The New Mexico Department of Transportation's

PAVEMENT MAINTENANCE MANUAL

Office of Transportation and Highway Operations
State Maintenance Bureau

2007 Edition

FORWARD

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This manual was prompted by a number of events that are occurring in the New Mexico Department of Transportation, the State of New Mexico, the Federal Government and the World at large. There is a trend towards aging infrastructure without the commitment of resources to reconstruction or replacement at all levels of government. There is also a changing dynamic on how taxes will be spent due to the demographics of our aging population. The demand placed on the facilities addressed in this manual is going to increase into the foreseeable future. The manual is being written with an eye towards these increased demands and limited funding.

With these trends in mind, we as Transportation Professionals will need to provide for these shortfalls by an elevated effort towards Pavement Maintenance. Especially important in these efforts will be our preservation programs which will have to extend the life of our facilities beyond the traditional reconstruction cycle models. It has been proven in all sorts of system whether it be your car, your health, or roads that preventative treatments will extend the quality of service as while as increase the life span of your system. To achieve these increases, you will need to make a modest investment in resources with the returns spread over time.

This is not solely preservation maintenance manual, because all forms of pavement maintenance have an effect over the life of the pavement. By way of example; when a pothole is filled the surrounding pavement often stops deteriorating because you have restored the structural integrity of the pavement. This will seal off the avenues for water to get into the pavements base and affect adjacent areas of the pavement. As you can see when any form of maintenance is performed it has a positive effect on the life of the pavement and the future of the system as a whole.

This manual was not created solely by my staff and I. I had lots of input from other State's Transportation Agencies, the Federal Highway Administration and Industry. The work these folks provided was taken and adjusted to meet our state's unique situation. Other members of the New Mexico Department of Transportation also play major roles in the development of this manual. In Particular Robert Young, Pavement Preservation Engineer and Mr. Dennis Ortiz, the State Maintenance Technical Support Engineer provided me with material incorporated into this document.

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INTRODUCTION

New Mexico is a unique state in the size of our population verse the size of our road network. Our state maintains one of the largest roadway networks per capita in the Western United States. New Mexico Department of Transportation has about 30,000 lane miles of roads that it is responsible for. The number of lane miles will continue to grow as the population of our state grows.

This makes for some unique challenges when it comes to providing customer service to the citizens that use these roads. The traditional model for handling our higher volume road network is to have a large construction program that builds and rebuilds the network every few years. Very little maintenance would be preformed in between rebuilds. Lower volume roads are largely chip seals over improved bases that generally only receive emergency maintenance between chip seals.

The purpose of this manual is to assist our maintenance professional in making good engineering and fiscal decisions to extend the life of our roads. By applying good strategic methods and applying the correct treatment, the service-life and customer satisfaction should be extended and tax dollars saved.

This Manual is set up in six parts.

Part 1 provides general information and background information for the manual. It contains and clarifies various policies plans and memorandums on maintenance that were generated prior to the writing of the manual.

Part 2 goes over the various types of maintenance which are broken down into pavement preservation/preventative maintenance, reactive/corrective maintenance and emergency maintenance. Each type is integral to the life cycle of the road but they are distinctive on how each type of maintenance is approached.

Part 3 List the types of distress commonly found in both Portland Cement Concrete Pavements and Asphalt Pavements. The section classified the distresses based primarily on the outward appearance of the failure modes of the distress. Each distress is comes with a disruption of the failure

Part 4 is a narrative on various maintenance treatments used for maintaining and repairing pavements. Each treatment goes over setting up a project and precautionary items about use of each treatment.

Part 5 goes over the annual condition survey generated by the Department. This is a useful tool for gauging the over success of our maintenance programs and should be used in conjunction with this manual to make a successful program.

Part 6 is a list of reference materials

PART 1 - PROGRAM GUIDELINES

As was noted earlier, the Department's Pavement on our roads is our single largest investment. With this investment comes a duty to the owners of this asset to protect it, keep it functional and maximize our return on investment. With this in mind we will begin our journey through this manual beginning with some directives that are in place or were in place at one time dealing with pavement maintenance.

Several Department directives and policies and the Federal Highway Administration Preventive Maintenance Eligibility Memorandum provide the framework for establishing and implementing the pavement preservation program. The directives and policies are as follows:

- FHWA Memorandum – Pavement Preservation Definitions
- Administrative Directive 239 – Pavement Preservation Maintenance
- Commission Policy 83 – Priority Determination for Highway Improvements
- Federal Highway Administration Preventive Maintenance Eligibility memorandum
- NMDOT Strategic Plan 2004 – Strategic Priority Two/Build, maintain and operate New Mexico's transportation and highway infrastructure system
- Performance and Planning Matrix, Decision Table, and Condition Assessment

Following is a discussion of each directive and policy:

U.S. Department of Transportation
Federal Highway Administration

Memorandum

FHWA MEMORANDUM – PAVEMENT PRESERVATION DEFINITIONS

Subject: **ACTION**: Pavement Preservation Definitions Date:

(*Original Signed by David R. Geiger, P.E.*)

From: David R. Geiger, P.E.
Director, Office of Asset Management

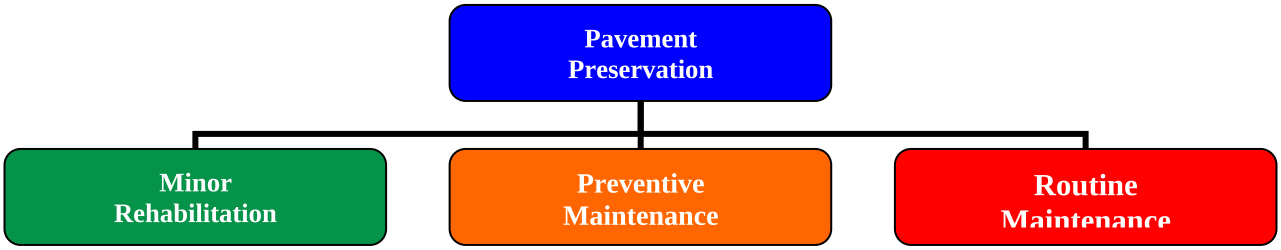
Reply to
Attn. of: HIAM-20

To: Associate Administrators
Directors of Field Services
Resource Center Director and Operations Manager
Division Administrators
Federal Lands Highway Division Engineers

As a follow-up to our Preventive Maintenance memorandum of October 8, 2004, it has come to our attention that there are differences about how pavement preservation terminology is being interpreted among local and State Transportation agencies (STAs). This can cause inconsistency relating to how the preservation programs are applied and their effectiveness measured. Based on those questions and a review of literature, we are issuing this guidance to provide clarification to pavement preservation definitions.

Pavement preservation represents a proactive approach in maintaining our existing highways. It enables STAs to reduce costly, time consuming rehabilitation and reconstruction projects and the associated traffic disruptions. With timely preservation we can provide the traveling public with improved safety and mobility, reduced congestion, and smoother, longer lasting pavements. This is the true goal of pavement preservation, a goal in which the FHWA, through its partnership with States, local agencies, industry organizations, and other interested stakeholders, is committed to achieve.

A Pavement Preservation program consists primarily of three components: preventive maintenance, minor rehabilitation (non structural), and some routine maintenance activities as seen in figure 1.



An effective pavement preservation program can benefit STAs by preserving investment on the NHS and other Federal-aid roadways, enhancing pavement performance, ensuring cost-effectiveness, extending pavement life, reducing user delays, and providing improved safety and mobility.

It is FHWA's goal to support the development and conduct of effective pavement preservation programs. As indicated above, pavement preservation is a combination of different strategies which, when taken together, achieve a single goal. It is useful to clarify the distinctions between the various types of maintenance activities, especially in the sense of why they would or would not be considered preservation.

For a treatment to be considered pavement preservation, one must consider its intended purpose. As shown in Table 1 below, the distinctive characteristics of pavement preservation activities are that they restore the function of the existing system and extend its service life, not increase its capacity or strength.

Pavement Preservation Guidelines					
	Type of Activity	Increase Capacity	Increase Strength	Reduce Aging	Restore Serviceability
	New Construction	X	X	X	X
	Reconstruction	X	X	X	X
	Major (Heavy) Rehabilitation		X	X	X
	Structural Overlay		X	X	X
Pavement Preservation	Minor (Light) Rehabilitation			X	X
Pavement Preservation	Preventive Maintenance			X	X
Pavement Preservation	Routine Maintenance				X
	Corrective (Reactive) Maintenance				X
	Catastrophic Maintenance				X

Table 1- *Pavement Preservation Guidelines*

<u>Definitions for Pavement Maintenance Terminology</u>

<u>Pavement Preservation</u> is "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations."
Source: FHWA Pavement Preservation Expert Task Group

An effective pavement preservation program will address pavements while they are still in good condition and before the onset of serious damage. By applying a cost-effective treatment at the right time, the pavement is restored almost to its original condition. The cumulative effect of systematic, successive preservation treatments is to postpone costly rehabilitation and reconstruction. During the life of a pavement, the cumulative discount value of the series of pavement preservation treatments is substantially less than the discounted value of the more extensive, higher cost of reconstruction and generally more economical than the cost of major rehabilitation. Additionally, performing a series of successive pavement preservation treatments during the life of a pavement is less disruptive to uniform traffic flow than the long closures normally associated with reconstruction projects.

<u>Preventive Maintenance</u> is "a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity)." *Source: AASHTO Standing Committee on Highways, 1997*

Preventive maintenance is typically applied to pavements in good condition having significant remaining service life. As a major component of pavement preservation, preventive maintenance is a strategy of extending the service life by applying cost-effective treatments to the surface or near-surface of structurally sound pavements. Examples of preventive treatments include asphalt crack sealing, chip sealing, slurry or microsurfacing, thin and ultra-thin hot-mix asphalt overlay, concrete joint sealing, diamond grinding, dowel-bar retrofit, and isolated, partial and/or full-depth concrete repairs to restore functionality of the slab; e.g., edge spalls, or corner breaks.

Pavement Rehabilitation consists of "structural enhancements that extend the service life of an existing pavement and/or improve its load carrying capacity. Rehabilitation techniques include restoration treatments and structural overlays." *Source: AASHTO Highway Subcommittee on Maintenance*

Rehabilitation projects extend the life of existing pavement structures either by restoring existing structural capacity through the elimination of age-related, environmental cracking of embrittled pavement surface or by increasing pavement thickness to strengthen existing pavement sections to accommodate existing or projected traffic loading conditions. Two sub-categories result from these distinctions, which are directly related to the restoration or increase of structural capacity.

> *Minor rehabilitation* consists of non-structural enhancements made to the existing pavement sections to eliminate age-related, top-down surface cracking that develop in flexible pavements due to environmental exposure. Because of the non-structural nature of minor rehabilitation techniques, these types of rehabilitation techniques are placed in the category of pavement preservation.
>
> *Major rehabilitation* "consists of structural enhancements that both extend the service life of an existing pavement and/or improve its load-carrying capability." *Source: AASHTO Highway Subcommittee on Maintenance Definition*

Routine Maintenance "consists of work that is planned and performed on a routine basis to maintain and preserve the condition of the highway system or to respond to specific conditions and events that restore the highway system to an adequate level of service." *Source: AASHTO Highway Subcommittee on Maintenance*

Routine maintenance consists of day-to-day activities that are scheduled by maintenance personnel to maintain and preserve the condition of the highway system at a satisfactory level of service. Examples of pavement-related routine maintenance activities include cleaning of roadside ditches and structures, maintenance of pavement markings and crack filling, pothole patching and isolated overlays. Crack filling is another routine maintenance activity which consists of placing a generally, bituminous material into "non-working" cracks to substantially reduce water infiltration and reinforce adjacent top-down cracks. Depending on the timing of application, the nature of the distress, and the type of activity, certain routine maintenance activities may be classified as preservation. Routine Maintenance activities are often “in-house” or agency-performed and are not normally eligible for Federal-aid funding.

Other activities in pavement repair are an important aspect of a STA’s construction and maintenance program, although they are outside the realm of pavement preservation:

Corrective Maintenance activities are performed in response to the development of a deficiency or deficiencies that negatively impact the safe, efficient operations of the facility and future integrity of the pavement section. Corrective maintenance activities are generally reactive, not proactive, and performed to restore a pavement to an acceptable level of service due to unforeseen conditions. Activities such as pothole repair, patching of localized pavement deterioration, e.g. edge failures and/or grade separations along the shoulders, are considered examples of corrective maintenance of flexible pavements. Examples for rigid pavements might consist of joint replacement or full width and depth slab replacement at isolated locations.

Catastrophic Maintenance describes work activities generally necessary to return a roadway facility back to a minimum level of service while a permanent restoration is being designed and scheduled. Examples of situations requiring catastrophic pavement maintenance activities include concrete pavement blow-ups, road washouts, avalanches, or rockslides.

Pavement Reconstruction is the replacement of the entire existing pavement structure by the placement of the equivalent or increased pavement structure. Reconstruction usually requires the complete removal and replacement of the existing pavement structure. Reconstruction may utilize either new or recycled materials incorporated into the materials used for the reconstruction of the complete pavement section. Reconstruction is required when a pavement has either failed or has become functionally obsolete.

ADMINISTRATIVE DIRECTIVE #239 - PAVEMENT PRESERVATION MAINTENANCE
(RESCINDED)

New Mexico had a policy in place that we will discuss below. It basically established goals and made preservation a priority for the system. It has been currently rescinded but still establishes some important principals so some discussion of it was included in this section of the manual.

With respect to our roadway infrastructure, the Department's overall goals are to:

- Eliminate deficient miles,
- Extend life cycles of pavements,
- Increase funding for preservation,
- And to increase flexibility for choices of maintenance strategies.

The Department recognizes the need for greater emphasis of preservation activities. Administrative Directive 239 establishes a preservation maintenance category for funding within the Statewide Transportation Improvement Program (STIP) and establishes the funding level for preservation maintenance at 10 to 40 percent per District within the STIP after statewide distribution.

The Department also recognizes the continued need for rehabilitation and reconstruction and is committed to maintaining existing corridors and routes at a desired level through a combination of each activity. However, by increasing preservation activities it is anticipated that funding levels for rehabilitation and reconstruction will be reduced.

The directive calls for the Performance and Planning Matrix process and the Pavement Management System to be used to prioritize measure cost effectiveness and performance of preservation activities. The directive also places emphasis on preservation focused on a corridor approach not segmental.

Finally, Administrative Directive 239 references attached Preservation Maintenance Guidelines, which describe the three elements of a Preservation Maintenance Program.

COMMISSION POLICY 83 - PRIORITY DETERMINATION FOR HIGHWAY IMPROVEMENTS

Commission Policy 83 establishes the policy that the Department's Statewide Transportation Improvement Plan and other roadway treatment projects be developed in accordance with the policy.

With regards to roadway projects, the policy requires that the Department's Pavement Management System and the Performance and Planning Matrix shall cover state highways, as well as, Federal-Aid highways, including rural arterial and major collectors and urban arterial collectors.

With regards to roadway projects, the policy requires:

- Development and implementation of a Performance and Planning matrix process and a Pavement Management System
- Needs identified by the Pavement Management System and the Performance and Planning Matrix process shall be considered in the Metropolitan and statewide planning process
- The Performance and Planning Matrix process and the Pavement Management System shall collect and maintain the appropriate data elements and facilitate the required analyses mandated by Federal legislation for highways.
- The Performance and Planning Matrix process and the Pavement Management System shall be the primary tools in the project prioritization and the pavement design process.

FEDERAL HIGHWAY ADMINISTRATION PREVENTIVE MAINTENANCE ELIGIBILITY MEMORANDUM

The FHWA memorandum discusses:

- Preventive maintenance as a cost effective way of extending the service life of highway facilities
- Preventive maintenance eligibility for Federal-Aid funding
- Provides the AASHTO definition of preventive maintenance as “the planned strategy of cost effective treatments to an existing roadway system and it’s appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system without increasing structural capacity.”
- The memorandum also states “projects that address deficiencies in the pavement structure or increase the capacity of the facility are not considered preventive maintenance and should be designed using appropriate 3R standards.”
- And that “functionally, Federal-aid eligible preventive maintenance activities are those that address aging, oxidation, surface deterioration, and normal wear and tear from day-to-day performance and environmental conditions.”
- Memorandum also encourages FHWA Division offices to proactively work with states to establish preservation programs
- And finally that FHWA supports the increased flexibility for using Federal-aid funding for cost effective preventive maintenance.

NEW MEXICO DEPARTMENT OF TRANSPORTATION STRATEGIC PLAN

Strategic Priority Three - Expand and Maintain a Safe Highway and Transportation System.

With respect to pavements, the Department's Strategic Plan measures and reports three desired results in relation to the Pavement Preservation Program as follows:

1. Number of combined system-wide miles in good and deficient condition
    a. Percent of Interstate Surface Miles Meeting Minimum Level of Performance
    b. Percent of Non-Interstate/NHS Surface Miles Meeting Minimum Level of Performance
    c. Percent of Non-NHS Surface Miles Meeting Minimum Level of Performance
2. Number of Lane Miles of Highways Meeting Minimum Level of Performance for each district
3. Number of statewide improved pavement surface miles

The two results use the Pavement Serviceability Index (PSI) as a measure of the condition of New Mexico's system of highways. The PSI of a roadway segment is calculated 60% from pavement roughness and 40% from distress measurements that are collected annually. Pavement roughness is measured electronically by NMDOT personnel using Inertial Profilometers mounted on Ford E350 vans. Pavement distress is measured by manual/visual surveys conducted by engineering students from UNM and NMSU. The Pavement Management System uses pavement roughness and distress measurements to compute the PSI of roadway segments and reports the total number of lane miles that are in good condition or are deficient. Interstate and Non-Interstate highway segments are considered to be in good condition when the PSI value is equal to, or greater than, 3.0 and 2.5, respectively. This measurement is updated once each year, in October.

The second result tracks the results of the Department's preservation activities to a roadway section to meet or extend the design life. The Departments uses the Highway Maintenance Management System to collect data on labor, equipment, and materials used to improve pavement surface miles through department maintenance and contract maintenance operations.

PERFORMANCE AND PLANNING MATRIX, DECISION TABLE, AND CONDITION ASSESSMENT

The Department's Performance and Planning Matrix was developed to provide a systematic and objective method of deciding between candidate highway construction and maintenance projects competing for limited funding. The combination of the Performance & Planning Matrix, Decision Table, and Condition Assessment Table outlines and sets definite guidelines for the process of selecting roadway projects for both the construction and maintenance programs based on roadway priority. The intent is to ensure timely and informed decisions based on impacts to the system rather than short-term gains or narrow interests and to incorporate policy and technical perspectives in an open process.

Preservation maintenance is established as a major program within the Performance & Planning Matrix and the Decision Table. Preservation maintenance can be performed on five of the six department established priority classifications. Consistent with Administrative Directive 239, the Decision Table also includes the funding availability for preservation maintenance both within the STIP program and state funded maintenance operations.

PART 2 - TYPES OF MAINTENANCE

PAVEMENT PRESERVATION

Pavement Preservation is "a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations."
Source: FHWA Pavement Preservation Expert Task Group

An effective pavement preservation program will address pavements while they are still in good condition and before the onset of serious damage. By applying a cost-effective treatment at the right time, the pavement is restored almost to its original condition. The cumulative effect of systematic, successive preservation treatments is to postpone costly rehabilitation and reconstruction. During the life of a pavement, the cumulative discount value of the series of pavement preservation treatments is substantially less than the discounted value of the more extensive, higher cost of reconstruction and generally more economical than the cost of major rehabilitation. Additionally, performing a series of successive pavement preservation treatments during the life of a pavement is less disruptive to uniform traffic flow than the long closures normally associated with reconstruction projects.

PREVENTIVE MAINTENANCE

Preventative Maintenance is "a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity)." *Source: AASHTO Standing Committee on Highways, 1997*

Preventive maintenance is typically applied to pavements in good condition having significant remaining service life. As a major component of pavement preservation, preventive maintenance is a strategy of extending the service life by applying cost-effective treatments to the surface or near-surface of structurally sound pavements. Examples of preventive treatments include asphalt crack sealing, chip sealing, slurry or microsurfacing, thin and ultra-thin hot-mix asphalt overlay, concrete joint sealing, diamond grinding, dowel-bar retrofit, and isolated, partial and/or full-depth concrete repairs to restore functionality of the slab; e.g., edge spalls, or corner breaks.

REACTIVE AND CORRECTIVE MAINTENANCE

Reactive and Corrective Maintenance activities are performed in response to the development of a deficiency or deficiencies that negatively impact the safe, efficient operations of the facility and future integrity of the pavement section. Corrective maintenance activities are generally reactive, not proactive, and performed to restore a pavement to an acceptable level of service due to unforeseen conditions. Activities such as pothole repair, patching of localized pavement deterioration, e.g. edge failures and/or grade separations along the shoulders, are considered examples of corrective maintenance of flexible pavements. Examples for rigid pavements might consist of joint replacement or full width and depth slab replacement at isolated locations.

CATASTROPHIC MAINTENANCE

Catastrophic or Emergency describes work activities generally necessary to return a roadway facility back to a minimum level of service while a permanent restoration is being designed and scheduled. Examples of situations requiring catastrophic pavement maintenance activities include concrete pavement blow-ups, road washouts, avalanches, or rockslides.

PART 3 - PAVEMENT DISTRESS

ASPHALT PAVEMENT DISTRESS

Cracking Distress

Block Cracking

Description: A pattern of cracks that divides the pavement into large, approximately rectangular, pieces that range in size from approximately 1 square foot to 100 square feet.

Figure 1: Block Cracking

Causes: Inability of the pavement to expand and contract with normal temperature changes, due to shrinkage of the asphalt binder and loss of pavement flexibility with aging. Block cracking is aggravated by poor choice of asphalt binder in the mix design.

Potential Actions:

- Crack Filling if the cracks if the cracks exhibit little movement (less than 0.1 inch), the pavement is only slightly or moderately deteriorated, the pavement is not fatigue-cracked and the cracking distress are minimal.

- Crack Sealing if the cracks are working cracks, if the pavement is in good condition, the pavement is not fatigue-cracked and cracking distress is minimal. Cracks greater than 0.25 inch wide should be cleaned, routed and sealed prior to any pavement preservation action.
- Chip Sealing, Fog Sealing, Sand Sealing Slurry Seal, Chip Seal, Scrub Seal or Microsurfacing can fill small cracks (less than 0.25 inch wide) if the cracks are non-working, there is no excessive bleeding and there is little structural deterioration such as structural rutting or fatigue cracking.
- Milling and Hot Mix Inlay/Overlay; Hot or Cold Pavement Remixing In-situ or Pavement Remixing at Plant if cracking is due to aging pavement and is confined to upper layers and there are no subgrade or base failures.
- Thin or Ultra-Thin Hot Mix Asphalt Overlay if cracking is of low or medium severity (less than 0.25 inch wide) and there are no subgrade or base failures.
- Crack Filling if the pavement is badly deteriorated until rehabilitation can be undertaken.

Edge Cracking

Description: Edge cracking is crescent-shaped cracks or fairly continuous cracks that intersect the pavement edge and are located within 2 feet of the pavement edge, adjacent to the shoulder. Edge Cracking includes longitudinal cracks outside of the wheel path and within 2 feet of the pavement edge. The term Edge Cracking only applies to pavements with unpaved shoulders.

Figure 2: Edge Cracking

Causes: Edge Cracking is caused by loss of foundation support due to water, insufficient pavement structure, weak support material or unstable shoulder.

Potential Actions:

- Crack Filling if the cracks if the cracks exhibit little movement (less than 0.1 inch) and the cracking are minor. Otherwise, not a candidate for preventative maintenance.
- Chip Sealing, Fog Sealing, Sand Sealing or Scrub Sealing can fill small cracks (less than 0.25 inch wide).

Fatigue (Alligator) Cracking

Description: Fatigue cracking is a series of interconnected cracks that develops into many-sided, sharp-angled pieces, usually less than 1 foot on the longest side, characteristically with a chicken wire/alligator skin pattern.

