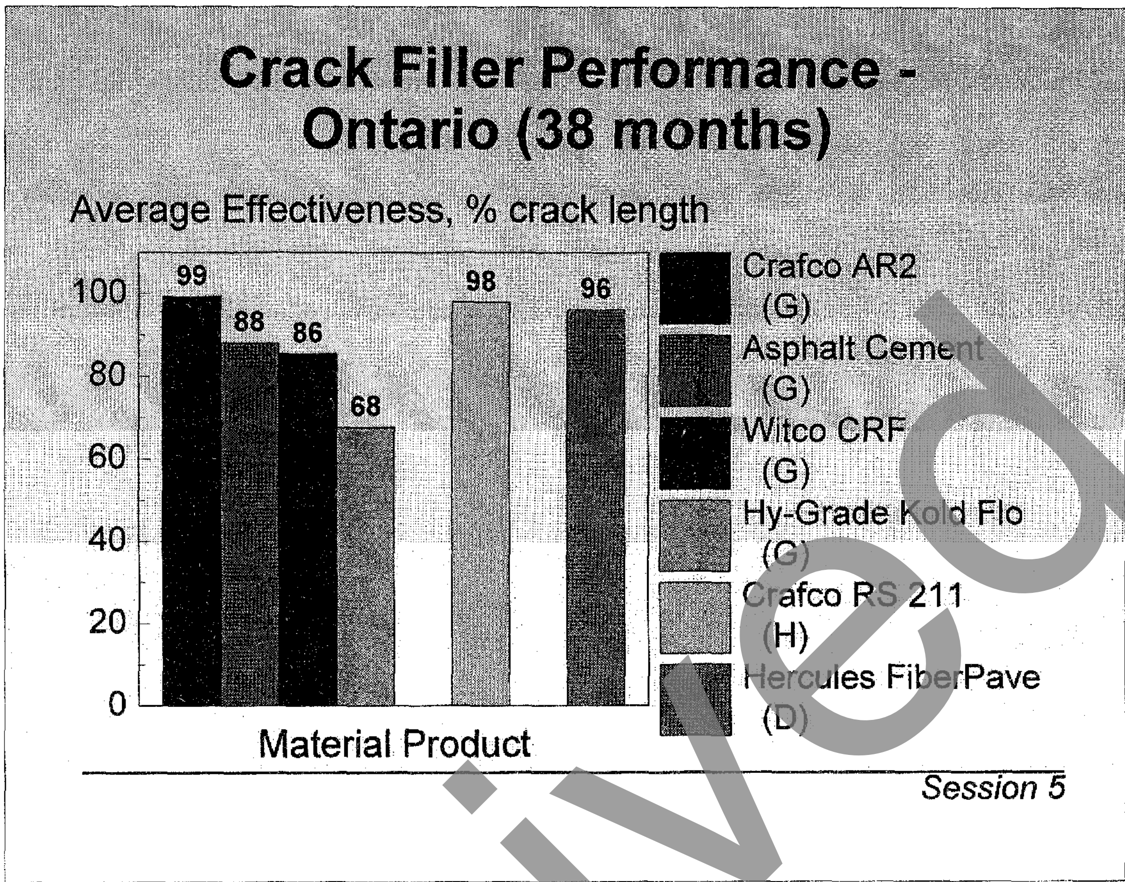
Sealant Configuration Performance
Slide #13

Looking at the performance of the four rubberized asphalt sealant configurations, we see that the best performance is being provided by the standard recessed band-aid, followed closely by the shallow recessed band-aid.

Compared to the standard recessed band-aid, the reservoir-and-flush shows about four percent less effectiveness, and the worst performing configuration, the simple band-aid, shows about 12 percent less effectiveness.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order



Crack Filler Performance - Ontario

Slide #14

The performance of crack filler materials at Ontario is shown in this slide. A direct comparison of the first four products placed in the flush-fill configuration shows Crafco AR2 (asphalt rubber) as the most effective. Asphalt cement and Witco CRF (proprietary emulsion) are not quite as effective but still show good performance. Hy-Grade Kold Flo, a proprietary rubberized emulsion, shows poor performance.

Although placed in different configurations, Crafco RS 211 (rubberized asphalt) and Hercules FiberPave (fiberized asphalt) show excellent performance as a longitudinal crack filler.

Figure not in Handbook

Top to Bottom Legend Order Corresponds with Left to Right Chart Order

Average Annual Cost Comparison - Materials (Kansas)

Crack Seal Treatment	Service Life, yrs to 90% effectiveness	Average Annual Cost, $/100 lin m
Hi-Spec*	5.0 (Est)	161
RS 515*	5.5 (Est)	151
9030*	4.5 (Est)	177
XLM*	4.5 (Est)	184
Boni-fiberized asphalt (simple band-aid)	0.5	1,102
890-SL (reservoir-and-recess)	2.25	489

* shallow recessed band-aid

Session 5

Average Annual Cost Comparison - Materials
Slide #15

Based on a 90-percent effectiveness level, the service life of each crack seal treatment at the Kansas (ideal-conditions) site has been estimated. These service life values and the estimated placement costs and user-delay costs associated with each treatment enabled the calculation of the average annual costs on a basis of $/100 linear meters of treated crack.

As you can see in this case, the most cost-effective seal types are the standard rubberized asphalts, followed very closely by the low-modulus rubberized asphalts. Nearly three 3 times more costly is the self-leveling silicone and roughly seven times more costly is the fiberized asphalt.

Average Annual Cost Comparison - Configurations (Kansas)

Crack Seal Configuration*	Service Life, yrs to 90% effectiveness	Average Annual Cost, $/100 lin m
Reservoir-and-flush	2.5	97
Std recessed band-aid	5.0 (Est)	51
Shallow recessed band-aid	5.0 (Est)	49
Simple band-aid	0.75	228

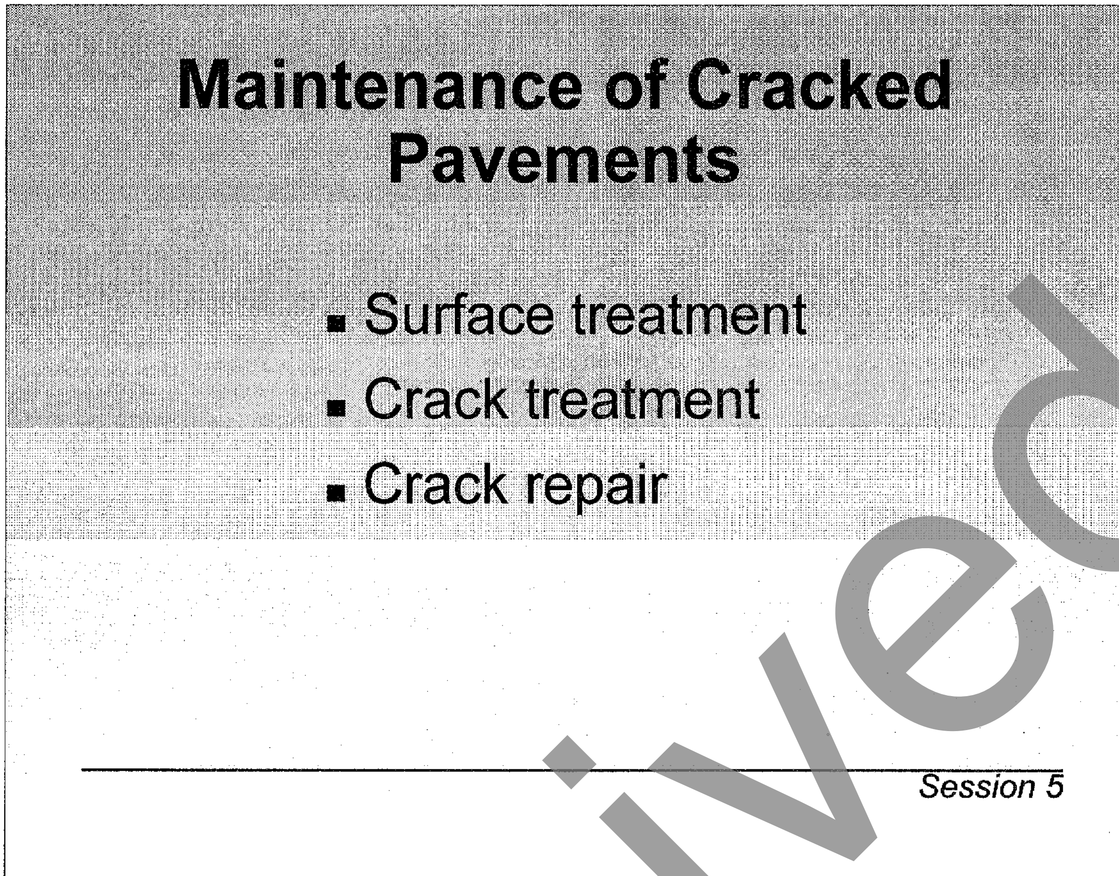
* Meadows Hi-Spec

Session 5

Average Annual Cost Comparison - Configurations
Slide #16

Focusing on one standard rubberized asphalt sealant placed in different configurations at the Kansas (ideal-conditions) site, we see that the most cost-effective placement configurations (based on a 90 percent effectiveness rating) are the two recessed band-aid configurations.

The reservoir-and-flush configuration is nearly twice as costly as the recessed band-aids and the simple band-aid configuration is roughly six times as costly as the recessed band-aids.



Maintenance of Cracked Pavements
Slide #17

Now, let's move on to discussing the recommended ways of planning, conducting, and monitoring crack treatment projects.

It is important that we understand how cracking in pavements should be dealt with. Since cracks develop in several ways and to varying degrees, they can be treated in different ways.

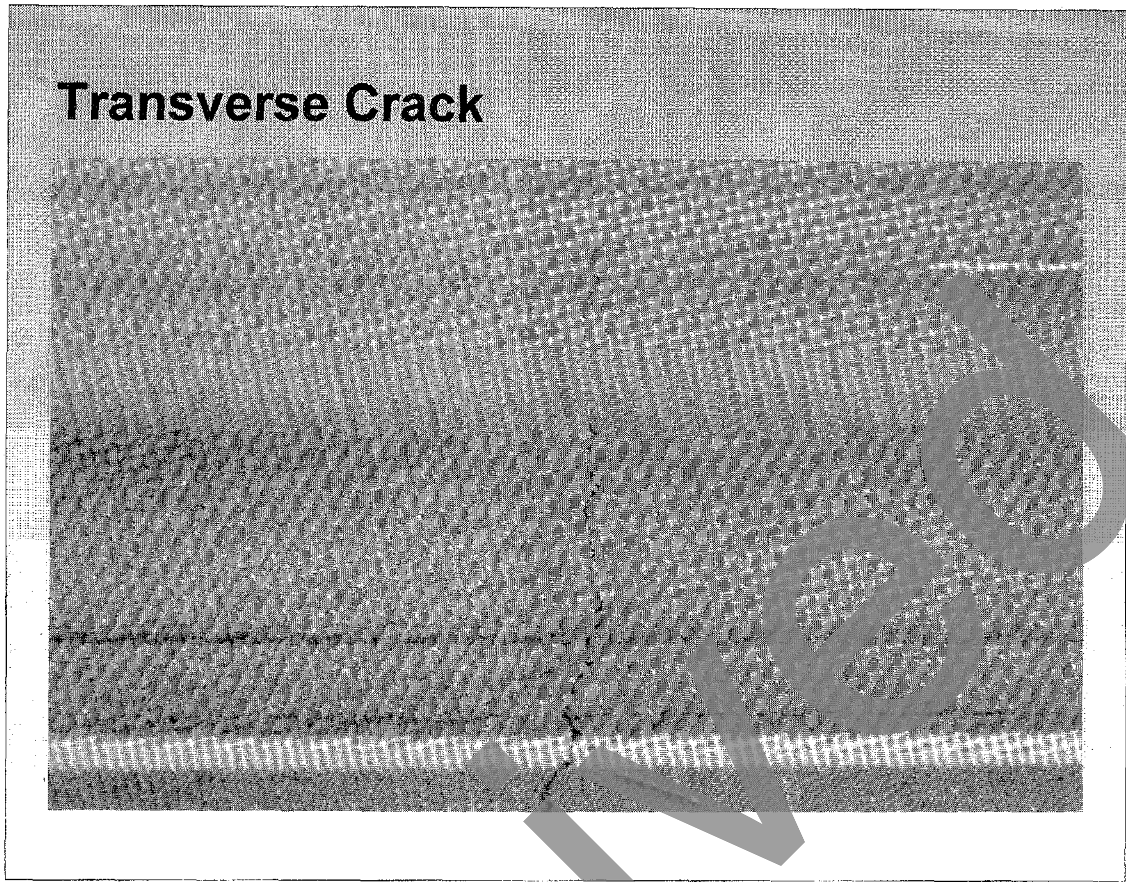
If crack density is fairly high, then a surface treatment, such as a chip seal or slurry seal, may be warranted. If, however, cracking is not excessive, then direct treatment will be more practical.

The type of direct treatment will depend on the average deterioration level of the cracks. Significantly spalled, alligatored, or deformed (i.e. cupped or rolled) cracks will normally require repair through milling and/or patching.

Cracks with minimal deterioration, however, are prime candidates for preventive maintenance operations, such as sealing or filling.

This last strategy, crack treatment, is what we are going to focus on in this session.

Pages 5-6 & 5-7



Transverse Crack
Slide #18

The next four slides illustrate some of the more common cracking phenomena that are encountered. I expect most of you have seen cracks like this, that extend across the pavement. Can anyone tell me what this type of crack is generally referred to as?

This is a transverse crack that is fully developed and mostly free of significant edge deterioration.

Longitudinal Crack

Longitudinal Crack
Slide #19

What about this crack? Can anyone describe this crack type?

This is a longitudinal crack that has developed at the cold joint between two paving lanes.

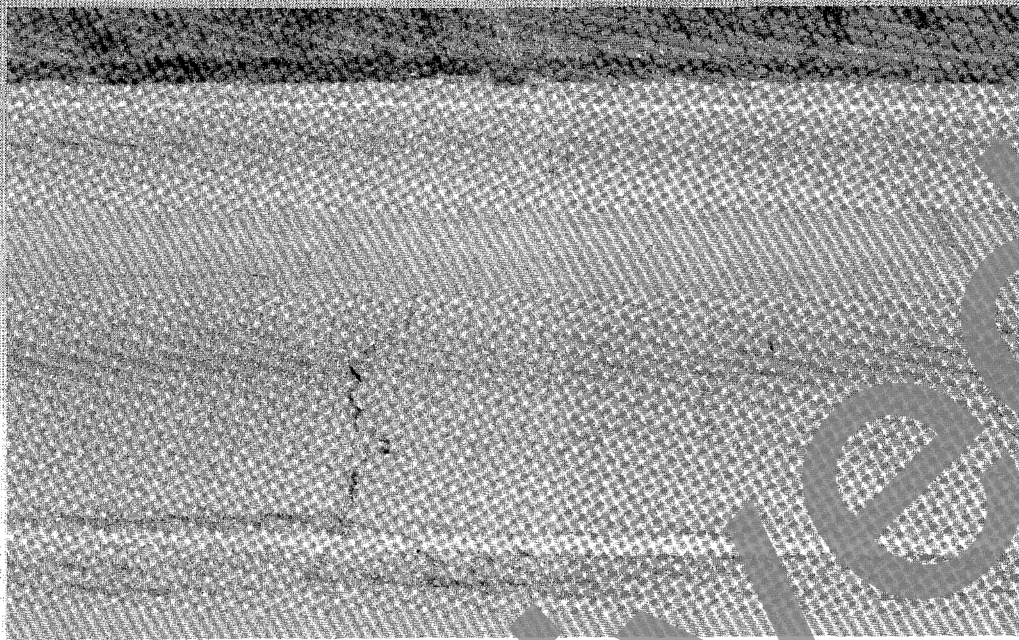
These first two cracks are good candidates for crack treatment.

Wide, Partly Deteriorated Crack

Wide, Partly Deteriorated Crack
Slide #20

Here, we see a wide, partially deteriorated transverse crack. This is a potential candidate for crack repair.

Excessive Cracks



Excessive Cracks
Slide #21

In this slide, we see cracks that have become excessively dense, making this pavement a candidate for surface treatment.

Objectives of Crack Treatment

- Sealing - to prevent the intrusion of water and incompressibles into working cracks
- Filling - to substantially reduce the infiltration of water into non-working cracks and reinforce the surrounding pavement

Session 5

Objectives of Crack Treatment
Slide #22

Crack sealing and crack filling are similar operations but each has a distinctive purpose.

Crack sealing is performed for the purpose of preventing the intrusion of water and incompressibles into working cracks. (Working cracks refer to cracks that undergo a considerable amount of movement. Incompressibles refer to materials that resist the compression of closing joints or cracks).

Crack filling, on the other hand, is intended to substantially reduce the infiltration of water into non-working cracks and reinforce the surrounding pavement.

Because the objective for sealing is more difficult, it involves greater forethought, the use of more specialized materials and sophisticated equipment, and, subsequently, greater costs.

Pages 5-6 & 5-7

Benefits of Proper and Timely Crack Treatment

- Extended pavement service life
  - greater pavement support
  - reduced rate of crack deterioration
- Increased safety

Session 5

Benefits of Proper and Timely Crack Treatment
Slide #23

When done correctly and at the right time, the benefits of crack treatment are profound.

First, pavement service life can be greatly extended by minimizing the adverse effects of water on base and subbase strength, as well as the adverse effects of water and air on existing cracks.

Second, overall safety is increased as the need for subsequent applications is reduced.

Planning the Crack Treatment Project

- Determining the appropriate crack treatment strategy
- Selecting a material
- Selecting a material placement configuration
- Determining resource requirements
- Performing a life-cycle cost analysis

Session 5

Planning the Crack Treatment Project
Slide #24

As with every maintenance operation, some degree of planning is required for crack treatment.

Among the more important steps in planning crack treatment operations are:

- determining the appropriate treatment strategy (i.e., seal or fill, temporary or long-term).
- selecting a material and a material placement configuration.
- determining the resource requirements for the project (i.e., material amounts, labor, equipment), and
- performing a life-cycle cost analysis, that takes into account material cost and installation cost, and the estimated service life.

Page 5-8

Determining the Appropriate Crack Treatment Strategy

- Amount of annual movement experienced by target crack type
- Type and orientation of cracks targeted for treatment
- Average crack width
- Amount of associated edge deterioration
- Pavement rehabilitation plans??

Session 5

Determining the Appropriate Crack Treatment Strategy
Slide #25

The first step in planning is to determine the appropriate crack treatment strategy. When it is determined whether target cracks should be sealed or filled, and for how long, subsequent decisions regarding which materials, equipment, and procedures to use are simplified.

The principal basis for determining whether to seal or fill is how much annual movement the target crack type undergoes. As a general rule, working cracks should be sealed and non-working cracks should be filled. Working cracks are considered to undergo more than 2 mm of average annual horizontal movement, whereas non-working cracks are considered to undergo 2 mm or less. Often, crack type and orientation are good indicators of whether cracks are working or non-working.

Other factors which should be considered are average crack width and amount of deterioration. Sealing, as we'll see shortly, is generally not recommended for cracks wider than 20 mm and having significant deterioration.

Finally, the threat of resurfacing or some other form of major rehabilitation in the next few years may warrant consideration of less costly, short-term treatments.

Recommended Criteria for Sealing and Filling

Crack Characteristics	Sealing	Filling
Annual horizontal movement, mm	≥ 2	< 2
Average width, mm	5 to 20	5 to 25
Edge deterioration, %	≤ 25	≤ 50
Type/orientation	transverse, diagonal	longitudinal, block

Session 5

Recommended Criteria for Sealing and Filling
Slide #26

This chart shows the recommended criteria for sealing and filling operations.

Again, we can see that average annual crack movement is the primary basis for justifying sealing or filling operations. Typically, working cracks are transverse or diagonal while non-working cracks are longitudinal or block patterns.

In general, it is desired that average crack width at the time of installation be greater than 5 mm. This way, a sufficient amount of material can be injected into the crack if a reservoir is not created. Likewise, if deterioration is too prevalent, then crack treatment becomes less effective.

Page 5-7 Table 5-3

Material Selection Considerations

- Type of crack treatment activity
- Available equipment
- Desirable properties of material
- Cost of purchasing/installing material
- Performance history of material

Session 5

Material Selection Considerations
Slide #27

Material selection is the next step in planning. Some of the most important factors that must be considered when selecting materials include:

- type of crack treatment operation to be performed (i.e. sealing or filling).
- type of equipment available for installing crack treatment materials.
- engineering properties desired of the material (minimal preparation, extremely flexible, very durable, etc.).
- overall cost of purchasing and installing the material, and
- performance history of the material.

Sealant Materials

Sealant Material	Example Products	Specification
Asphalt rubber	Crafco AR2, Koch 9000	ASTM D 5078
Rubberized asphalt	Crafco RS 221, Meadows Hi-Spec, Koch 9005	ASTM D 1190 & D 3405
Low-modulus rubberized asphalt	Crafco RS 231, Meadows XLM, Koch 9030	Modified ASTM D 3405
Self-leveling silicone*	Dow 890-SL	Mfgr specs

* Cold-applied

Session 5

Sealant Materials
Slide #28

Thermoplastics-Materials that harden upon cooling or that set by the release of solvents or the breaking of emulsions on exposure to air.
Thermosets-Materials that cure from a liquid to solid state by chemical reaction or by the release of solvent.

There are basically four types of materials that are suitable for sealing purposes. Each of these material types are specially formulated to provide the adhesive and flexibility properties necessary for stretching and relaxing with crack movement.

Asphalt rubber is a hot-applied thermoplastic material that conforms to ASTM specification D 5078 or various state specifications. This material consists simply of ground rubber particles mixed in (at the plant or at the job site) with heated asphalt cement. Rubberized asphalt is a hot-applied thermoplastic that conforms to either ASTM D 1190 or D 3405. It differs from asphalt rubber in that the ground rubber is first melted and then mixed in with heated asphalt cement. Low-modulus rubberized asphalt is a softer (softer grade of asphalt cement), more yielding version of rubberized asphalt. It, too, is hot applied thermoplastic, for which various state-modified D 3405 specifications exist.

Self-leveling silicone is a relative newcomer to asphalt crack sealing. It is a one-component, cold-applied thermosetting material which is currently only specified by its manufacturer.

Page 5-10   Table 5-4

Filler Materials

Filler Material	Example Products	Specification
Asphalt emulsion*	CRS-2, HFMS-1	ASTM D 977 & D 2397
Polymer-modified asphalt emulsion*	Elf CRS-2P, Hy-Grade Kold Flo	Mfgr & State specs
Asphalt cement	AC-10, AC-20	ASTM D 3381
Fiberized asphalt	Hercules Fiber-Pave, Kapejo Bonifibers + AC	Mfgr & State specs
Asphalt rubber	Koch 9000, Crafco AR2	ASTM D 5078

* Cold- or warm-applied

Session 5

Filler Materials
Slide #29

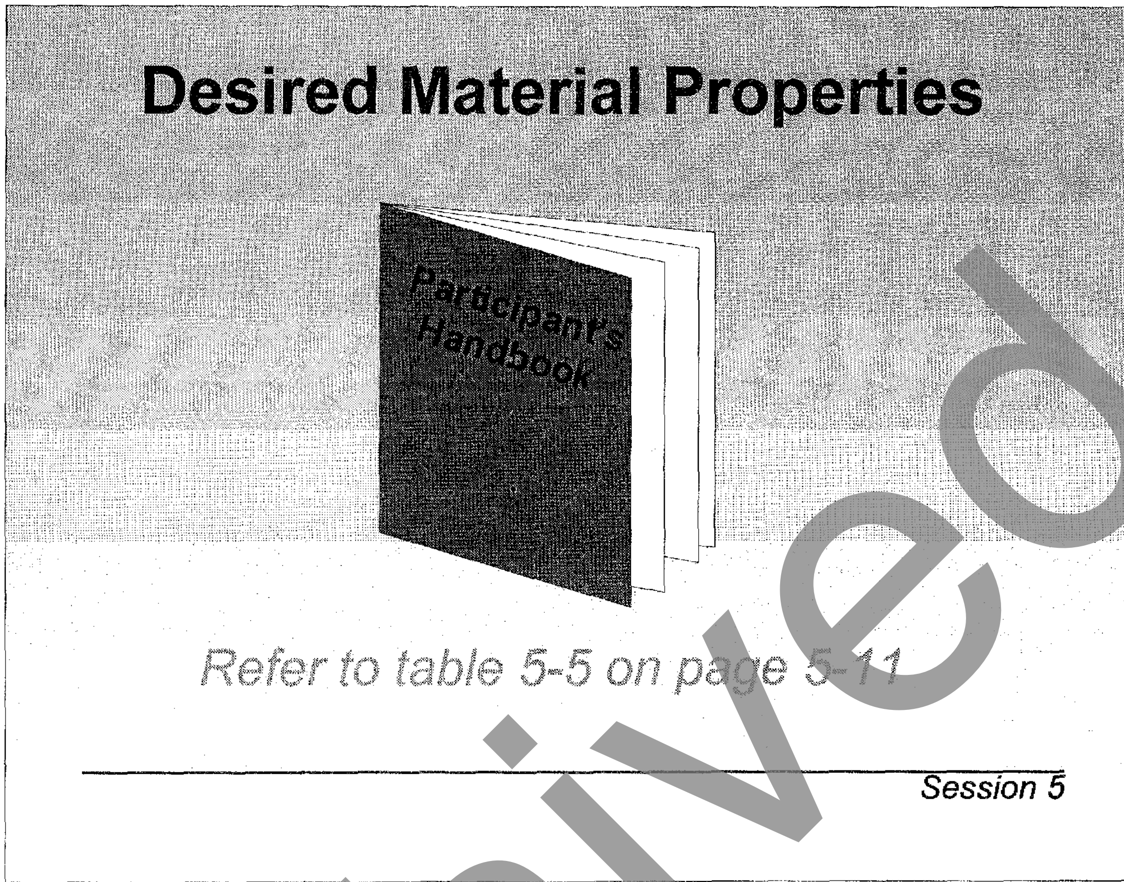
This is a list of the primary materials used in crack filling operations. These materials are plain or modified asphalt materials that have no or some flexibility.

Plain and polymer-modified emulsions can be applied cold or partially heated. They are typically made to conform to ASTM specifications D 977 or D 2397, or to various state specifications.

Asphalt cement is hot-applied and usually conforms to ASTM D 3381.

Fiberized asphalt is a hot applied material that conforms to manufacturer or State specifications.

Page 5-10 Table 5-4



Desired Material Properties
Slide #30

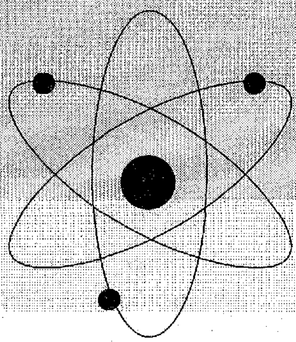
There are many desired material characteristics, for which no one material has a monopoly. Table 5-5 on page 5-11 of your handbook lists the many desirable properties and gives an indication of how well each material type exhibits those properties.

As you can see, moving across this table from left to right results in many more fulfilled desirable properties. At the same time, however, the material cost increases too.

Question: What types of materials and material products does your State use for sealing and for filling?

Page 5-11 Table 5-5

Laboratory Material Testing



- Highly recommended
- Good performance not guaranteed by compliance with spec

Session 5

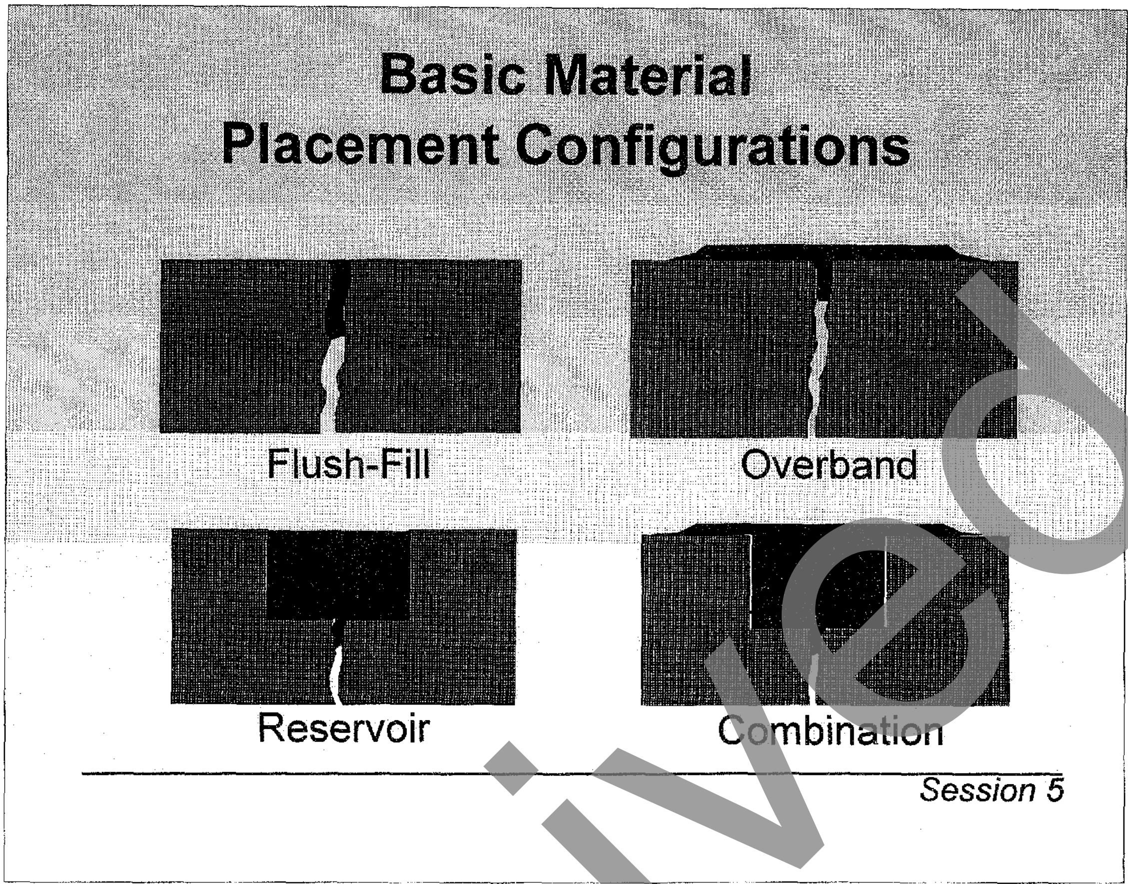
Laboratory Material Testing
Slide #31

Laboratory testing of the selected treatment material is highly recommended, as it ensures that the material acquired for a project exhibits the properties for which it was selected.

There are several testing procedures available through sources such as ASTM, AASHTO, and Federal Specs. We won't get into these in this workshop, but each source generally has a set of testing procedures and accompanying requirements for the various material types, as we saw earlier.

The main point about laboratory testing is that if a material fails to meet the standards professed by the manufacturer, it should be rejected. On the other hand, it's important to realize that just because a material meets specifications, that is no guarantee of good performance.

Page 5-9 & 5-12



Basic Material Placement Configurations
Slide #32

Another part of planning is determining the fashion in which the treatment material should be applied to the cracks.

Should the cracks be left uncut, as shown in the top two configurations, or should they be widened to form a reservoir, as seen in the bottom configurations?

Also, is an overband of material desired, like those in the overband and combination configurations, or is flush strike-off or recessment preferred?

In the case of the overband, there is concern with the potential for tracking and damage done by traffic. Moreover, depending on the overband thickness, ride quality may be effected. However, as we mentioned earlier, the H-106 study indicates that the overband, used in conjunction with a reservoir, provides very good mid-term performance.

Page 5-13 Figure 5-2

Selecting a Material Placement Configuration

- Type of operation
- Type of material to be used
- Available equipment
- Amount of edge deterioration
- Traffic level
- Desired performance
- Cost
- Aesthetics

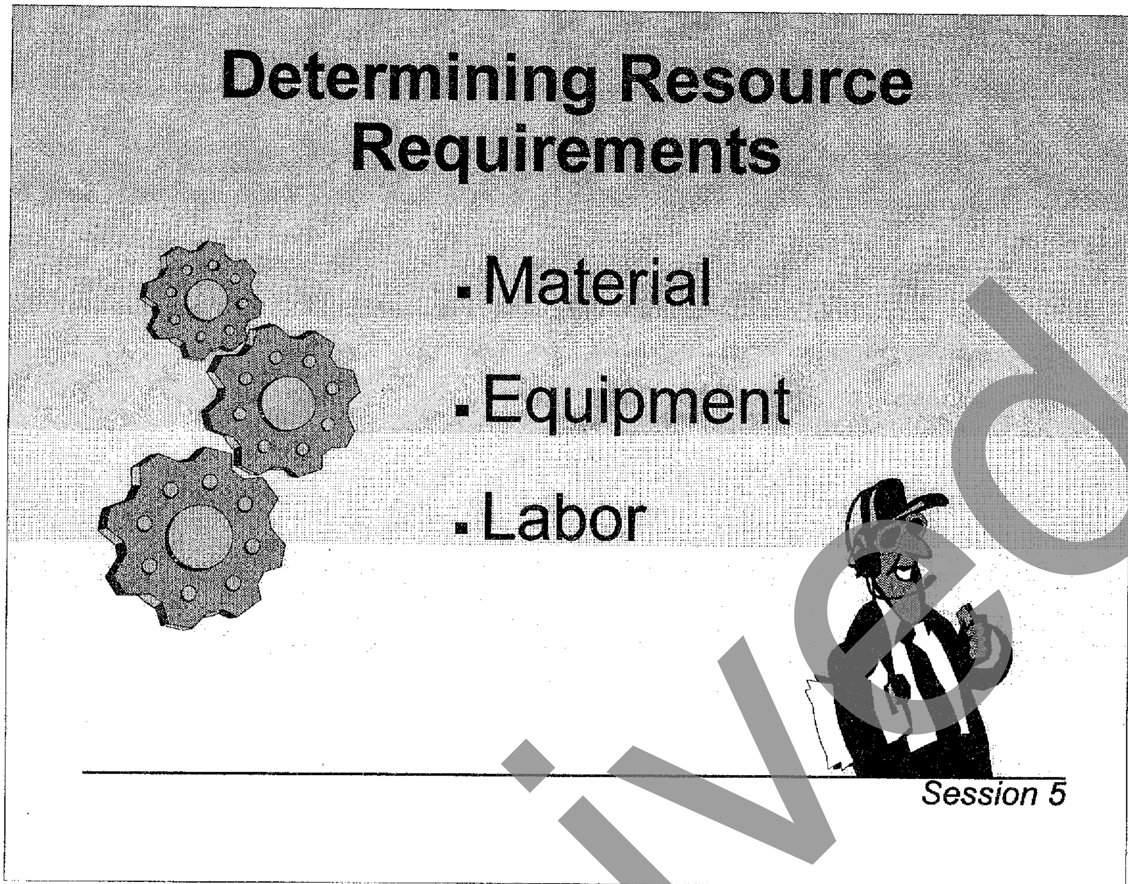
Session 5

Selecting a Material Placement Configuration
Slide #33

Some of the main factors to be considered when selecting a configuration include:

- type of operation (crack cutting usually performed only in sealing operations).
- type of material to be used (silicone must be recessed, so it is not exposed to traffic).
- type of equipment available (routers/saws for crack cutting?).
- amount of edge deterioration (overbanding can be used to fill and cover secondary cracks).
- traffic characteristics (overband configurations are prone to wear under traffic).
- desired performance (for long-term performance, reservoir and combination configurations are recommended).
- cost (omitting crack-cutting operation reduces equipment and labor costs; reservoir and combination configurations use much more material resulting in higher material costs), and
- aesthetics (overband and combination configurations detract from appearance of pavement).

Page 5-15   Table 5-6



Determining Resource Requirements
Slide #34

The next step in planning is to determine the resources required for doing the work. This includes:

- estimating the amount of material needed for treating the cracks, and
- determining the equipment and amount of labor needed for conducting the operation.

If more than 1 treatment option remains feasible after having gone through the planning process, a decision on which option to use can be made by doing a cost-effectiveness analysis. Key variables in this type of analysis are overall installation cost (including material cost) and estimated treatment performance.

Cost-effectiveness example
Pages 5-18 thru 5-20

Example Problems

- Estimating material quantities
- Determining the most cost-effective treatment option
- Typical manpower requirements and productivity rates

Pages 5-16 thru 5-20

Session 5

Example Problems
Slide #35

Although we won't dwell on them here, there are example problems in your participants' handbook on estimating material requirements and determining the most cost-effective treatment. Also, there is a table that lists typical manpower requirements and productivity rates for the various crack treatment steps. These are found on pages 5-16 thru 5-20.

Example Problem - Material Requirements   Page 5-17   Figure 5-3
Example Problem - Cost-Effectiveness   Page 5-19   Figure 5-4

Installation

1. Crack cutting (optional)
2. Crack cleaning and drying
3. Material preparation and application
4. Material finishing/shaping (optional)
5. Blotting (optional)

Session 5

Installation
Slide #36

Moving on to installation, we see there are a minimum of two and a maximum of five steps associated with the installation process. Crack cutting, material finishing, and blotting may not be necessary and/or desirable in some instances.

In order to ensure proper installation, it is important that persons in each operation know what their work objective is and that their workmanship is closely monitored. This latter task should be done by the crew foreman or an appointed inspector.

Page 5-21

Safety

- Traffic control
- Equipment and materials

Session 5

Safety
Slide #37

As most of you will agree, safety should be the #1 goal when working the highway.

The proper traffic control setups will help minimize conflicts between the operation and traffic. And, injuries to crewpersons can be substantially avoided if each worker is well informed about equipment operations and material hazards.

First-aid kits and materials safety data sheets (MSDS) should be kept on-hand at all times.

Pages 5-21 & 5-22

Crack Cutting

Objective - to create a uniform, rectangular reservoir, centered as closely as possible over the crack, while inflicting as little damage as possible to the surrounding pavement

Session 5

Crack Cutting
Slide #38

If utilized, crack cutting is the first operation performed. The objective of crack cutting is:

> to create a uniform, rectangular reservoir, centered as closely as possible over the crack, while inflicting as little damage as possible to the surrounding pavement.

Of course, this sounds simple and straightforward, but crack cutting can be quite difficult, particularly when high productivity is encouraged.

Page 5-22

Crack-Cutting Equipment

- Routers
  - Vertical-spindle
  - Rotary-impact
- Saws

Session 5

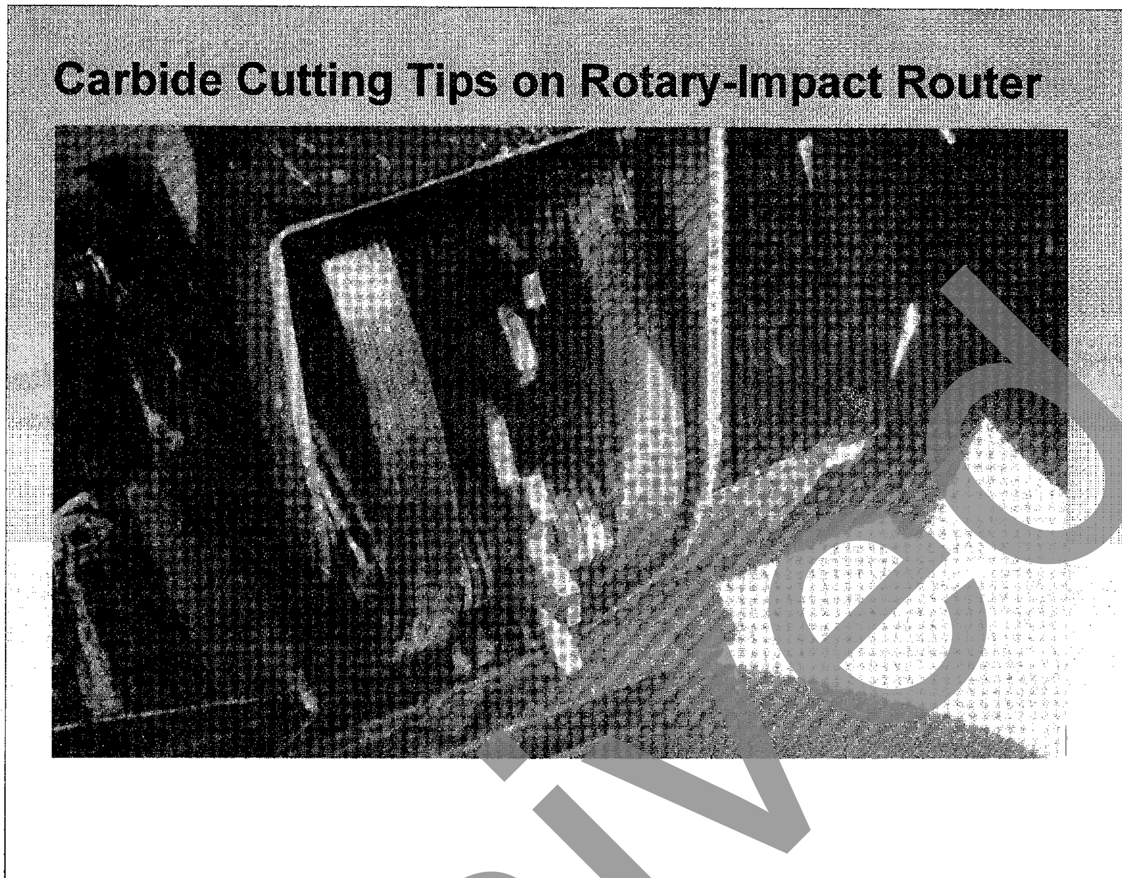
Crack-Cutting Equipment
Slide #39

There are essentially three types of crack cutting devices available:

- Vertical-spindle routers, the cutters of which rotate about a vertical axis like a wood router.
- Rotary-impact routers, which have a set of cutters that are spun about a horizontal axis, and
- Random-crack saws.

Vertical-spindle routers are by far the least productive; however, they are also believed to be the least damaging.

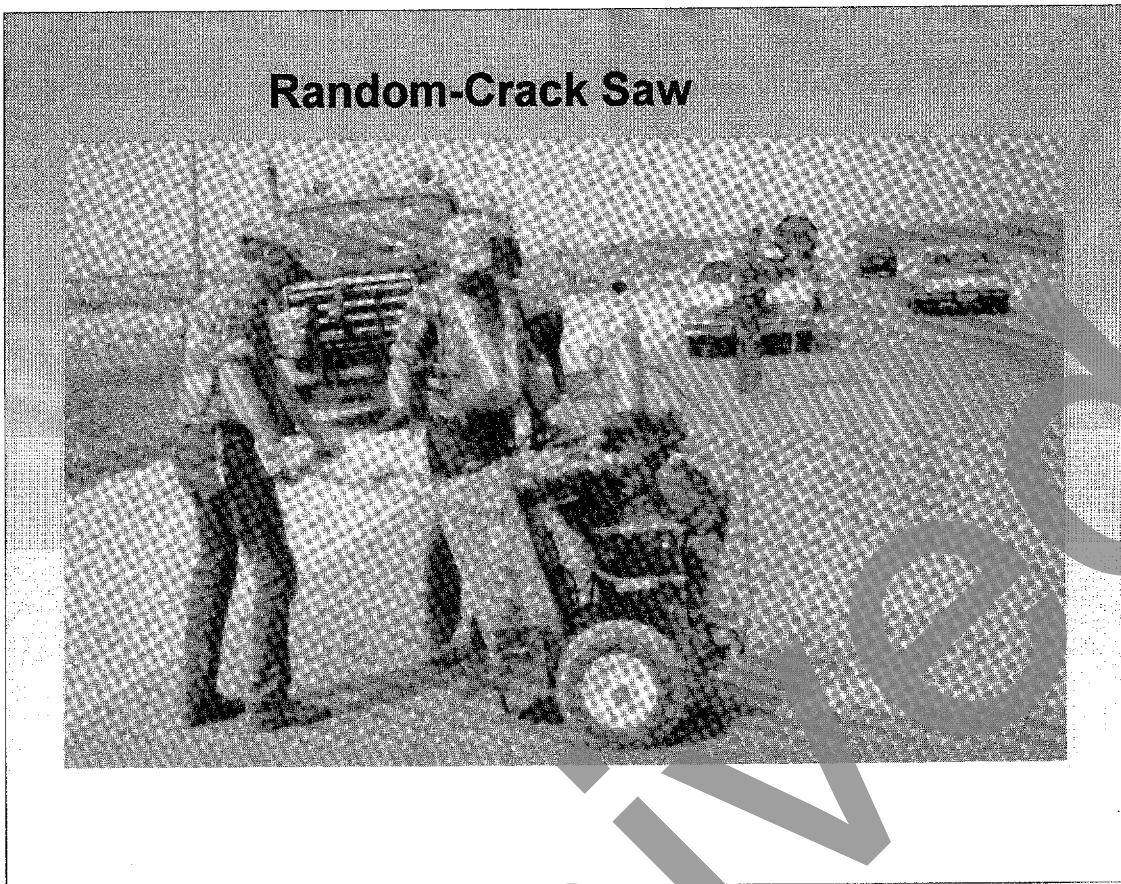
Pages 5-22 & 5-23



Carbide Cutting Tips on Rotary-Impact Router
Slide #40

The most common piece of equipment used for cutting cracks is the rotary-impact router. These machines perform best when equipped with new carbide-tipped cutters, as shown here.

Page 5-22



Random-Crack Saw
Slide #41

Dry random-crack saws, such as this one equipped with a 200-mm diameter diamond blades, are seeing more and more use. However, they are generally slower than rotary-impact routers and have more difficulty following cracks.

Page 5-23

General Recommendations for Crack Cutting

- Use sharp diamond or carbide blades/bits
- Uniform width and depth
- Minimum 95% accuracy in following crack
- Unspalled edges
- Cut secondary cracks?

Session 5

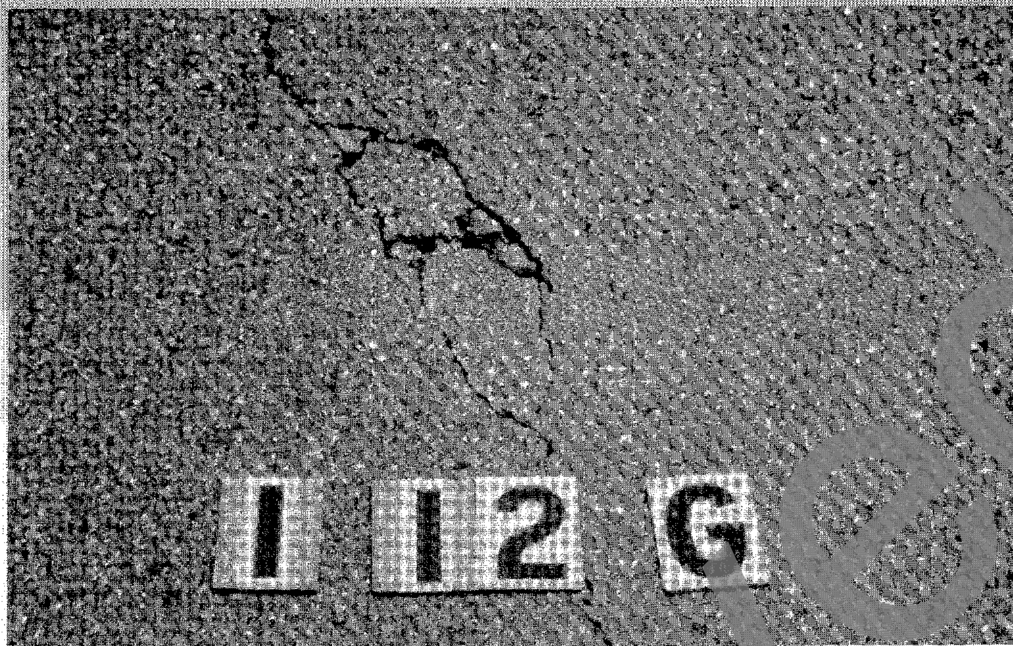
General Recommendations for Crack Cutting
Slide #42

Some of the key items to be alerted to when cutting cracks are as follows:

- ensuring that diamond or carbide blades/ bits are sharp.
- creating a reservoir of uniform width and depth.
- making sure that high accuracy is achieved in following cracks (minimum of 95% is a good target).
- making sure that crack edges are not spalled by the cutting equipment, and
- exercising good judgment when determining whether to cut secondary cracks.