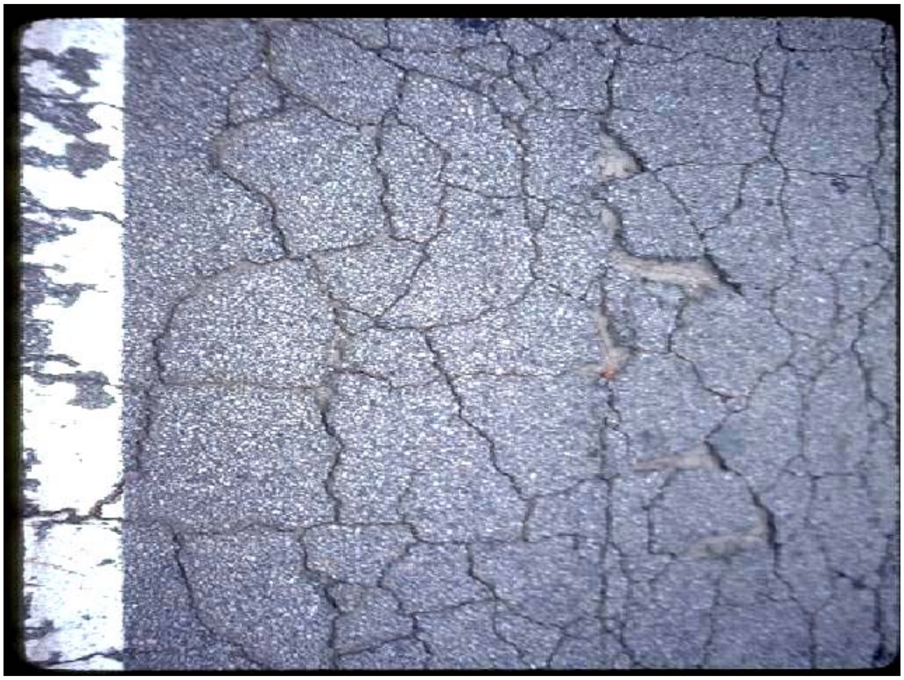


Figure 3: Fatigue (Alligator Cracking)

Causes: Inadequate structural design, poor construction (inadequate compaction), inadequate structural support due to higher than normal traffic loadings, normal loadings on aged and brittle pavement or excessive deflection due to loading or loss of foundation support due to water, insufficient pavement structure or weak support material. Small, localized fatigue cracking is indicative of a loss of subgrade support. Large fatigue cracked areas indicative of general structural failure.

Potential Actions:

- If the area is small remove the cracked pavement area then dig out and replace the area of poor subgrade. Patch over the repaired subgrade.
- If the area is large blade patch over the entire pavement surface. The overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contributes little or no strength.
- Chip Sealing, Fog Sealing, Sand Sealing or Scrub Sealing can fill small cracks if the cracks are small (less than 0.25 inch wide) and have not yet begun to interconnect or spall (Chip

Sealing, Fog Sealing, Sand Sealing or Scrub Sealing will not improve the pavement's structural capacity and fatigue cracking may continue).

- Crack Filling if the pavement is badly deteriorated until substantial rehabilitation can be undertaken.
- Hot In-Place Recycling if the load associated cracking is minor.
- Otherwise, not a candidate for preventative maintenance.

Longitudinal Cracking

Description: Longitudinal cracks are cracks that are parallel to the pavement centerline. The types of Longitudinal Cracking include Wheel Track, Mid-Lane and Center Line.

Figure 4: Longitudinal Cracking

Causes: If on centerline or outside of wheel path – usually poorly constructed paving joint. If in wheel path – usually excessive deflection due to loading or loss of foundation support probably due to water, insufficient pavement structure or weak support material. Longitudinal cracks within the wheel path are much more serious.

Potential Actions:

- Crack Filling if the cracks if the cracks exhibit little movement (less than 0.1 inch), the pavement is only slightly or moderately deteriorated, the pavement is not fatigue-cracked and the cracking distress are minimal.
- Crack Sealing if the cracks are working cracks, if the pavement is in good condition, the pavement is not fatigue-cracked and cracking distress is minimal. Cracks greater than 0.25 inch wide should be cleaned, routed and sealed prior to any pavement preservation action.
- Chip Sealing, Fog Sealing, Sand Sealing Slurry Seal, Chip Seal, Scrub Seal or Microsurfacing can fill small cracks (less than 0.25 inch wide) if the cracks are non-working, there is no excessive bleeding and there is little structural deterioration such as structural rutting or fatigue cracking.

- Milling and Hot Mix Inlay/Overlay; Hot or Cold Pavement Remixing In-situ or Pavement Remixing at Plant if cracking is due to aging pavement and is confined to upper layers and there are no subgrade or base failures.
- Thin or Ultra-Thin Hot Mix Asphalt Overlay if cracking is of low or medium severity (less than 0.25 inch wide) and there are no subgrade or base failures.
- Crack Filling if the pavement is badly deteriorated until rehabilitation can be undertaken.

Transverse Cracking

Description: Transverse cracks are cracks that are predominantly perpendicular to the pavement centerline and are not located over joints or cracks in an underlying Portland Cement Concrete Pavement layer.

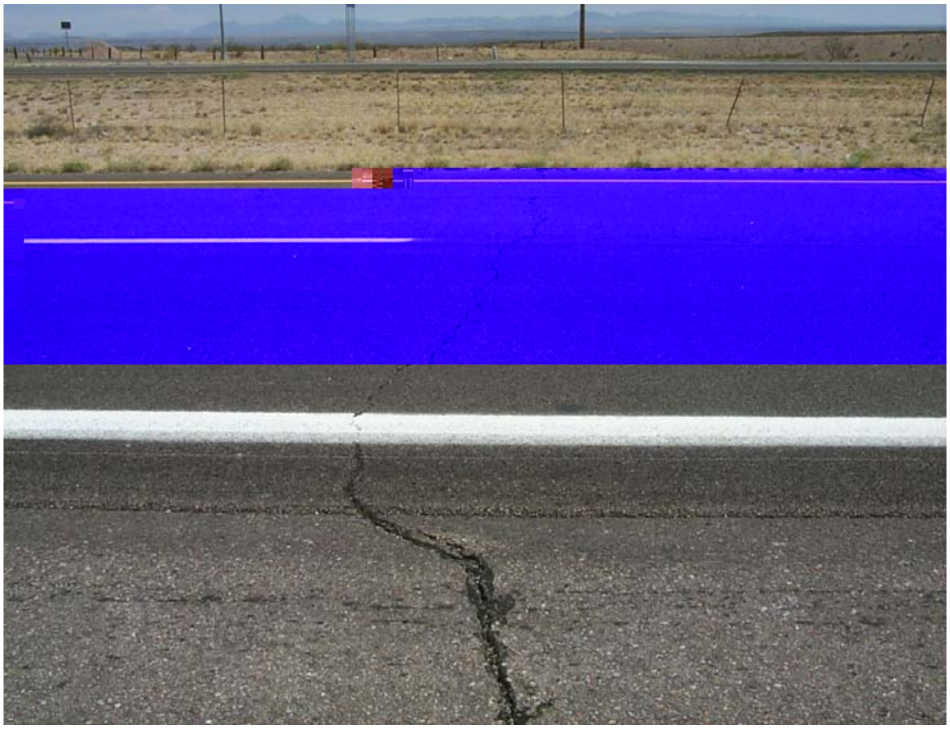


Figure 5: Transverse Cracking

Causes: Pavement expansion and contraction due to temperature changes, shrinkage of asphalt binder with aging.

Potential Actions:

- Crack Filling if the cracks if the cracks exhibit little movement (less than 0.1 inch), the pavement is only slightly or moderately deteriorated, the pavement is not fatigue-cracked and the cracking distress are minimal.
- Crack Sealing if the cracks are working cracks, if the pavement is in good condition, the pavement is not fatigue-cracked and cracking distress is minimal. Cracks greater than 0.25 inch wide should be cleaned, routed and sealed prior to any pavement preservation action.
- Chip Sealing, Fog Sealing, Sand Sealing Slurry Seal, Chip Seal, Scrub Seal or Microsurfacing can fill small cracks (less than 0.25 inch wide) if the cracks are non-working, there is no excessive bleeding and there is little structural deterioration such as structural rutting or fatigue cracking.

- Milling and Hot Mix Inlay/Overlay; Hot or Cold Pavement Remixing In-situ or Pavement Remixing at Plant if cracking is due to aging pavement and is confined to upper layers and there are no subgrade or base failures.
- Thin or Ultra-Thin Hot Mix Asphalt Overlay if cracking is of low or medium severity (less than 0.25 inch wide) and there are no subgrade or base failures.
- Crack Filling if the pavement is badly deteriorated until rehabilitation can be undertaken.

Reflection Cracking

Description: Cracks in an upper asphalt pavement layer that occurs over cracks or joints in a supporting (usually concrete) pavement layer.

Figure 6: Reflection Cracking

Causes: Working Cracks in underlying pavement layers.

Potential Actions:

- Crack Sealing if the pavement is in good condition, the pavement is not fatigue-cracked and cracking distress is minimal.
- Crack Filling if the pavement is badly deteriorated until rehabilitation can be undertaken.
- Not a candidate for Slurry Seals or Microsurfacing.

Surface Distress

Bleeding

Description: Bleeding is excess bituminous binder on the pavement surface. It may create a shiny, glass-like, reflective surface that may be tacky to the touch. It is usually found in the wheel paths.

Figure 7: Bleeding

Causes: Bleeding is usually caused by too much asphalt binder in the pavement mix, excessive prime coat or tack coat or by too low an air void content in the pavement mix. Bleeding can also result by using too much oil during Fog Seal or Chip Seal operations or from not using enough oil during Chip Seal operations resulting in rock loss and a pavement surface covered with oil. Bleeding is aggravated by hot weather which causes the softening and expansion of the asphalt binder.

Potential Actions:

- Minor bleeding can often be corrected by applying coarse sand to blot up the excess asphalt binder.
- Chip Seal
- Not a candidate for slurry seals or Microsurfacing.

Rutting

Description: A longitudinal depression in the wheel path. Rutting is sometimes associated with shoving.

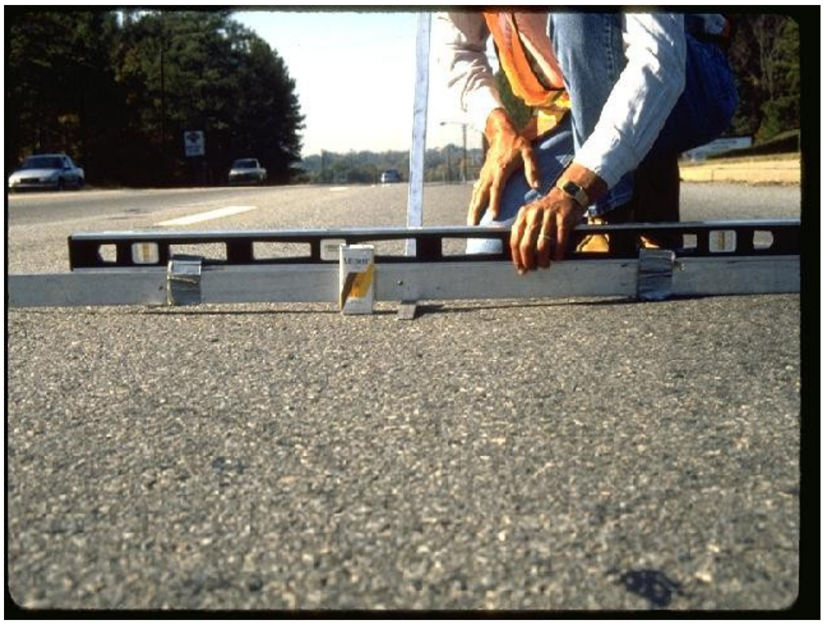


Figure 8: Rutting

Causes: Permanent deformation of any layer due to weakened support layers, poorly compacted layers and unstable wearing surface or overloading.

Severe rutting is often caused by excessive asphalt binder in the pavement mixture. Aggregates in these mixtures do not have aggregate-on-aggregate contact so the material flows instead of being locked in place.

Rutting is aggravated by hot weather which causes the softening of the asphalt binder.

Potential Actions:
- Microsurfacing
- Chip Seal if rutting is minor and non-structural.
- Milling and Hot Mix Inlay/Overlay, Plant or In-situ Remixing if rutting is limited to the upper surface layers and there are no subgrade or base failures.

Shoving

Description: Shoving is a longitudinal displacement of a localized area of the pavement surface. It is generally caused by braking or accelerating vehicles and is often located on hills or curves, or at intersections. It may also have associated vertical displacement. Shoving is aggravated by hot weather which causes the softening and expansion of the asphalt binder.

Figure 9: Shoving

Causes: Poor mix design coupled with large horizontal pressure due to structural failure on straight stretches and turning traffic at intersections and on curves. Shoving is usually associated with rutting.

Potential Actions:

- Shoving is a material problem and Milling and action to fill ruts is a temporary fix until a substantial rehabilitation can be undertaken.

Raveling

Description: Raveling is the wearing away of the pavement surface because of dislodged aggregate particles and loss of asphalt binder.

Figure 10: Raveling

Causes: Oxidation, aged pavement surface, bad workmanship or materials. Raveling is aggravated by hot and wet weather which causes oxidation and stripping of the asphalt binder.

Potential Actions:
- Fog Seal, Sand Seal or Scrub Seal can reduce raveling.
- Chip Seal if the raveling is not severe.
- Slurry Seal, In-Place Hot or Cold Recycling or Thin Hot Mix Overlay if the raveling is limited to the upper layers.

Oxidation and Weathering

Description: Chemical oxidation, stripping and degradation of the asphalt binder.

Figure 11: Oxidation and Weathering

Causes: Uneven or insufficient binder application, selection of inappropriate binder, loss of asphalt binder due to aging or poor mix design. Oxidation is aggravated by hot and wet weather and by traffic action.

Potential Actions:

- Milling can remove deteriorating upper pavement layers.
- Chip Sealing, Fog Sealing, Slurry Sealing, Sand Sealing, Scrub Sealing or Rejuvenators can soften and enrich dry and weathered surfaces and retard further oxidation.
- Thin Hot Mix Overlay

Aggregate Polishing

Description: Aggregate polishing is the wearing away of the surface mortar and texturing to expose coarse aggregate.

Figure 12: Aggregate Polishing

Causes: The wearing away of the pavement surface due to soft aggregate.

Potential Actions:

- Chip Seal
- Tack Coat and Thin Hot Mix Overlay
- Thin cold treatment

Delamination

Description: Delaminating pavement layers.

Figure 13: Delamination

Causes: The most common cause of delamination is water seeping into cracks in the surface of the road during wet, freezing weather. The water freezes, expands, and pushes the upper layer up from the lower layers. The vibration of vehicle tires over the cracked area and stresses to the pavement by the weight of trucks causes the pavement to break up and come out of the pavement.

Delamination is often caused by layers with different properties resulting in the layers not working as a unit, uneven or insufficient binder application, loss of asphalt binder due to aging or poor mix design and deterioration of the upper pavement layer due to oxidation and weathering. Delamination is also caused by aging of the upper pavement layer and poor construction.

Potential Actions:

- Patching or blade patching with hot or cold patching material is required before any pavement preservation action can be taken.
- In-Place Recycling if separation is confined to the upper layers.

Potholes

Description: Potholes are bowl-shaped openings that usually have raveled edges and can be up to 10 inches deep. They occur when the top layer or asphalted surface of the roadway has worn away, exposing the road subbase.

Figure 14: Potholes

Causes: The most common cause of potholes is water seeping into cracks in the surface of the road during wet freezing weather. The water causes the roadbed to weaken. The water freezes, expands, and pushes down on the weakened roadbed under the asphalt. The vibration of vehicle tires over the cracked area and stresses to the pavement by the weight of traffic causes the pavement to sink. The vibration of vehicle tires over the cracked area and stresses to the pavement by the weight of trucks causes the pavement to break up and come out of the pavement and a pothole results. Potholes can also be caused by bad workmanship or materials or by deterioration of the upper pavement layer. Potholes can occur under dry conditions when trucks pass over weak spots in the subsurface causing structural failure.

Another common way of pothole formation is when water seeps into cracks in the surface of the road and, combined with the vibration of the tires over the cracks, causes the asphalt to fail. That is why there are more potholes after it rains. Potholes are also created when the roadway is stressed by trucks and buses, which can cause a movement of the subsurface. Once there is a weak spot, every car that travels over it makes the problem worse, and eventually a section of the material will fail, causing a pothole

Roads with high traffic volumes have more potholes due to amount of use. Bridges and ramps, which receive heavy doses of snow removal chemicals in the winter, are more prone to potholes.

Potential Actions:

- Patching or blade patching with hot or cold patching material is required before any pavement preservation action can be taken. The weakened area must be completely removed and the pavement restored to match the surrounding pavement.
- In-Place Recycling if separation is confined to the upper layers.

Patching

Description: An area of pavement where part of the original pavement has been replaced or covered with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs.

CONCRETE PAVEMENT DISTRESS

On the following pages are descriptions of various distresses that occur in Portland Cement Concrete pavement, their causes and various pavement preservation treatments to mitigate them.

Cracking Distress

Corner Breaks

Description: A portion of the slab separated by a crack which intersects the adjacent transverse and longitudinal joints at an approximately 45 degree angle. The lengths of the sides are from 1 foot to one-half the width of the slab, on each side of the corner. Cracks extend vertically through the entire slab thickness.

Figure 16: Corner Breaks

Causes: Loss of support often due to infiltration of water through cracks and damaged joint seals. Corner Breaks are aggregated by loading, pumping, inadequate drainage and erosion.

Potential Actions:

- Full-depth repair.

Durability Cracking

Description: Closely spaced crescent-shaped hairline cracking pattern occurring adjacent to joints or free edges. The cracks initiate in the slab corners. The concrete is more darkly colored in the cracking pattern and surrounding areas.

Figure 17: Durability Cracking

Causes: Freeze-thaw susceptible aggregate.

Potential Actions:

- Repairs other than slab replacement will only provide temporary relief from spalling and roughness due to durability cracking.

Longitudinal Cracking

Description: Cracks that are predominantly parallel to the pavement centerline.

Figure 18: Longitudinal Cracking

Causes: Unbalanced loading on slabs as traffic transverses the pavement.

Potential Actions:

- Crack Sealing if there is minimal structural deterioration and the cracks are less than 0.5 inch wide and have minimal spalling.
- Full-depth repairs or slab replacement or structural enhancement (such as an overlay) are recommended for cracks of moderate and high severity.
- Full-depth repairs are recommended for cracking caused by compressive stress buildup, improper joint construction techniques or working cracks caused by shrinkage, fatigue or foundation movement.
- Diamond grinding can mitigate crack faulting if the faulting is not progressive and if it is done before the faulting reaches critical levels.

Transverse and Diagonal Cracking

Description: Cracks that are predominately perpendicular to the pavement centerline. Medium or high severity cracks are working cracks, and are considered major structural distresses.

Figure 19: Transverse and Diagonal Cracking

Causes: Unbalanced loading on slabs as traffic transverses the pavement.

Potential Actions:

- Crack Sealing if there is minimal structural deterioration and the cracks are less than 0.5 inch wide and have minimal spalling.
- Full-depth repairs or slab replacement or structural enhancement (such as an overlay) are recommended for cracks of moderate and high severity.
- Full-depth repairs are recommended for cracking caused by compressive stress buildup, improper joint construction techniques or working cracks caused by shrinkage, fatigue or foundation movement.
- Diamond grinding can mitigate crack faulting if the faulting is not progressive and if it is done before the faulting reaches critical levels.

Surface Distress

Spalling of Joints and Cracks

Description: Cracking, breaking, chipping or fraying of slab edges within 2 feet of longitudinal or transverse joints or cracks. Spalling does not extend vertically through the slab, but angles through the slab to the joint or crack. It results in loose debris on the pavement, roughness, generally an indicator of advanced joint/crack deterioration

Figure 20: Spalling of Joints and Cracks

Causes: Localized areas of scaling, weak concrete, clay balls or high steel, dowel bar misalignment or lock-up due to misalignment or corrosion; disintegration of the PCC from freeze-thaw action, durability "D" cracking or alkali-aggregate reactivity; reinforcing steel that is too close to the surface; inadequate air void system; excessive stresses at the joint/crack caused by infiltration of incompressible materials and subsequent expansion (can also cause blowups) or weak PCC at a joint caused by inadequate consolidation during construction (This can sometimes occur at a construction joint if low quality PCC is used to fill in the last bit of slab volume).

Potential Actions:

- Spalling less than 3 inches from the crack face can generally be repaired with a partial-depth patch. Partial-depth repair is recommended for low severity spalling of longitudinal and construction joints where slab deterioration is located primarily in the upper one-third of the slab and the existing load transfer devices (if any) are still functional.

- Partial-depth repair is recommended if there is intrusion of incompressible materials into the joints (in conjunction with removal of incompressible materials and joint resealing) or for localized areas of scaling, weak concrete, clay balls or high steel.
- Full-depth repair are recommended for medium or high-severity spalling of longitudinal and construction joints or for spalling involving compressive stress buildup in long-jointed pavements, dowel bar misalignment or lock-up, durability cracking, reactive aggregate, reinforcing steel that is too close to the surface or an inadequate air void system. Spalling greater than 3 inches from the crack face may indicate spalling at the joint bottom and should be repaired with a full-depth patch.
- If spalling is due to a material problem, repairs other than slab replacement will only provide temporary relief.
- Joint Resealing will prevent further intrusion of water or incompressible materials into joints.

Faulting of Transverse Joints and Cracks

Description: A difference in elevation across a joint or crack usually associated with undoweled Jointed Plain Concrete Pavement. Usually the approach slab is higher than the leave slab due to pumping, the most common faulting mechanism. Faulting is noticeable when the average faulting in the pavement section reaches about 0.1 inch.

Figure 21: Faulting of Transverse Joints and Cracks

Causes: Most commonly, faulting is a result of slab pumping. Faulting can also be caused by slab settlement, curling, warping and loss of support often due to infiltration of water through cracks and damaged joint seals. Faulting is aggregated by loading, pumping, inadequate drainage and erosion. Faulting can be prevented by a proper load transfer system (dowel bars).

Potential Actions:

- Any pumping area should be repaired with a full depth patch to remove any deteriorated slab areas. Consideration should be given to using dowel bars to increase load transfer across any significant transverse joints created by the repair. Consideration should be given to stabilizing any slabs adjacent to the pumping area as significant amounts of their underlying base, subbase or subgrade may have been removed by the pumping. Any sources of water or cause of poor drainage should be addressed.
- Load transfer restoration if there is none.
- Slab replacement or a structural enhancement (such as an overlay) is recommended if the faulting is due to structural failure.
- Diamond grinding can mitigate low severity (less than 0.15 in) slab faulting if the faulting is not progressive. Diamond grinding addresses serviceability problems but it will not address

the cause of faulting, nor will it prevent roughness in the future as a result of additional faulting.

- Slab jacking can sometimes mitigate loss of slab support.
- Undersealing can sometimes stop further faulting by filling voids under the slab.

Pop Outs

Description: Small pieces of pavement broken loose from the pavement surface, normally ranging in diameter from 1 inch to 4 inches and from ½ inch to 2 inch deep. Pop outs themselves are not serious but they can spall into potholes.

Figure 22: Pop Outs

Causes: Pop outs usually occur as a result of poor aggregate durability. Poor durability can be a result of a number of items such as:

- Poor aggregate freeze-thaw resistance
- Expansive aggregates
- Alkali-aggregate reactions

Potential Actions:

- Isolated low severity pop outs may not warrant repair.
- Medium pop outs can be filled with epoxy patching material before they can spall into potholes.
- Larger pop outs or a group of pop outs can generally be repaired with a partial-depth patch.

Reinforcement Failure

Description: Localized slab portion broken into several pieces.

Figure 23: Reinforcement Failure

Causes: Steel corrosion, inadequate amount of steel, excessively wide shrinkage cracks or excessively close shrinkage cracks.

Potential Actions:

- Full Depth Repairs, Slab replacement or structural enhancement (such as an overlay).

Joint Seal Damage

Description: Any condition which allows incompressible materials or water to infiltrate into the joint from the surface. Types of Joint Seal Damage include Joint Sealant Stripping, Joint Sealant Extrusion, Weed Growth, Hardening of Filler, and Loss of Bond to Slab Edges or Absence of Joint Sealant.

Figure 24: Joint Seal Damage

Causes: Deterioration or damage to joint seals due to improper installation, incompatibility with the concrete or contamination.

Potential Actions:

- Joint Resealing whenever the existing material is damaged or is no longer performing its intended function.

Lane-to-Shoulder Drop-Off or Heave

Description: Difference in elevation between the edge of slab and outside shoulders; typically occurs when the outside shoulder settles.

Figure 25: Lane-to- Shoulder Drop-Off or Heave

Causes: Settlement or heave of roadway and/or shoulders due to different rates of settlement and compaction.

Potential Actions: Shoulder repair**,** milling of the surface with the higher elevation or adding structure to the surface with the lower elevation.

Potholes and Patch Deterioration

Description: Bowel shaped openings in the pavement surface where the original concrete or a subsequent patch has deteriorated.

Figure 26: Potholes and Patch Deterioration

Causes: The most common cause of potholes and patch deterioration is water seeping into cracks in the surface of the road or under a patch during wet, freezing weather. The water freezes, expands, and pushes up from below the cracked area. The vibration of vehicle tires over the cracked area and stresses to the pavement by the weight of trucks causes the pavement to break up and come out of the pavement.

Potential Actions: Small potholes and deteriorated cracks can be fixed temporarily using patch material. Potholes or patch deterioration can be permanently repaired by full-depth repairs, partial depth repairs or slab replacement depending on the reason for and the size and depth of the pothole or deteriorated patch.

Punchouts

Description: Localized slab portion broken into several pieces. The area enclosed by two closely spaced (usually less than 2 feet) transverse cracks, a short longitudinal crack and the edge of the pavement or a longitudinal joint. Also includes “Y” cracks that exhibit spalling, breakup and faulting.

Figure 27: A Punchout.

Causes: Construction defects such as insufficient design or inadequate consolidation. Overloading. In CRCP, punchouts can be caused by steel corrosion, inadequate amount of steel, excessively wide shrinkage cracks or excessively close shrinkage cracks.

Potential Actions: Selective slab replacement. Full depth repair.

PART 4 – PAVEMENT TREATMENTS AND REPAIR METHODS

Pavement distresses contribute to pavement failure in different ways. The most common flexible pavement distresses are cracking, roughness, weathering, raveling, rutting and bleeding.

If distresses identified in a pavement are related to structural deficiencies, the pavement is most likely not a candidate for preventative maintenance treatment and should instead be scheduled for rehabilitation or reconstruction.

Other distresses can be corrected with preventive, corrective or emergency treatments. To be effective, an engineering approach should be taken to select and construct the treatment. It is critical that the proper maintenance treatment be done at the right time for the pavement to function as designed and for the maintenance program to be effective.

Types of Treatments

ASPHALT PAVEMENT TREATMENTS

Crack Treatments

Crack Sealing

Sealing cracks in HMA pavements is one of the most effective methods of preventative maintenance. Correctly applied, and properly timed, the application of a crack sealant material will help reduce moisture infiltration, retain material strength and reduce the potential for moisture-related distresses such as stripping, pumping of fines and accelerated fatigue cracking. Crack sealing is a more comprehensive operation than crack filling that is typically performed on working cracks (movement equal to or more than 0.1 inch) and involves through crack preparation and placement of high-quality materials.

Crack Filling

Crack filling serves the same purposes as crack sealing but is less comprehensive. Its preparation is typically limited to "blowing out" the cracks with compressed air. Crack filling is normally conducted on cracks that experience little movement (less than 0.1 inch) and are only slightly or moderately deteriorated.

Full Depth Crack Repairs

When cracks get excessive or too close together, often it is better to affect a full depth repair of the area rather then work on the individual crack. Usually when cracking is of this nature it is better to address the underlying problems causing the cracking as well as the effects.

Surface Treatments

Fog Sealing

As a pavement ages its components undergo a variety of chemical and physical changes. Pavement will undergo oxidation of it asphalt cement making the pavement brittle and susceptible to cracking and raveling. Fog sealing is overlying an existing pavement surface with an asphalt binder, sometimes topping with sand. Fog sealing is analogous to putting skin lotion on one's arm to make the skin soft and keep it healthy.

Chip Sealing

Chip sealing is the adhering a layer of crushed aggregate to an existing roadway surface using an asphalt binder. Chip seals are one of the most cost effective ways to add skid resistance, seal and rejuvenate the pavement surface and improve the ride quality of the pavement.

Slurry Sealing

In areas that a chip seal cannot be applied because of traffic volumes etc., another treatment to seal the road may be needed. Slurry seals do not have quite as nice of frictional characteristics or the longevity but they do seal water out. Slurry seals are usually done on low volume roads.

Scrub Seals

Sometimes pavements are so old and aged that crack sealing is not an option. Scrub Sealing is a pavement preservation treatment during which a membrane of modified binder is pressed or scrubbed into a cracked and aged surface. It's like an all-over crack seal. The existing surface may be chipped, sanded and then made smooth as with a slurry or chip seal.

Microsurfacing

Microsurfacing is overlaying an existing pavement surface with an emulsified asphalt/ aggregate slurry. Microsurfacing is a type of slurry sealing is used to restore the ride/comfort to the users of a road. It will not add any structural value to the road but will seal off minor cracking and fill ruts. Asphalt roads are susceptible to rutting which is often cured by planning the road and overlaying which is very expensive. A less expensive alternative is to fill the ruts with Micro-Surfacing to restore the original pavement profile. This is especially cost effective when only needing a few years of improvement prior to a reconstruction project.

Cape Sealing

Cape seals are a combination of a chip seal covered with a slurry seal or a micro-surface. The idea behind this treatment is to provide a smoother surface then a chip seal can by itself. The slurry seal portion also fills in the space between the chip seal aggregate providing additional stability to the chip seal aggregate and giving a thicker membrane. This process prevents water intrusion into the subsurface better then either process alone.

Pavement Remixing at the Plant

Often when dealing with pavements you reach a point that simple overlays and various surface treatments are no longer appropriate. This can be because you wish to add shoulders, the pavement is so badly cracked or you need to rework the subgrade. At this point you basically have a choice between conventional reconstruction and recycling the road. Reconstruction by adding new asphalt is by far the best approach to achieving the desired roadway. Recycling has its advantage in the for many parts of the state, asphalt has to be delivered from a plant 100+ miles distant making new asphalt uneconomical. Recycling also has the advantage to reusing what is essentially a waste material.

Milling and Hot Mix Inlay/Overlay

Often a road can not be use overlaid because its surface is rough or badly oxidized. In this case the surface of the road needs to be prepared before and inlay/overlay can be applied. The poor quality or rough asphalt is cold planed off using a milling machine in preparation for the new layer of hot-mix asphalt and overlayed with hot Plant Mixed Bituminous Pavement (PMBP). Sometimes milling is to keep the same profile on a road adjacent to curb and gutter.

NovaChip Overlay

A NovaChip Overlay is the placing an asphalt membrane on an existing pavement then overlying it with an ultra-thin, coarse aggregate hot mix. It prevents further decay and provides a new wearing surface but does not provide any structural improvement. NovaChip projects provide same driving characteristic of OGFC but is a better sealant and adheres better to certain surfaces.

Heater Scarification and Overlay

Heater Scarification and Overlay, also referred to as Hot In-Place Recycling (HIR), is an effective pavement preservation treatment to improve the functional performance of an existing pavement. Totally repaving an existing surface may not be necessary if the pavement is structurally adequate and has a stable base. During the Heating and scarifying process, the top portion of an existing pavement, sometimes combining that material with recycling agent and/or fresh aggregate on site, replacing and compacting the reworked material and overlaying it with hot Plant Mixed Bituminous Pavement.

Cold In-Situ Recycle & Overlay

Cold In-Situ Recycle & Overlay is the removing the top portion of an existing pavement, combining that material with recycling agent and sometimes fresh aggregate on site, replacing and compacting the reworked material and overlaying it with hot Plant Mixed Bituminous Pavement.

White Topping on Asphalt

White Topping on Asphalt, sometimes referred to as Thin PCC Overlays or Ultra-Thin White Topping, is a pavement preservation technique wherein the surface of an existing hot-mix asphalt (HMA) pavement is cold milled to enhance the bond between the existing HMA and the PCC overlay and a very thin (2 to 4 inch) Portland Cement Concrete (PCC) overlay is placed over the existing HMA. White topping overlays are sawed into short slabs, typically between 2 and 6 feet square to help reduce bending and thermal stresses.

Localized Failure Treatments

Blade Patching

Pothole Patching

Potholes are a danger to the travelling public and can lead to serious accidents and injuries. On principal roadways potholes are considered dangerous if they are vertically sided, are more than 1 inch deep and have an area of greater than one sq foot. On non-principal roadways potholes are considered dangerous if they are vertically sided, are more than 2 inches deep and have an area greater than one square foot. If left unattended, potholes will enlarge and cause the degrading of more of the road surface. Pothole patching includes repairing sewer cuts, utility cuts, crevices, surface subsidence, sinks and dips as well as potholes.

CONCRETE PAVEMENT TREATMENTS

Crack Treatments

Joint Resealing and Crack Sealing

The purpose for sealing concrete pavement joints and cracks is primarily to minimize the passage of water through joints and cracks to the pavement subbase. Water accumulating under the slab can contribute to distresses such as pumping, loss of support, faulting and corner breaks. Sealing concrete pavement joints and cracks is also necessary to prevent incompressible materials, such as pebbles and stones, from filling the joints and cracks. Incompressible materials that infiltrate poorly sealed joints or cracks interfere with their normal opening and closing movement, causing compressive stresses in the slab and increasing the potential for spalling. If the compressive stresses exceed the compressive strength of the deteriorated pavement, blowups or buckling will occur. Resealing is necessary whenever the condition of an existing sealant does not fulfill these functions, either because the sealant is missing or because it is deteriorated.

Full-Depth Repairs

Portland cement concrete pavements showing structural distresses may require full-depth repairs. Full-depth repair is a concrete pavement restoration technique used to restore the structural integrity and rideability to concrete pavements having distresses. Full-depth repairs are cast-in-place concrete repairs that extend through the full thickness of the existing PCC slab.

Joint Spalling Repairs

Joint spalling repairs are a concrete pavement restoration technique of repairing joint spalling scaling, and popouts in Portland Cement Concrete (PCC). Joint spalling repairs are similar to Partial Depth Repairs but are used to correct smaller, localized areas of pavement where removal of large amounts of concrete is not warranted, usually areas less than 6 inches in length and 1.5 inches in width at the widest point. Joint spalling repairs improve ride quality, and extend the service life of pavements that have spalled or distressed joints.

Surface Treatments

Surface Sealing

The primary purpose of Surface Sealing is to reduce the intrusion of water into Portland Cement Concrete PCC pavement to prevent freeze damage. However, surface sealing also reduces the intrusion of stains, oils and dirt into PCC pavement surfaces and can be used for visual as well as functional reasons. Surface sealing offers visual improvement by intensifying the PCC pavement colors. Some sealants add a glossy sheen or "wet" look to the pavement. Surface sealing offers some color enhancement and produce a low sheen, or a flat finish.

Diamond Grinding and Diamond Grooving

Diamond Grinding and Diamond Grooving are processes that use a series of diamond-tipped saw blades mounted on a shaft or arbor to shave the upper surface of a pavement to remove bumps, restore pavement rideability, mitigate noise and improve surface friction.

White Topping on Concrete

White Topping on Concrete, sometimes referred to as Thin Portland Cement Concrete (PCC) Overlays and Bonded Concrete Overlays (BCOL), is a pavement preservation technique wherein the surface of an existing PCC pavement is shot blasted and then a very thin (2 to 4 inch) PCC overlay is placed over the existing PCC. The surface of the existing PCC pavement is shot blasted to enhance the bond between the existing PCC pavement and the PCC overlay. White topping overlays are sawed into short slabs, typically between 2 and 6 feet square to help reduce bending and thermal stresses

Faulting Slab Repairs

Crack and Seat

A Crack and Seat operation is the fracturing of an existing PCC pavement and overlaying it with hot Plant Mixed Bituminous Pavement (PMBP). This treatment alleviates problems with PCC pavements that are not properly supported. The fractured concrete seats itself and provides base support to the overlying PMBP pavement. This is a good treatment for slabs that are "rocking".

Undersealing

Loss of support beneath Portland Cement Concrete (PCC) pavement is a major cause for deterioration of PCC pavement. Undersealing is a pavement preservation technique wherein flowable material is injected beneath the PCC slab or subbase to fill voids. Undersealing is not the same as slab jacking, also known as the URETEK™ method. Undersealing is not meat to raise slabs. Undersealing is only meant to existing voids before slab subsidence or damage occurs. Lifting of slabs can create additional voids and may cause cracking.

Pop-Outs, Potholes and Shattered Slabs

Selective Slab Replacement

Portland cement concrete (PCC) pavements showing severe structural distresses may require selective slab replacement. Selective slab replacement involves removing the deteriorated concrete down to the base, repairing the disturbed base, installing load-transfer devices, and refilling the excavated area with new concrete. By removing and replacing selective slabs, the pavement may replacement may be restored close to its original condition.

Re-Enforcement Treatments

Dowel-Bar Retrofit

Load transfer is the ability of a joint to transfer wheel loads from one side of a joint to the other. The amount of load transfer influences the magnitude of deflections at joints, and is a major factor influencing the structural performance of a Portland Cement Concrete (PCC) pavement. Poor load transfer across transverse joints can lead to pumping, faulting, corner breaks, and possibly spalling; poor load transfer across existing cracks in PCC pavements can lead to spalling, faulting, and further deterioration of the crack. One way of addressing poor load transfer before it results in deterioration of the pavement is through load transfer restoration referred to as dowel-bar retrofit (DBR). DBR is a technique used to rehabilitate jointed concrete pavements where faulting is a problem, but are otherwise in good condition.

Cost-Effectiveness of Treatments

The following table lists some costs of pavement preservation treatments in 1992 and 1997 and shows how costs for these treatments are escalating:

Treatment	Cost/Lane Mile in 1992	Cost/Lane Mile in 1997	Percent Increase
Fog Sealing	$1,045	$1,156	11%
Crack Sealing	$3,600	$14,600	306%
Chip Sealing	$4,852	$7,893	63%
Open Graded Friction Course (OGFC) Overlay	$10,920	$32,160	195%
Plant Mix Wearing Course Overlay (Nova Chip)		$43,400	
2” Hot Mix Overlay	$34,027	$80,960	138%
In Plant Recycle (Brazer)		$49,000	
Heater Scarification & Overlay (Cutler)	$9,504	$64,125	575%
Microsurfacing	$37,500	$58,560	56%
Cold Mill/Inlay	$175,000	$359,000	105%
Cold In-Situ Recycle Overlay	$200,000	$350,000	75%
Rehabilitation	$500,000	$750,000	50%
Reconstruction	$1,125,000	$1,835,000	63%

The following table lists some pavement preservation treatments and the extension of pavement life that they provide. Note that these time ranges are the expected life-extending benefit given to the pavement and not the anticipated longevity of the treatment.

Pavement Treatment	Extended Service Life
Fog Seal	2 to 5 Years[a]
Crack Filling	Up to 2 Years[b]
Crack Sealing	Up to 3 Years[b]
Chip Seal	3 to 7 Years[b]
Slurry Seal	3 to 7 Years[a]
Microsurfacing	3 to 6 Years[b]
Thin Hot Mix Overlay	3 to 5 Years[b]
1.5” Hot Mix Overlay	5 to 10 Years[b]

Source: a ”Selecting A Preventive Maintenance Treatment For Flexible Pavements” – Foundation For Pavement Preservation
b “Pavement Preservation Compendium” – FHWA Publication No. FHWA-IF-03-21

The following figure shows two strategies, one involving pavement preservation treatments and the other not. It is obvious that pavement preservation is can be cost effective:

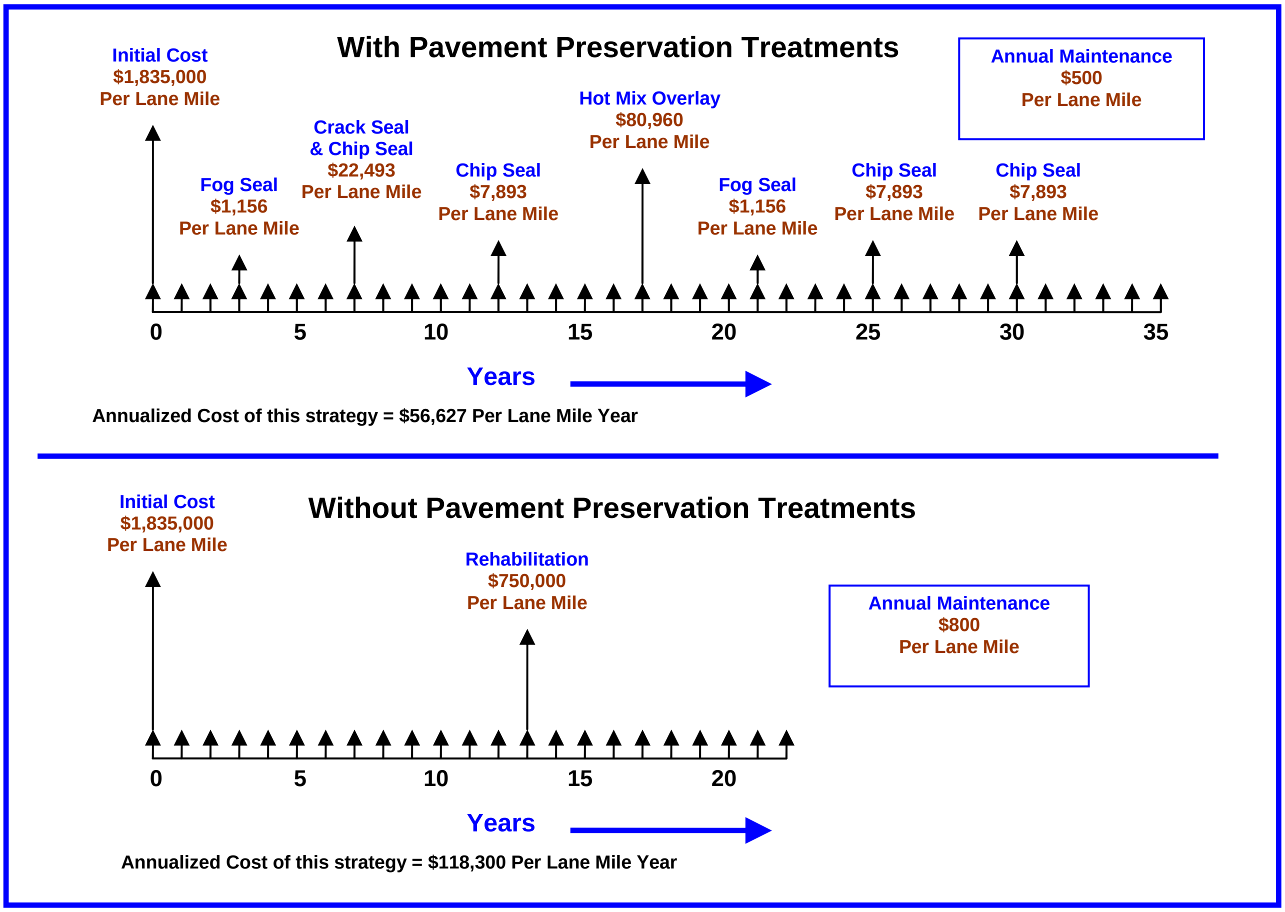


Figure 28: Time line showing the cost effectiveness of pavement preservation treatments.

Selection of Treatments

The following figure is the classic pavement deterioration curve showing how maintenance dollars spent at the right time, on the right pavement, will save many more dollars later in the pavement's life. The curve illustrates the typical life cycle of a section of pavement and the categories of treatments that are appropriate at different times for varied conditions.

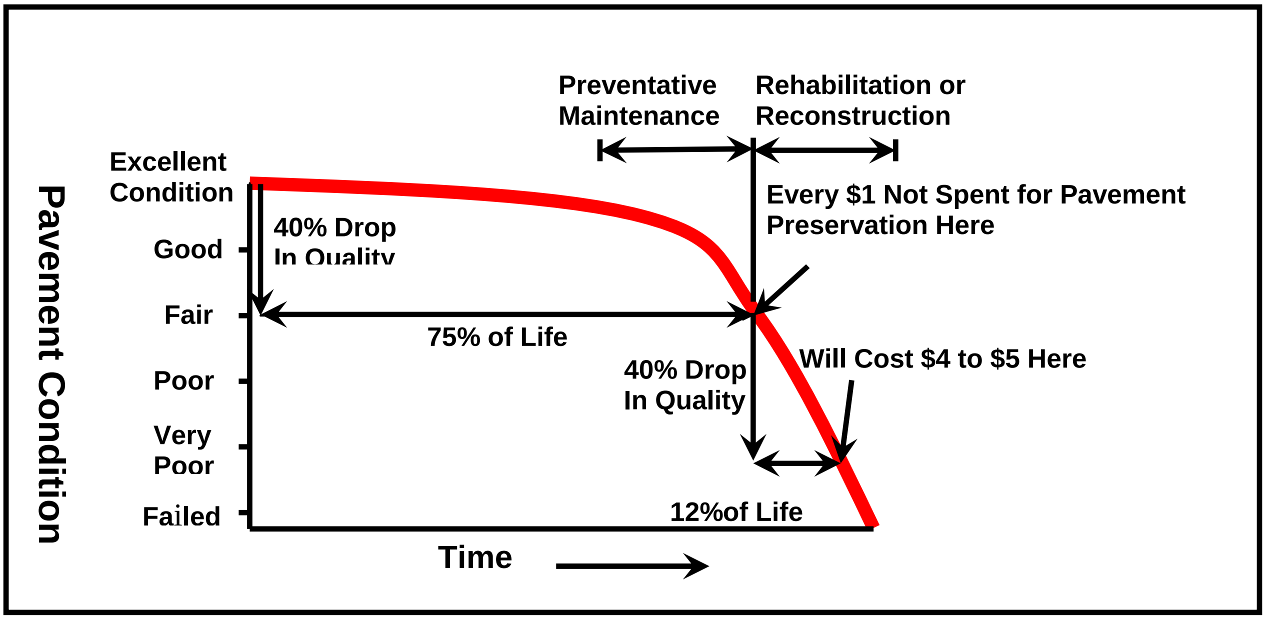


Figure 29: Classic Pavement Deterioration Curve

The next figure shows that pavement preservation treatments can be used early in the life of a pavement, while it is still in relatively good condition, can extend the life of the pavement and save money in the long run.