Page 5-23

Secondary Cracks

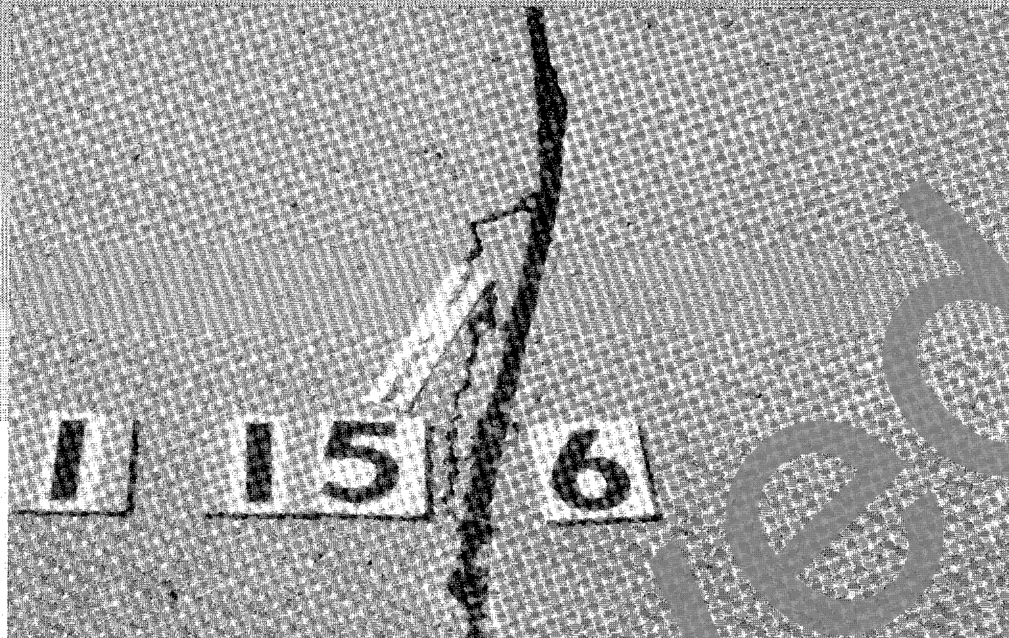


Secondary Cracks
Slide #43

Jagged primary cracks and secondary cracks can often pose problems during cutting operations. Cutting equipment may not be able to follow jagged cracks, thereby resulting in missed crack segments.

Page 5-23

Uncut Secondary Crack

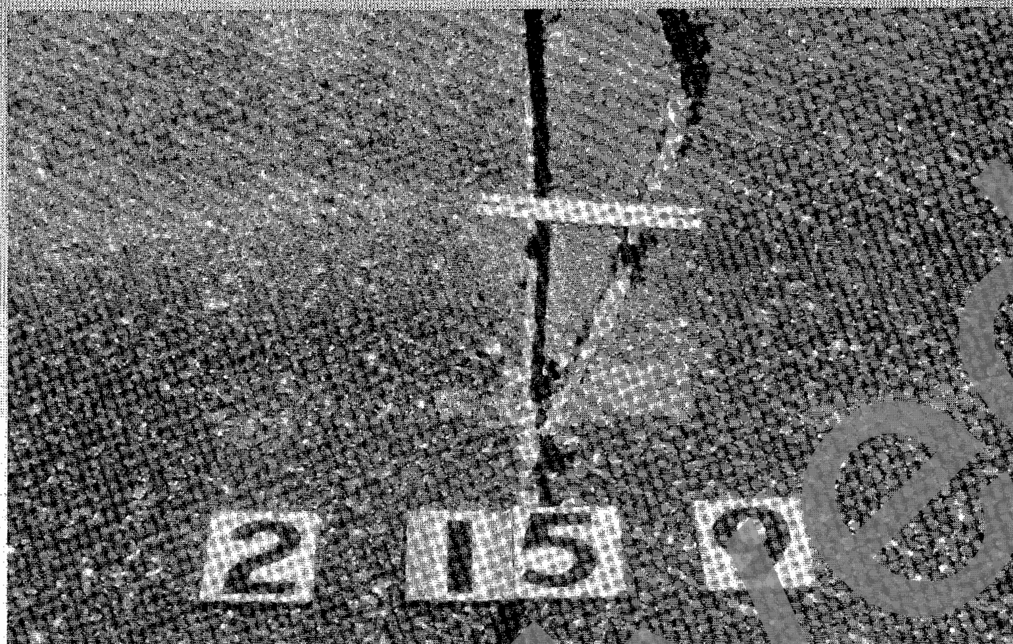


Uncut Secondary Crack
Slide #44

In addition, cutting operators occasionally must decide whether to cut secondary cracks. If secondary cracks are too close to the primary crack, cutting both cracks could greatly weaken the pavement along those segments.

Page 5-23

Cut Secondary Crack



Cut Secondary Crack
Slide #45

A general rule is to cut only secondary cracks spaced farther than 300 mm from a primary crack. Secondary cracks closer than 300 mm should be cleaned and sealed only.

Page 5-23

Crack Cleaning and Drying

Objective - to provide a clean, dry crack channel, free of loosened AC fragments, in which treatment material can be properly applied

Session 5

Crack Cleaning and Drying
Slide #46

Crack cleaning and drying is the next operation in the installation process. The objective of this step is:

- to provide a clean, dry crack channel, free of loosened AC fragments, in which treatment material can be properly placed.

Page 5-24

Cleaning and Drying Methods

- High-pressure airblasting
- Hot airblasting
- Wirebrushing
- Sandblasting

Session 5

Cleaning and Drying Methods
Slide #47

The four primary methods of cleaning crack channels are:

- Airblasting with high-pressure compressed air.
- Hot airblasting, using a hot compressed air (HCA) lance, or heat lance.
- Wirebrushing, using a power brush in conjunction with compressed air, and
- Sandblasting, using a sandblaster connected to an air compressor.

Question: What is used most often in your State?

Page 5-24

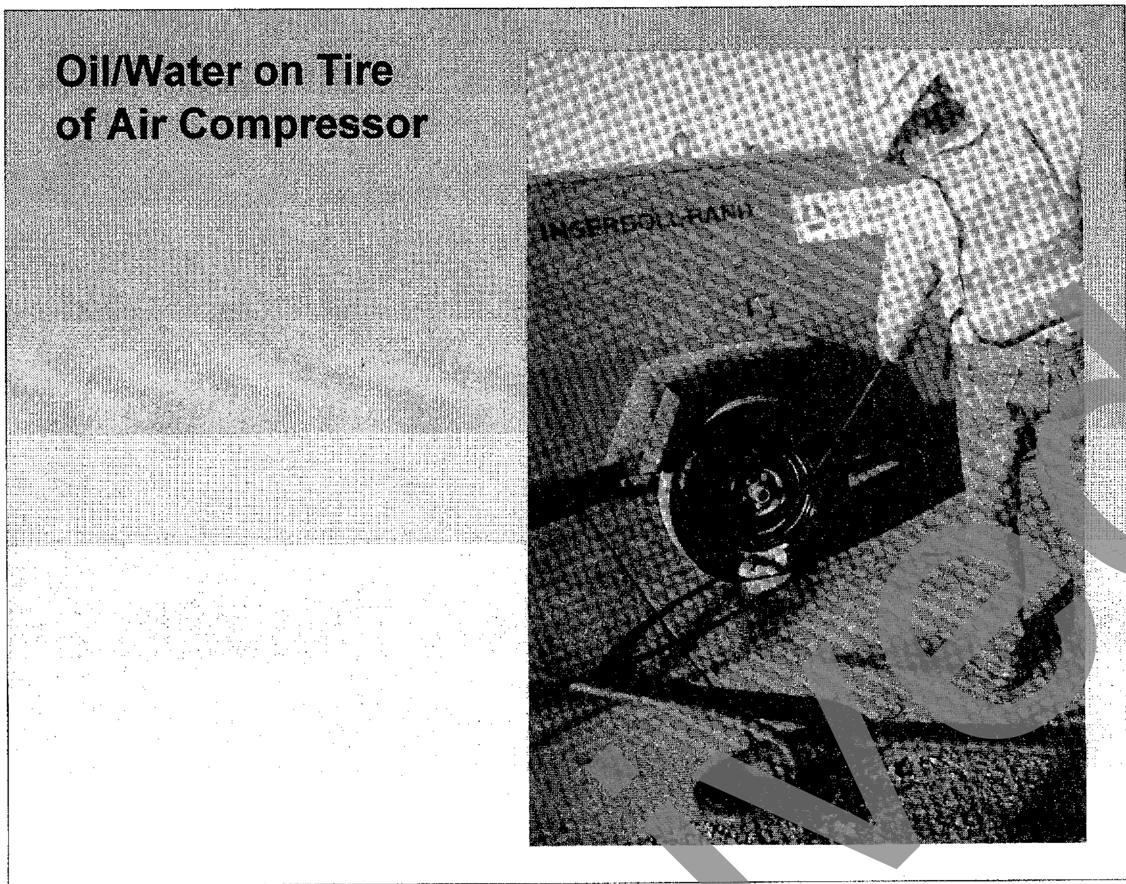
High-Pressure Airblasting

High Pressure Airblasting with Nozzle Close to Crack
Slide #48

High-pressure airblasting has been the conventional means of crack cleaning for years. General recommendations for airblasting with high-pressure air include:

- using it only to clean dry cracks.
- making sure that it the compressed air unit provides oil-and moisture-free compressed air at a minimum of 620 kPa and 4.3 m^3/min, and
- holding the wand nozzle no more than 50 mm away from the crack, as shown here, to provide optimal cleaning.

Pages 5-24 & 5-25

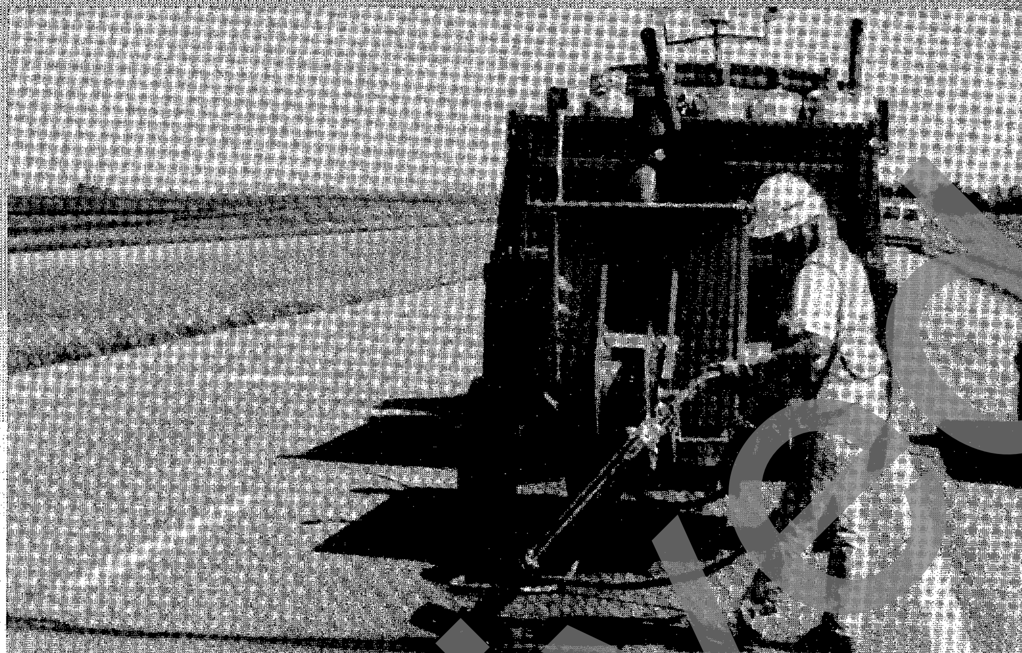


Oil/Water on Tire of Air Compressor
Slide #49

In this slide, we see a combination of moisture and oil being blown out with the compressed air. Would anyone feel comfortable placing sealant in the crack covered with this matter?

Page 5-25

Heat Lance



Heat Lance
Slide #50

Within the last 10 years, hot compressed-air (HCA) lances, or heat lances, have become the preferred cleaning equipment when using hot-applied asphalt materials.

Page 5-26   Figure 5-7

Hot Airblasting

- Cleaning, drying moist cracks, warming cold cracks
- Oil- and moisture-free compressed air
- Minimum 1370°C and 610 m/s blast
- No direct flame
- Slight darkening of crack periphery
- Nozzle ≤ 50 mm from crack

Session 5

Hot Airblasting
Slide #51

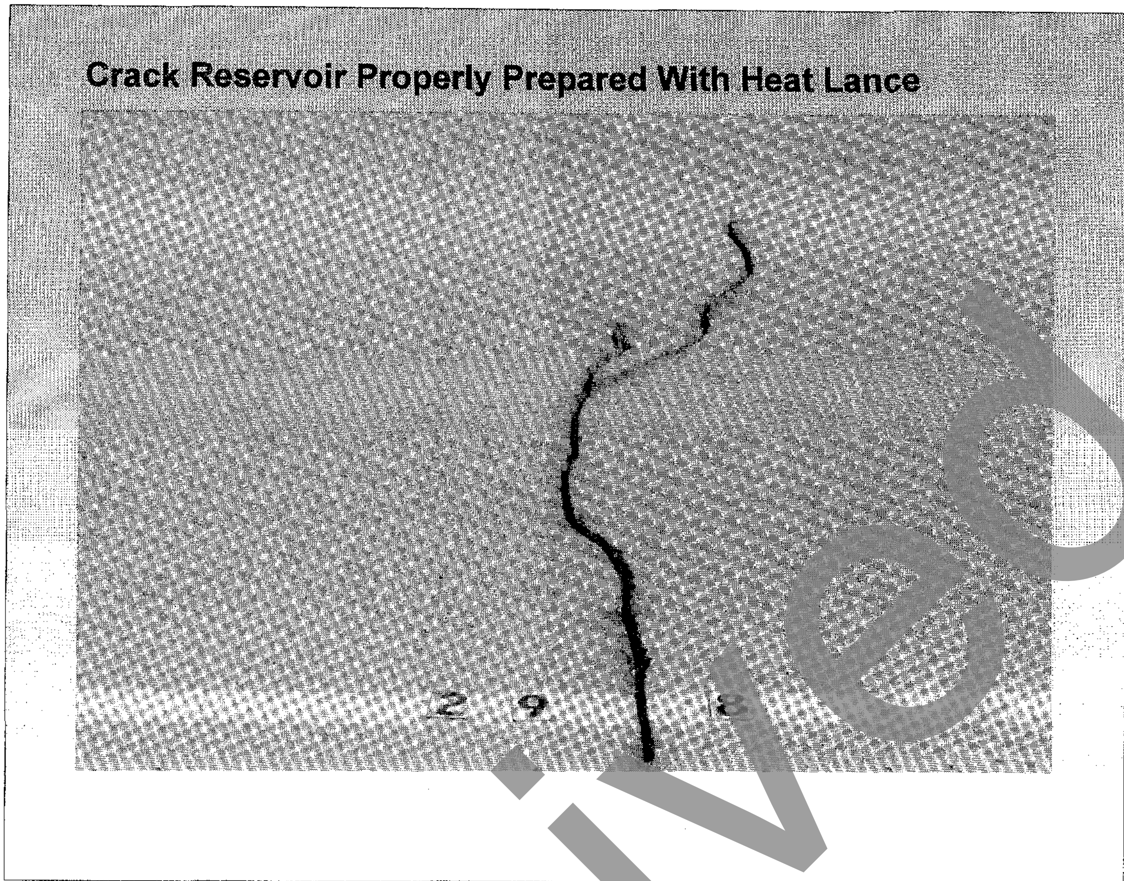
Not only is hot airblasting effective at cleaning, it can be used to warm and dry cold, damp cracks.

As with airblasting, it is important that oil- and moisture-free compressed air is used and that the nozzle be held no more than 50 mm from the crack.

Heat lances capable of producing 1370°C and 610 m/s blast rates are generally recommended. In addition, heat lances with direct flames should not be used.

A properly heated crack will exhibit a slight darkening of the asphalt along the crack periphery.

Pages 5-25 thru 5-27



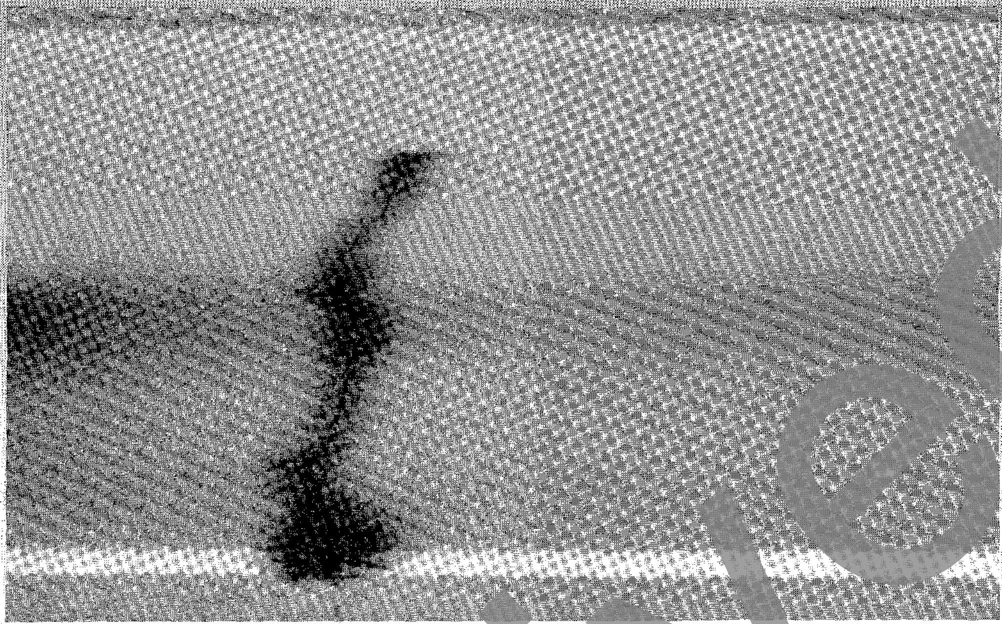
Crack Reservoir Properly Prepared With Heat Lance
Slide #52

Hot airblasting requires greater concentration than high-pressure airblasting. This is because the operator must take the time to adequately clean and dry the crack channel without overheating the asphalt concrete.

Here is what a properly hot airblasted crack channel should look like. You'll notice that the crack periphery is only slightly darkened by the heat lance.

Page 5-26

Pavement Burned from Hot Airblasting



Pavement Burned from Hot Airblasting
Slide #53

This slide shows an overcooked crack channel. The burnt asphalt surface is highly oxidized and "grit-like," and, as such, is not as well adhered to the rest of the asphalt concrete. Since the surface is what the sealant bonds to, the potential for failure is greater.

Page 5-26

Sandblasting

- Cleaning dry cracks
- Oil- and moisture-free compressed air
- Minimum 620 kPa and 4.3 m^3/min
- Venturi nozzle ≤ 6 mm
- Nozzle 100 to 150 mm from crack
- Adjustable guide
- Follow with compressed air

Session 5

Sandblasting
Slide #54

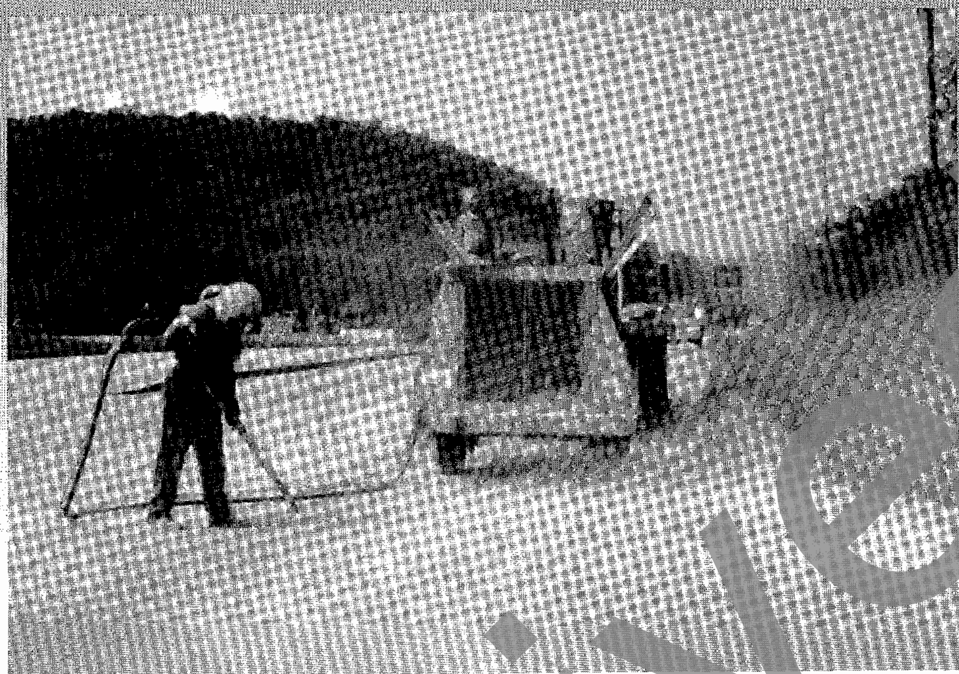
Sandblasting is appropriate only for cleaning dry cracks.

Oil- and moisture-free air must be furnished to the sandblaster at a minimum of 620 kPa and 4.3 m^3/min. Other recommendations include:

- using a wand fitted with a 6-mm venturi nozzle and an adjustable guide.
- holding the wand between 100 and 150 mm from the crack sidewalls, and
- supplementing the sandblasting operation with airblasting.

Page 5-27

Sandblasting Operation

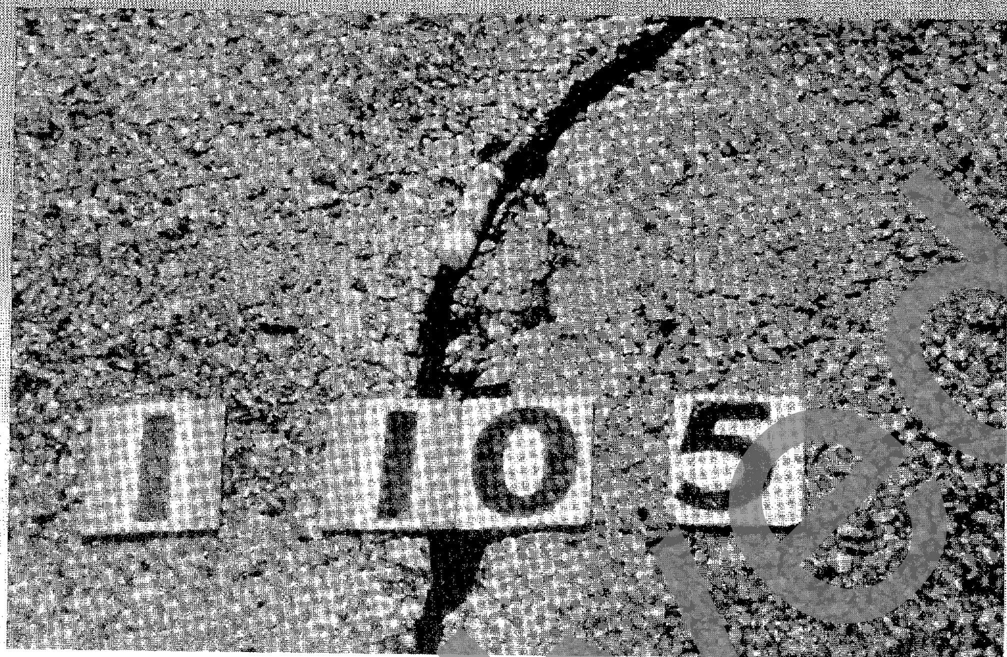


Sandblasting Operations
Slide #55

To reduce operator fatigue and to help the operator maintain the proper angle and height, a wooden rod or angle iron can be attached to the blasting hose.

Page 5-27

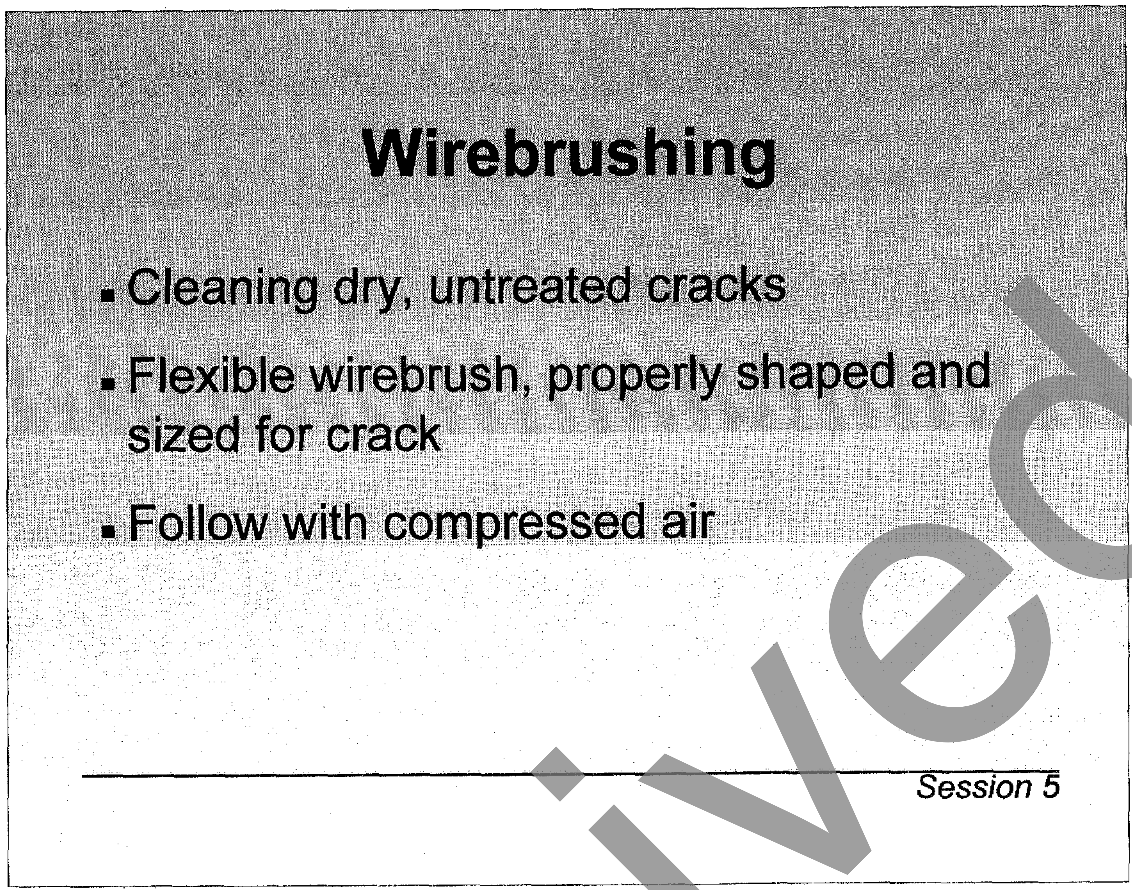
Sandblasted Crack



Sandblasted Crack
Slide #56

As can be seen, the effects of sandblasting are fairly noticeable. A certain amount of aggregate polishing occurs.

Page 5-26



Wirebrushing
Slide #57

Wirebrushing is, perhaps, the least effective of the four cleaning procedures discussed in this session. However, it is capable of adequately cleaning dry, untreated cracks.

The key to wirebrushing is using a flexible wirebrush that is properly shaped and sized for the prepared crack channels.

Supplemental cleaning with compressed air is highly recommended.

Pages 5-27 & 5-28

General Recommendations for Crack Cleaning and Drying

- Direct blast operations away from traffic
- Sufficient number of passes
- Blow debris from roadway/shoulder
- Remove by hand loosened AC fragments
- Keep closely ahead of sealing operation

Session 5

General Recommendations for Crack Cleaning and Drying
Slide #58

General recommendations for all crack cleaning operations include:

- directing blast operations away from traffic.
- making a sufficient number of passes to get crack channels clean.
- blowing debris from the roadway and shoulder to prevent the debris from blowing back into the crack channel or into the installed material.
- removing any loosened AC fragments, and
- keeping immediately ahead of the material application operation so as to maximize crack cleanliness.

Material Preparation and Application

Objective - to install any accessory materials, adequately prepare sealant or filler material, and apply proper amount of material to crack

Session 5

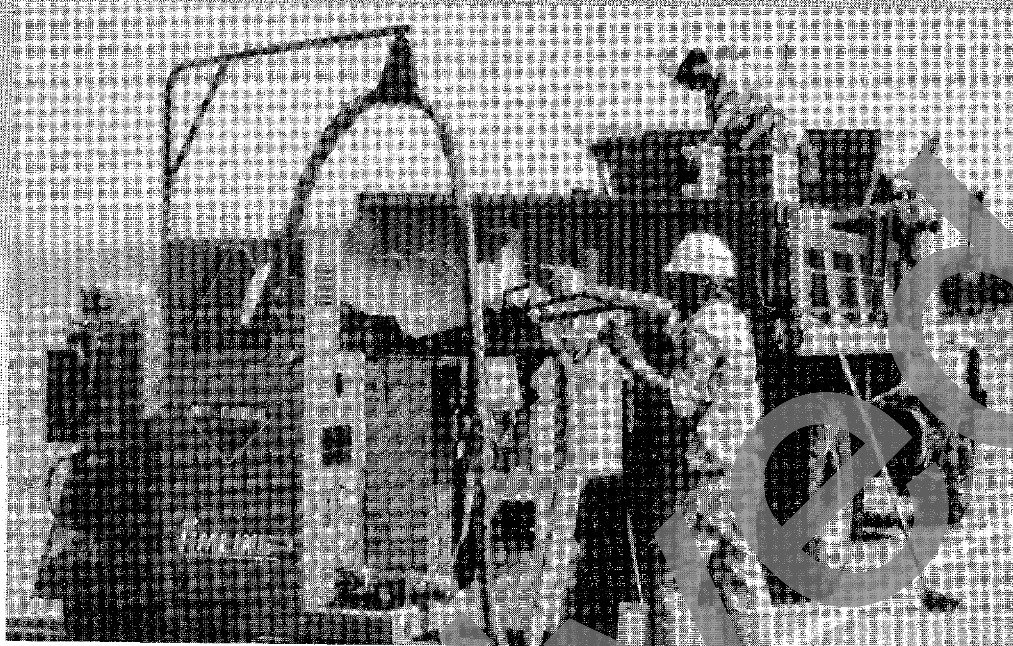
Material Preparation and Application
Slide #59

The objective of the next operation, material preparation and application is:

- To install any accessory materials into the crack channel, prepare the treatment material for recommended application, and apply the proper amount of material to the crack being treated.

Page 5-28

Asphalt Kettle



Asphalt Kettle
Slide #60

Double-jacketed asphalt kettles, like the one shown here, are a must when installing hot-applied, modified asphalt materials. In addition, they may be an option, along with asphalt distributors, when installing hot asphalt cement or warm emulsion materials.

Pages 5-28 & 5-29

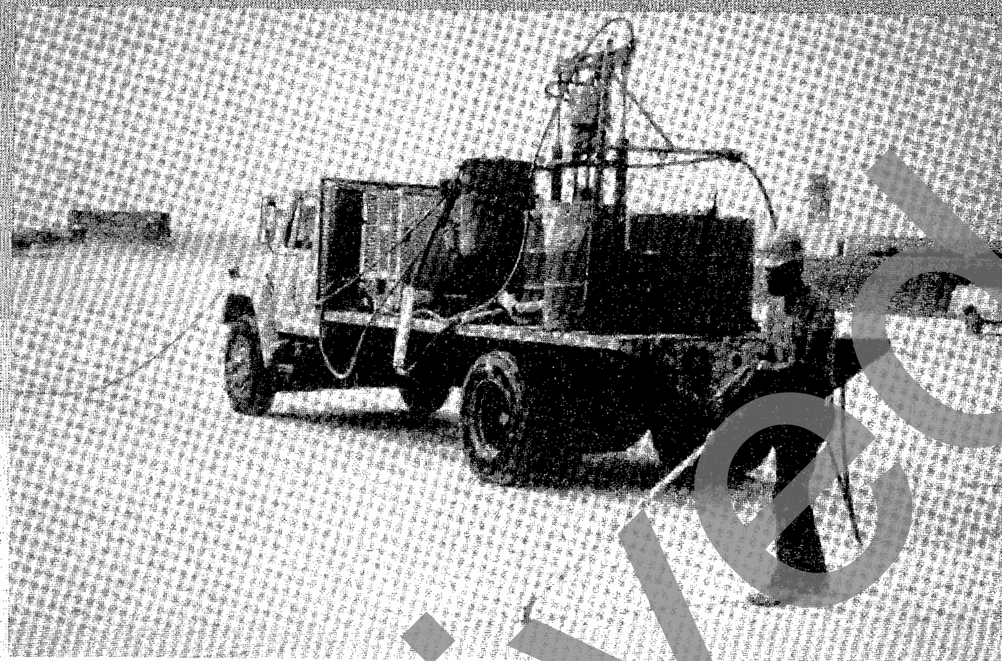
Hand-Held Pour-Pot

Hand-Held Pour-Pot
Slide #61

Hand-held pour-pots are occasionally used for dispensing emulsion materials, and

Page 5-31

Silicone Pump



Silicone Pump
Slide #62

Pumps are necessary for installing silicone contained in 208-L drums or 19-L pails.

Although the silicone sealant is being used on concrete pavement in this picture, the intent is to show the silicone pumping equipment.

Inserting Backer Rod

- Use rod 25% larger than crack reservoir width
- Insert rod into crack reservoir using suitable insertion tool
- Roll a second time to ensure proper depth
- Insert additional or wider pieces where needed

Session 5

Backer Rod Insertion
Slide #63

The use of backer rod in asphalt pavement crack sealing operations is quite rare, and is usually only used in conjunction with silicone.

The installation of backer rod is fairly simple and quick. However, a few helpful suggestions are to:

- use rod 25% larger than the crack reservoir width. This way the rod becomes sufficiently compressed such that it stays at the desired depth.
- use an insertion tool that will easily place the rod to the desired depth without damaging the rod.
- insert additional or wider backer rod pieces where it's needed.

Page 5-28

Heating Hot-Applied Materials

- Prior to heating, note
  - recommended application temperature, safe heating temperature, and allowable extended heating period
  - effects of overheating and prolonged heating

Session 5

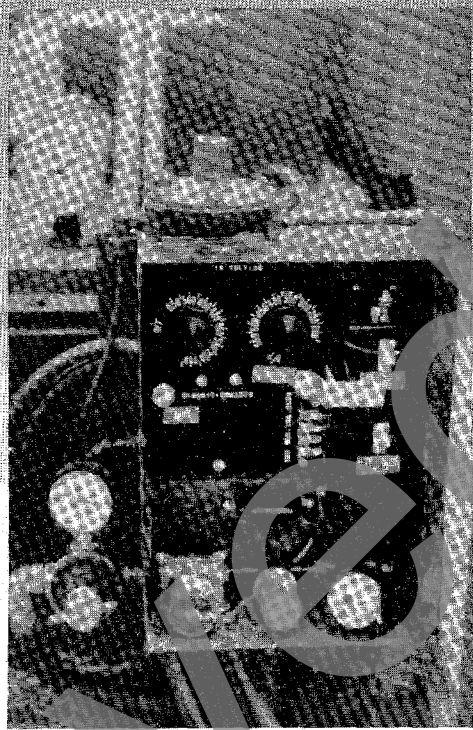
Heating Hot-Applied Materials
Slide #64

Prior to heating the selected hot-applied asphalt material, it is essential that the kettle operator learns the important aspects associated with heating the material. In particular, the recommended application temperature, the maximum safe heating temperature, and the allowable extended heating time.

It is also recommended that the operator know the effects of overheating and prolonged heating of the selected material. Some materials have a tendency to gel or thicken while others thin out.

Page 5-29

Kettle Gauges and Controls



Kettle Gauges and Controls
Slide #65

Periodic monitoring of the heating oil and material temperatures ensures that the material is brought to application temperature without burning or overheating. Key recommendations for heating hot-applied materials include:

- starting the agitator as soon as possible to help expedite the melting process.
- periodically monitoring heating oil and material temperatures, and
- verifying material temperatures using an appropriate thermometer.

Page 5-29

Thermometer Probe

Thermometer Probe
Slide #66

A thermometer probe, such as this one, can be dipped into the kettle vat from time to time as a means of double checking material temperature. This is highly recommended as the temperature gauges on asphalt kettles are sometimes prone to becoming inaccurate with time.

Page 5-29

Installing Hot-Applied Materials

- Maintain ample supply of material
- Do not overheat
- Apply at recommended application temperature
- Fill crack channel from bottom up
- Apply proper amount, reapply where needed
- Re-circulate material during idle periods

Session 5

Installing Hot-Applied Materials
Slide #67

While installing hot-applied materials, it is important to continue monitoring the material temperature in the vat, and to maintain an ample supply of heated material.

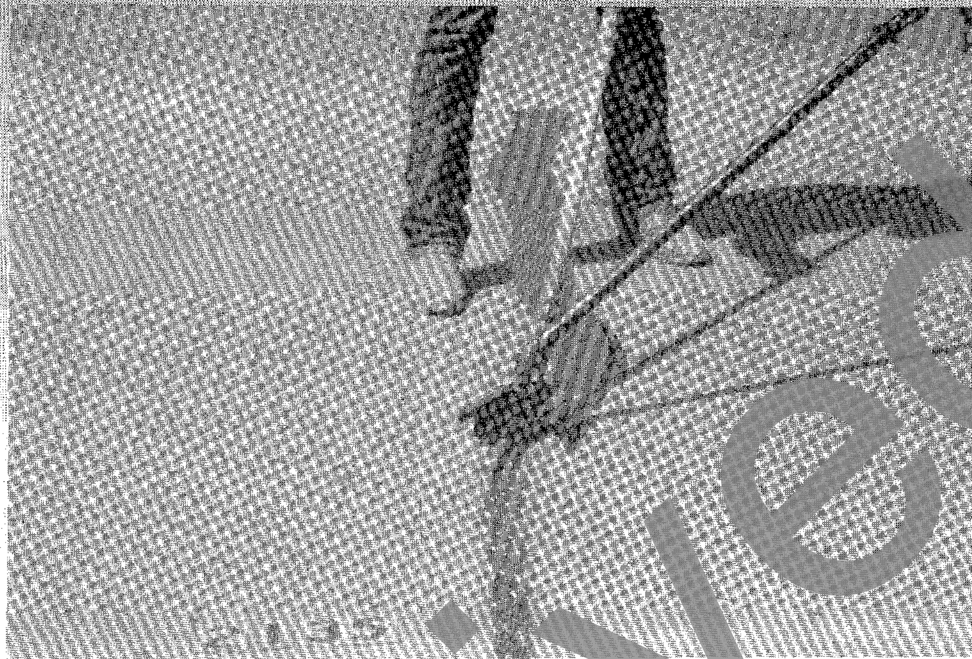
It is good practice, also, to check the temperature of the material coming out of the nozzle and make sure it is at the recommended application temperature. There can be a significant drop in temperature between the vat and the nozzle, particularly on cold and/or windy days.

Cracks should be filled with material from the bottom up until a proper amount has been applied, given the type of configuration required. Re-application may be necessary where material sinks.

Finally, in order to keep material in the application lines at the recommended temperature and possible avoid freezing the lines, it is a good idea to re-circulate the material during idle periods.

Pages 5-30 & 5-31

Hot-Applied Material Installation

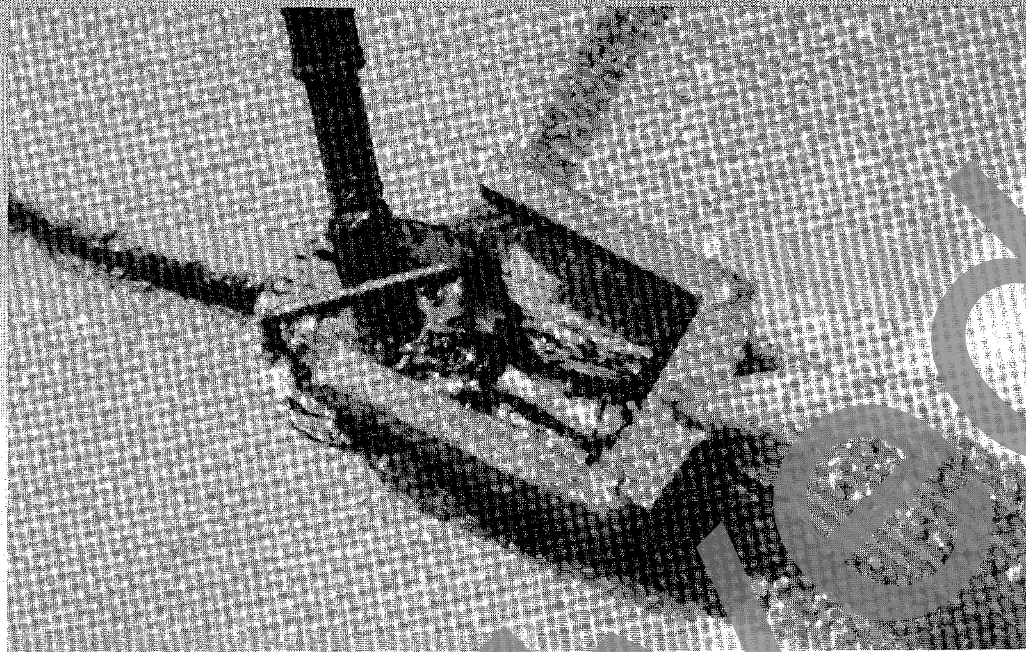


Hot-Applied Material Installation
Slide #68

Here we see hot-applied sealant being placed, from the bottom up into a wide shallow reservoir, and then being shaped into a band-aid with a squeegee.

Page 5-31   Figure 5-8

Finishing Tools



Finishing Tools
Slide #69

In operations where finishing is required, the objective is simple:

- to shape or mold the applied material to the desired configuration.

Two types of finishing tools that have been successfully used are dish attachments and U or V-shaped squeegees, both of which are shown here.

Squeegees are the more common finishing tool. The rubber inserts on these tools can usually be cut to form a specific mold. Although not as common, dish attachments come in various sizes and generally allow for one step application and overband finishing.

Pages 5-32 & 5-33

Recommendations for Finishing/Shaping

- Ensure that finishing tool provides desired configuration
- Center finishing tool over crack channel
- Operate squeegee closely behind material application wand
- Keep finishing tool free from buildup of material

Session 5

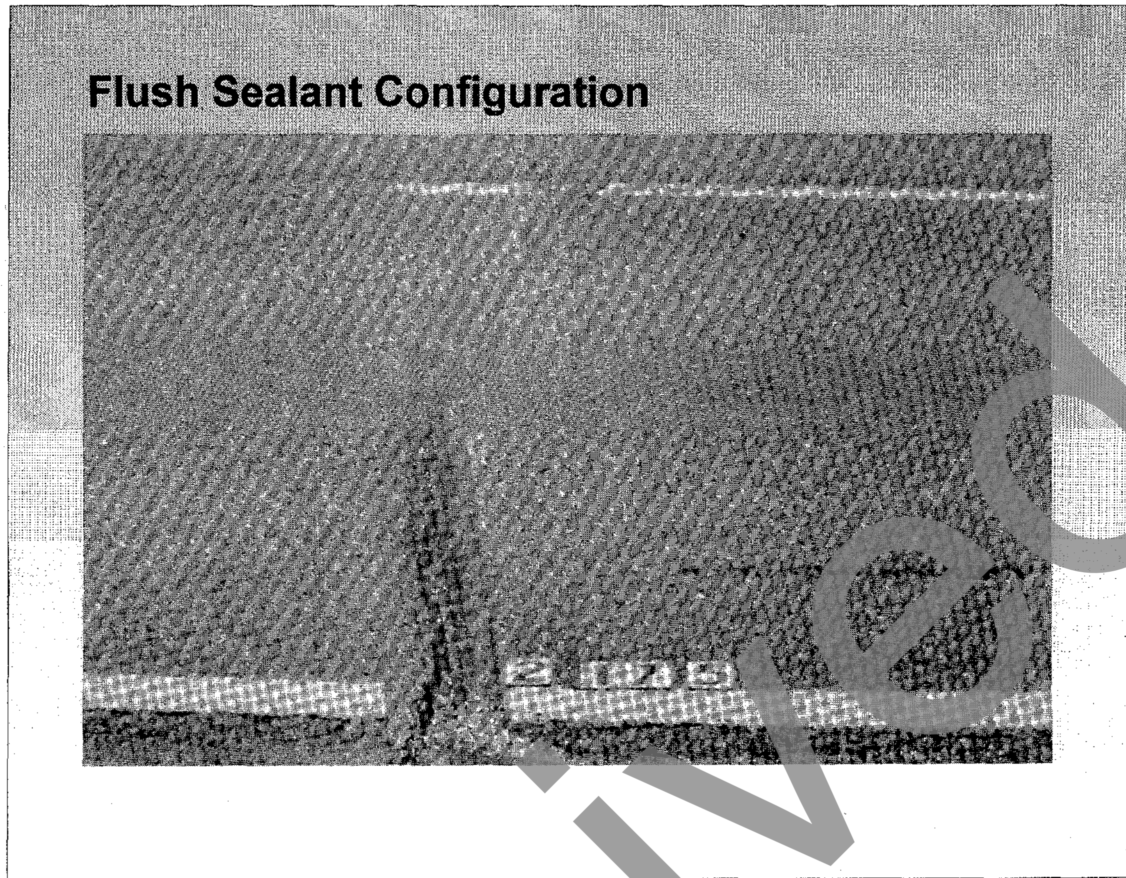
Recommendations for Finishing/ Shaping
Slide #70

Here, we see some basic recommendations for finishing. Obviously, the finishing tool should provide the desired configuration and be centered over the crack as much as possible.

In most instances, it is best to operate squeegees closely behind the material application wand, as shown in the third slide back. This is particularly true for band-applications where hot-pour materials benefit from "hot-bonding."