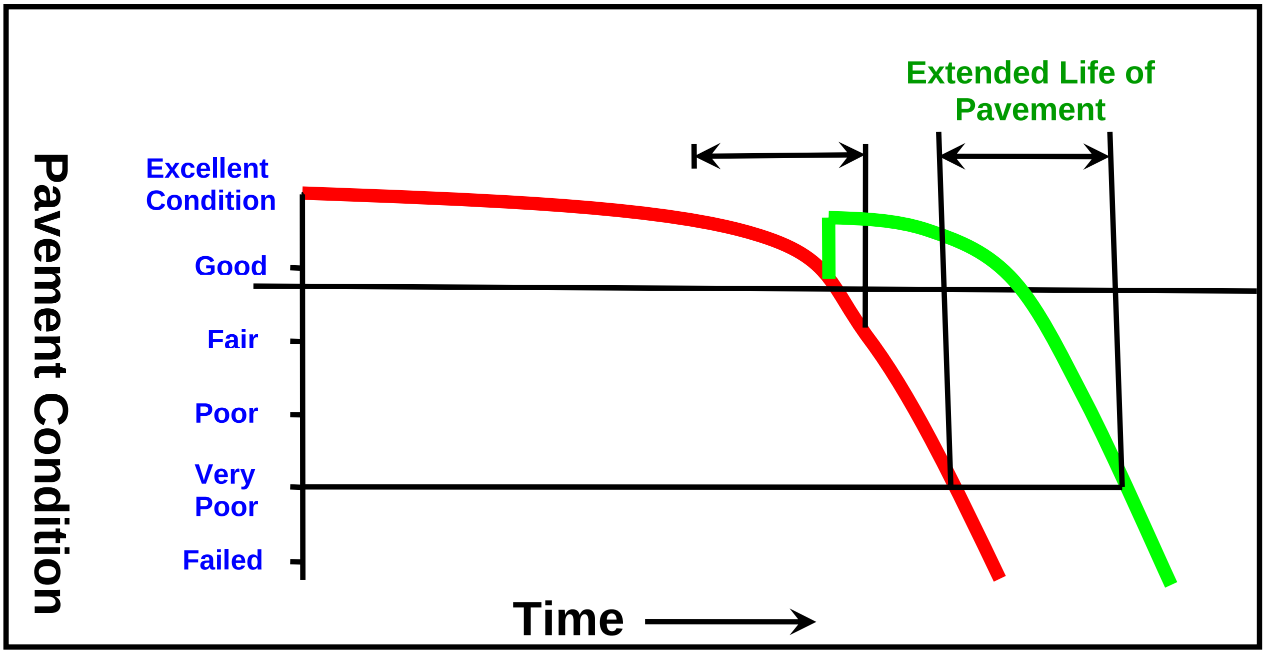


Figure 30: Pavement preservation can extend the life of a pavement.

ASPHALT TREATMENTS

Crack Treatments

Crack Sealing

Crack Sealing is the sealing of cracks in pavement with sealant material. It prevents water from entering the underlying materials which may cause stripping, pumping, subgrade and base failure.

Background: Bituminous pavements for a variety of reasons will crack over time. Pavements that do not crack generally are very susceptible to rutting, shoving and various shear failures. Once a crack is formed in the mat the pavement will loose some of its integrity.

Figure 31: Crack Sealing

Without a continuous system, materials enter an exit the roadway system. Water then may directly enter the under laying materials which may cause changes such as pumping, swelling and migration of finer materials. Another problem that will often occur is that incompressible materials enter the pavement prism. Subsequent expansion will occur which loads up the surrounding pavement creating further distress.

Some of the structural properties will also be lost from the pavement and failures may occur such as subsequent cracking, spalling on the edge of the crack and in rare cases some faulting. Structural losses generally lead to pothole formation and large crack formation very quickly in older brittle pavements.

Procedures:

Set up the project.

1) Make an assessment of the road you are thinking of crack sealing. Check the records if available to see what type of asphalt cement make up the road. Check and see if it is scheduled for reconstruction in the next few months so you don't waste resources on a road that would be replace anyway. Determine the best type of crack sealing material to be used.

2) Next go to the project site and first analyze the cracks to see if they are a good candidate for sealing or if another crack treatment is warranted. Normally cracks with a width of greater than ¾ of an inch are filled instead of being sealed.

3) Get an estimate of the amount of cracking per lane mile. This will take some experience to get proficient at determining the quantities. It would be advisable to meet with your industry representative the first couple of times to get some help in determining your estimate. (They get paid on actual quantities so they have no reason to skew their quantitative analysis)

4) Determine a preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic. You may have to put a project together that the work performed is done at night in order to maintain traffic flow. Also a staging area should be located in order to minimize the disruption to traffic and provide a safe stockpile site out of the clear zone.

5) Set up paperwork for a contract maintenance project or if looking for a really large scale effort you might need to produce a book project.

Material Types

A number of types of creak sealing materials exist on the market today. These materials are designed for use in various environments and on various pavement types. Generally stiffer more heat resistant materials are used in hot environments and softer materials are used in mountainous cold weather areas. Also generally softer more flexible material are used with blow and fill, crack seals and slightly stiffer materials are used for routing and filling techniques.

All hot poured crack sealing materials must be on the Approved Products List for the Department. All materials must conform to Section 411 of the New Mexico State Highway and Transportation Department's Standard Specifications for Highway and Bridge Construction 2000 Edition or District Maintenance Engineer's signed acceptance. All hot poured crack sealant must comply with AASHTO M-324 (ASTM D-6690) materials specification.

The New Mexico Department of Transportation does not currently have a specification for cold pour crack sealing materials. These products if they are to be used must be on the Approved Products List and approved for use by the District Maintenance Engineer in the District the work is to take place. The materials use in cold pour methods generally go from a liquid to a solid through a chemical process. Care should be taken to make sure the chemical reaction does not react with the adjoining pavement creating a bigger problem.

Crack Sealing Configurations

There are four basic configurations used in crack sealing. They are:

1. **Flush-filling** Flush filling consists of simply blowing out a crack with compressed air and filling it with crack sealing material. The crack filling material is inserted into the pavement and then struck off level with the pavement surface. The advantage to this type of crack sealing is speed and cost. The down side to this method is that you don't not have a lot of material to work inside the crack to they tend to fail fairly rapidly. Another problem is that the cracks are not routed so loose and/or oxidized material may exist on the sides of the crack creating a zone of weakness which may break subsequently to repair.

2. **Overband Filling** Overband filling consists of simply blowing out the crack with compressed air and filling a excess of crack sealing material so the a band of sealant caps the crack as while as fills it. The advantages to this type of crack sealing are speed, cost and a little more durability over flush filling. The disadvantages to this type of crack sealing is it leave a surface on top the can be scraped away during snow plow operations and the bands make noise as tires pass over them. It is recommended that the band (cap) be shaped using a squeegee as to not create a bump making for a more comfortable ride especially for motorcycles.

3. **Rout and Fill** This method has the crack routed or sawed to a predetermined width (usually 13 to 19 mm), and a predetermined depth (19 to 25 mm) and then filled level with or slightly depressed (6 to 9 mm below) the surface with sealant. The advantages to this method are that you have a clean un-oxidized surface after routing for better bonding, a consistent amount of material for better flexibility and easier introduction of the sealant into the crack. The disadvantages are it more labor intensive to route the pavement and it

requires a greater quantity of material which increases the initial cost. This is the method which is currently the method described in section 411 of the New Mexico State Highway and Transportation Department Standard Specifications for Highway and Bridge Construction 2000 Edition.

Figure 32: Routing Cracks.

4. **Rout and Overband** This method is a combination of the rout method with and overband applied over the crack. In this method the crack is routed as in method 3 but then banded beyond the reservoir. The method has the advantage of increased stability for the joint overall. The disadvantages are the noise associated with tire driving over the bands and the increased costs for the extra material. This method has been used on the Interstates in District 3 in the past with good results.

Weather Requirements and Pavement Conditions

The roadway needs to be clean and dry prior to sealing operations. An adequate bond will not form when the surface of the cracks are wet. This is especially true when using Hot Poured Sealants.

The roadway temperature needs to be above freezing with the air temperature above 40 degrees and rising. It is also recommended the temperature not be excessively hot or above 70 degrees when doing hot poured operations. The manufacturer recommendation for the sealant should be adhered to when placing material unless experience has proven otherwise.

The roadway surface and cracks should be clean and free of deicing chemicals. Blowing out cracks may be difficult with materials that will adhere to the sides of the crack if filling is used without routing.

Problems to Avoid

If crack sealing in conjunction with a fog seal it is better to fog seal the road and wait several months before crack sealing. If the crack sealing is done first, the tires of the vehicles passing over the freshly sealed cracks have been known to pull the crack sealing material out of the cracks. Occasionally though very rare the oil from a fog seal will also break the bond of the crack seal even when it's been down for a few years. When fog sealing over a crack seal if possible run a small test section to insure you don't end up with a big problem.

When blowing out materials from cracks, care should be taken to blow material away from adjacent traffic. Rocks and flying debris has in the past been a source of claims paid to motorist in the past. It is also advisable to sweep if possible after the operation is complete prior to opening to traffic.

When cleaning out the hoses from the melting pot after use, a method of collecting the waste material is imperative. This is both unsightly and a potential for claim.

If the section of roadway needs to be opened to traffic quickly after crack sealing it is permissible to sand the stretch. The sand needs to be free of any gravel that can be pushed into the still soft crack sealing material.

Often fresh/new crack sealing materials will bleed through Open Graded Friction Coarse overlays. Though generally this does not present a problem to the integrity of the road it is unsightly.

Life Expectancy

General The life expectancy is greater for the hot applied products then the cold applied. The over banded processes give you additional life because the extra material give a better bond to the treatment.

Flush Filling This is the lease long lived crack filling technique. This treatment usually only last one to two years before cracking returns.

Overband Filling This treatment usually lasts two to three years before the cracks return.

Rout and Fills Historically this treatment lasts about four years. Failures are usually a combination of crack edge failures and material cracking.

Rout and Overband Generally this method will last at least five years. Some projects in the past have even lasted seven to eight years.

Crack Filling

Background: Bituminous pavements for a variety of reasons will crack over time. Pavements that do not crack generally are very susceptible to rutting, shoving and various shear failures. Once a crack is formed in the mat the pavement will loose some of its integrity.

Without a continuous system, materials can enter and exit the roadway system. Water then may directly enter the underlying materials which may cause changes such as pumping, swelling and migration of finer materials. Another problem that will often occur is that incompressible materials enter the pavement prism. Subsequent expansion will occur which loads up the surrounding pavement creating further distress.

Some of the structural properties will also be lost from the pavement and failures may occur such as subsequent cracking, spalling on the edge of the crack and in rare cases some faulting. Structural losses generally lead to pothole formation and large crack formation very quickly in older brittle pavements.

If left untreated cracks will widen over time. In some rare cases cracks will form and widen out at a very rapid due to pavement shrinkage or major thermal changes. Cracks that exceed ¾ of an inch wide are considered to be large cracks. In any case from time to time you will have to deal with large cracks and repairs.

Figure 33: Crack Filling.

Figure 34: Close-up of Crack Filling.

Procedures:

Set up the project.

1) Make an assessment of the road you are going to do large crack repairs on. Check the records if available to see what type of asphalt cement makes up the road. Check and see if it's scheduled for reconstruction in the next few months so you do not waste resources on a road that would be replaced anyway. Be sure to do emergency repairs anyway if the road represents a safety hazard to the motoring public even if the road is scheduled for reconstruction. Determine the best product/method to be used in repairing the road.

2) Go to the project site and first analyze the cracks to see if they are good candidate for filling. If they are thin enough, less then ¾ of an inch you may be able to use conventional crack sealing methods which are generally cheaper. Look at the asphalt roadway to see if the edges of the crack are strong enough to just fill with materials or if sawing the cracks is needed.

3) Get an estimate of the amount of cracking per lane mile. This will take some experience to get proficient at. Working with an experience manager from one of the nearby patrols will help for folks doing the first couple of estimates.

4) Determine a preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic. You may have to put a project together that the work performed is done at night in order to maintain traffic flow. Also a staging area should be located in order to minimize the disruption to traffic and provide a safe stockpile site out of the clear zone.

5) Order your materials and schedule equipment if needed or get with your District's Technical Support Engineer to process a book job to contract the work.

Material Types

Materials used in wide crack filling range from elastic slurry fillers that are used with straight fills or rout and fill techniques to standard hot mix used to fill in excised sections. The method chosen will depend a lot on whether the crack is moving, the pavements condition and the underlying cause of the cracking.

Elastic slurry fillers are generally used in cracks that have expanded over time that could have been treated with a standard crack seal earlier in the life of the roadway. These are generally an elastic modified asphalt cement material combined a bridging aggregate. These are generally proprietary products so they will need to appear on the New Mexico Department of Transportation's Approved Products List prior to use. The crack can be treated as is or routed when using these treatments.

Cold mix fillers. These are emulsified or modified asphalt cements with mineral aggregate filler. These are generally binder rich materials to make the product more adhesive and for easier introduction into the repair area. These are fed into the cracks to act as both a sealant and a bridging material. The cracks may be sawed or routed out prior to introduction of the cold mix materials. Some common premixed pothole fillers work well for this application.

Hot mix fillers. These are generally fine graded plant mix bituminous pavement materials used for paving operations. When using this material you need to first check with the District lab to find out what current mix designs are available for the supplier on contract. Generally you will be using a ½ inch or smaller SHRP design mix. Hot mix fills are almost exclusively used where you saw out a crack much like a utility cut and fill it.

Crack Filling Configurations

There are three basic configurations used for crack filling operations. These are:

1. **Flush filling** Flush filling consists of simply blowing out a crack with compressed air and filling it with crack fill material. The crack filling material is inserted into the pavement and then struck off level with the pavement surface. Some effort may be needed to get the crack completely filled because some of the above mentioned materials do not flow very well. The advantage to this type of crack sealing is speed and cost. The down side to this method is that you don't not have a lot of material to work inside the crack to they tend to fail fairly rapidly. Another problem is that the cracks are not routed so loose and/or oxidized material may exist on the sides of the crack creating a zone of weakness which may break subsequently to repair.
2. **Rout and Fill** This method has the crack routed or sawed to a predetermined width (usually 25 mm or more), and a predetermined depth (19 to 25 mm) and then filled and struck off level with the surrounding surfaces. The advantages to this method are that you have a clean un-oxidized surface after routing for better bonding, a consistent amount of material for better flexibility and easier introduction of the filler into the crack. The disadvantages are it more labor intensive to route the pavement and it requires a greater quantity of material which increases the initial cost.
3. **Sawing** This method takes the crack and saws away the rounded or failing edges and provides for a smooth walled trench much like a utility cut to be filled. The advantage to this method is you can rework the base materials below the crack restoring there integrity and providing a larger area to introduce hot mix or cold mix into the repair. Elastic slurry fillers are not generally used in this method because they are too soft and flexible to bridge this large of a gap. The sides of the cut out crack need to be tacked for maximum adhesion.

Weather Requirements and Pavement Conditions

The roadway needs to be clean and dry for crack filling operations. An adequate bond will not form when the surface of the cracks are wet. Though for emergency operations, some of the premixed cold patching materials will work.

Cracks need to be free of deicing chemicals which will often break the bond between the filler and the sides of the crack. Cracks need to be blown out prior to the addition of the fillers. Cracks that are saw cut should be tacked.

Problems to Avoid

Cold mix patching materials tend to run very high in oil. Care should be used when fog sealing that the patch does not become so rich that it will not perform its function.

When blowing out materials from cracks, care should be taken to blow material away from adjacent traffic. Rocks and flying debris has been a source of claims paid to motorists in the past.

Cold and Hot mix materials produce loose gravel. Upon completion of the repair sweeping is a must.

Life Expectancy of Repairs

Flush Fills and Rout and Fills These techniques can be expected to last up to **four years**. Generally a failure occurs when material migrates out of the crack or the crack continues to widen.

Sawing Cracks that are sawed out and carefully filled in with hot mix will last the remaining life of the road.

Full Depth Crack Repairs

Background When cracks get excessive or too close together, often it is better to affect a full depth repair of the area rather then work on the individual crack. Usually when you have cracking of this nature it is being causes by an underlying problem with the section of the road and you will be able to address to cause as well as the effect.

The most common cause of heavy cracking is a soft subgrade acting as the foundation for the roadway. You have a semi-ridged that is placed over the softer material and when a load is applied you get cracking. The only way to repair something like this is to remove the section of pavement and rebuild it from the bottom up.

The very common cause of heavy cracking in an area is poor asphalt mixes. Usually this occurs when the asphalt comes from the plant in the original operation in a brittle condition. Asphalt cements that have been burned during mixing are a common cause of this condition. In this situation the section of pavement should be removed, the base course and subgrade examined and compacted as needed. New hot asphalt concrete mix should then be placed to match the section.

These repairs are a basically the same method used in sawing and filling for wide cracks as above. Only difference is that you are removing an area of closely space multiple cracks it the asphalt and replacing it.

Procedures:

Set up the project.

1. Make an assessment of the road you are going to do crack repairs on. Check the records if available to see what type of asphalt cement makes up the road. Check and see if it's scheduled for reconstruction in the next few months so you do not waste resources on a road that would be replaced anyway. Be sure to do emergency repairs anyway if the road represents a safety hazard to the motoring public even if the road is scheduled for reconstruction. Determine the best method to be used in repairing the road.

2. Examine the pavement to see what is causing the failure. If need be dig up a small area and look at the subgrade. The cause of the cracking will have a profound effect on the equipment needed for the repair.

3. Get an estimate of the amount of cracking that you will need to repair. Measure the length and width of the area to be removed. Be sure to get well into the adjoining good pavement for a good stable continuous pavement section.

4. Determine a preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic. You may have to put a project together that the work performed is done at night in order to maintain traffic flow. Also a staging area should be located in order to minimize the disruption to traffic and provide a safe stockpile site out of the clear zone.

5. Order your materials and schedule equipment if needed or get with your District's Technical Support Engineer to process a book job to contract the work.

Material Types

The materials used in these types of repairs are either Hot Mix Asphalt Concrete or Cold Mix Asphalt Concrete. Hot Mix should be used as much as possible because you essentially restore the road to its original condition if the repair is done correctly. Cold Mix will have to be used when working far away from a plant that produces Hot Mix or when working off hours in the urban area when Hot Mix is not available.

Full Depth Crack Configurations

There are two basic method of achieving the same results primarily differentiated by the equipment used in the process and the size of the failures.

1. **Mill and Fill** Here you are going to bring in a milling machine and grind out area of cracked pavement. You then re-process the subgrade and base course and rebuild the section to match existing pavements. Be sure to apply tack to the sides of the pavement adjacent to the repair. This will be used when you have a large number of scattered failures or a large failure zone on a stretch of roadway. It would not be cost effective for a few scattered areas or a small localized area that fails.

2. **Saw and Fill** Here you are going to slice out a small localized failure or problem crack and rebuild the subgrade and base course prior to restoring the asphalt pavement. Be sure to apply tack to the sides of the adjacent pavement prior to placing the asphalt patch.

Weather Requirements and Pavement Conditions

The roadway needs to be clean and dry for crack repair operations.

Problems to Avoid

Always take a good look at the underlying material when doing this sort of repair. Water probably will have gotten into the subgrade and will often make it soft. Also look at the material under the cracked area for clays and malleable materials. Clays and silts need to be removed and replaced for a firm stable roadway.

Allow plenty of time to affect the repair. Often when you remove the surfacing you find the problem is more extensive then it appeared on the surface and additional resources need to be employed.

Life Expectancy of Repairs

If done correctly, these repairs can last for the remaining life of the road by either method.

Surface Treatments

Fog Seals and Sand Seals

Fog seals are the overlying of an existing pavement surface with an asphalt binder. A Sand Seal is topping the asphalt binder with sand. Fog seals and sand seals coat, protect and rejuvenate the existing pavement, seal and water-proof minor cracks in the pavement surface, prevent further stone loss and reduce raveling and rejuvenate dry and weathered surfaces. Sand seals restore pavement surface friction.

Background: As a pavement ages its components undergo a variety of chemical and physical changes. Pavement will undergo oxidation of it asphalt cement making the pavement brittle and susceptible to cracking and raveling.

Pavement is a lot like the skin on your arm. Occasionally you need to put lotion on it to make it soft and keep it healthy.

Figure 35: A Fog Seal Operation.

Figure 36: A Fog Seal over a finished Chip Seal.

Figure 37: Close-up of a Fog Seal over a Chip Seal.

Procedure:

Set up the project:

1) Make an assessment of the road you are going to fog seal. Make a check of the plan for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replace anyway. Determine the best type of material, (usually an emulsion), to fog seal with based on traffic loads and regional setting. Emulsions are combinations of refined asphalt, water and a surfactant to keep the oil and water from separating.

2) Go to the project site and see what condition the road is in. You will need to adjust the application rate to match the pavement's condition. Newer roads generally take a lower application rate and older more oxidized roads take a higher rate. **At <u>no time</u> should you**

exceed 15 hundredths of a gallon of the emulsion per square yard for your application rates. Higher rates of application will over soften the asphalt and you will get rutting.

3) Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion order:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards
- Determine the gallons of emulsion needed for the fog seal project:
  Application Rate in Gallons × Area in Square Yards = Gallons of Emulsion
- Convert gallons of emulsion to weight in pounds:
  Gallons of Emulsion × 8.33 Pounds per Gallon = Pounds of Emulsion
- Convert pounds of emulsion to tons for ordering:
  Pounds of Emulsion ÷ 2000 Pounds per Ton = Tons of Emulsion

4) Determine you preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Also locating a staging area for transferring from the transport tanker to the distributor and to park a load of sand for emergencies is advisable.

5) Order the emulsions and schedule the equipment or get with your District's Technical Support Engineer to process a book job.

Figure 38: Applying Emulsion.

Figure 39: Spreading sand during a Sand Seal project.

Material Types

Asphalt Cements used on the road come in many forms. There are refined asphalts which are used binders in plant mix bituminous pavements and some types of chip seals. There are asphalt cement that have been mixed with petroleum solvents known as cut backs. The other type of fog sealing material is an emulsion which is a mixture of Asphalt cement mixed with water and a surfactant. All can be used in fog sealing but it is rare to see a non-emulsion used to seal a road.

Refined Asphalts are great for forming a hard layer over a road. They are not used very often because they do not penetrate much beyond the surface that it is applied. Asphalt cements are generally graded four ways. They can be the same material just listed as differently under systems as follows:

- **AC Grading –** This is a method of grading asphalt based on it viscosity. The viscosity is tested prior to conditioning (not heat in a thin film oven). Here you are only testing the raw product and not accounting for any thermo-hardening used in the processes the asphalt is slated for. Common grades are AC-2.5, AC-5, AC-10, AC-15 and AC-20. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
- **AR Grading –** The A in this system stands for asphalt and the R stands for residue. This is a method of grading asphalt cement based on its viscosity. The viscosity is test after the asphalt has been conditioned in a thin film oven. The idea behind this method of grading is that it simulates hardening of the cement in the mix plant. Common grades under this system as AR-10, AR-20, AR-40, AR-80 and AR-160. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
- **Penetration Grading** - Asphalt cement classified under this system is graded based on its standard penetration at 25˚C and its absolute penetration at 60˚C. Common grades under this system are 40-50, 60-70, 85-100, 120-150 and 200-300. This grading system can still be encountered periodically, but is being replaced by the SHRP grading system.
- **SHRP Grading also called Performance-Graded Asphalt Binder–** This is the current grading system used by the State of New Mexico as well as the majority of the rest of the United States. This system uses maximum temperature at the placement location for the upper limit of the grading system and the minimum temperature for the lower number for selecting the binder to be used on the roadway. A number of physical properties are then assigned to this temperature range per AASHTO M-320 and verified per testing listed under R-29. This is a good system but it does not address adhesion, cohesion, polymerization and a number of other properties the asphalt cements have. Common grades under this system are on the top end PG 46, PG 52, PG 58, PG 64, PG 70, PG 76 and PG 82 with the bottom end ranging -10 al the way down to -46 in six degree increments, (see table 1 under AASHTO M-320). An example binder used in New Mexico is PG 76-22.

Polymerized Asphalt Cements also can be used to seal a surface. These are actually covered under the SHRP Grading system listed above but are also found as an offshoot of the Viscosity Grading System. At present the only polymer asphalt cements are based on the Viscosity Grading System commonly used in the NMDOT are PAC-10, PAC-20 and PAC-40. These are not used very often because like the other binders listed above because they do not penetrate into the asphalt concrete they are being applied to.

The products that are more commonly used in fog sealing operations are emulsions. These are broken down based on their chemical properties, float test (AASHTO T-50) and by their ability to setup (harden). The float test is used to characterize the flow behavior of the emulsion. Another major characterization for an emulsion is whether it is Cationic or Anionic depending on its internal electrical charge. These characteristic are how the following list of commonly used emulsions is classified.

<u>High Float Emulsions</u>

HFE Emulsions – These are the High Float Emulsions that are commonly used throughout New Mexico. You will commonly see them listed as HFE – 100's, HFE-150 etc.; as HFE – 100P, HFE - 150P etc. or occasionally HFRS-2, HFMS-1, HFMS-2 etc. The 'H" is there designation is what denoted them as a High Float Emulsion which also means that they have met or surpassed 1200 seconds at 60˚ on the float test (AASHTO T-50). High Float Emulsions have very good workability (fluid) characteristics and are used in not only fog sealing but also in slurry sealing, chip sealing and occasionally in micro surfacing.

<u>Slow-Setting Emulsions</u>

SS-1 and CSS-1 Emulsions – These are common Slow Setting Emulsions that are used throughout New Mexico. The C is CSS-1 stands for Cationic Slow Stetting Emulsion. As the name implies, these emulsions take some time to setup and have more time to penetrate into the road you are fog sealing. The drawback to these are that if you need to open the road back up to traffic you will need to wait extra time while it sets up.

<u>Medium-Setting Emulsions</u>

MS-1, MS-2, CMS-1 and CMS-2 – These are the common Medium Setting Emulsions that are used throughout New Mexico. Like the slow setting emulsions, the "C" in CMS-1 and CMS-2 stands for Cationic meaning a positively charged emulsion. The setup time on these emulsions is a faster then the slow sets giving more flexibility to how fast traffic is put back on the treated pavement and the workable time.

<u>Rapid-Setting Emulsions</u>

RS-1, RS-2, CRS-1 and CRS-2 – These are the rapid setting emulsions that are available in New Mexico. RS-1 and CR-1 have both been used in the Albuquerque area for fog sealing. With the CRS-1 the road was returned to traffic in as little as 30 minutes without sanding the roadway.

<u>Quick-Setting Emulsion</u>

QS-1H – This is the fastest setting emulsion available.

<u>Polymer-Modified Asphalt Surface Sealer</u>

PASS® is a relatively new modified emulsion to New Mexico. It comes in a number of configurations which run from medium setting to rapid setting.

Construction:

<u>Traffic Control</u>

Traffic Control should be in place before work forces and equipment enters onto the roadway or into the work zone. Traffic control is required both for the safety of the traveling public and the personnel performing the work. Traffic control includes construction signs, construction cones and/or barricades, flag personnel and pilot cars to direct traffic clear of the maintenance operation. For detailed traffic control requirements refer to the Federal Manual on Uniform Traffic Control Devices (MUTCD) or agency requirements.

Traffic control is also required to protect the integrity of the application. The curing time for the fog seal material will vary depending on the pavement surface conditions and the weather conditions at the time of application. Under ideal conditions, it is suggested that the traffic be kept off the fog seal material for at least 2 hours.

<u>Surface Preparation</u>

Immediately before applying a fog seal the pavement surface must be cleaned with a road sweeper, power broomed, or flushed with a water pump unit to remove dust, dirt and debris. The pavement surface must be clean and dry before applying the fog seal. Any existing distress that required to be repaired should have been done so.

Equipment Needs

At a minimum you will need:

- Asphalt distributor
- Brooms
- Water truck
- Traffic Control vehicles
- Backup equipment (optional)

At the beginning of each day the supervisor should make sure that the equipment is in good mechanical condition. For example, all equipment should be free of leaks, calibrated and clean. More specific equipment inspection recommendations include the following:

- Brooms: The brooms used to clean the pavement surface should be inspected to make sure the bristles are of proper length and in good condition and that the vertical pressure on the broom can be adjusted.
- Spray Distributor: A visual inspection of the spray distributor should be conducted to ensure that the spray bar is at its proper height, all nozzles are uniformly angled 15° to 30° from the spray bar and that all nozzles are free of clogs. Next, the spray distributor should be tested to check that the spray pattern is uniform and the proper overlap (double or triple) is being achieved, the proper application pressure is being used and that a working and calibrated thermometer is on site.

Asphalt Distributor

The asphalt distributor is the most critical element in the construction of fog seals. Many of the problems associated with the construction of fog seals can be traced back to improper asphalt application. The distributor consists of a truck-mounted insulated tank with a system of spray bars and nozzles at the back of the tank to apply a uniform application of asphalt. The tank has a heater and a circulation system that heats and circulates the asphalt in the tank and a supply system that transports the asphalt from the tank to the spray bar. The amount of asphalt that is transported to the spray bar and applied to the road surface is controlled through a valve system, an asphalt pump with a pump speed or pressure controls and nozzles of a prescribed size. These are tied together with a distance and speed measuring system to set application rates.

Before a job is begun, the equipment should be calibrated to ensure that the manufacturer's settings provide the quantities of material specified in the manufacturer's literature. It should never be assumed that the published settings for pump speed and vehicle speed are going to provide the application rate (gallon/minute) stated in the equipment manual. The actual output will vary with equipment age and type of material applied and its viscosity which is manufacturer and temperature dependent. For calibration, the distributor nozzles may be placed over a pan of known size, and the asphalt sprayed into the pan for a specified time. The amount of asphalt collected in the pan should be measured and compared with the amount predicted by the specified setting. Any differences should be noted, recorded and used to adjust the settings in the field.

This procedure ensures that the equipment is functioning properly. However, it does not ensure that the required amount of asphalt will be sprayed onto the pavement. A field calibration must be performed and checked at regular intervals. An initial section of roadway should be designated as a test strip prior to construction. The distributor should be weighed full and the proper pump settings made. The asphalt should then be applied to the pre-measured area at the pump settings to provide the desired coverage and the actual yield computed and compared to that required. If the amounts do not agree, the settings on the distributor should be adjusted, and another strip test strip placed if a large adjustment was required. The chips should be placed and rolled as planned for normal construction.

A 2 foot by 2 foot pad of cotton, or some other appropriate material, may be placed at different locations within the test strip to determine the coverage both longitudinally and transversely on the pavement. The pads should be weighed before and immediately after the distributor passes over them to prevent evaporation of solvent from altering the weights on the pads. The weight of asphalt on the pad and the area of the pad are used to compute the coverage of asphalt in gallons/square yard.

Other variables to be observed during the test strip construction include the spray bar height and the nozzle settings. The height of the spray bars should be set such that the required amount of asphalt is applied in a uniform manner without streaking. The height of the spray bar controls the amount of overlap. The best results are usually achieved with double overlap, although triple overlap can sometimes be used for spray bars with nozzles spaced at 4 inch intervals. Spray fans at higher height settings may be susceptible to wind effects.

The angle of the nozzle will control the uniformity of the spray pattern. These should be monitored during the test strip and continually during construction. Generally, the angle should be set between 0.26 and 0.52 radians (15° and 30°).

<u>Application Rates and Spraying</u>

Properly calibrated distributor trucks are used to apply the emulsion. Spray nozzles with 4 to 5 mm (0.16 to 0.2 inch) openings are recommended. The emulsion may be heated to 122 °F maximum, although, generally the emulsion is sprayed at ambient temperature. The emulsion is sprayed at a rate that is dependent on the surface conditions (see the following table). As discussed above, a test section representative of the entire surface should be chosen to approximate application rates. Typical application rates for diluted emulsion (50/50) range from 0.10 to 0.12 gallon/yard^2, depending on the surface conditions.

Suggested Fog Seal Application Rates

% Emulsion (Emulsion + Water)	Dilution Ratio (Emulsion + Water)	Type of Surface to be Fog Sealed	
		Dense Surface (Low Absorption), gallon/yard^2	**Open Surface (High Absorption), gallon/yard^2**
Net residual asphalt desired (no dilution)		0.01 to 0.03	0.03 to 0.05
50	1 + 1	0.03 to 0.11	0.09 to 0.23
40	2 + 3	0.04 to 0.13	0.12 to 0.30
25	1 + 3	0.06 to 0.21	0.19 to 0.47
20	1 + 4	0.08 to 0.25	0.24 to 0.59
16.7	1 + 5	0.09 to 0.31	Too High
14.3	1 + 6	0.12 to 0.41	Too High
12.5	1 + 7	0.13 to 0.47	Too High

Ideally, one-half of the application should be sprayed in each direction to prevent a "rain shadow" effect and build up on one side of stones (this is particularly important in the case of fog seals). Build up on one side can result in a slippery surface and inadequate binder to fully enrich the surface or hold the chips.

Estimating Optimum Application Rate

To estimate the application rate, take a one-quart can of diluted emulsion (usually 50/50) and pour evenly over an area of 1 yard^2. This is a diluted application rate of 0.024 gallon/foot^2. If the emulsion is not absorbed into the surface after 2 to 3 minutes, decrease the amount of emulsion (i.e., increase the dilution rate) and apply to a new 1 yard^2 area. Repeat this process until the approximate application rate is found. If after the first test the surface looks like it can absorb more emulsion, increase the amount of emulsion (i.e., decrease the dilution rate) and spread it over a new 1 yard^2 area. Repeat until the approximate application rate is found.

Checking Application Rate

The emulsion application rate should be monitored throughout the project. Two different methods are used depending on whether the rate is being checked for calibration purposes or as part of a random check during the construction process.

Recommended Method for Calibration

The asphalt distributor is typically calibrated prior to construction by placing a 1 yard^2 pan or non-woven geotexile of known weight on level ground. Next, the emulsion is applied over the pan or geotexile fabric. The weight of the applied emulsion applied on the pan or geotexile fabric is determined by subtracting the before application weight from the weight of the pan or fabric after being sprayed with emulsions. Finally, the application rate is determined by converting the weight of the applied emulsion to a volume and dividing the volume of applied emulsion by the area of the pan or fabric.

Recommended Method for Random Checks

Random checks of the application rate should be accomplished using test sections. Specifically, the following steps are used:

- Park the distributor on level ground and measure and record the number of gallons of emulsion in the tank.
- Measure the area of a test section.
- Apply emulsion to the test section.
- Re-measure the number of gallons of emulsion in the tank.
- Determine the application rate by dividing the amount of emulsion applied over the test section.

Asphalt Distribution

After the surface has been prepared by sweeping the binder is sprayed onto the surface of the existing pavement. During the application of the emulsion the following activities should be included:

- Building paper should be used at the starting and stopping points of the treatment to create straight edges.
- Check to confirm that the emulsion is within the required application temperature range.
- Conduct visual checks to make sure that the emulsion application appears uniform and no drilling or streaking is visible.
- Check the nozzles to make sure that they are not plugged.
- Perform random checks of the application rate.
- If applicable, make sure that the distributor adjusts speed to match the chip spreader speed to prevent stop-start operations.
- Stop the distributor and make the necessary adjustments if any problems are observed.

Post Treatment Considerations

Sand blotters may be used at approximately 1.84 pound/yard^2 to allow early opening to traffic. Sweeping may be required. The supervisor should assess this after application and opening to traffic. If it is believed that the surface friction characteristics have been reduced to unsatisfactory levels this can be measured with a skid tester or other surface texture measuring device. The pavement should not be opened to traffic if adequate friction has not been restored, especially if wet weather is anticipated.

Problem	Typical Cause(s)	Typical Solution(s)
Spattering of the emulsion	• Emulsion has been diluted too much. • Spray bar is not at proper height. • Spray pressure is too high.	• Adjust the emulsion dilution rate. • Make necessary adjustments to the spray bar height and pressure.
Streaking or drill marks appearing in the emulsion	• Emulsion is too cold. • Viscosity of the emulsion is too high. • All nozzles are not at the same angle. • Spray bar is not at proper height. • Spray bar pressure is too high. • Nozzle is plugged.	• Review emulsion temperature requirements. • Verify that the selected emulsion is appropriate for site conditions. • Check the spray bar height and pressure and the nozzle angles and make necessary adjustments. • Check nozzles for obstructions and clear any that are found to be plugged.
Flushing or bleeding of the emulsion	• Emulsion application is too high.	• Review the selected application rate and adjust as necessary.

Weather Requirements and Pavement Conditions

Fog sealing with emulsions is best done in warm weather but not really hot weather. If you fog seal when it is really hot (above 90˚F) you run the risk of the emulsion flash setting on you and not disbursing into all of the nooks and crannies in the roadway. Fog sealing is also not done in freezing weather because the product can freeze-up before it sets and it can take a really long time to setup (break) so putting traffic onto the roadway may become problematic.

Fog seals should never applied on windy days. The emulsion will not be applied uniformly and may blow onto passing automobiles causing damage. The fog seal may also flash set because the water is extracted to fast giving poor penetration.

Pavements to be fog seal should be in fairly good condition. The emulsions used for fog seals will not glue back severely cracked roads. Fog seals are most effective on moderately oxidized roads. Pavement should be clean (swept) and free of debris. Roads that fog seals are applied to should not have excess fat spots or bleeding.

Problems to Avoid

Fog Seals (emulsions) should never be applied at application rates greater than 15 hundredths of a gallon per square yard. Applying too much emulsion can cause the pavement to rut and shove. The reason this happens is that you get too much asphalt in the pavement matrix, causing the particles to float apart and without aggregate interlock the pavement is becomes ductile.

Never apply a fog seal to bleeding asphalt. It only compounds the slipperiness of the pavement when wet causing automobiles to have driving difficulties. The road can also shove or have rutting problems.

Always check to see that the emulsion is compatible with other maintenance treatments such as crack seals before applying. Some crack seals are severely weakening by the ionic reaction of various emulsions and will come out of the cracks.

Never fog seal over a fresh crack sealing project. The emulsion will stick to the tires of the automobiles bonding with the surface of the crack sealing material. The crack sealing material with then be lifted out of the crack creating a bigger problem.

Life Expectancy of Treatment

The life of a fog seal treatment is about 3 years.

Chip Seals

Chip Seals are a type of pavement surface treatment in which one or more layers of crushed aggregate (chips) are "glued" to an existing roadway surface using an asphalt binder. The resulting treatment is then rolled to embed the aggregate into the asphalt.

Chip seals coat, protect and/or rejuvenate the existing pavement, retard the rate of oxidation and asphalt hardening with age, a seal narrow crack in the pavement surface from the infiltration of moisture, stops raveling and restores pavement surface friction. Chip seals are very effective at restoring pavement surface friction and sealing narrow cracks in the pavement surface from the infiltration of moisture. They are also effective at retarding the rate of oxidation and asphalt hardening in the underlying HMA surface. Because of these benefits, and their relatively low cost, chip seals are a very popular and effective form of preventative maintenance.

Background: As a road ages it usually looses its frictional characteristics because of wear on the surface aggregates. The tires of an automobile will not grip the surface as effectively leading to an increased risk of loss of control. Braking will be come increasing difficult adding length to the stop. The pavement will also lose aggregates from its surface effecting at structure of the pavement and its overall surface composition. This can cause the pavement to deflect and crack allowing water to penetrate the roadway. One of the most cost effective ways of dealing with the previously mentioned conditions is to add a chip seal. Chip Seals add skid resistance, seal the pavement surface and improve the pavement ride quality.

Proper applications of chip seals include:

- Providing a low-cost, all-weather surface for light to medium traffic.
- Providing a waterproof layer to prevent the intrusion of moisture into the underlying courses.
- Providing a skid-resistant surface for pavements that have become slippery because of bleeding or polishing of surface aggregates. These pavements may be treated with sharp, hard aggregate to restore skid resistance.
- Giving new life to dry, weathered pavement surfaces. A pavement that has become weathered to the point where raveling might occur can be restored to useful service by application of a single-surface or multiple surface treatment.
- Providing a temporary cover for a new base-course that is to be carried through a winter or for planned stage construction. The surface treatment makes an excellent temporary surface until final HMA course is placed.
- Salvaging an old pavement that has deteriorated because of aging, shrinkage cracking or stress cracking. Although the surface treatment has little or no structural strength, it can serve as an adequate stopgap measure until a more permanent upgrading can be funded and completed.
- Defining shoulders so they won't be mistaken as traffic lanes.

- Poor surface friction.
- Bleeding on the pavement surface (if properly accounted for during construction).
- Fatigue cracking in which the cracks have not yet begun to interconnect and spall (the chip seal will not improve the structural capacity and fatigue cracking may continue).
- Non-structural rutting that is less than ⅜ inch deep.

Chip seals, like other thin surface treatments, generally do not provide any significant structure to the existing pavement so pavements that are structurally deficient are not candidates for chip seals. Specifically, chip seals are not good candidates for pavements that have medium-to-high severity fatigue (alligator) cracking, unstable rutting (those driven by structural defects), surface rutting (that are confined to the surface layer) in excess of ⅜ inch, a large amount of potholes or a very rough surface. In addition, because wide cracks or cracks experiencing large movements (i.e. working cracks) are expected to reflect through the chip seal treatment, pavements with a large number of working cracks are not good candidates for chip seal projects.

You will need to adjust the application rate of the emulsion that tacks the chips to the road to match the pavement's condition. Newer roads generally take a lower application rate and older more oxidized roads and cracked roads take a higher rate. You will also need to scout out some stockpile sites and get them cleared through the environmental process if they have not been used as stockpile site before. **(This can take some time so start as soon as possible in order to not be held up!)**

3. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion and aggregate order:

    a. Convert (distance) miles from odometer to feet:
    Miles Measured × 5280 Feet = Feet of Distance
    b. Calculate area in square feet from distance and width:
    Feet of Distance × Width Measured in Feet = Area in Square Feet
    c. Convert square feet of area to square yards of area:
    Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards
    d. Determine the gallons of emulsion (usually between an application rate between 0.35 and 0.50 gallons per square yard) needed for the Chip Seal project:
    Application Rate in Gallons × Area in Square Yards = Gallons of Emulsion
    e. Convert gallons of emulsion to weight in pounds:
    Gallons of Emulsion × 8.33 Pounds per Gallon = Pounds of Emulsion
    f. Convert pounds of emulsion to tons for ordering:
    Pounds of Emulsion ÷ 2000 Pounds per Ton = Tons of Emulsion

g. Determine the weight of aggregate, (usually the application rate is between 25 and 35 pounds per square yard), needed for the Chip Seal project:
   Application Rate of Aggregate × Area in Square Yards = Pounds of Aggregate
h. Convert weight to tons for ordering aggregate:
   Pounds of Aggregate ÷ 2000 Pounds per Ton = Tons Needed

It is strongly recommended that you order 10% more aggregate than needed! Often some chips are stolen, contaminated or the road varies slightly.

4. Determine your preliminary traffic control plan.
   a. Look at detours or phasing to get the work done and maintain traffic flow.
   b. You need a safe location for the trucks to enter and exit the roadway to stockpile sites or account for flaggers. Also locating a staging area for transferring from the transport tanker to the distributor and to park a load of sand for emergencies is advisable.
   c. Remember to provide signs advising the traveling public about loose gravel.
   d. On narrow two lane roads you will need to have a pilot car setup during operations.
   e. Order temporary striping tape or Chip Seal markers for temporary striping.
   f. It's advisable but mandatory to visit with local maintenance crew to see if there are any trouble spots that might require additional signing.

5. Order the aggregate, emulsions and schedule the equipment or get with your District's Technical Support Engineer to process a book job.

6. Prepare or have the road prepared for the seal project. Fill the cracks and blade patch the really bad areas. **A Chip Seal will not function if the road below it is not in good condition prior to its placement!**

7. Build stockpile sites to keep Chip Seal aggregates from getting contaminated.

Figure 40: Loading Chips.

Figure 41: Spreading emulsified asphalt.

Figure 42: Spreading Chips.

Figure 43: Rolling Chips.

Figure 44: Brooming loose chips.

Figure 45: A finished Chip Seal project.

Figure 46: A close-up of a Chip Seal project.

Figure 47: A Fog Seal further encapsulates the aggregate.

Material Types:

Refined Asphalts can be used in Chip Sealing operations. When they are used they go down very hot and the aggregates have to be applied almost immediately. They are not used very often in an unmodified form because of there tendency to strip and the Chip Seal to ravel. If they are ever used here is the information on the grading systems.

- **AC Grading –** This is a method of grading asphalt based on it viscosity. The viscosity is tested prior to conditioning (not heat in a thin film oven). Here you are only testing the raw product and not accounting for any thermo-hardening used in the processes the asphalt is slated for. Common grades are AC-2.5, AC-5, AC-10, AC-15 and AC-20. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
- **AR Grading –** The A in this system stands for asphalt and the R stands for residue. This is a method of grading asphalt cement based on its viscosity. The viscosity is test after the asphalt has been conditioned in a thin film oven. The idea behind this method of grading is that it simulates hardening of the cement in the mix plant. Common grades under this system as AR-10, AR-20, AR-40, AR-80 and AR-160. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
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Polymerized Asphalt Cements and Polymerized Asphalt Cement with Tire Rubber are used to Chip Sealing. These are actually covered under the SHRP Grading system listed above but are also found as an offshoot of the Viscosity Grading System. At present the only polymer asphalt cements are based on the Viscosity Grading System commonly used in the NMDOT are PAC-

10, PAC-20, PAC-40, PAC-10TR and PAC-20TR. When polymerized asphalt cements are used it is strongly recommended to use a coated aggregate.

The products that are more commonly used in Chip Sealing operations are emulsions. These are broken down based on their chemical properties, float test (AASHTO T-50) and by their ability to setup (harden). The float test is used to characterize the flow behavior of the emulsion. Another major characterization for an emulsion is whether it is Cationic or Anionic depending on its internal electrical charge. These characteristic are how the following list of commonly used emulsions is classified.

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RS-1, RS-2, CRS-1 and CRS-2 – These are the rapid setting emulsions that are available in New Mexico. With the CRS-1 the road was returned to traffic in as little as 30 minutes without sanding the roadway.

Quick-Setting Emulsion

QS-1H – This is the fastest setting emulsion available

Polymer-Modified Asphalt Surface Sealer

PASS® is a relatively new modified emulsion to New Mexico. It comes in a number of configurations which run from medium setting to rapid setting. PASS emulsion has been used in a few Chip Sealing projects but so far has been mainly used for scrub seals and fog sealing.

Aggregate:

Aggregates used in Chip Sealing operations are generally crushed rock passing the ⅜ inch sieve. The material should also contain very little material passing the number 10 sieve. To limit dust and to ensure proper coating of the aggregate, the amount of fines (material passing the No. 200 sieve) should be limited to 1 to 2 percent. Dirty aggregates containing should be thoroughly washed prior to stockpiling to remove minus number 40 sieve materials.

Aggregate should be clean and durable; clean to enhance the coating of the asphalt and durable to resist wear from traffic. Selection of the binder should also take into account the compatibility of the asphalt binder. The aggregate should be crushed and screened to as close as one size as possible. The size of the aggregate will largely dictate the resultant thickness of the chip seal. The recent trend has been toward the use of smaller chips (⅜ inch) to help limit the amount of damage from loose chips.

The ideal aggregate shape for chip seals is cubical. Flat or elongated particles tend to align on their flat sides and may be completely covered with asphalt, whereas rounded particles may roll under traffic and dislodge. The amount of flat and elongated partials is typically limited to 25 30 percent. In construction the goal is to achieve about 70 percent embedment of the aggregate immediately after compaction of the chip seal, with additional embedment (up to 90 percent) occurring from traffic. Aggregates may be damp when emulsions are used but should be dry when hot asphalt binders are used.

Caliche is used from time to time but strongly discouraged. It is usually more cost effective on a life cycle basis to ship in crushed rock.

Figure 48: Chips should be slightly damp when using emulsion.

Construction:

Once started, the total operation of asphalt application, chip spreading and rolling must always be completed as quickly as possible. If delays occur, the asphalt will set or cure and this will prevent the rolling from effectively seating the aggregate, which will cause chip loss. Ideally, the emulsion should begin to break just after the first roller pass has been made. Typically, the chip sealed surface can be opened to traffic in about 2 hours. Earlier opening times may be possible if vehicle speeds are limited to below 25 mi/hr.

The construction sequence for most chip seal projects is as follows:

- Pre-construction checks.
- Calibration of the asphalt distributor.
- Calibration of aggregate spreader.
- Cleaning/sweeping of the existing pavement surface.
- Application of asphalt at the desired rate.
- Application of aggregate (chips) at the desired rate prior to emulsion or cutback breaking.
- Rolling of aggregate immediately after aggregate spreader.
- Curing of binder (will vary depending on the effects of temperature and relative humidity on breaking of emulsion or cutback materials).
- Brooming of loose aggregate after binder is cured (the time typically ranges from 15 to 24 hours).
- Cleanup, especially the asphalt distributor.