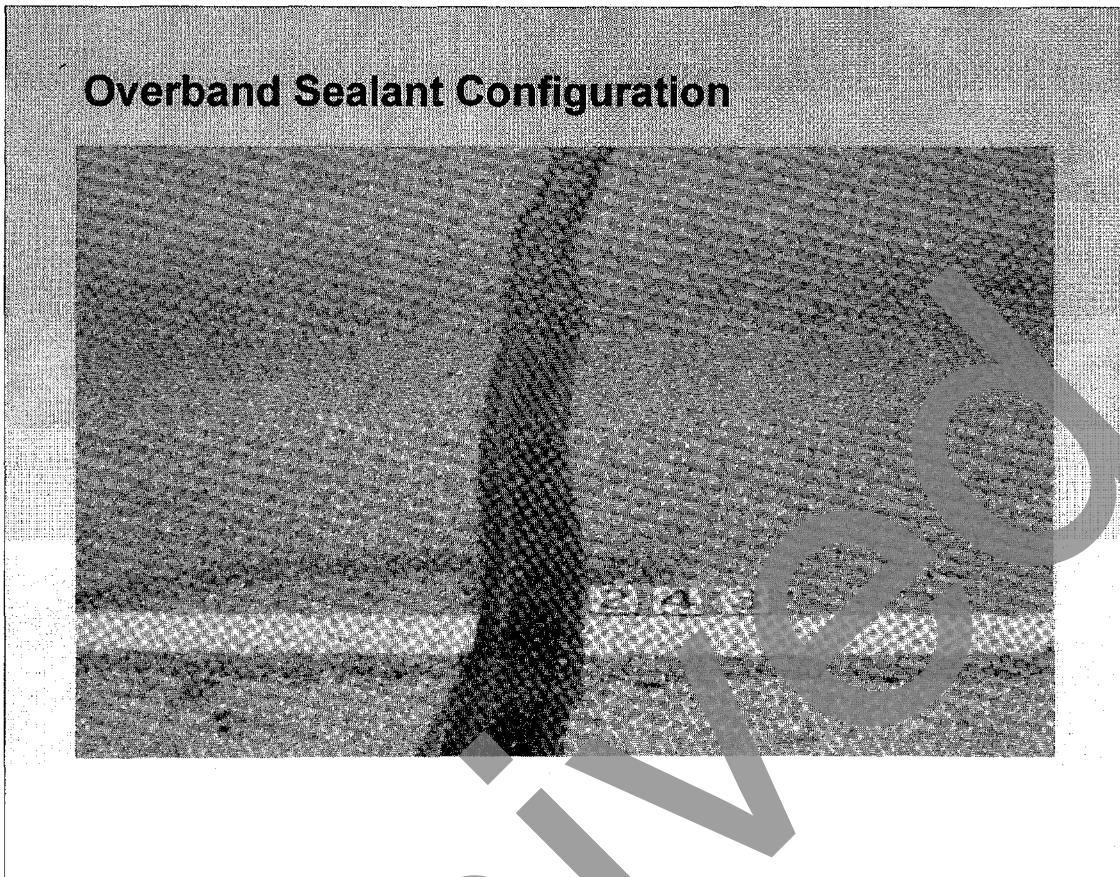
And, finally, material buildup on finishing tools must also be monitored so that placement configurations are not altered.

Page 5-33



Flush Sealant Configuration
Slide #71

These next two slides show the primary finishes for hot-pour materials. Here, we see a hot-applied, rubberized asphalt placed flush in a routed crack.



Band-Aid Sealant Configuration
Slide #72

And here, we have a hot-applied, rubberized asphalt placed in a band-aid configuration. As we mentioned earlier, this type of seal can track or be pulled out by traffic if not allowed to sufficiently cool, and it may add to ride discomfort, if placed too thick.

Blotting

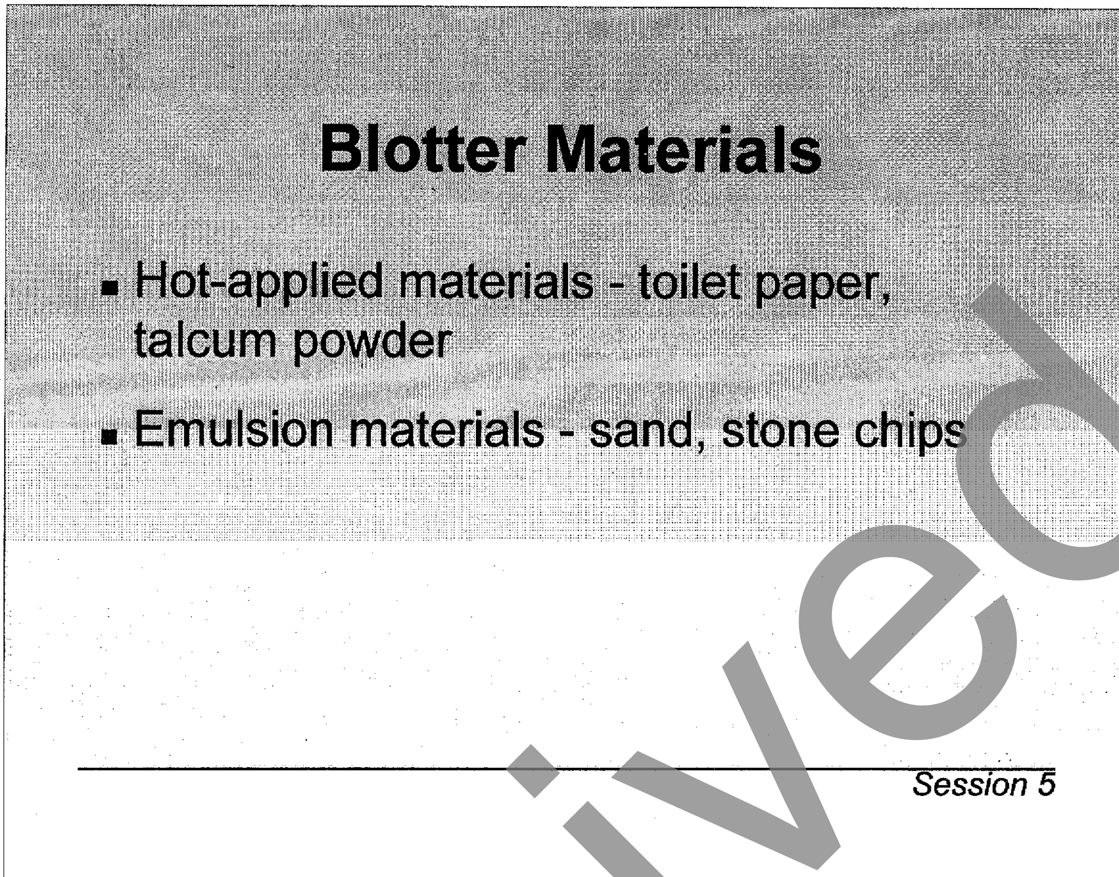
Objective - to protect uncured treatment material from being tracked

Session 5

Blotting
Slide #73

Blotting is sometimes necessary to protect uncured treatment material from being tracked or pulled up by traffic.

Page 5-33



Blotting Materials
Slide #74

For hot-applied materials, toilet paper and talcum powder work pretty well.

And, for emulsion materials, sand and stone chips are often successfully used.

Question: What type of blotter materials are used in your State?

Page 5-33

Installing Cold-Applied Silicone

- Fill crack reservoir from bottom up
- Keep silicone uniformly recessed below pavement surface
- Reapply material to segments where material has sunk

Session 5

Installing Cold-Applied Silicone
Slide #75

With the exception of material heating, silicone sealant installation is quite similar to hot-applied sealant installation. The sealant is pumped from the storage container, through a dispensing wand, and into the crack reservoir.

The crack reservoir is filled from the bottom until the proper recess is achieved and re-application may be necessary where material has sunk.

Work Inspection

- Crack cutting
- Crack cleaning and drying
- Material installation
- General

Session 5

Work Inspection
Slide #76

As we discussed earlier, it is important that workmanship throughout the entire operation be closely monitored. Among the items that should be examined are:

- the dimensions of the reservoir and any pavement damaged resulting from the crack cutting operation.
- crack cleanliness and moisture, and pavement burning if a heat lance is used.
- overband dimensions, bubbling, sunken segments, and tracking of the installed material, and
- general aspects regarding the sequence of operations, such as safety and the proximity of individual operations.

Performance Evaluation

- Visual inspection once a year
- Locate sample section
- Examine treatment for failure distresses
  - Full-depth adhesion loss
  - Full-depth cohesion loss
  - Complete pull-out of material
  - Edge deterioration

Session 5

Performance Evaluation
Slide #77

Upon completion of the installation process, it is useful to periodically examine how the treatment is performing. A visual inspection at least once a year, not only indicates how the treatment is performing, but can be used to project how long the treatment will last. This can be a valuable planning tool.

Evaluations can be performed fairly quickly and accurately by locating a small representative sample section, say 150 m long. The treatments within that sample section can be visually examined for failure distresses such as:

- full-depth adhesion and cohesion loss.
- complete pull-outs of material, and
- edge deterioration, including spalls, secondary cracks, and potholes.

Page 5-34

Performance Criteria

- Determine percentage of crack length failed
  - Failure>>>allowance of water through sealant/filler system
    - Excellent (0 - 10% failure)
    - Good (11 - 20%)
    - Fair (21 - 35%)
    - Poor (36 - 50%)
    - Very poor or failed (> 50%)
- Compute percentage of crack treatment effectiveness
  - %Eff = 100 - %Fail

Session 5

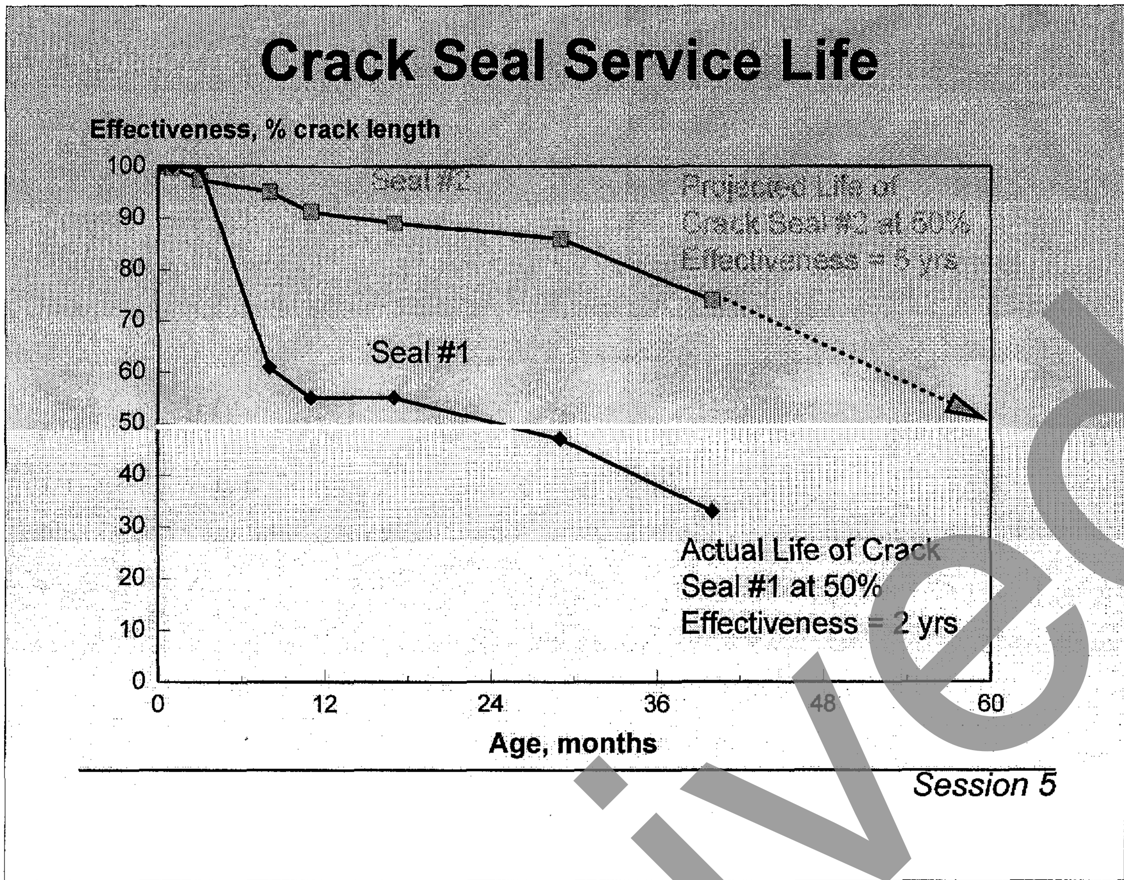
Performance Criteria
Slide #78

The assessment of crack treatment performance is typically made on the basis of percentage of crack length failed, with failure meaning that the treatment is letting water enter into the pavement system. The percentage of crack length failed is simply determined by summing the lengths of failed crack segments and dividing by the total length of treated crack examined, and then multiplying by 100.

The same rating guideline used for joint sealants is also applicable for crack treatments. If the percentage of failure is below 10, then the treatment is providing excellent performance. Between 11 and 20 percent, the treatment is giving very good performance. Between 21 and 35 percent, the treatment is providing fair performance. Between 36 and 50 percent, the treatment is giving poor performance. And, above 50 percent, the treatment is considered failed.

Treatment effectiveness is again computed by subtracting the percentage of failure from 100 percent.

Pages 5-34 & 5-35



Crack Seal Service Life
Slide #79

To estimate how long a particular crack treatment will last and subsequently determine it's cost-effectiveness, the performance of the treatment can be plotted over time, as shown in this slide.

Here, the percent effectiveness of two different crack seals have been tracked out to about 3.25 yrs (39 months). After 3.25 yrs, seal #2 shows about 75 percent effectiveness, whereas seal #1 shows about 32 percent effectiveness.

By designating a minimum effectiveness level, which might serve as a trigger for resealing or other maintenance or rehabilitation work, the service life of a treatment can be determined or even estimated. In this example, at 50 percent effectiveness, seal #1 has about a 2-yr service life, whereas seal #2 has a projected 5-yr service life.

Question: Does your State have a nominal effectiveness (or failure) level by which future maintenance is planned?

Page 5-35 Figure 5-9

Test and Evaluation

Crack Treatment

1. Identify material-procedure combinations
2. Identify test site location
3. Lay out site
4. Install experimental treatments
5. Monitor treatment performance
6. Analyze and report performance data

Session 5

Test and Evaluation (Crack Treatment)
Slide #80

As mentioned in previous sessions, the FHWA is sponsoring a technical assistance program for States interested in doing their own field studies of maintenance materials and techniques. One area of pavement maintenance that States can receive technical assistance on is AC crack treatment.

There are essentially six steps associated with performing a test and evaluation study in this area, with assistance being available for each step. The steps are:

1. Identifying the combinations of materials and procedures you wish to evaluate.
2. Identifying a suitable location for conducting the study.
3. Laying out the site (i.e., marking the cracks to be sealed or filled).
4. Installing the experimental treatment materials.
5. Periodically inspecting the treatments for performance, and
6. Analyzing and reporting the performance data.

The Test and Evaluation Work Plans describe in more detail the work associated with each step. Again, if your agency is interested in this kind of study, the Technical Assistance Application must be filled out and submitted to the FHWA for consideration.


SESSION 6
AC Pothole Repair
Pavement Maintenance Effectiveness/
Innovative Materials Workshop

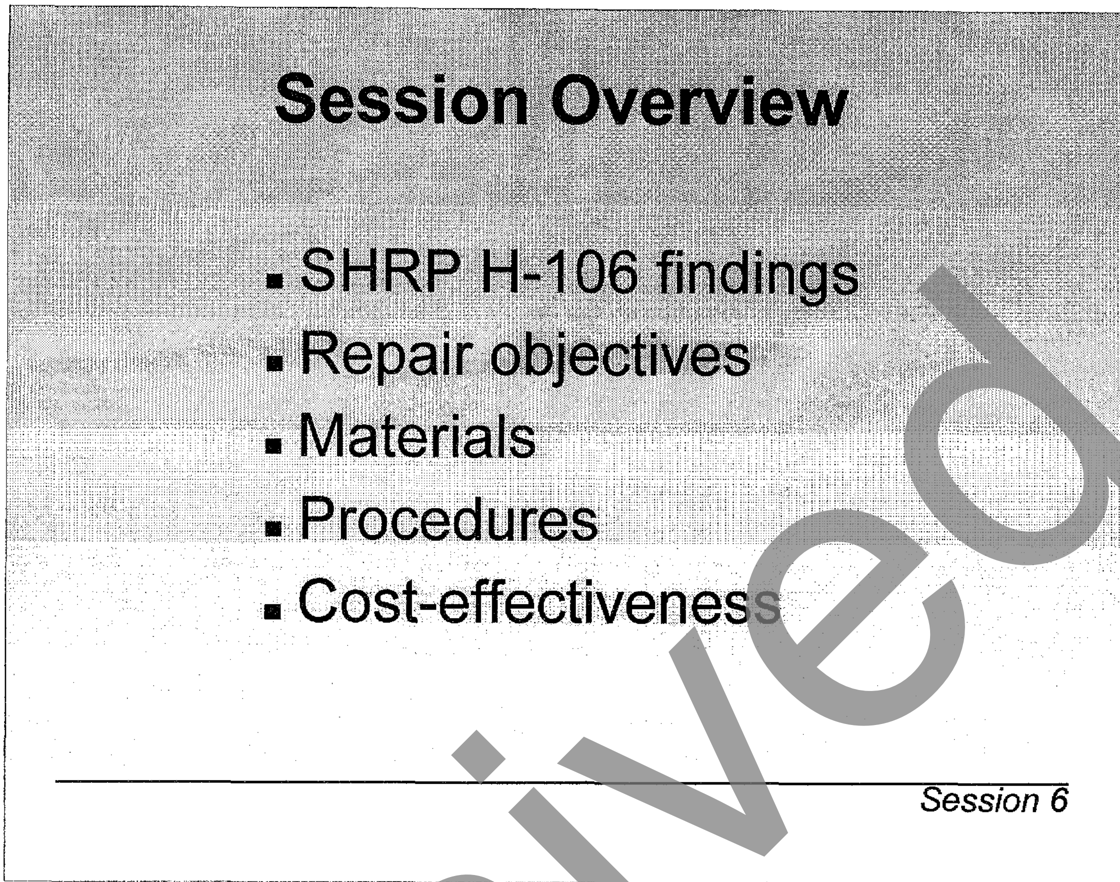
Session 6 AC Pothole Repair

Slide #1

Session 6 of this workshop is entitled, "AC Pothole Repair," and is designed to inform highway maintenance workers, supervisors, and engineers of the state of the practice in asphalt pavement pothole patching.

In this session presentation, we hope to generate an increased awareness of the need for better materials and placement procedures, thereby improving the quality of patches and lowering the overall cost of patching operations.

Page 6-1



Session Overview
Slide #2

We'll begin this session with a quick overview of the SHRP H-106 pothole repair experiment and tell you what the most recent findings are with respect to materials and procedures.

Then, we will proceed into the "how to" portion of the session, first discussing the objectives of pothole patching and distinguishing between permanent and emergency repairs. We'll then discuss the recommended materials and procedures for performing pothole repairs, and, lastly, show how cost-effectiveness can be determined.

Session Objectives

- Recall SHRP H-106 findings to date
- State objective of pothole repair operations
- Select the most appropriate and cost-effective materials and procedures
- List the works tasks associated with the various types of patching procedures

Session 6

Session Objectives
Slide #3

At the conclusion of this session, you will be able to:

- Recall the latest findings of the SHRP H-106 pothole repair experiment.
- State the objective of pothole patching operations.
- Select the most appropriate and cost-effective materials and procedures for routine pothole patching operations, and
- List the specific work tasks associated with the various types of patching procedures.

Page 6-1

SHRP H-106
Pothole Repair Experiment Results

Session 6

SHRP H-106 Pothole Repair Experiment Results
Slide #4

Let's take a quick look at the SHRP H-106 pothole repair experiment and its latest findings.

Page 6-1

Test Site Locations

- *FM 1570* Greenville, Texas
- *ON 2* Prescott, Ontario
- *I-70* Vandalia, Illinois
- *NM 518* Las Vegas, New Mexico
- *I-15 Frontage* Draper, Utah
- *US 395* Alturas, California
- *VT 28* Bradford, Vermont
- *US 97* Modoc Point, Oregon

Session 6

Test Site Locations
Slide #5

As you can see, this experiment included eight test sites located in the U.S. and Canada.

- *Farm-to-market (FM) 1570* in Greenville, TX was installed in March 1991.
- *I-70* in Vandalia, IL, *NM 518* in Las Vegas, NM, and *I-15 frontage* road in Draper, UT were all put down in April 1991.
- *US 395* in Alturas, CA and *VT 28* in Bradford, VT were placed in May 1991.
- *ON 2* in Prescott, ON was installed in January 1992, and
- *US 97* in Modoc Point, OR was put down in February 1992.

Six of the eight sites (IL, NM, UT, CA, VT, and OR) were lost to rehabilitation work in 1993. The remaining two sites (TX and ON) were evaluated up through November 1995 under the *LTM* project.

Page 6-2

SHRP H-106 Pothole Repair Sites

Session 6

SHRP H-106 Pothole Repair Sites
Slide #6

As you can see, this map shows the locations of the eight pothole repair sites with respect to the SHRP-defined climatic zones.

Three sites---Ontario, Illinois, and Vermont---represented wet-freeze climatic conditions. Three additional sites---California, Oregon, and Utah---represented dry-freeze climatic conditions. The Texas site represented wet-nonfreeze conditions, whereas the Las Vegas, New Mexico site represented dry-nonfreeze conditions.

Map not in handbook

Experiment Features

- 7 experimental patching materials and 8 local patching materials
- 6 repair procedures
  - Throw-and-roll
  - Semipermanent
  - Edge seal
  - Spray injection
  - Surface seal
  - Tack-and-heat
- Control: UPM High Performance Cold Mix (throw-and-roll)

Session 6

Experiment Features
Slide #7

The pothole experiment included the placement of seven experimental patching materials at each site (three proprietary, three agency-specified, and one spray injection), and one local material included by each of the eight participating State highway agencies.

The proprietary and agency-specified materials were placed using any of throw-and-roll, semipermanent, and edge seal procedures. The spray-injection mix was installed using an automated patching machine and two local materials were placed using the surface seal and heat-and-tack procedures. Each patch type, or combination of material and procedure, was placed in conjunction with a control patch type, that being the UPM throw-and-roll patch type.

Table 6-1 in your handbook shows the specific materials included in the study and summarizes the combinations of material and method that were used at each site.

Page 6-3 Tables 6-1 & 6-2

Statistical Differences in Pothole Repair Survival

Test Site	Better Repair Type	Poorer Repair Type
CA	Control	Spray-Injection
IL	Control	Local (throw-and-roll)
	Control	PennDOT 486 (throw-and-roll)
	Control	Local (surface seal)
NM	Control	HFMS-2 (throw-and-roll)
	UPM (edge seal)	Control

Control: UPM (throw-and-roll)

Session 6

Statistical Differences in Pothole Repair Survival
Slide #8

Statistical analyses on field performance data collected up through the fall of 1994 have resulted in the following breakdown of pothole patch survival. The control patch type (UPM throw-and-roll) has typically been among the best performing patch types at each site, and thus has provided a good measure for comparing all other patch types.

With respect to material performance, the control has significantly outperformed local materials at Illinois, Oregon, and Texas. In addition, it has significantly outperformed PennDOT 485 at Illinois, HFMS-2 at New Mexico, and QPR 2000 at Ontario. On the flip side, it has been outperformed by PennDOT 485 at Texas and Perma-Patch at Vermont.