The overall success of a chip seal project depends upon:

- The adequacy of the design.
- The quality of the materials.
- The attention given to material placement and rolling curing construction.

At a minimum you will need:

- A Chip Spreader.
- Asphalt Distributor.
- A Loader.
- Dump trucks (tandems preferable) or flow boys.
- Blooms.
- Rollers.
- Water truck.
- Traffic Control vehicles.
- Backup equipment (optional).

Pre-construction Checks

Following is a checklist of pre-construction precautions that should be taken before beginning a chip seal project:

Project Review	• Is the pavement a good candidate for a chip seal? • How much rutting is present? • How much and what type of cracking is present? • Is crack sealing the correct treatment? • Does the pavement exhibit much bleeding?
Document Review	• Bid specifications. • Special provisions. • Construction manual. • Traffic control plan. • Agency requirements. • Asphalt and equipment manufacturer's instructions. • Material Safety Data Sheets (MSDS).
Material Checks	• What quantities of asphalt and aggregate are needed? • Is the type of binder to be used compatible with the aggregate? • Is the binder from an approved source? • Are the chips the correct size and close to the same size? • Are the chips clean and free of excess fines? • Are the chips used with emulsions in a surface-damp condition? • Is the emulsion temperature within application temperature specification?

Following is a checklist of equipment precautions that should be taken before beginning a chip seal project:

Broom	• Are the bristles the proper type and length? • Can the broom be adjusted vertically to avoid excess pressure?
Distributor	• Is the spray bar the proper height? • Are the nozzles uniformly angled 15 to 30 degrees from the spray bar? • Are all the nozzles free of clogs? • Is the spray pattern uniform and does it properly overlap (double or triple)? • Is the application pressure correct? • Is the distributor properly calibrated?
Chip Spreader	• Do the spreader gates function properly and are their settings correct? • Is the scalping screen in good condition? • Is the spreader's calibration uniform across the entire chipper head? • Are the truck hook-up hitches in good condition?
Rollers	• What type of roller will be used on the project? Pneumatic rollers are recommended. • Do the roller tires, ratings and pressures comply with the manufacturer's recommendations and specifications? • Are the tire pressures the same on all tires? • Do all the tires have smooth surfaces?
Haul Trucks	• Is the truck box clean and free of debris and other materials? • Is the truck hook-up hitch in working order? • Is the truck box apron or extension required for loading the chip spreader?

The following items should be inspected immediately before beginning a chip seal project:

Surface Preparation	• Is the surface clean and dry? • Have all pavement distresses been repaired? • Has the existing surface been inspected for drainage problems?
Weather Requirements	• Do the contract specifications describe a range of dates when chip sealing can be done? • Have the air and surface temperatures been checked at the coolest location on the project. Are the air and pavement surface temperatures above 60°? • Are high winds expected? High winds can cause problems with emulsion application. • Will the expected weather conditions delay the breaking of the emulsion? High temperatures, humidity and wind will affect how long the emulsion takes to break. • Have steps been taken to ensure that the application of emulsion will not begin if rain is likely?
Determining Application Rates	• Has a chip seal design been done? • Is the pavement surface oxidized or porous? More oil will need to be applied to dried-out and/or porous surfaces. • What is the traffic volume on the road? More oil needs to be applied on roads with low traffic volumes. • Is the surface smooth, non-porous or bleeding? Less oil needs to be applied on smooth, non-porous and/or asphalt-rich surfaces. • Is the traffic volume on the road high? Less oil needs to be applied on roads with high traffic volumes. • Are the chips embedded to the proper depth after rolling and curing? The chips should be embedded between 50 to 70 percent. • Is there a "salt and pepper" appearance after the chips have been applied?

The following items should be inspected immediately before beginning a chip seal project and systematically throughout the duration of a chip seal operation:

Traffic Control	• Are the signs and devices in accordance with the traffic control plan? • Does the work zone comply with Department standards and specifications? • Are the flaggers holding traffic for extended periods of time? • Are unsafe conditions reported immediately to a supervisor? • Does the pilot car lead traffic slowly, 24 mph or less, over fresh chips? • Are signs removed or covered when they do not apply?
Binder Application	• Is building paper being used to start and stop binder application to ensure straight edges? • Is the air and asphalt temperature above 60 °F? • Does the binder application look uniform? • Are any nozzles plugged? • Is there any drilling or streaking visible? • Do random checks of the application rate fall within project requirements? • Is the distributor speed being adjusted to match the chip spreader speed to prevent stop-start operations? • Stop the distributor if any problems are observed.
Chip Application	• Are enough trucks on hand to maintain a steady supply of chips to the spreader? • Is building paper or roofing felt used at the start and end of the application? • Does the application start and stop with neat, straight edges? • Does the chip spreader follow closely behind the distributor, within 33 yards, when an emulsion is used? • Does the chip spreader travel slowly enough to prevent chips from rolling when they hit the pavement surface? • Are the chips used with an emulsion in a surface damp condition? • Check to make sure that there is no binder on top of the chips. • Is the application stopped as soon as any problems are detected? • Does the application appear uniform? • Do the chips have a salt and pepper appearance? • Check the percent embedment in the emulsion and adjust the emulsion and/or chip application rates if required.
Truck Operation	• Are the trucks staggered across the fresh seal coat to avoid driving over the same area? • Do the trucks travel slowly on the fresh seal? • Are starts, stops and turns made gradually? • Do the truck operators avoid driving over exposed binder/emulsion? • Do the trucks stagger their wheel paths when backing into the chip spreader? This will help eliminate chip rollover and aid in rolling.
Rolling	• Do the rollers follow closely behind the chip spreader? • Is the entire pavement surface rolled at least twice? • Are roller speeds kept at a maximum of 5 mph? • Are the rollers first pass on the meet line? • Do the rollers stay off of exposed binder/emulsion? • Are all starts, stops and turns made gradually?

Longitudinal Joints	• Is the meet line only as wide as the spray from the end of the nozzle, about 8 inches? • Does the distributor line up so that the end nozzle sprays the meet line? • Are steps taken to keep the meet lines from being in the wheel paths? Meet lines should be at the edge of a lane, center of a lane or the center of the road. • Are the meet lines covered overnight?
Transverse Joints	• Do all binder applications begin and end on building paper? • Do all chip applications begin and end on building paper or roofing felt? • Are the building paper and/or roofing felt disposed of properly?
Brooming	• Does the brooming operation dislodge aggregate? • Does brooming begin as soon as possible, but not until sufficient bond has formed between the chip and the binder? Check with the binder manufacturer for their recommendation or refer to agency requirements. • Is a flush truck required for placing water on the surface before brooming to reduce dust?
Opening the Chip Seal to Traffic	• Does traffic travel slowly, 24 mph or less, over the fresh chip seal until the surface is broomed and opened to normal traffic? • Are reduced speed limit signs posted when pilot cars are not being used? • After brooming, are pavement markings placed before opening the chip seal to normal traffic? • Are all construction-related signs removed before opening the chip seal to normal traffic?
Clean-Up	• Plan before-hand where to clean the asphalt distributor. The place must be in accordance with State laws and Department guidelines to protect the environment • Is the distributor truck thoroughly cleaned, especially its spray bar and nozzles, at the end of each day. • Is all loose aggregate from brooming removed prior to opening chip seal to normal traffic? • Are all binder spills cleaned-up?

Calibration of Asphalt Distributor

The asphalt distributor is the first piece of equipment in the chip seal construction sequence and one of the most critical. Many of the problems associated with the construction of chip seals can be traced back to improper asphalt application or poor equipment maintenance. The distributor consists of a truck-mounted insulated tank with a system of spray bars and nozzles at the back of the tank to apply a uniform application of asphalt. The tank has a heater and a circulation system that heats and circulates the asphalt in the tank and a supply system that transports the asphalt from the tank to the spray bar. The amount of asphalt that is transported to the spray bar and applied to the road surface is controlled through a valve system. These are tied together with a distance and speed measuring system to set application rates. On newer distributors, all of these functions are computer-controlled.

Before material placement begins, the equipment should be calibrated to ensure that the manufacturer's settings provide the quantities of material specified in the manufacturer's literature. It should never be assumed that the published settings for pump speed and vehicle speed are going to provide the application rate (gal/min) stated in the equipment manual. The actual output will vary with equipment age and type of material applied and its viscosity (manufacturer and temperature dependent). For calibration, the distributor nozzles may be placed over a pan of known size, and the job asphalt should be sprayed into the pan for a specified time. The amount of asphalt collected in the pan should be measured and compared with the amount predicted for the specified setting. Any differences should be noted, recorded and used to adjust the equipment settings in the field. After adjustment, the calibration procedures should be repeated to ensure proper operations.

This procedure ensures that the equipment is functioning properly; however, it does not ensure that the required amount of asphalt will be sprayed onto the pavement. A field calibration must be performed and checked at regular intervals. An initial section of roadway should be designed as a test strip prior to construction. The distributor should be weighed full and the proper computer settings made. The asphalt should then be applied to the pre-measured area at the pump settings to provide the desired coverage. The actual yield is then computed and compared to the mix design. If the amounts do not agree, the settings on the distributor should be adjusted and another test strip placed if a large adjustment was required. The chips should be placed and rolled as planned for normal construction.

A 2 foot by 2 foot pad of cotton, or some appropriate material, may be placed at different locations within the test strip to determine both the longitudinal and transverse asphalt coverage on the pavement. The pads should be weighed before and immediately after the distributor passes over them to prevent evaporation of solvent from altering the weights on the pads. The weight of asphalt on the pad and the area of the pad are used to compute the coverage of asphalt in ga/yd^2. An alternative means of determining the asphalt application rate is the procedure outlined in ASTM D 2995. However, this procedure is tedious and more time is required to obtain the test results.

Other variables to be observed during the test strip construction include the spray bar height and the nozzle settings. The height of the spray bars should be set such that the required amount of asphalt is applied in a uniform manner without streaking. The height of the spray bar controls the amount of overlap. The best results are usually achieved with double overlap, although triple overlap can sometimes be used for spray bars with nozzles spaced at 4-inch intervals. Note that spray fans at a higher height setting may be susceptible to wind effects.

Following is a summary of the recommended method for the initial calibration of the asphalt distributor before construction begins:

1. The weight of a 1 yd^2 carpet, pan or non-woven geotexile material is recorded.
2. The carpet, pan or non-woven geotexile material is placed of the road surface
3. The distributor applies oil over the carpet, pan or non-woven geotexile material.

4. The weight of the carpet, pan or non-woven geotexile material without oil is subtracted from the weight of the material with emulsion.
5. The weights applied to the material in lb/yd^2 must be converted to gal/yd^2 using the specific gravity of the emulsion. If the distributor is not spraying the binder at the correct application rate, adjustments must be made to the controls and the process described above repeated until the correct application rate is achieved.

Following is a summary of the recommended method for calibrating the asphalt distributor during random checks during construction:

1. Park the distributor on level ground and measure the number of gallons of emulsion.
2. Measure off the length of a test section.
3. Ask the distributor to apply emulsion to the test section.
4. Park the distributor on level ground and re-measure the number of gallons of emulsion.
5. Subtract the number of gallons after application from the original number of gallons to determine the number of gallons applied.
6. Divide the gallons of emulsion applied by the square yards covered by emulsion to get the application rate.
7. If the distributor is not spraying the binder at the correct application rate, adjustments must be made to the controls and the process repeated until the correct application rate is achieved.

Calibration of Aggregate Spreader

The aggregate (or chip) spreader is the second piece of equipment used in constructing chip seals. Aggregate spreaders vary from simple vane types that attach to truck tailgates, to very effective, self-propelled types. Tailgate type equipment should only be used for small, isolated work like maintenance patching. A modern, self-propelled mechanical aggregate spreader should be used for all chip seals on pavement surface rehabilitation projects.

A self-propelled pneumatic tired, motorized unit has a hopper on the front where the chips are dumped. The chips are then transported to the back where a specialized gate system drops the chips uniformly across the pavement. This equipment also includes a screen on the hopper to reject oversized rock, individually controlled gates that allow varying rock application rates across the pavement and a system using sloped screens that can separate out the larger chips and drop them ahead of the smaller chips.

The aggregate spreader should be calibrated in a manner similar to the distributor during the construction of the test strip. Pans of a specified size should be placed in front of the spreader at regular intervals across the pavement.

The aggregate placed on the pans by the spreader should be weighed to calculate the aggregate application rate in lb/yd^2 as follows:

$$\text{Aggregate Application Rate} = \frac{WT}{L \times W}$$

Where:

WT = Weight of aggregate on pan (lb)
L = Length of pan (yd)
W = Width of pan (yd)

The actual application rate is computed and compared to the required amount and if they do not agree the settings on the chip spreader should be adjusted. If a significant adjustment is required another test strip should be constructed and the processes repeated. Chip embedment should also be checked at this time to confirm design application rates.

Following is a summary of the recommended method for the initial calibration of the chip spreader before construction begins:

1. Weigh a one yd^2 piece of tarp or geotexile material.
2. Place the material on the road surface.
3. Ask the chip spreader to apply chips over the material.
4. Weigh the material with the chips.
5. Subtract the original weight from the weight of the material with the chips. Divide the weight of the chips by the area of the material to get the application rate.

Following is a summary of the recommended method for calibrating the chip spreader during random checks during construction:

1. Weigh the empty haul truck.
2. Load the haul truck with chips and re-weigh the truck.
3. Subtract the weight of the empty truck from that of the loaded truck to obtain the weight of the chips.
4. Empty all of the chips into the chip spreader.
5. Have the chip spreader apply all of the chips from the weighed truck.
6. Measure the length and width of the area over which the chips were spread.
7. Divide the weight of the chips by the area over which they were spread to determine the actual application rate.

Cleaning/Sweeping of the Existing Pavement Surface

Chip Seals should never be preformed on wet pavement. The emulsions will not break properly and the chips will not stick.

Application of Asphalt at the Desired Rate

The spray bar on the asphalt distributor should be free of clogged nozzles and set to have triple overlap. The bar should be adjusted to the correct height. Is the distributor is not properly adjusted, the Chip Seal may come out with a drilled texture, (corn rows) and will not ride smoothly or last.

Care should be taken to avoid excess overlap on the longitudinal joints. When excess overlap occurs, it looks unsightly and does not ride well on the finished product. Transfer joints should be kept clean and precise. A roll of hard paper laid out will get a nice clean joint. Overlapped transverse joints ride rough.

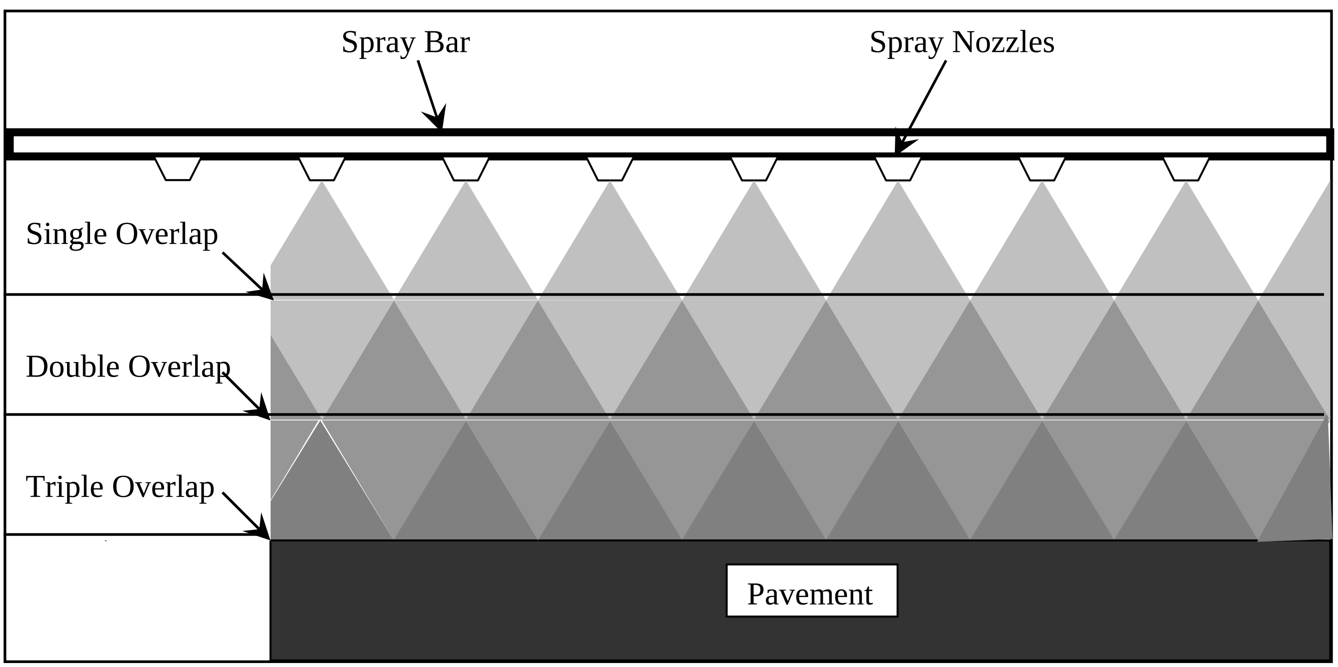


Figure 49 – Spray bar height to establish proper overlap.

The angle of the nozzle will control the uniformity of the spray pattern. These should be monitored during the test strip and continually during construction. Generally, the angle should be set between 15° and 30°.

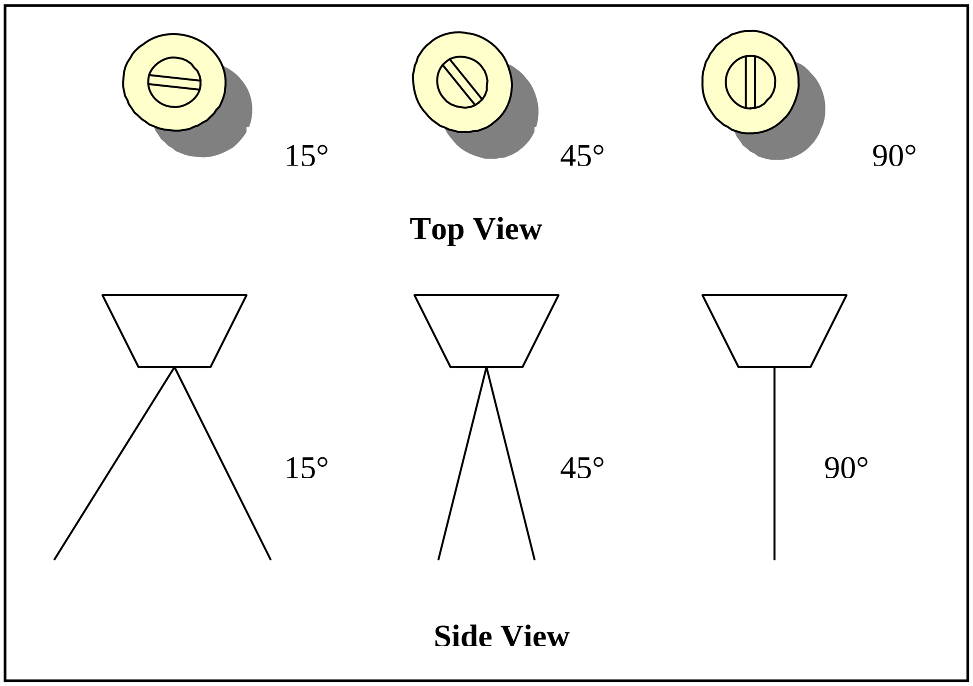


Figure 50 – Angle of spray nozzle and angle of overlap.

Application of Aggregate at the Desired Rate

Chip Sealing should never be done with dusty aggregates. The dust will interfere with the bond between the aggregate and the emulsion causing stone loss.

The chip spreader should be checked prior to the first days run to make sure the gates are set at the proper height. If the gate is set to low an insufficient amount of rock will be spread and you will get bare spots. If the gates are too high, you will use excess aggregate and have a lot of waste.

The chips should be thoroughly examined to determine if they have any contaminates such as dust of large stones. Large stone contaminates with clog the gates of the spreader causing strips in the pavement profiles and hand work to fix. Large stones can be a pain to remove from the hopper that is full of aggregate so it better not to get them in the spreader in the first place.

Rolling

Rolling should begin immediately after the aggregate has been spread. The purpose of the rolling is not compaction in the traditional sense, but rather seating or embedment of the chips. Typically, 5 ton pneumatic-tired rollers are used although rollers with weights of 3 to 8 tons are also used. Steel-wheeled rollers are not used because they may crush the aggregate and have a tendency to bridge over low spots so that no embedment occurs in those areas.

A sufficient number of rollers must be available to ensure full coverage of the application before the asphalt sets or hardens. Once the asphalt begins to harden the aggregate cannot be adequately seated and may be pulled out by traffic. The minimum amount of rolling should be no fewer than three passes. One pass of an 8 ton roller is sufficient for proper seating of the aggregate.

The finished Chip Seal should be monitored for excess aggregate loss. The pavement should be re-broomed if aggregate is continues to come up and a secondary treatment scheduled. If the Chip Seal starts losing excess aggregates a fog seal may need to be applied to tack down the aggregate. Care should be taken to make sure that the fog seal does not compound the problem.

It is very important that the distributor truck, especially its spray bar and nozzles, thoroughly cleaned at the end of each day.

<u>Cleanup, Especially the Asphalt Distributor</u>

The distributor truck, especially the spray bar and nozzles, must be thoroughly cleaned at the end of each day. Preventative maintenance, including cleaning the screens, must be done at least once a week. The distributor will clean easier when it is still warm.

Plan before-hand where to clean the asphalt distributor. The place for clean-up must be in accordance with State law and Department guidelines to protect the environment. It is not permissible to clean the asphalt distributor in a patrol yard. One idea is to clean the distributor on a pad of millings that is at least 6” thick. The clean-up will adhere to the millings and the millings can be mixed and used on a future project.

One way to dispose of distributor clean-up is to shoot the clean-up on a pile at least 6” thick of millings, mix the millings and use the millings on a future project.

Diesel oil and many release agents, including citrus oil, will burn your eyes and are highly irritating to the skin. Be sure to practice safe procedures during cleanup. Be sure to wear a face shield, goggles and protective clothing including disposable overalls and rubber gloves. Citrus oil will especially burn the skin. Some crews prefer to only use citrus at the end of the season. Remove contaminated clothing and wash any areas of your body that come in with Diesel oil or release agents immediately. If you get Diesel oil or release agents in your eyes flush your eyes with plenty of water.

Diesel oil and many release agents, including citrus oil, are highly flammable. Be careful of diesel oil, release agents or citrus oil or their fumes coming in contact with the burners in on the steam cleaner.

Soybean oil works well as a pre-coat.

All loose aggregate from brooming must be removed prior to opening chip seal to normal traffic and all binder spills must be cleaned-up and properly disposed of

Weather Requirements:

Chip Sealing should only be done in warm weather during the spring, summer or fall seasons. A chip seal project should not be attempted when air and pavement surface temperatures are below 60 °F. The aggregate will not stick to oil and the emulsions will not break in cold weather. The existing pavement surface should be dry. It is advisable not to Chip Seal in very windy conditions because the emulsion may become contaminated with dust and debris.

Problems to Avoid:

Most problems during chip seal operations can be avoided by proper planning and by taking the proper precautions. Following is a chart of typical problems and their causes encountered during chip seal projects:

Typical Cause		Problem									
		Excessive Loss of Aggregate	**Crushing**	**Pickup**	**Adhesion**	**Raveling**	**Streaking**	**Transverse Patches**	**Failure Under Tree**	**Polishing**	**Poor Mosaic**
General	Poor Traffic Control	√		√		√			√		√
	Poor Equipment	√		√		√		√	√		√
	Spray Temperature	√		√		√	√	√	√		
	Vehicle Speeds	√				√	√	√	√		√
	Jets	√				√	√		√		
Climatic Conditio	Cold Surfaces	√			√	√			√		√
	Wet	√			√	√			√		√
	Windy	√			√	√			√		
Binder	Wrong Binder	√		√	√	√	√		√		√
	Too Little Binder	√			√	√			√		√
	Too Much Binder	√		√							√
Aggregate	Too Little	√									√
	Too Much	√	√		√	√		√	√		√
	Wet	√			√	√			√		
	Dirty	√			√	√			√		
	Quality	√	√		√	√			√	√	
	Wrong Size	√				√			√	√	√
Pre-Coat	Too Little	√			√	√			√		
	Too Heavy	√				√					

Following is a chart of common problems and related solutions on chip seal projects:

Problem	Solution(s)
Computer on Distributor not Working	• Check the ground wires. • If a battery goes dead the computer will lose calibration.
Streaking or Drill Marks in the Emulsion	• Check that the emulsion is at the correct application temperature. • Check emulsion viscosity to ensure that it is not too high. • Check that the spray nozzles are at the same angle. • Check that the height of the spray bar ensures proper overlap. • Check that the spray bar pressure is not too high. • Examine the nozzles to see if any are plugged.
Exposed Emulsion After Chip Application	• Check spreader application rate. • Check that the chip spreader gate is not clogged or malfunctioning.
Excessive Chips/Many Chips with Small Amounts of Emulsion	• Check that the chip spreader gate is not malfunctioning and that the chipper head in not overloaded. • Lower the application rate.
Uneven Chip Application	• Recalibrate the chip spreader and check that all spreader gates are set the same.
Emulsion on the Top of Chips	• Check that the chip spreader is not operating too fast. • Check that the trucks, rollers and pilot cars are operating correctly.
Chips Being Dislodged	• Check that the emulsion application rate is not too light. • Check that the chips are not dirty or dusty. • Check that the traffic and equipment speeds are not too high. • Check that the proper rolling techniques are being followed. • Check that the brooming does not occur before the emulsion is properly set.
Emulsion Bleeding of Flushing	• Check that the emulsion application rate is not too high.
Loss of Chips at Centerline After Brooming	• Check the centerline procedure.
Excessive Splattering of the Emulsion	• Lower the spray pressure.

Life Expectancy of Chip Seals:

The life of a Chip Seal treatment is about 5 years. With the addition of an intermediate fog seal the life can be extended to about 8 years. Of course a lot depends on the traffic volume of the road, the amount of snow plowing, and the amounts of turning movements the road is subjected to.

Slurry Seals

Slurry sealing is the overlaying an existing pavement surface with an emulsified asphalt/ aggregate slurry. It coats, protects and/or rejuvenates the existing pavement, seals and water-proofs cracks in the pavement surface, stops stone loss, fills minor ruts and improves pavement surface friction.

Background: As a pavement ages its components undergo a variety of chemical and physical changes. Pavement will undergo oxidation of it asphalt cement making the pavement brittle and susceptible to cracking and raveling. Often slight imperfection will appear in the roadway as it ages which interfere with ride and give way to water infiltration.

In areas that a Chip Seal cannot be applied because of traffic volumes etc. another treatment to seal the road may be needed. Slurry seals do not have quite as nice of frictional characteristics or the longevity but they do seal water out. Slurry seals are usually done on low volume roads.

Procedure:

Set up the project:

1) Make an assessment of the road you are going to slurry seal. Make a check of the plan for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway. Determine the best type of emulsion and fine aggregate to be use in your slurry seal.

2) Go to the project site and see what condition the road is in. Slurry seal will not work on highly cracked pavements (greater then 10 % alligator cracking). Set up patching and crack repairs to take care of problem areas. Slurry seals do not fix structural deficiencies in pavements.

3) Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion and aggregate order:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:

Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number if contracting by square yards)

- Determine amount weight of slurry to be use on project in pounds:
  Area in Square Yards × Application Rate (usually between 17 and 18 pounds per square yard) = Pounds of Slurry Seal (if contracted in pounds stop here)
- Convert pounds of to tons:
  Pounds of Slurry Seal ÷ 2000 Pounds per Ton = Tons of Slurry Seal (if contracted in tons stop here)

4) Determine your preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Also locating a staging area for transferring from the transport tanker to the distributor and to stockpile fine aggregate.

5) Order the project off of a price agreement or get with your District's Technical Support Engineer to process a book job.

Material Types

Slurry Seals are generally binder rich mixtures with between 8.0% and 10% bitumen. Normally an emulsion is used for slurry sealing. Whether it's cationic or anionic is largely a function of the surface condition of the roadway to be treated and the emulsion's interaction with the aggregates.

Slow-Setting Emulsions

SS-1 and CSS-1 Emulsions – These are common Slow Setting Emulsions that are used throughout New Mexico. The C in CSS-1 stands for Cationic Slow Stetting Emulsion. As the name implies, these emulsions take some time to setup and have more time to penetrate into the road you are fog sealing. The drawback to these are that if you need to open the road back up to traffic you will need to wait extra time while it sets up.

Quick-Setting Emulsion

QS-1H – This is the fastest setting emulsion available.

Aggregates:

The aggregate for slurry seals are usually 85 - 100% crushed sand with a sand equivalent of 55 or greater. Non crushed angular materials are sometime used but only after the source is carefully scrutinized. No current specifications are written in the standard specifications so it is advisable to use historical specifications, current industry recommendations and specifications from other state that more commonly use this product. Slurry sealing comes in three types based on the sized of the aggregate used as follows:

Classification→	Type I	Type II	Type III
Sieve Size	% Passing	% Passing	% Passing
3/8 (9.5 mm)	100	100	100
#4 (4.75 mm)	100	90-100	70-90
#8 (2.36 mm)	90-100	65-90	45-70
#16 (1.18 mm)	65-90	45-70	28-50
#30 (600 µm)	40-65	30-50	19-34
#50 (330 µm)	25-42	18-30	12-25
#100 (150 µm)	15-30	10-21	7-8
#200 (75 µm)	10-20	5-15	5-15
Sand Equivalent	45 min	45 min	45 min

Note: These are just ranges for the design curve. An actual design should be produced and the target values should be within ±5% for the #30 and larger sieve, ±4% for the #50 sieve, ±3% for the #100 sieve and ±2% for the #200 sieve.

Primary recommended uses:

Type I – Parking lots, urban and residential streets and airport runways.
Type II – Urban and residential streets and airport runways.
Type III – Higher traffic volume roads.

Weather Requirements and Pavement Conditions:

Slurry sealing is done in warm dry weather. Wet pavements and cold pavements will interfere with the set time of the emulsion in the slurry seal.

Problems to Avoid:

Make sure aggregate stockpiles are free of debris and large stones which will catch in the placement process and cause drag marks in the finished product. If the debris makes into the mat and is flat enough, it has been known to come up leaving a hole in the mat.

Be sure to have a clean roadway surface. Slurry seals will delaminate if it does not thoroughly bond to the underlying surface.

Never use this product on a road that you are later planning on recycling. It will give you an overall pavement that contains too many fines and the mixture will have to have larger aggregate added to give you a more balanced mixture.

Life Expectancy:

Slurry sealing can be expected to add approximately 5 years to the life of the pavement it is applied to. Heavy traffic will shorten its life by about a year. Heavy turning movements will also shorten it by a year.

Scrub Seals

Background:

Sometimes pavements are so old and aged that crack sealing is not an option. Scrub Sealing is a pavement preservation treatment during which a membrane of modified binder is pressed or scrubbed into a cracked and aged surface. It's like an all-over crack seal. The existing surface may be chipped, sanded and then made smooth as with a slurry or Chip Seal.

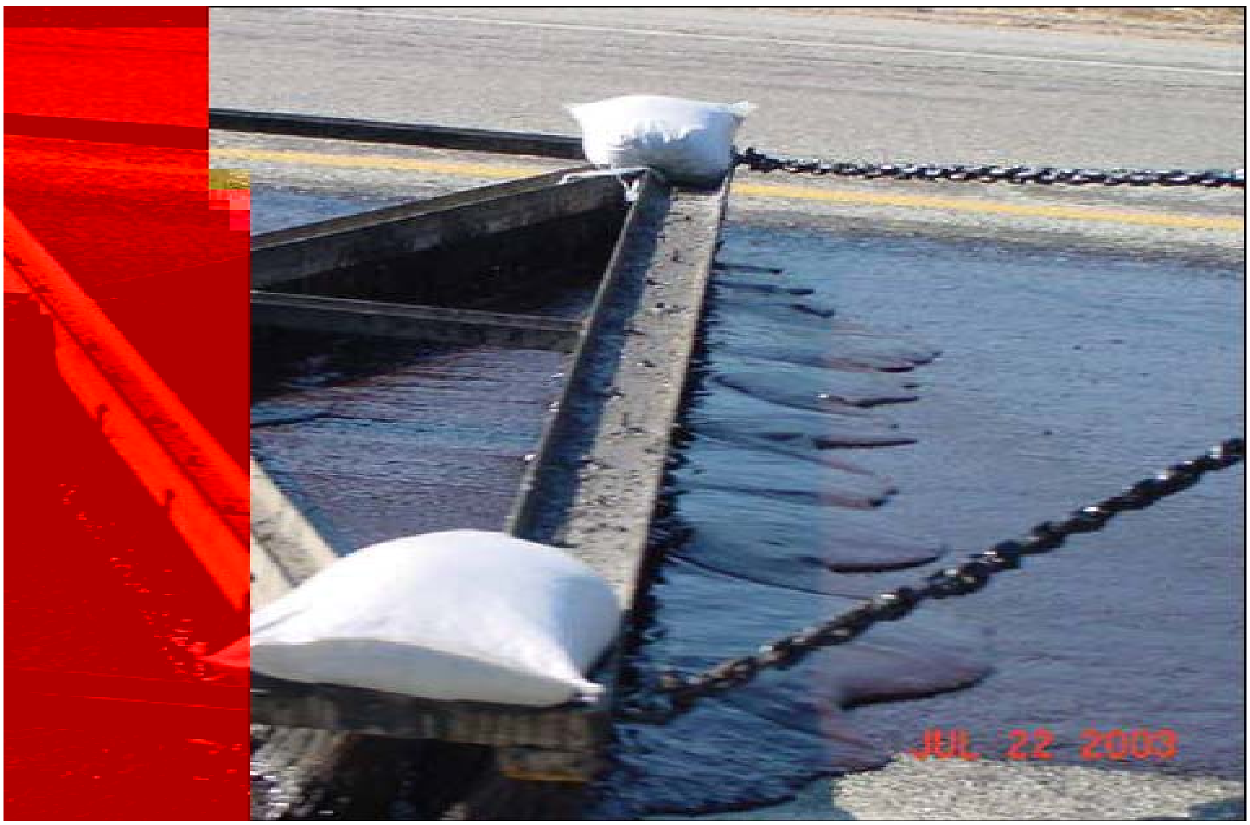


Figure 51: Scrub Broom used in Construction.

The normal procedure for performing a scrub seal treatment is:

1. Polymer-modified asphalt or an asphalt binder is applied to the surface of an existing Hot Mix Asphalt (HMA) pavement surface.
2. The asphalt is broomed into the voids and cracks of the existing pavement.
3. Sometimes, but not always, a layer of sand or small-size aggregate is laid onto the surface.
4. The surface is broomed again.
5. The surface is rolled with a pneumatic-tired roller.

The difference between a scrub seal and a chip or sand seal is that a scrub seal uses brooms to push the emulsion into the surface cracks in the pavement and to seat the binder and aggregate into the pavement surface.

Cracked and aged pavements are ideal for scrub seals. Generally highly active cracks cannot be treated with emulsion systems and an asphalt rubber scrub seal applied hot is preferred.

Purposes of scrub seals are to seal, waterproof and rejuvenate the asphalt surface and prevent further aggregate loss by holding aggregate in place. Brooming is done to help fill voids and surface cracks with asphalt. The asphalt binder acts as a rejuvenator to improve the properties of the existing asphalt. Sometimes a combination of asphalt binder and propriety chemicals to increase the rejuvenator properties of the asphalt is used.

Scrub seals are not an appropriate treatment on pavements with structural deficiencies or are bleeding.

Procedure:

Set up the project:

1) Make an assessment of the road you are going to scrub seal. Check that this road is not scheduled for re-construction or rehabilitation so you don't waste resources on a road that will be replaced anyway. Determine the best type of emulsion, sand or fine aggregate to be use in the scrub seal.

2) Go to the project site and see what condition the road is in. Scrub seals will not work on highly cracked pavements (greater then 10 % alligator cracking). Set up patching and crack repairs to take care of problem areas. Scrub seals do not fix structural deficiencies in pavements. Make an assessment of the surface absorption and any bleeding of the existing pavement.

3) Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape

measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion and sand or fine aggregate order:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number if contracting by square yards)
- Determine amount weight of asphalt and sand or fine aggregate to be use on project in pounds:
  Area in Square Yards × Application Rate (usually between 0.10 to 0.12 gallons per square yard depending on the surface conditions) = Pounds of polymer modified emulsion

4) Determine your preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Also locating a staging area for transferring from the transport tanker to the distributor and to stockpile sand or fine aggregate.

5) Order the project off of a price agreement or get with your District's Technical Support Engineer to process a book job.

Material Types:

<u>Polymer-Modified Asphalt</u>

Scrub seals are similar ton sand or Chip Seals in their material and application rates. The emulsions used for scrub seals are often polymer modified and not diluted. Polymer modification reduces temperature susceptibility, provides increased adhesion to the existing surface and allows the road to be opened to traffic earlier. When polymerized asphalt cements are used it is strongly recommended to use coated aggregate.

PASS® is a relatively new modified emulsion used in New Mexico for scrub seals. PAC-10, PAC-20, PAC-40, PAC-10TR and PAC-20TR, other polymer asphalt cements currently used by the NMDOT, are classified according to the Viscosity Grading System. Polymerized Asphalt Cements and Polymerized Asphalt Cement with Tire Rubber are classified according to the SHRP Grading system but are also included in the Viscosity Grading System. The SHRP Grading System selects the binder to be used on the roadway by using the maximum temperature at the placement location for the upper limit of the grading system and the minimum temperature for the lower number. A number of physical properties are then assigned to this temperature range per AASHTO M-320 and verified per testing listed under R-29. The SHRP Grading System does not address adhesion, cohesion, polymerization and a number of other properties of asphalt cements. Common grades under SHRP Grading System are on the top end; PG 46, PG 52, PG 58, PG 64, PG 70, PG 76 and PG 82 with the bottom end ranging -10 al the way down to -46 in six degree increments (see table 1 under AASHTO M-320). PG 76-22 is sometimes used in New Mexico.

Polymerized Asphalt Cements and Polymerized Asphalt Cement with Tire Rubber used for scrub sealing are actually covered under the SHRP Grading system listed above but are also found as an offshoot of the Viscosity Grading System. At present the only polymer asphalt cements are based on the Viscosity Grading System commonly used in the NMDOT are PAC-10, PAC-20, PAC-40, PAC-10TR and PAC-20TR. When polymerized asphalt cements are used it is strongly recommended to use a coated aggregate.

<u>Refined Asphalts</u>

Refined Asphalts can be used in scrub sealing treatments. When Refined Asphalts are used they go down very hot and the aggregates have to be applied almost immediately. Refined Asphalts are not used very often in an unmodified form because of there tendency to strip and the chips to ravel. If they are ever used here is the information on the grading systems.

- **AC Grading –** This is a method of grading asphalt based on it viscosity. The viscosity is tested prior to conditioning (not heat in a thin film oven). Here you are only testing the raw product and not accounting for any thermo-hardening used in the processes the asphalt is slated for. Common grades are AC-2.5, AC-5, AC-10, AC-15 and AC-20. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
- **AR Grading –** The A in this system stands for asphalt and the R stands for residue. This is a method of grading asphalt cement based on its viscosity. The viscosity is test after the asphalt has been conditioned in a thin film oven. The idea behind this method of grading is that it simulates hardening of the cement in the mix plant. Common grades under this system as AR-10, AR-20, AR-40, AR-80 and AR-160. This grading system can still be in countered periodically but is being replaced by the SHRP grading system.
- **Penetration Grading** - Asphalt cement classified under this system is graded based on its standard penetration at 25˚C and its absolute penetration at 60˚C. Common grades under this system are 40-50, 60-70, 85-100, 120-150 and 200-300. This grading system can still be encountered periodically, but is being replaced by the SHRP grading system.
- **SHRP Grading also called Performance-Graded Asphalt Binder–** This is the current grading system used by the State of New Mexico as well as the majority of the rest of the United States. This system uses maximum temperature at the placement location for the upper limit of the grading system and the minimum temperature for the lower number for

selecting the binder to be used on the roadway. A number of physical properties are then assigned to this temperature range per AASHTO M-320 and verified per testing listed under R-29. This is a good system but it does not address adhesion, cohesion, polymerization and a number of other properties the asphalt cements have. Common grades under this system are on the top end PG 46, PG 52, PG 58, PG 64, PG 70, PG 76 and PG 82 with the bottom end ranging -10 al the way down to -46 in six degree increments, (see table 1 under AASHTO M-320). An example binder used in New Mexico is PG 76-22.

Emulsified Asphalts

Emulsified Asphalts are commonly used in scrub sealing. Emulsified Asphalts are classified according to their chemical properties, float test (AASHTO T-50) and by their ability to setup (harden). The float test is used to characterize the flow behavior of the emulsion. Another major characterization for an emulsion is whether it is Cationic or Anionic depending on its internal electrical charge. These characteristic are how the following list of commonly used emulsions is classified.

High Float Emulsions

HFE Emulsions – These are the High Float Emulsions that are commonly used throughout New Mexico. You will commonly see them listed as HFE – 100's, HFE-150 etc.; as HFE – 100P, HFE - 150P etc. or occasionally HFRS-2, HFMS-1, HFMS-2 etc. The 'H" is there designation is what denoted them as a High Float Emulsion which also means that they have met or surpassed 1200 seconds at 60˚ on the float test (AASHTO T-50). High Float Emulsions have very good workability (fluid) characteristics and are used in not only scrub sealing but also in slurry sealing, fog sealing and occasionally in micro surfacing.

<u>Slow-Setting Emulsions</u>

SS-1 and CSS-1 Emulsions – These are common Slow Setting Emulsions that are used throughout New Mexico. The C is CSS-1 stands for Cationic Slow Stetting Emulsion. As the name implies, these emulsions take some time to setup and have more time to penetrate into the road you are sealing. The drawback to these are that if you need to open the road back up to traffic you will need to wait extra time while it sets up.

<u>Medium-Setting Emulsions</u>

MS-1, MS-2, CMS-1 and CMS-2 – These are the common Medium Setting Emulsions that are used throughout New Mexico. Like the slow setting emulsions, the "C" in CMS-1 and CMS-2 stands for Cationic meaning a positively charged emulsion. The setup time on these emulsions is a faster then the slow sets giving more flexibility to how fast traffic is put back on the treated pavement and the workable time.

<u>Rapid-Setting Emulsions</u>

RS-1, RS-2, CRS-1 and CRS-2 – These are the rapid setting emulsions that are available in New Mexico. With the CRS-1 the road was returned to traffic in as little as 30 minutes without sanding the roadway.

<u>Quick-Setting Emulsion</u>

QS-1H – This is the fastest setting emulsion available.

<u>Sand and Aggregate</u>

Material requirements for sand and aggregate design are found in the sections on sand seals and Chip Seals, respectively.

Construction:

<u>Traffic Control</u>

Traffic Control should be in place before work forces and equipment enters onto the roadway or into the work zone. Traffic control is required both for the safety of the traveling public and the personnel performing the work. Traffic control includes construction signs, construction cones and/or barricades, flag personnel and pilot cars to direct traffic clear of the maintenance operation. For detailed traffic control requirements refer to the Federal Manual on Uniform Traffic Control Devices (MUTCD) or agency requirements.

Traffic control is also required to protect the integrity of the application. The curing time for the scrub seal material will vary depending on the pavement surface conditions and the weather conditions at the time of application. Under ideal conditions, it is suggested that the traffic be kept off the scrub seal material for at least 2 hours.

Surface Preparation

Immediately before applying a scrub seal the pavement surface must be cleaned with a road sweeper, power broomed, or flushed with a water pump unit to remove dust, dirt and debris. The pavement surface must be clean and dry before applying the scrub seal. Any existing distress that required to be repaired should have been done so.

Equipment Needs

At a minimum you will need:

- A chip spreader
- Asphalt distributor
- A Loader
- Dump trucks (tandems preferable) or flow boys
- Brooms
- Rollers
- Water truck
- Traffic Control vehicles
- Backup equipment (optional)

At the beginning of each day the supervisor should make sure that the equipment is in good mechanical condition. For example, all equipment should be free of leaks, calibrated and clean. More specific equipment inspection recommendations include the following:

- Brooms: The brooms used to clean the pavement surface should be inspected to make sure the bristles are of proper length and in good condition and that the vertical pressure on the broom can be adjusted.
- Spray Distributor: A visual inspection of the spray distributor should be conducted to ensure that the spray bar is at its proper height, all nozzles are uniformly angled 15° to 30° from the spray bar and that all nozzles are free of clogs. Next, the spray distributor should be tested to check that the spray pattern is uniform and the proper overlap (double or triple) is being achieved, the proper application pressure is being used and that a working and calibrated thermometer is on site.
- Sand Spreader: For treatments that include an application of sand, the sand spreader needs to be inspected to check the gate control and settings, the spreader's calibration across the entire

spreader head and the truck hookup hitches. The supervisor should also check to make sure that the sand is flowing freely from the spreader.
- Haul Trucks: Each haul truck must be inspected to make sure that the truck box is clean and free of debris and that the truck hookup hitch is in working order. If a truck box apron or extension is required for loading the sand spreader make sure that it is available on site.

Asphalt Distributor

The asphalt distributor is the most critical element in the construction of scrub seals. Many of the problems associated with the construction of scrub seals can be traced back to improper asphalt application. The distributor consists of a truck-mounted insulated tank with a system of spray bars and nozzles at the back of the tank to apply a uniform application of asphalt. The tank has a heater and a circulation system that heats and circulates the asphalt in the tank and a supply system that transports the asphalt from the tank to the spray bar. The amount of asphalt that is transported to the spray bar and applied to the road surface is controlled through a valve system, an asphalt pump with a pump speed or pressure controls and nozzles of a prescribed size. These are tied together with a distance and speed measuring system to set application rates.

Before a job is begun, the equipment should be calibrated to ensure that the manufacturer's settings provide the quantities of material specified in the manufacturer's literature. It should never be assumed that the published settings for pump speed and vehicle speed are going to provide the application rate (1 gallon/minute) stated in the equipment manual. The actual output will vary with equipment age and type of material applied and its viscosity which is manufacturer and temperature dependent. For calibration, the distributor nozzles may be placed over a pan of known size, and the asphalt sprayed into the pan for a specified time. The amount of asphalt collected in the pan should be measured and compared with the amount predicted by the specified setting. Any differences should be noted, recorded and used to adjust the settings in the field.

This procedure ensures that the equipment is functioning properly. However, it does not ensure that the required amount of asphalt will be sprayed onto the pavement. A field calibration must be performed and checked at regular intervals. An initial section of roadway should be designated as a test strip prior to construction. The distributor should be weighed full and the proper pump settings made. The asphalt should then be applied to the pre-measured area at the pump settings to provide the desired coverage and the actual yield computed and compared to that required. If the amounts do not agree, the settings on the distributor should be adjusted, and another strip test strip placed if a large adjustment was required. The chips should be placed and rolled as planned for normal construction.

A 2 foot by 2 foot pad of cotton, or some other appropriate material, may be placed at different locations within the test strip to determine the coverage both longitudinally and transversely on the pavement. The pads should be weighed before and immediately after the distributor passes over them to prevent evaporation of solvent from altering the weights on the pads. The weight of asphalt on the pad and the area of the pad are used to compute the coverage of asphalt in gallons/square yard.

Other variables to be observed during the test strip construction include the spray bar height and the nozzle settings. The height of the spray bars should be set such that the required amount of asphalt is applied in a uniform manner without streaking. The height of the spray bar controls the amount of overlap. The best results are usually achieved with double overlap, although triple overlap can sometimes be used for spray bars with nozzles spaced at 4 inch intervals. Spray fans at higher height settings may be susceptible to wind effects.