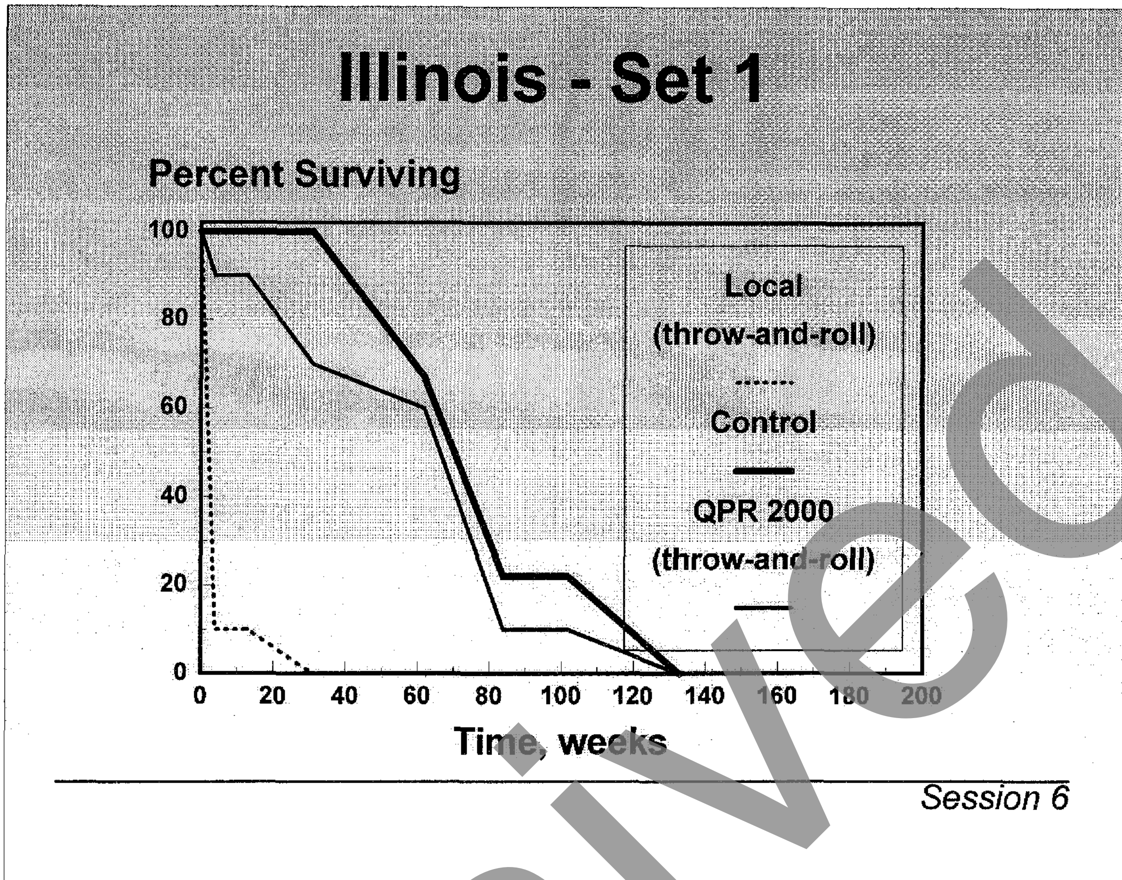
Among repair procedures, the only significant survival difference has been the better performance by the edge seal at New Mexico.

Statistical Differences in Pothole Repair Survival (cont)

Test Site	Better Repair Type	Poorer Repair Type
OR	Control	Local (throw-and-roll)
TX	Control	Local (throw-and-roll)
	PennDOT 485 (throw-and-roll)	Control
VT	Perma-Patch (throw-and-roll)	Control
ON	Control	QPR 2000 (throw-and-roll)

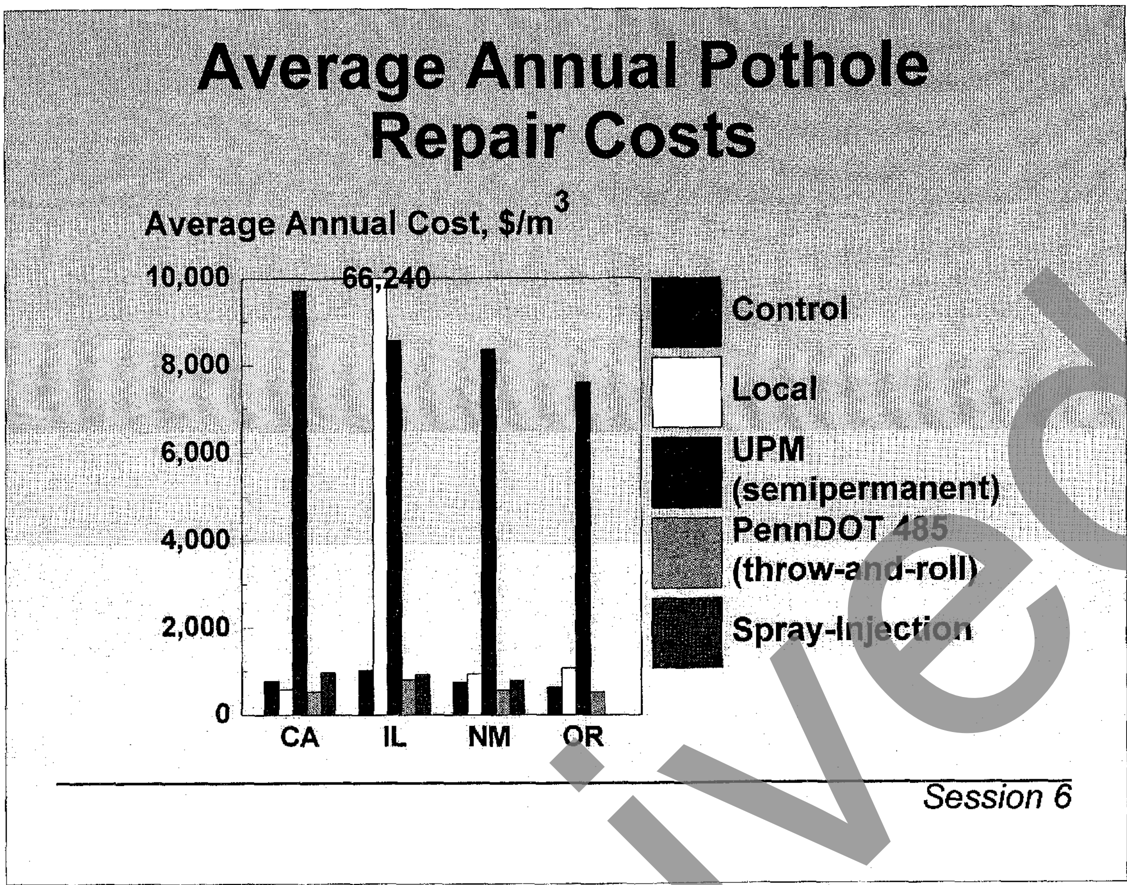
Session 6

Statistical Differences in Pothole Repair Survival (cont)
Slide #9



Illinois - Set 1
Slide #10

This slide illustrates the statistically significant difference determined for the local throw-and-roll patch and the control at Illinois. As you can see, the local material failed tremendously after only a few weeks, whereas the UPM control material and QPR 2000 both held up for over 1 year.

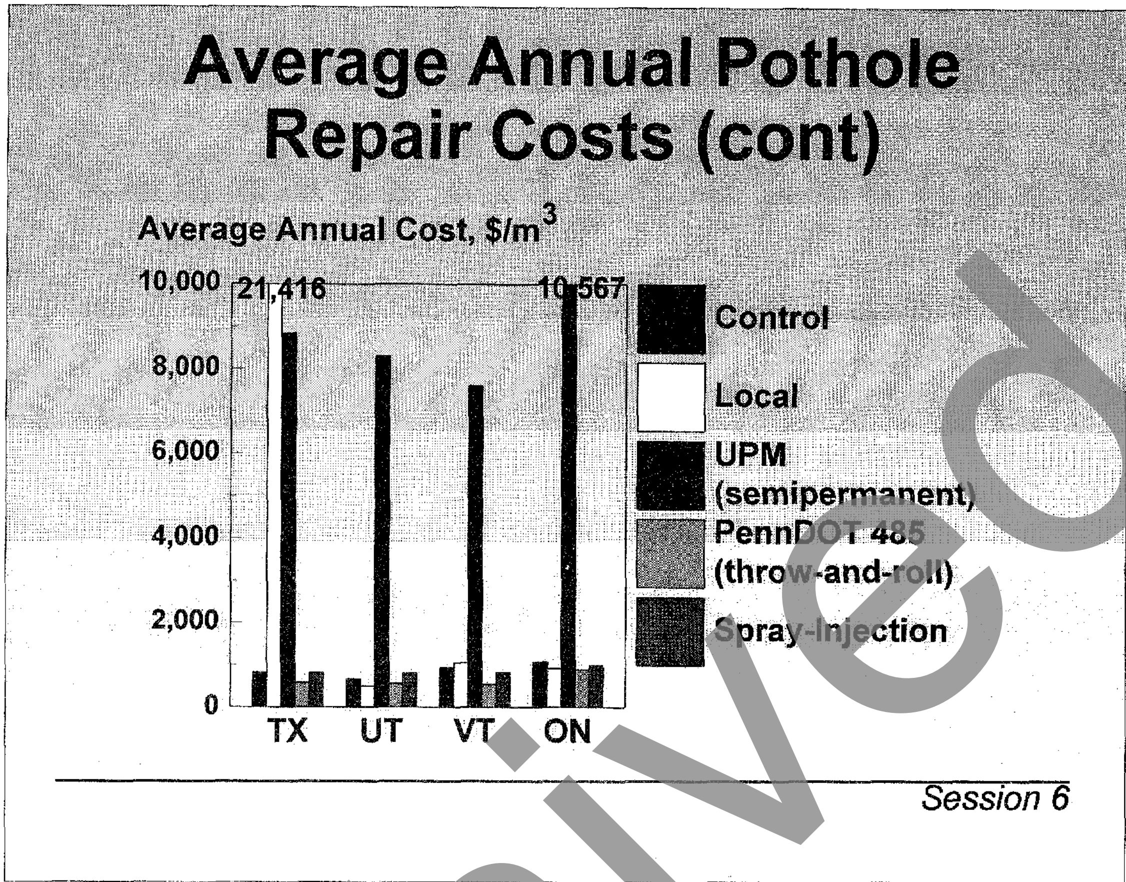


Average Annual Pothole Repair Costs
Slide #11

Using the documented survival rates and estimated placement costs, average annual costs were calculated for each patch type at each site. This slide shows the resulting values of the control, local, UPM semipermanent, spray-injection, and PennDOT 485 throw-and-roll patch types placed at California, Illinois, New Mexico, and Oregon.

As you can see, even though the local materials cost way less than agency-specified and proprietary materials, the performance they provide often does not make them the most cost-effective option. And, although the UPM semipermanent patch types provide similar performance as the control patch types, the extra effort required of this type of repair makes it very cost-ineffective.

PennDOT 485, which has a significantly lower purchase cost than proprietary materials, has provided very good performance, generally making it the most cost-effective patch type. And, compared to the control, the spray-injection patch type is about the same or slightly higher in average annual cost.



Average Annual Pothole Repair Costs (cont)
Slide #12

This slide shows the average annual costs for the same five repair types at the Texas, Utah, Vermont, and Ontario sites. Again, it is apparent that UPM semipermanent patch type is cost-<u>in</u>effective, and that occasionally the local patch type is very cost-<u>in</u>effective.

The spray-injection patch type is similar in cost with the control, and the PennDOT 485 is the most cost-effective.

Objective of Pothole Repair

To place the longest lasting patch possible in each pothole

Session 6

Objective of Pothole Repair
Slide #13

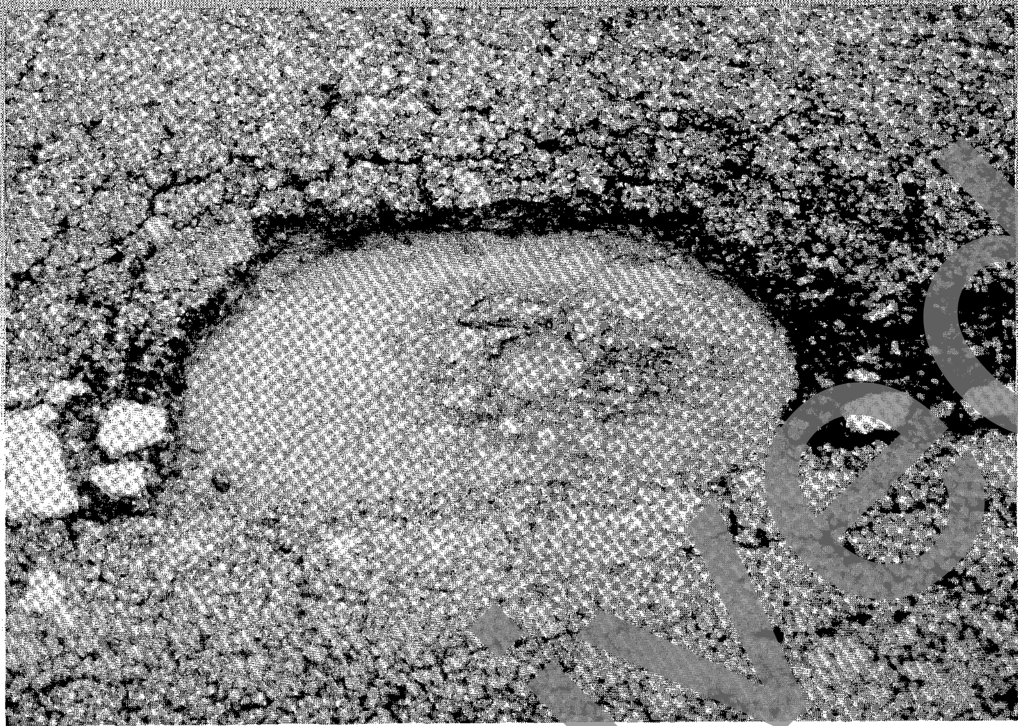
As with partial-depth spall repair, the objective of pothole repair is simple. It is to place the longest lasting patch possible in each pothole. Repairs that must be made repeatedly increase crew exposure to traffic, and result in additional agency costs <u>and</u> user costs.

Page 6-4

Pothole Patching

Pothole Patching
Slide #14

Pothole patching is one of the most common activities for maintenance crews. Although there are millions of potholes repaired by thousands of maintenance workers every year, there has been little agreement as to the most effective method for patching these distresses.



Pothole Example
Slide #15

Many agencies and pavement researchers feel that what is needed is a rigorous effort to clean out a pothole, square up the sides, and compact the material to get a quality, long lasting patch. Many maintenance crews are more partial to the "throw-and-go" method where cold-mix is quickly dumped into a pothole and left for traffic to compact. In certain instances, both of these methods may be appropriate.

This presentation will detail the proper times for using each of these procedures, as well as other methods, such as the throw-and-roll and spray-injection patching method. The advantages and disadvantages of each procedure will be presented to help you decide which is the best way for your crew to patch potholes.

Everyone would agree that potholes can present a serious aggravation and hazard to motorists if they are not repaired and begin to grow. The ultimate goal of this workshop session is to help get potholes repaired as efficiently as possible, in a way that will provide the longest lasting patches for lowest overall cost.

Page 6-5

Interstate Patching

Interstate Patching

Slide #16

Patching operations are carried out on all types of roads, from high-volume interstates to two-lane country blacktops. Because of the differences in patching locations, there are different levels of repair needed, and many combinations of materials and methods to get patches which meet those needs.

Manual Patching

Manual Patching

Slide #17

The two areas of emphasis in this presentation are the materials and the methods used to repair potholes. The materials presented here are stockpiled cold-mix asphalt products. Even though hot-mix asphalt concrete (HMAC) should be used whenever possible, the fact is that most potholes develop during the late winter and early spring when hot mix may not be available in some parts of the country. This makes cold-mix the only good alternative for patching potholes for many agencies.

Page 6-5

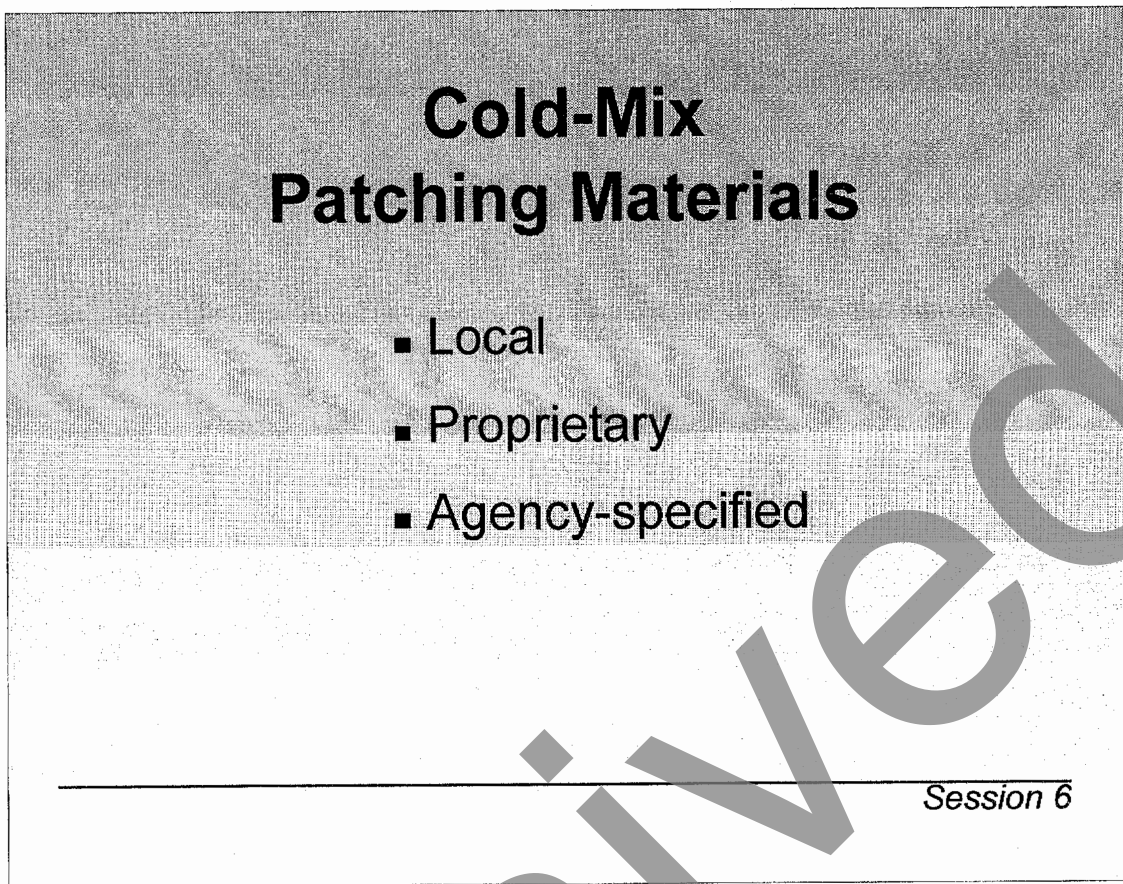
Spray-Injection Patching

Spray-Injection Patching

Slide #18

The second area of emphasis for quality patching is the method used. Several different methods are available for placing pothole patches, and certain situations often dictate which method is the most viable.

Page 6-5



Patching Materials
Slide #19

Let's take a look now at the types of cold-mix patching materials that are typically available to maintenance agencies. As you can see, there are local materials, proprietary materials, and agency-specified materials.

Local materials are those that are produced by a local asphalt plant using the available aggregate and binder. These types of materials are not produced according to a mix design procedure, rather they are produced using whatever materials are locally available.

Page 6-6

Proprietary Materials

- Examples
  - UPM High-Performance Cold-Mix
  - QPR 2000
  - Perma-Patch
- Cost about $77/Mton to purchase

Session 6

Proprietary Materials
Slide #20

UPM High-Performance Cold-Mix, QPR 2000, and Perma-Patch are just some examples of the proprietary materials available. These materials generally cost about $77/Mton, not including delivery.

In general, these materials have been tested for compatibility and performance by the manufacturer, which improves the quality of the material. The use of binder additives to enhance performance is also done with most proprietary mixes.

Page 6-6

Agency-Specified Materials

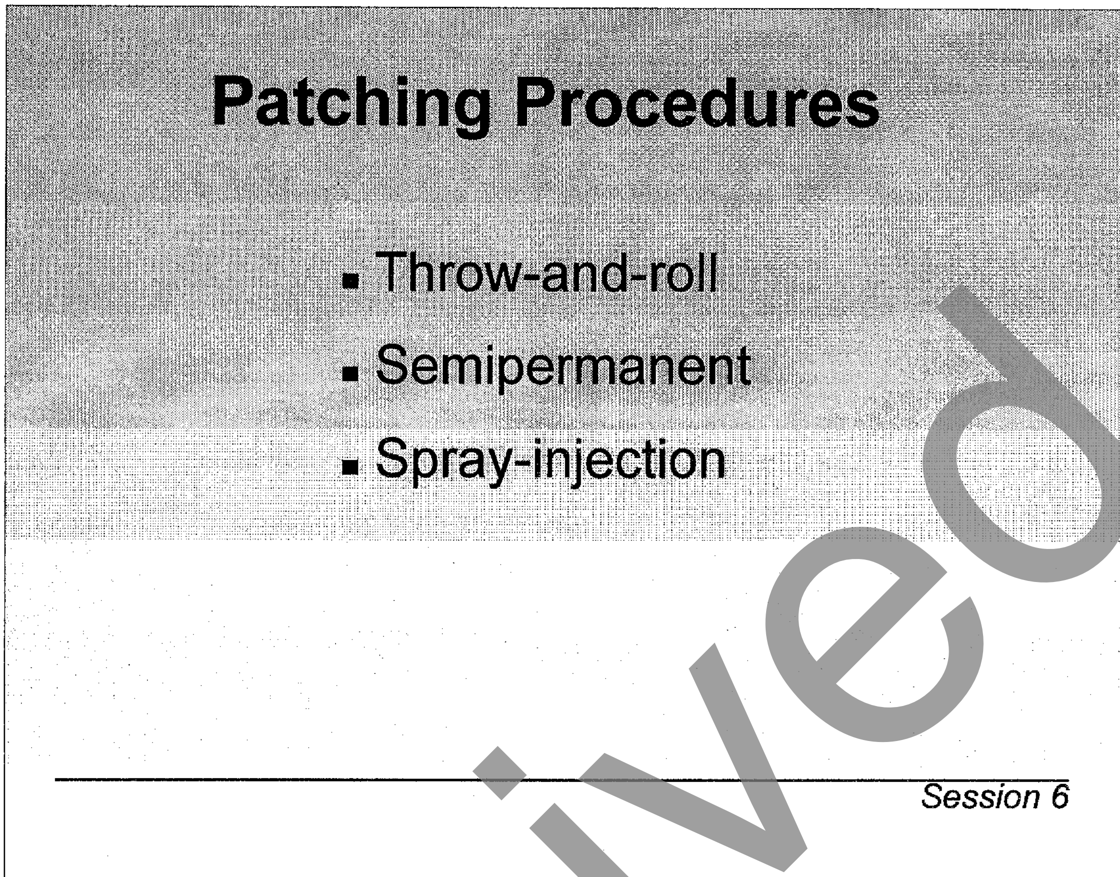
- Examples
  - PennDOT 485
  - PennDOT 486
  - High Float Medium Set Emulsion (HFMS-2)
- Cost between $38 and $66/Mton

Session 6

Agency-Specified Materials
Slide #21

Agency-specified materials such as Pennsylvania DOT 485 or a high-float medium-setting emulsion can also be used with good results. These materials are generally produced for between $38 and $66/Mton, depending on the types of additives used in the binder. Additives can be used to improve workability or reduce stripping, or to improve other material properties.

Page 6-6



Patching Procedures
Slide #22

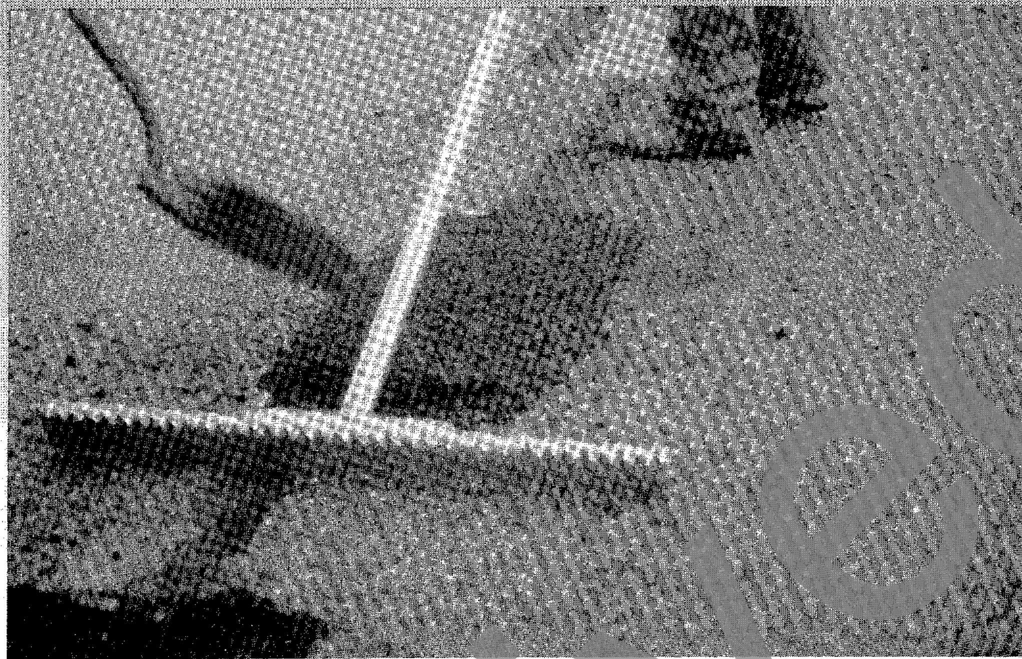
There are several different techniques for patching potholes. These range from the throw-and-go to the placement of full-depth repairs that include base removal and replacement. Our focus in this session will be on those techniques primarily evaluated in the SHRP H-106 pothole repair experiment. These include the following:

- throw-and-roll.
- semipermanent.
- spray-injection.

Three other procedures---the edge seal, the surface seal, and the heat-and-tack---were studied in the H-106 experiment and are described in your handbook, but we'll not discuss them in this presentation.

Page 6-8

Throw-and-Roll (Shoveling Material)

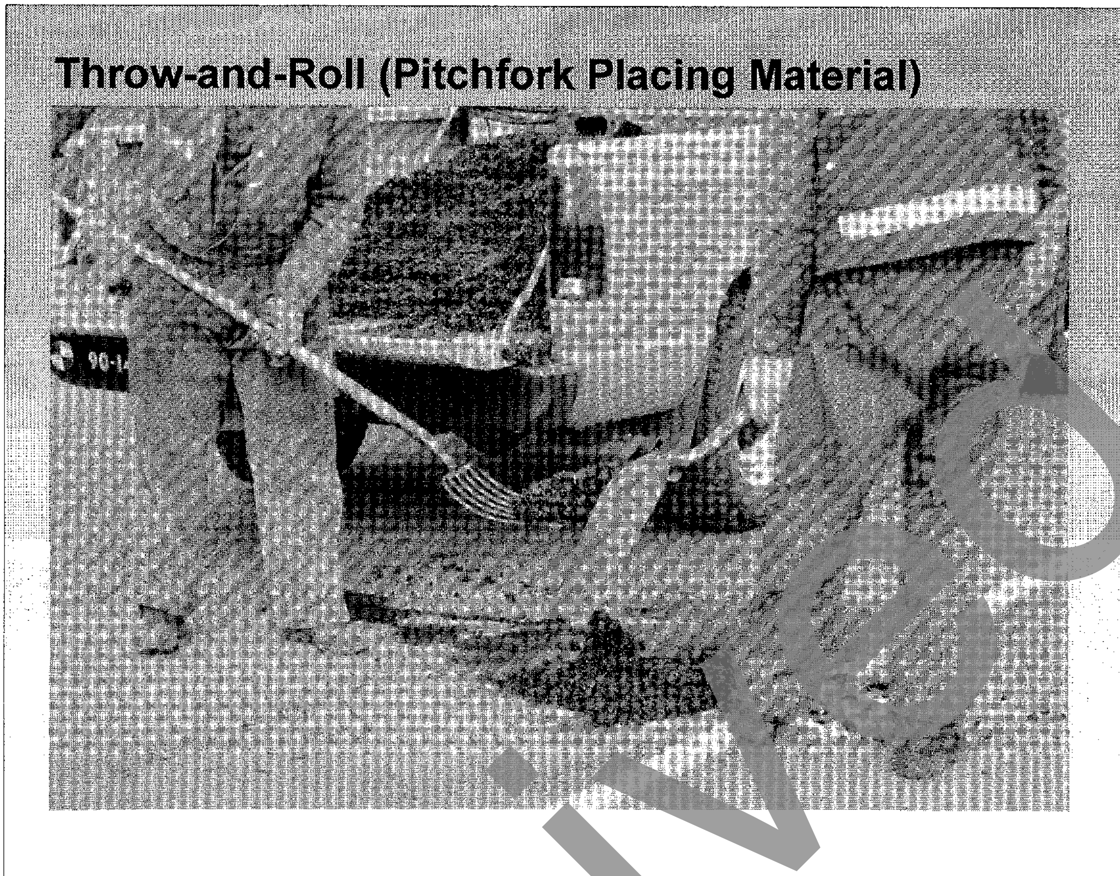


Throw-and-Roll (Shoveling Material)
Slide #23

The throw-and-roll procedure is similar to the throw-and-go procedure in that no preparation is done to the potholes prior to placing the cold-mix.

Water and debris are left in the hole, and are covered or displaced by the cold-mix. Any type of hand tool can be used for placing the materials, though a shovel is the most common.

Page 6-8

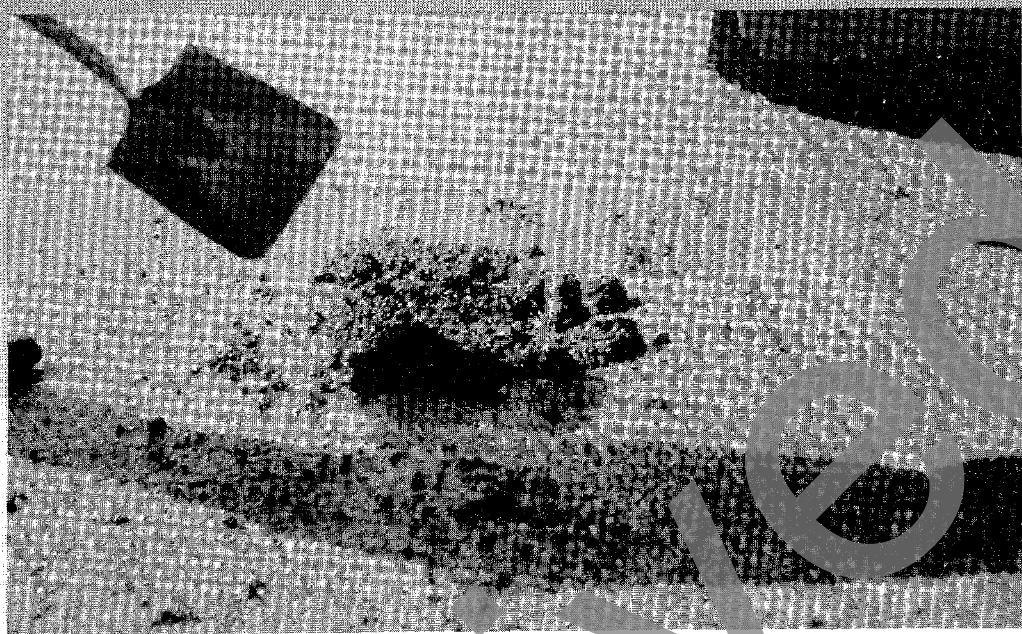


Throw-and-Roll (Pitchfork Placing Material)
Slide #24

Pitchforks and other sharper tools can be used when the cold-mix is very stiff, especially when temperatures are below freezing. Loading material from a stockpile onto a truck which can then be parked in a heated garage overnight is one way to improve the workability and compactability of cold-mix.

Page 6-8

Throw-and-Roll (Loose Material)



Throw-and-Roll (Loose Material)

Slide #25

The cold-mix should be placed in the pothole so that there is some crown in the center. One rule of thumb to use 15 mm above the pavement surface for every 40 mm below the surface before compaction. When placing material into a pothole filled with water, it can be difficult to judge how deep the hole is, so that the experience of the crew should be used.

Page 6-8

Throw-and-Roll (Truck Tires Compacting)

Slide #26

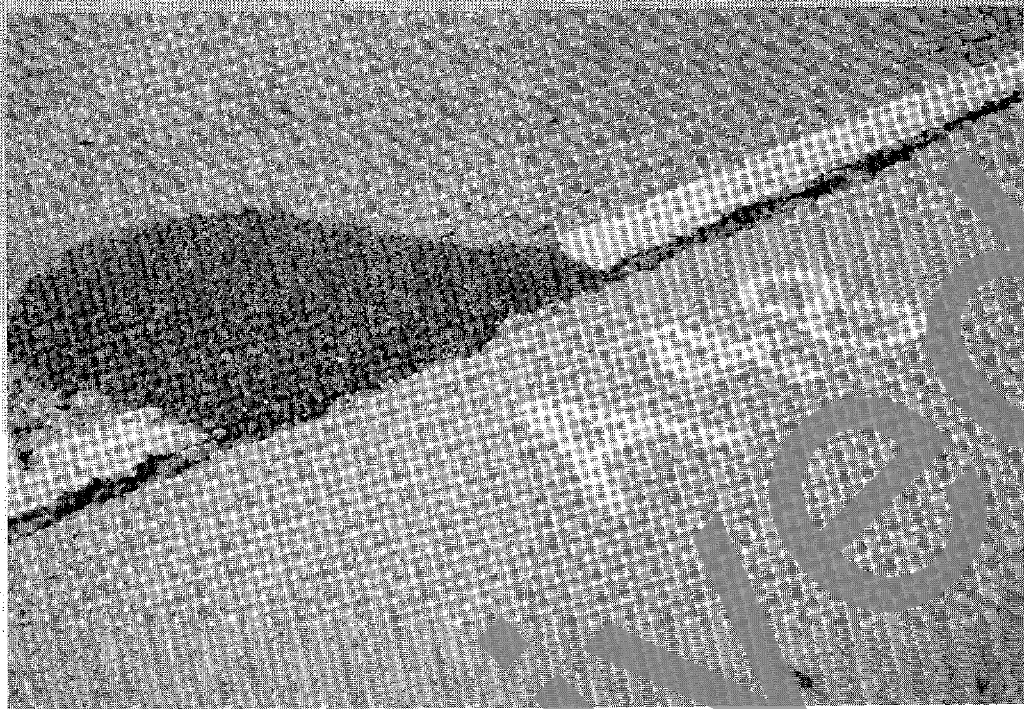
The major difference between the throw-and-go and throw-and-roll repair methods is the rolling of the patches by the material truck. By rolling 6 to 8 times with the truck tires, the cold-mix is packed better into the hole and is less likely to be pulled out by passing traffic.

After the truck has rolled the material 6 or 8 times, the level of the patch surface can be checked to make sure that the center of the patch is slightly above the pavement, somewhere between 5 and 10 mm.

If the patch is low, more cold-mix should be added to the low spots, smoothed and rolled until the surface is smooth and slightly above the pavement. The finished patch should be left slightly above the pavement so that traffic can continue to compact the material without resulting in a depression, and also to allow for better shedding of water from the patch.

Page 6-8

Throw-and-Roll (Finished Patch)



Throw-and-Roll (Finished Patch)
Slide #27

Patches that sink below the surrounding pavement tend to collect water, which can lead to potential hydroplaning for traffic, and raveling of the material as the asphalt is stripped from the aggregate. For patching with the throw-and-roll technique, any number of proprietary cold-mixes can be used.

Page 6-8

Semipermanent

- Remove water/debris from pothole
- Cut pothole edges straight and in sound pavement
- Place material into cleaned and squared pothole
- Compact using compaction device
- Move on to next pothole

Session 6

Semipermanent
Slide #28

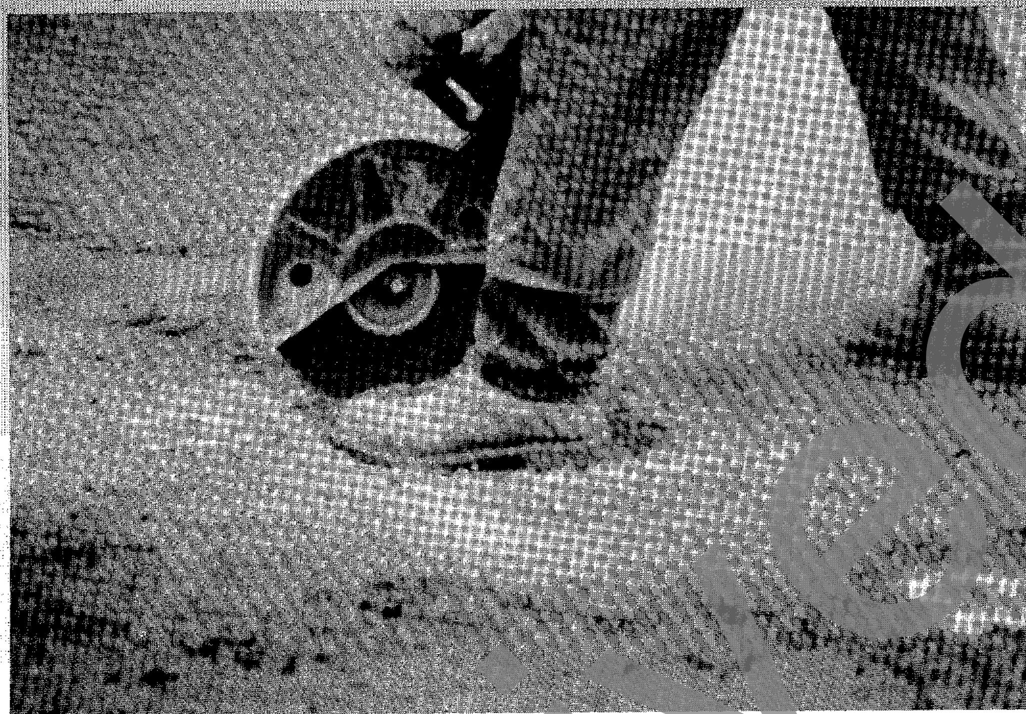
Another procedure that can be used is the semipermanent repair method. This procedure involves more steps than the throw-and-roll, and requires more equipment and labor. In many instances, it is possible to improve the performance of patches by using this procedure.

The steps of the semipermanent procedure include:

- removing debris and water from the hole.
- using a jackhammer or pavement saw to cut the pothole edges in sound pavement.
- placing the material into the cleaned and squared hole, and
- compacting the patch with a compaction device.

Pages 6-10 & 6-11

Semipermanent (Pavement Saw)



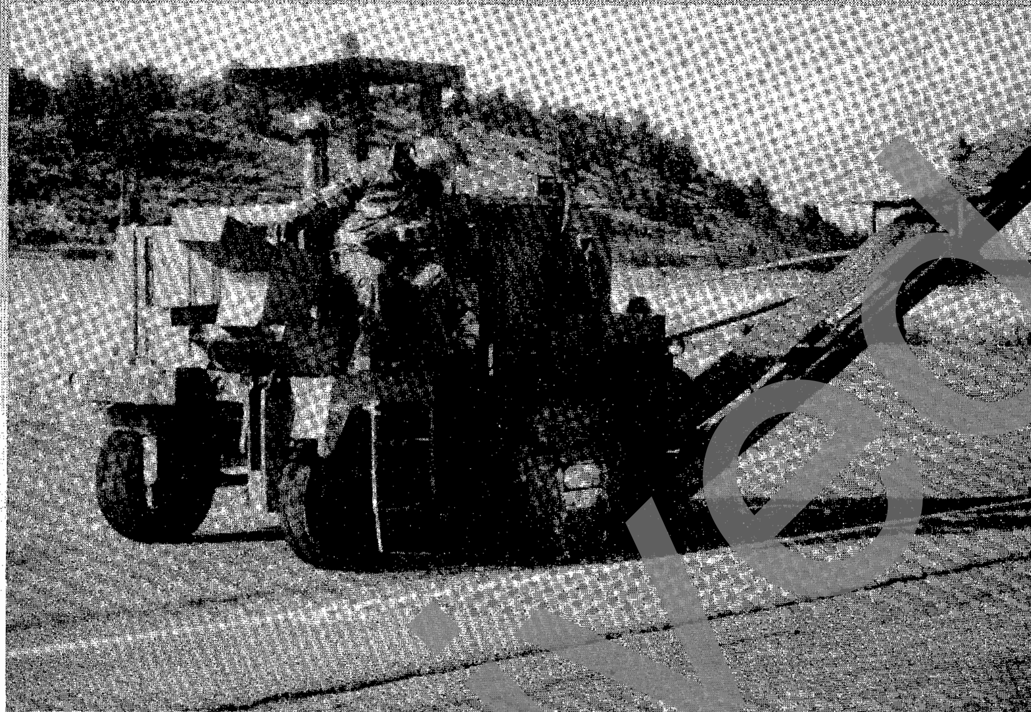
Semipermanent (Pavement Saw)
Slide #29

Edge straightening can be done using a jackhammer equipped with a clay spade bit, or a portable pavement saw, depending on what is available.

The reason for straightening the sides is so that the patching material has good support on all sides from the surrounding pavement. The sides should be made as vertical as possible to provide the best support.

Page 6-11 Figure 6-2

Semipermanent (Milling Machine)



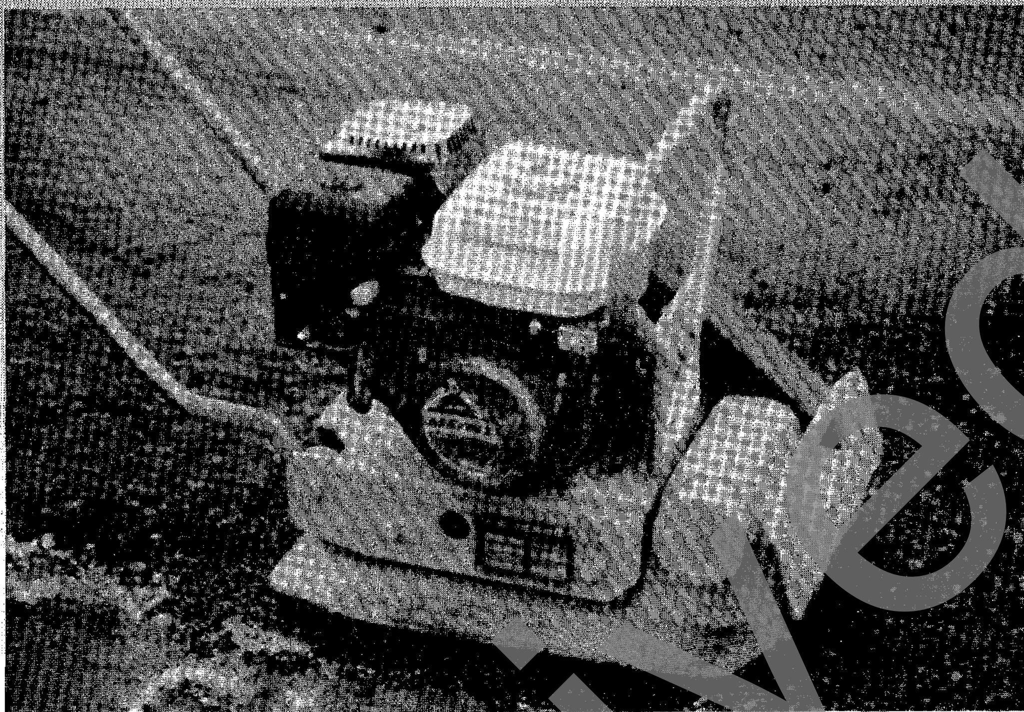
Semipermanent (Milling Machine)
Slide #30

One other option for straightening pothole edges is to use a milling machine similar to the one pictured here. This device has an 460-mm milling head and can produce straight edges very quickly, though the level of control is not as good as for the pavement saw or jackhammer.

Placement of the cold-mix into a cleaned, squared hole is done with the same type of hand tools used in the throw-and-roll procedures. The level of loose material should be above the pavement surface before compaction, similar to the throw-and-roll patches.

Pages 6-10 & 6-11

Semipermanent (Vibratory Plate Compactor)



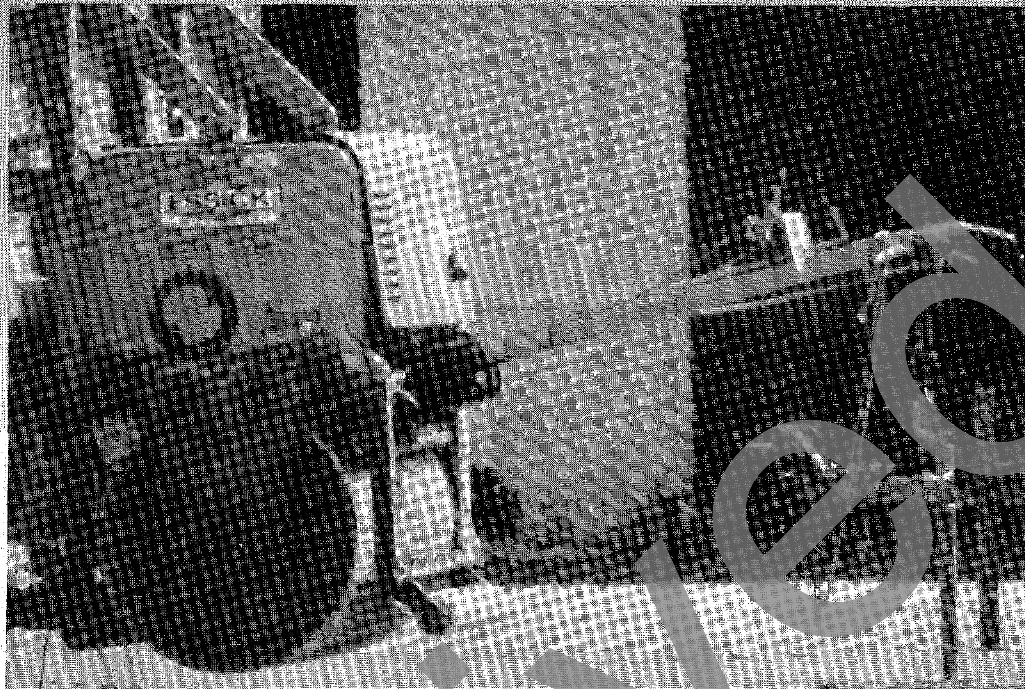
Semipermanent (Vibratory Plate Compactor)
Slide #31

One device that has been used successfully for compacting semipermanent repairs is the vibratory plate compactor. The size of this device allows for good control by a single operator as the patch is being compacted.

The compaction of the semipermanent procedures should begin in the center and work out toward the edges. This approach provides a pinching action for the material, providing better compaction at the edges and in the corners.

Pages 6-10 & 6-11

Semipermanent (Single-Drum Vibratory Roller)

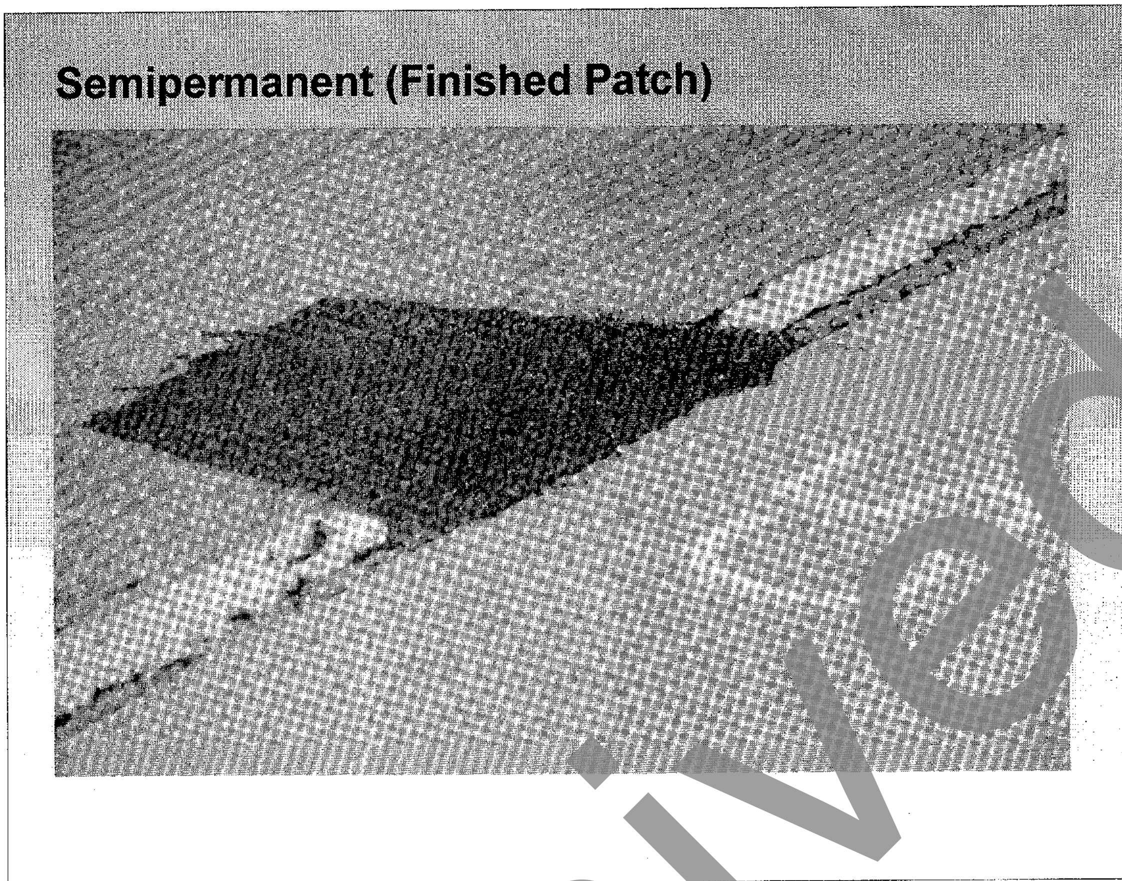


Semipermanent (Single-Drum Vibratory Roller)
Slide #32

An alternative for compacting semipermanent patches is to use a single-drum vibratory roller. This device is heavier than the vibratory plate, and offers less control, but can still be used effectively to compact the materials into the corners.

The roller should be used in both longitudinal and transverse directions where safety permits, and the level of the compacted patch should be checked to make sure that there is some crown above the pavement surface. Bridging of the patch can be a problem, especially in rutted wheel paths, and must be avoided to get good compaction.

Pages 6-10 & 6-11



Semipermanent (Finished Patch)
Slide #33

The semipermanent patches require more equipment and manpower to complete than the throw-and-roll patches. Any of the materials listed for throw-and-roll repairs can also be used for semi-permanent repairs including UPM, QPR 2000, Perma-Patch, PennDOT 485, or the high-float medium-set emulsion.

Pages 6-10 & 6-11

Spray-Injection

- Blow water/debris from pothole
- Spray layer of tack coat into pothole
- Spray aggregate and binder into pothole
- Spray layer of aggregate only on top of patch
- Move on to next pothole

Session 6

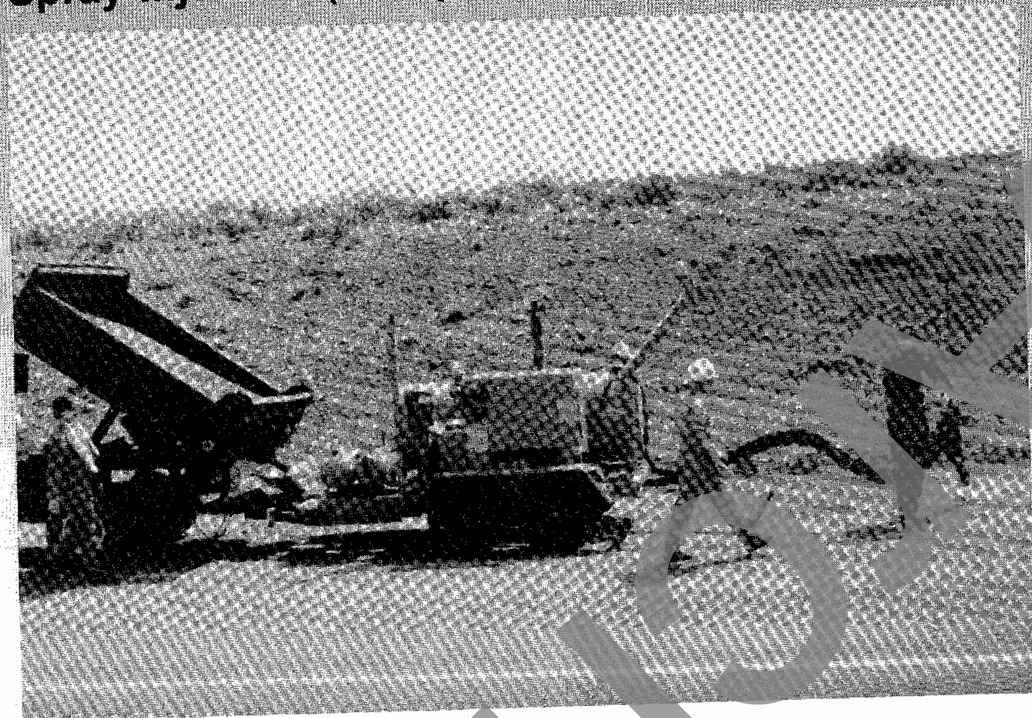
Spray-Injection
Slide #34

An alternative to either the throw-and-roll and semipermanent procedures is spray-injection patching. The sequence of this type of repair consists of:

- blowing water and debris from the pothole.
- spraying a layer of tack material into the pothole.
- spraying aggregate and binder into the pothole, and
- spraying a cover layer of aggregate on top of the patch.

Pages 6-11 & 6-12

Spray-Injection (Durapatcher)

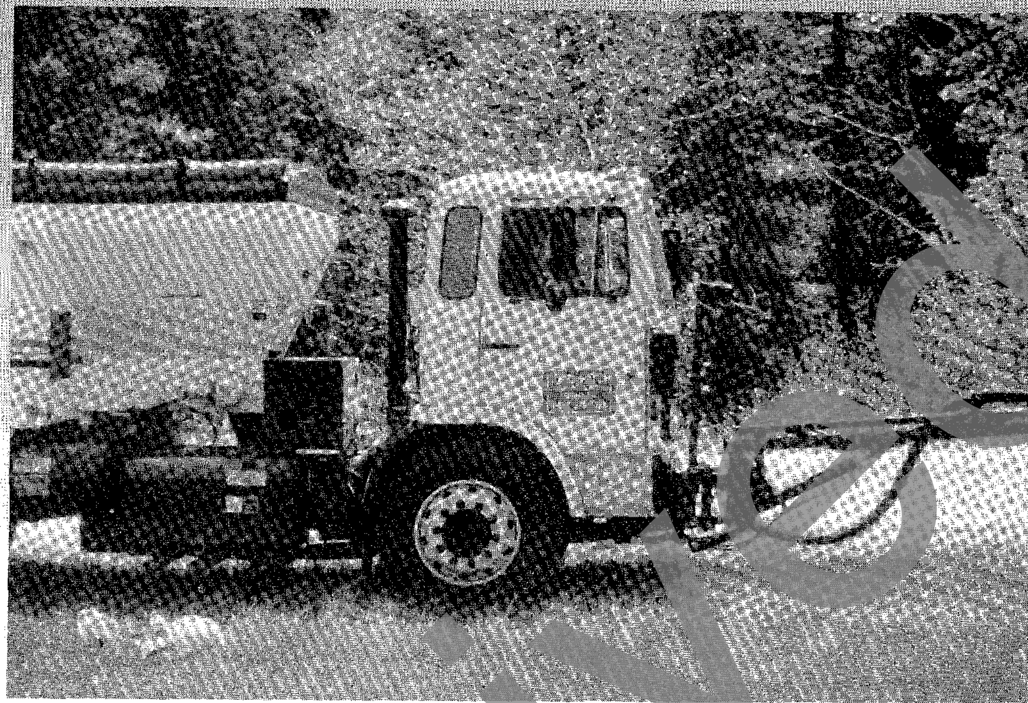


Spray-Injection (Durapatcher)
Slide #35

The spray-injection procedure requires a spray-injection device, aggregate, and emulsified asphalt. The device can be either a trailer unit which is towed behind a truck carrying the aggregate, or . . . . . .

Page 6-13 ***Figure 6-4***

Spray-Injection (Wildcat)



Spray-Injection (Wildcat)
Slide #36

. . . a single vehicle which contains an aggregate hopper, an asphalt tank, and delivery system. Spray-injection devices can be purchased new from the manufacturer, or they can be rented from equipment rental companies.

In some instances, spray-injection services can be hired. No matter which device is used for spray injection, there has to be a compatible mixture of aggregate and emulsion for the patches to be effective. "Garbage in-garbage out" applies to spray-injection patches when an incompatible combination of emulsified asphalt and aggregate are used together, no matter how adequate the machine is. Various tests are available to determine the compatibility of emulsions and aggregates.

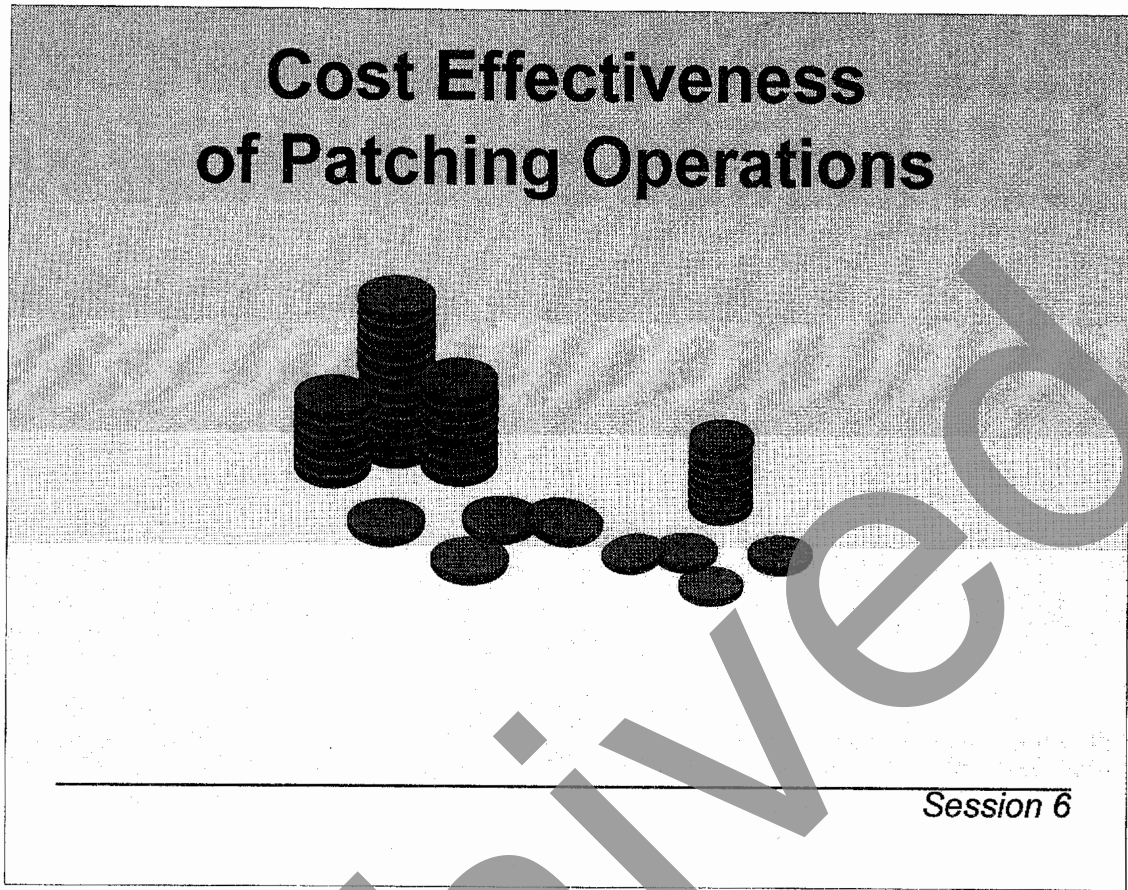
Page 6-13 Figure 6-3

Winter Patching

Winter Patching
Slide #37

When patching operations are to be carried out in adverse weather while traffic is diverted to other lanes, the most important criteria for deciding what procedures to use should be the productivity.

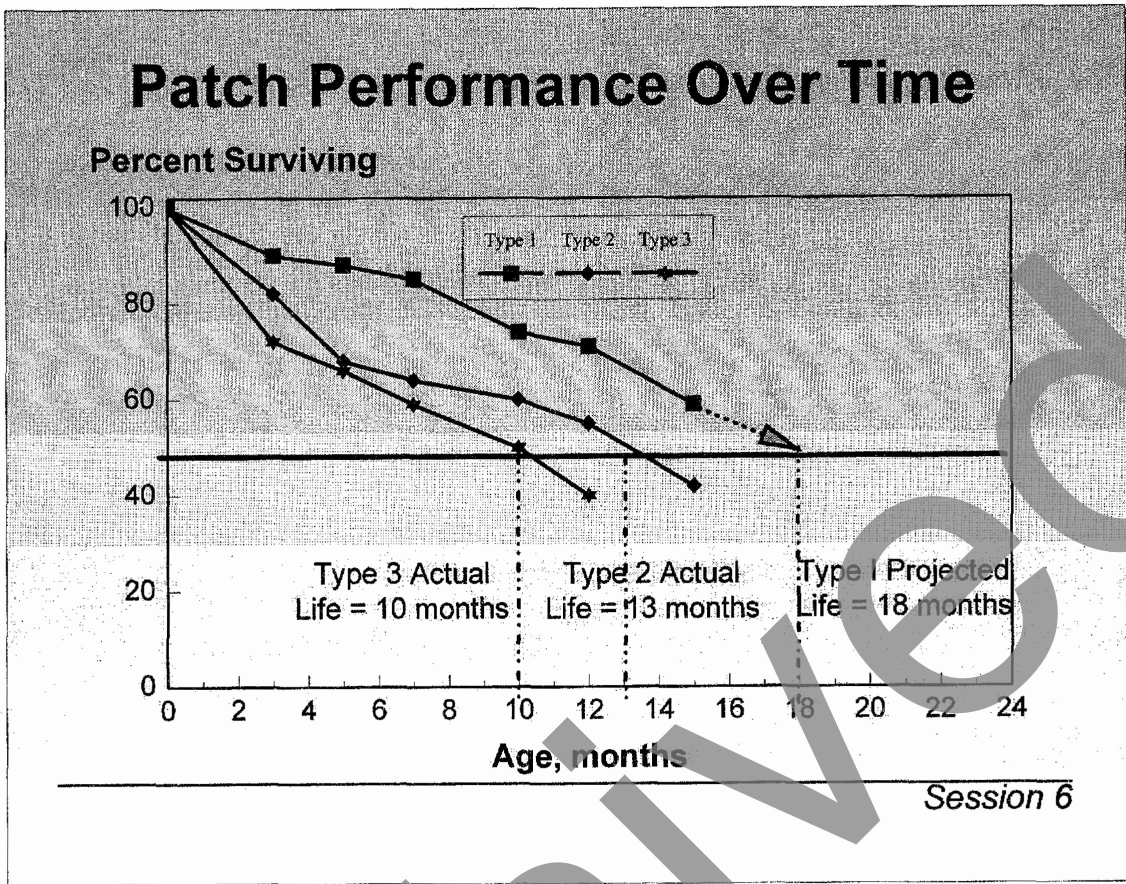
Long-lasting patches can be achieved using high-quality materials and the throw-and-roll or spray-injection procedure under adverse conditions. With the high rates of the production possible with both, they should be used whenever patching needs to be done in hazardous weather.



Cost Effectiveness
Slide #38

For most agencies, there is a source of good-quality cold-mix available, similar to the materials described here. These materials generally cost more than the conventional lower quality cold-mixes, but they are usually able to reduce the overall patching expenses due to their increased service lives.

Page 6-6



Patch Performance Over Time

Slide #39

Any patching material that is used will eventually develop some failures. The number of failures over a given period of time can be quite different for different materials.

When comparing the cost-effectiveness of different materials or patch types, it is necessary to look at the total cost of patching potholes over time, which includes the repeated cost of replacement of the patches.

This graph shows survival plots of three different types of patches. The median service lives of types 2 and 3 are 13 and 10 months, respectively. The type 1 patch is projected to have a median service life of 18 months, making it the longest lasting patch type.

Figure not in handbook

Costs for Pothole Patching Operations

- Labor Costs
- Material Costs
- Equipment Costs
- User Delay Costs

Session 6

Patching Costs
Slide #40

Patching costs are generally made up of material costs, equipment costs and labor costs. Because in most cases material costs are less than labor and equipment costs, better quality materials which cost more and last longer, can reduce the overall long-term costs by reducing the amount of repatching which needs to be done.

Cost Effectiveness Assumptions

- Total volume of potholes: 34 m^3 (at 2000 kg/m^3, 68 Mtons needed initially)
- Labor cost: $100/day for each laborer
- Traffic control: $200/day
- Repairs made to failed patches will last the remainder of the year

Session 6

Cost-Effectiveness Assumptions

Slide #41

Let us now run through a few cost-effectiveness calculations for different types of pothole patches. For each case, we'll assume that an agency has 34 m^3 of potholes to be patched. In addition, we'll assume that the labor cost is $100/day for each laborer and that the traffic control set-up costs are $200/day.

Cost-Effectiveness Calculation

$$C = (12/L) \times (TC + MC + LC + EC + UC)$$

Where:

C = Annual cost of patching operation, $
L = Expected median life of patches, months
TC = Traffic control costs ($/day x days patching)
MC = Material costs ($/Mton x initial tons needed)
LC = Labor cost ($/day x days patching)
EC = Equipment cost ($/day x days patching)
UC = User delay cost ($/day x days patching)

Session 6

Cost-Effectiveness Calculation
Slide #42

This slide shows the equation that is used to calculate the annual cost of a patching operation. It requires an estimate of the expected median life of the patches, along with estimates of the material, traffic control, labor, equipment and user delay costs.

The material cost should only be for the initial potholes that develop and should no longer include material needed for repatching. The other costs are generally calculated as $/day costs, and multiplied by the number of days needed to patch the initial potholes, again not including days for repatching. The days for patching can be determined by dividing the total metric tons to be placed by the average productivity in metric tons per day.

Throw-and-Roll (Local)

- Material cost: $22/Mton delivered
- Estimated median life: 3 months
- 2 laborers needed for patching ($200/day total labor cost)
- Productivity: 4.5 Mtons/day (15 days)
- Equipment cost: $20/day (truck)
- Total yearly cost: $31,200

Throw-and-Roll (Local)
Slide #43

For a local, low-quality cold-mix, that costs $22/Mton and has an effective life of 3 months (meaning that the median life of all patches placed will be 3 months), a throw-and-roll operation with two laborers patching at a rate of 4.5 Mtons/day with a single truck at $20/day and standard traffic control, the estimated yearly cost would be $31,200.

Throw-and-Roll (Proprietary)

- Material cost: $77/Mton delivered
- Estimated median life: 18 months
- 2 laborers needed for patching ($200/day total labor cost)
- Productivity: 4.5 Mtons/day (15 days)
- Equipment cost: $20/day (truck)
- Total yearly cost: $7,700

Session 6

Throw-and-Roll (Proprietary)
Slide #44

On the other hand, for a high-quality proprietary cold-mix at $77/Mton, with a median life of 18 months, and the same crew, productivity and traffic control, the estimated yearly cost would be $7,700. This is a savings of about 75 percent. In situations with higher labor and equipment costs, or a greater volume of potholes, the overall savings would have been even greater.

Semipermanent (Local)

- Material cost: $22/Mton delivered
- Estimated median life: 18 months
- 4 laborers needed for patching ($400/day total labor cost)
- Productivity: 1.36 Mtons/day (50 days)
- Equipment cost: $100/day
- Total yearly cost: $24,330

Session 6

Semipermanent (Local)
Slide #45

If the same local material is placed using a semipermanent procedure with two additional workers, more equipment costs, a lower productivity, and a median patch life of 18 months, the total overall costs would be $24,330, which is less than the local material using the throw-and-roll, but more than the proprietary material placed using the throw-and-roll method.

Spray-Injection

- Material cost: included in equipment cost
- Estimated median life: 18 months
- Laborers: included in equipment cost
- Productivity: 4.8 Mtons/day (14 days)
- Equipment cost: $900/day (single unit)
- Total yearly cost: $10,270

Session 6

Spray-Injection
Slide #46

With the spray-injection, the cost of labor and material is included in the equipment cost, which is estimated to be $900/day for a single unit. Productivity is slightly higher than the throw-and-roll procedure, and if a median patch life of 18 months is achieved, the total annual cost is computed to be $10,270.

Summary of Costs

- Throw-and-roll (local) $31,200
- Throw-and-roll (proprietary) $7,700
- Semipermanent (local) $24,330
- Spray-injection $10,270

Session 6

Summary of Costs
Slide #47

In general, the throw-and-roll procedure using the high-quality, proprietary materials will have a lower overall cost than methods using less expensive cold-mixes that will not perform as well. The spray-injection devices will operate at essentially the same or slightly higher overall cost as the throw-and-roll operations with proprietary materials, but that procedure will be more dependent on the skill of the operator than the throw-and-roll procedure.

Summary

- Good performance = cost-effectiveness
- Cost of material is small portion of total patching cost, especially when repatching is necessary
- Every effort should be made to reduce time in traffic for crews

Session 6

Summary
Slide #48

The cost-effective repair of potholes will reduce the amount of time that maintenance crews need to be in traffic, especially in bad weather. This reduces the risk to both workers and drivers.

Although pothole repair is usually considered only a temporary repair, the efficient placement of long-lasting repairs is possible with the use of the materials and procedures that have been described.

Test and Evaluation

Pothole Repair

1. Identify material-procedure combinations
2. Identify test site location
3. Lay out site
4. Install experimental repairs
5. Monitor repair performance
6. Analyze and report performance data

Session 6

Test and Evaluation (Pothole Repair)
Slide #49

As mentioned in previous sessions, the FHWA is sponsoring a technical assistance program for States interested in doing their own field studies of maintenance materials and techniques. One area of pavement maintenance that States can receive technical assistance on is AC pothole repair.

There are essentially six steps associated with performing a test and evaluation study in this area, with assistance being available for each step. The steps are:

1. Identifying the combinations of materials and procedures you wish to evaluate.
2. Identifying a suitable location for conducting the study.
3. Laying out the site (i.e., marking the locations to be patched).
4. Installing the experimental repairs.
5. Periodically inspecting the repairs for performance, and
6. Analyzing and reporting the performance data.

The Test and Evaluation Work Plans describe in more detail the work associated with each step. Again, if your agency is interested in this kind of study, the Technical Assistance Application must be filled out and submitted to the FHWA for consideration.

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TECHNOLOGY APPLICATIONS

Innovation Through Partnerships

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