The angle of the nozzle will control the uniformity of the spray pattern. These should be monitored during the test strip and continually during construction. Generally, the angle should be set between 0.26 and 0.52 radians (15° and 30°).

Application Rates and Spraying

Properly calibrated distributor trucks are used to apply the emulsion. Spray nozzles with 4 to 5 mm (0.16 to 0.2 inch) openings are recommended. The emulsion may be heated to 122 °F maximum, although, generally the emulsion is sprayed at ambient temperature. The emulsion is sprayed at a rate that is dependent on the surface conditions (see the following table). As discussed above, a test section representative of the entire surface should be chosen to approximate application rates. Typical application rates for diluted emulsion (50/50) range from 0.10 to 0.12 gallon/yard^2, depending on the surface conditions.

Suggested Scrub Seal Application Rates

% Emulsion (Emulsion + Water)	**Dilution Ratio (Emulsion + Water)**	**Type of Surface to be Scrub Sealed**	
		Dense Surface (Low Absorption), gallon/yard^2	**Open Surface (High Absorption), gallon/yard^2**
Net residual asphalt desired (no dilution)		0.01 to 0.03	0.03 to 0.05
50	1 + 1	0.03 to 0.11	0.09 to 0.23
40	2 + 3	0.04 to 0.13	0.12 to 0.30
25	1 + 3	0.06 to 0.21	0.19 to 0.47
20	1 + 4	0.08 to 0.25	0.24 to 0.59
16.7	1 + 5	0.09 to 0.31	Too High
14.3	1 + 6	0.12 to 0.41	Too High
12.5	1 + 7	0.13 to 0.47	Too High

Ideally, one-half of the application should be sprayed in each direction to prevent a “rain shadow” effect and build up on one side of stones (this is particularly important in the case of scrub seals). Build up on one side can result in a slippery surface and inadequate binder to fully enrich the surface or hold the chips.

Estimating Optimum Application Rate

To estimate the application rate, take a one-quart can of diluted emulsion (usually 50/50) and pour evenly over an area of 1 yard^2. This is a diluted application rate of 0.024 gallon/foot^2. If the emulsion is not absorbed into the surface after 2 to 3 minutes, decrease the amount of emulsion (i.e., increase the dilution rate) and apply to a new 1 yard^2 area. Repeat this process until the approximate application rate is found. If after the first test the surface looks like it can absorb more emulsion, increase the amount of emulsion (i.e., decrease the dilution rate) and spread it over a new 1 yard^2 area. Repeat until the approximate application rate is found.

Checking Application Rate

The emulsion application rate should be monitored throughout the project. Two different methods are used depending on whether the rate is being checked for calibration purposes or as part of a random check during the construction process.

Recommended Method for Calibration

The asphalt distributor is typically calibrated prior to construction by placing a 1 yard^2 pan or non-woven geotexile of known weight on level ground. Next, the emulsion is applied over the pan or geotexile fabric. The weight of the applied emulsion applied on the pan or geotexile fabric is determined by subtracting the before application weight from the weight of the pan or fabric after being sprayed with emulsions. Finally, the application rate is determined by converting the weight of the applied emulsion to a volume and dividing the volume of applied emulsion by the area of the pan or fabric.

Recommended Method for Random Checks

Random checks of the application rate should be accomplished using test sections. Specifically, the following steps are used:

- Park the distributor on level ground and measure and record the number of gallons of emulsion in the tank.
- Measure the area of a test section.
- Apply emulsion to the test section.
- Re-measure the number of gallons of emulsion in the tank.
- Determine the application rate by dividing the amount of emulsion applied over the test section.

<u>Asphalt Distribution</u>

After the surface has been prepared by sweeping the binder is sprayed onto the surface of the existing pavement. During the application of the emulsion the following activities should be included:

- Building paper should be used at the starting and stopping points of the treatment to create straight edges.
- Check to confirm that the emulsion is within the required application temperature range.
- Conduct visual checks to make sure that the emulsion application appears uniform and no drilling or streaking is visible.
- Check the nozzles to make sure that they are not plugged.
- Perform random checks of the application rate.
- If applicable, make sure that the distributor adjusts speed to match the chip spreader speed to prevent stop-start operations.
- Stop the distributor and make the necessary adjustments if any problems are observed.

Then the binder is scrubbed into the surface with a broom to fill the cracks and voids. Then a layer of fine aggregate or sand is applied using a chip spreader. During the application of sand or chips the following activities should be included:

- Verify that enough trucks are on hand to keep a steady supply of sand or chips for the spreader.
- Check that building paper is being used to create straight edges at treatment starting and stopping points.
- Conduct visual checks to make sue that the sand application appears uniform and that no emulsion is on top of the sand.
- Stop the sand or chip application and make necessary adjustments if any problems are observed.
- The operation of trucks at the job site should be monitored to ensure that practices are being used that will not damage the freshly placed treatment. First truck operators should avoid driving over the freshly applied exposed emulsion. If an aggregate cover layer has been used trucks should travel slowly and be staggered across the fresh treatment to avoid driving over the same area. Stops and turns should be made gradually to avoid dislodging aggregate.

The final operation is several passes from a muli-tyred roller.

The road is usually opened to traffic after sweeping or may be opened to slow moving traffic almost immediately. However, until the applied emulsion is given adequate time to cure; traffic on the treatment must be closely monitored. Ideally, a pilot car should be used to control traffic speed. Traffic speed should be kept below 25 mph on the fresh seal coat until it is deemed acceptable to open to normal traffic. If pilot cars are not an option for the project, reduced speed limit signs should be used. The facility should not be opened to normal traffic until adequate friction is restored.

Post Treatment Considerations

Sand blotters may be used at approximately 1.84 pound/yard^2 to allow early opening to traffic. Sweeping may be required. The supervisor should assess this after application and opening to traffic. If it is believed that the surface friction characteristics have been reduced to unsatisfactory levels this can be measured with a skid tester or other surface texture measuring device. The pavement should not be opened to traffic if adequate friction has not been restored, especially if wet weather is anticipated.

Weather Requirements

To be effective scrub seals need to break quickly (revert to solid asphalt) and cure completely (lose water to form a cohesive film). This should be at a rate that allows traffic to be accommodated without the binder being picked up by vehicle tires. To achieve this goal, the film forming properties must be adequate (i.e. the binder must be able to coalesce into a continuous film prior to allowing traffic on the new seal). Because asphalt films do not form well at low temperatures in the absence of low viscosity diluents, warm conditions with no chance of rain are necessary to ensure successful applications. The aggregate will not stick to oil and emulsions will not break well in cold weather. Scrub sealing should only be done in hot dry weather during the spring, summer or fall seasons. Scrub seals should not be applied when the temperature is below 40 °F or when pavement temperatures are below 60 °F. It is not advisable to scrub seal in very windy conditions because the emulsion may become contaminated with blowing dust and debris.

At the beginning of each day the expected weather conditions should be compared to those conditions specified as being acceptable for construction. In general, the following weather-related guidelines should be considered:

- The supervisor should ensure that air surface temperatures have been checked at the coolest location on the project and that these observed temperatures meet agency requirements.

Problems to Avoid

Be sure to have a clean, dry roadway surface. Scrub seals will delaminate if it does not thoroughly bond to the underlying surface.

Scrub seals should never be done with dusty sand or fine aggregates. The dust will interfere with the bond between the aggregate and the emulsion causing stone loss.

The spray bar on the asphalt distributor should be free of clogged nozzles and set to have triple overlap. The bar should be adjusted to the correct height. Is the distributor is not properly adjusted, the scrub seal may come out with a drilled texture, (corn rows) and will not ride smoothly or last.

The chip spreader should be checked prior to the first days run to make sure the gates are set at the proper height. If the gate is set to low an insufficient amount of rock will be spread and you will get bare spots. If the gates are too high, you will use excess sand or fine aggregate and have a lot of waste.

The chips should be thoroughly examined to determine if they have any contaminates such as dust of large stones. Large stone contaminates with clog the gates of the spreader causing strips in the pavement profiles and hand work to fix. Large stones can be a pain to remove from the hopper that is full of sand or fine aggregate so it better not to get them in the spreader in the first place. Debris and large stones will catch in the placement process and cause drag marks in the finished product. If the debris makes into the mat and is flat enough, it has been known to come up leaving a hole in the mat.

Care should be taken to avoid excess overlap on the longitudinal joints. When excess overlap occurs, it looks unsightly and does not ride well on the finished product.

Transfers joint should be kept clean and precise. A roll of hard paper laid out will get a nice clean joint. Overlapped transverse joints ride rough.

The finished scrub seal should be monitored for excess aggregate loss. The pavement should be re-broomed if aggregate is continues to come up and a secondary treatment scheduled. If the scrub seal starts losing excess aggregates a scrub seal may need to be applied to tack down the aggregate. Care should be taken to make sure that the scrub seal does not compound the problem. The following table provides some trouble shooting guidelines for scrub seals:

Problem	Typical Cause(s)	Typical Solution(s)
Spattering of the emulsion	• Emulsion has been diluted too much. • Spray bar is not at proper height. • Spray pressure is too high.	• Adjust the emulsion dilution rate. • Make necessary adjustments to the spray bar height and pressure.
Streaking or drill marks appearing in the emulsion	• Emulsion is too cold. • Viscosity of the emulsion is too high. • All nozzles are not at the same angle. • Spray bar is not at proper height. • Spray bar pressure is too high. • Nozzle is plugged.	• Review emulsion temperature requirements. • Verify that the selected emulsion is appropriate for site conditions. • Check the spray bar height and pressure and the nozzle angles and make necessary adjustments. • Check nozzles for obstructions and clear any that are found to be plugged.
Flushing or bleeding of the emulsion	• Emulsion application is too high.	• Review the selected application rate and adjust as necessary.

Life Expectancy of Treatment

The life of a scrub seal treatment is about 5 years. With the addition of an intermediate scrub seal the life can be extended to about 8 years. Of course a lot depends on the traffic volume of the road, the amount of snow plowing, and the amounts of turning movements the road is subjected to.

Microsurfacing

Microsurfacing is the overlaying an existing pavement surface with an emulsified asphalt/ aggregate slurry. It coats, protects and/or rejuvenates the existing pavement, seals and water-proofs cracks in the pavement surface, stops stone loss, fills minor ruts and improves pavement surface friction.

Background: As a pavement ages its components undergo a variety of chemical and physical changes. Pavement will undergo oxidation of it asphalt cement making the pavement brittle and susceptible to cracking and raveling. Often slight imperfection will appear in the roadway as it ages which interfere with ride and give way to water infiltration.

Microsurfacing is a type of slurry sealing is used to restore the ride/comfort to the users of a road. It will not add any structural valve to the road but will seal off minor cracking and fill ruts. Asphalt roads are susceptible to rutting which is often cured by planning the road and overlaying which is very expensive. A less expensive alternative is to fill the ruts with Micro- Surfacing to restore the original pavement profile. This is especially cost effective when only needing a few years of improvement prior to a reconstruction project.

Figure 52: A Microsurfacing operation.

Procedure:

Set up the project:

1) Make an assessment of the road you are going to Microsurface. Make a check of the plan for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway. Determine the best type of emulsion and fine aggregate to be use in your microsurfacing project with the help of your contractor.

2) Go to the project site and see what condition the road is in. Microsurfacing will not work on highly cracked pavements (greater then 10 % alligator cracking). Set up patching and crack repairs to take care of problem areas. Microsurfacing does not fix structural deficiencies in pavements.

3) Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion and aggregate order:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number if contracting by square yards)
- Determine amount weight of microsurfacing to be use on project in pounds:
  Area in Square Yards × Application Rate (usually between 17 and 18 pounds per square yard) = Pounds of Microsurfacing (if contracted in pounds stop here)
- Convert pounds of to tons:
  Pounds of Microsurfacing ÷ 2000 Pounds per Ton = Tons of Microsurfacing (if contracted in tons stop here)

4) Determine your preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Also locating a staging area for transferring from the transport tanker to the distributor and to stockpile fine aggregate.

5) Order the project off of a price agreement or get with your District's Technical Support Engineer to process a book job.

Material Types:

Microsurfacing mixes are generally binder rich mixtures with between 8.0% and 10% bitumen. Normally an emulsion is used for microsurfacing is an advance polymer that is heavily modified to add strength and durability. Whether it's cationic or anionic is largely a function of the surface condition of the roadway to be treated and the emulsion's interaction with the aggregates. Generally a rapid setting emulsion is used for microsurfacing in order to get traffic back on the road as soon as possible.

Rapid-Setting Emulsions:

RS-1P and CRS-1P Emulsions – These are common Polymerized Rapid Setting Emulsions that are used throughout New Mexico. The C is CRS-1P stands for Cationic Slow Stetting Emulsion. As the name implies, these emulsions take some time to setup and have more time to penetrate the mix and the road below the surfacing. The drawback to these are that if you need to open the road back up to traffic you will need to wait extra time while it sets up.

Quick-Setting Emulsion:

QS-1H – This is the fastest setting emulsion available. They have similar properties to the rapid setting emulsions but do set up much quicker.

Aggregates:

Microsurfacing is essentially a type of slurry sealing with a greater degree of crushed stone and some additives to increase strengths. Microsurfacing is classified under the same system as a slurry seal but you use Type II and Type III aggregate gradations. General specifications are as follows:

Classification→	Type II	Type III
Sieve Size	% Passing	% Passing
3/8 (9.5 mm)	100	100
#4 (4.75 mm)	90-100	70-90
#8 (2.36 mm)	65-90	45-70
#16 (1.18 mm)	45-70	28-50
#30 (600 µm)	30-50	19-34
#50 (330 µm)	18-30	12-25
#100 (150 µm)	10-21	7-18
#200 (75 µm)	5-15	5-15
Sand Equivalent	65 min	65 min

Never use this product on a road that you are later planning on recycling. It will give you an overall pavement that contains too many fines and the mixture will have to have larger aggregate added to give you a more balanced mixture.

Make sure the microsurfacing paving machine is properly adjusted so that you do not get chatter cracking or marking on the mat.

Be sure to place the longitudinal joints at the edges of the traffic lane.

Life Expectancy:

The life expectancy of this treatment is about 5 years. Low volume roads have gotten as much as 7 years in the past. Snow plowing and heavy traffic can lower this time by 1 to 2 years.

Cape Seals

Background: Cape seals are a combination of a Chip Seal covered with a slurry seal or a micro-surface. The idea behind this treatment is to provide a smoother surface then a Chip Seal can by itself. The slurry seal portion also fills in the space between the Chip Seal aggregate providing additional stability to the Chip Seal aggregate and giving a thicker membrane. This process prevents water intrusion into the subsurface better then either process alone.

Procedure: Design a Chip Seal per the Chip Seal section of this document. Make sure you will be able to have the Chip Seal in place for a minimum of two weeks without the addition of the microsurfacing. If your Chip Seal is in an extremely high traffic area you may have to reduce traffic speeds for a short time so that the Chip Seal does not come apart before the microsurfacing is added.

Design the microsurfacing to cover the Chip Seal.

Place the Chip Seal on your project area. Generally since microsurfacing is order off of a contract it will control when the Chip Seal is placed. This coordination is best achieved if the project is planned out before the beginning of the construction season.

Once the Chip Seal is in place you will need to let it set up for a minimum of two weeks prior to placing the microsurfacing. This allows the emulsion used in the Chip Seal to cure/harden. Place the micro surfacing and order the pavement marking.

Material s: See the sections under Chip Sealing and microsurfacing.

Equipment: See the sections under Chip Sealing and microsurfacing.

Weather Conditions and Pavement Conditions: See the sections under Chip Sealing and microsurfacing.

Problems to Avoid: The Chip Seals needed to be thoroughly swept prior to placing the microsurfacing. The Chip Seal must have a uniform texture with no projections that will interfere with the placement of microsurfacing. Chip Seals should be given additional time if they were placed just prior to wet weather so that they are thoroughly cured before the microsurfacing is placed.

The same concerns listed under each respective process also apply here.

Life Expectancy: The life expectancy of a cape seal is 7 years. The life expectancy can be expected to go down in heavy snow regions. In light traffic areas in remote locations a cape seal may last up to ten years.

Pavement Remixing In-Situ

Pavement Remixing In-Situ is the removing the top portion of an existing pavement, combining that material with recycling agent and sometimes fresh aggregate on site, replacing and compacting the reworked material and overlaying it with hot Plant Mixed Bituminous Pavement. It removes, remixes and replaces upper layers of deteriorating pavement, corrects surface defects such as deep rutting and minor cracking, adds structural strength.

Background: It seems intuitive that an asphalt road can be heated up, remixed and put back down. After all, the glue that binds the road together is Asphalt Cement which is heated up in the first place. It is not quite that simple, asphalt cement as it ages looses various constitutes and becomes brittle. Fine materials migrate into the pavement from tracking on automobile tires and wing blown debris causing gradation changes that need to factor in. The basic principal is sound but various rejuvenating agents and or aggregates may need to be added.

Figure 53: A Cold In-Situ Recycle Operation.

Figure 54: A Hot In-Situ Recycling Operation.

Procedure: Set up the project:

1. Make an assessment of the road you are going to apply your In-Situ Recycling Treatment too. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so yon don't waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Heavily cracked roads and roads with base failures are not good candidates for this process. This process works best for roads with minor surface imperfections and raveling do to oxidation.

3. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape

measure. From your measurements determine the number of square yards to be recycled as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)

4. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

5. When construction begins, you should start with a test strip to determine the application rate of rejuvenator to be added.

Materials: The only material for the vast majority of these projects is a rejuvenating agent. These are usually proprietary products that contain asphalt cement softeners.

Equipment: All equipment is provided by the contractor assigned to recycle the pavement. Their equipment will consist of a heaters and mills that feed a lay down machine. You will also have a number of trucks supplying Asphalt rejuvenating Agents and if needed aggregate.

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer), dry and wind free days. Windy days cause the material to cool down to quick for proper compaction. Rain interferes with the bonding of the layers and can interfere with proper adhesion of the particles.

Problems to Avoid: Be sure that the proper amount of rejuvenator is being added to the mix. Too little rejuvenator with result on a loss of cohesion in the mat and raveling will occur. Too much rejuvenator will cause the mat to become overlay malleable and the finished product will be prone to bleeding and rutting.

On higher volume roads it is recommended that a surfacing course be use in combination with the recycle. This seems to extend the life of the product quite a number of years.

Life Expectancy: The life span of this treatment appears to be about 7 years.

Pavement Remixing At the Plant

Background: Often when dealing with pavements you reach a point that simple overlays and various surface treatments are no longer appropriate. This can be because you wish to add shoulders, the pavement is so badly cracked or you need to rework the subgrade. At this point you basically have a choice between conventional reconstruction and recycling the road. Reconstruction by adding new asphalt is by far the best approach to achieving the desired roadway. Recycling has its advantage in the for many parts of the state, asphalt has to be delivered from a plant 100+ miles distant making new asphalt uneconomical. Recycling also has the advantage to reusing what is essentially a waste material.

Figure 55: A Warm Lay (Braiser) Operation.

Procedure: Set up the project:

1. Make an assessment of the road you are going to apply your Recycling Treatment too. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so yon don’t waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Grab samples of the pavement or adjacent millings stockpiles to determine what is needed for the mix design. Be sure that the treatment is appropriate. Other less costly treatments may be available which may provide approximately the same economic/engineering value. This process is used when reconstruction is needed because the road is so far deteriorated that maintenance is impractical or the surfacing geometry needs to be changed.

3. Schedule project around traffic flows if in the semi-urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

4. Coordinate between contractors if necessary. Often one contractor will be milling up the old roadway that is being recycled and another contractor will be remixing the cuttings for placement back on the roadway. The two operations do not necessarily have to be done at the same time, but on low volume roads without much surfacing this is often the only way of using this technique.

Materials:

The materials used in this process are basically recycled asphalt pavement cuttings and a polymerized or un-polymerized high float emulsion.

The cuttings need to be processed through a screening plant to generate a uniform aggregate that has a one inch nominal maximum sized.
The high float emulsion shall be established during the mix design. A sample of cuttings or pavement shall be tested by the contractor so that the percentage rate of emulsion added to the mix is established. The type of emulsion to be used will also be determined during this design process. One the contractor has established the mix design it shall be reviewed and approved by the Department. The emulsion shall meet the requirements of section 402 of the New Mexico department of Transportation Department’s most current addition of the Standard Specifications for Highway and Bridge Construction.

Equipment:

Portable Crushing/Screening Plant with Integral Pug mill Mixer. This plant shall reduce the size of the cuttings to a one inch nominal maximize and thoroughly mix the cutting with emulsion for placement on the roadway

Trucking from the plant to the job site is an essential part of the process. The number of trucks should be balanced so that output of the pant is arriving at the paving machine in a continuous fashion and the Paving machine is always moving.

Self Propelled Paving Machine. A standard self propelled paver used in normal hot mix asphalt paving operations is normally used. The heating elements on the screed will be turned off.

Rollers. A combination of rubber tired and steel wheel rollers are normally used. These rollers need to be equipped with a water spraying system and pads to aide in the prevention of the material from sticking to the wheels. The weight of these rollers shall conform to section 415.31 of the New Mexico Department of Transportation Department's Standard Specifications for Highway and Bridge Construction.

Weather and Pavement Conditions: This process is temperature sensitive. It must be placed at 60˚F or higher. The wind chill factor should never go below 35˚F.

This process is also very moisture sensitive. The material should never be placed on wet surfaces or in the rain.

Problems to Avoid: The treated material should be kept at constant moisture. If the material gets too dry it will become friable and ravel.

Care should be taken to properly screen the cuttings to specification. When the cuttings are not properly crushed to the proper size, the resulting placement will have soft spots (resulting in density problems) or drag marks.

Life Span of treatment: This treatment has an expected life span of 7 years.

Hot-Mix Overlay

A Hot-Mix Overlay is the overlaying an existing pavement with hot Plant Mixed Bituminous Pavement (PMBP). It adds structural strength, corrects surface defects such as deep rutting and minor cracking and extends pavement life.

Background: One of the most used and more successful treatments that can be used in road maintenance is a simple thin lift overlay. Overlays are both a preventative treatment and in reconstruction maintenance. For the most part in this manual we will be looking at a thin 2 to 3 inch treatment that is used as a preservation treatment to seal backup the roadway and provide additional wearing surfacing. This is for the most part, the technique that is used on higher volume roads that can’t be Chip Sealed. This is usually done at 10 to 15 years into the lifespan of your higher volume roads.

Figure 56: A Plant Mix Bituminous Pavement overlay.

Procedure: Set up the project:

1. Make an office assessment of the road you are going to overlay with hot-mix asphalt concrete. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so you don’t waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Road that have completely failed are not good candidates for this treatment. The road may have localized failures that should be corrected by digging them out and replacing them. This approach should never be used on a road that is so far decayed that it can't be built over. If this is the case the, road should be reconstructed.

3. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. From your measurements determine the number of square yards or ton of hot-mix to be used in the overlay as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)
- Convert square yards of area to volume:
  Thickness of Overlay in Inches ÷ 36 Inches per Yard = Thickness in Yards
  Thickness in Yards × Area in Yards = Volume of Overlay in Cubic Yards
- Convert Cubic Yards of Material to Tons:
  Cubic yards of Hot-Mix × Unit Weight of Material (Provided by Lab) = Tons of Hot Mix. (Use this number if contracting of placing yourself)

4. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

5. When construction begins, you should start with a test strip to determine the amount of compaction to be applied to the mat.

Materials: New Mexico Department of Transportation uses the Super-Pave classification and test methods as a basis classification of our hot-mix materials in this state. We do have a number of grades of asphalt cement that have been set up for various regions of the state depending on the climate. Be sure to check with the Central Laboratory for the latest recommendation and discuss any localized factors such as traffic loads, terrain or temperature extremes that may assist the lab in proper asphalt cement selection.

If you are working off of a price agreement for either the material or a finished product, you must use an approved mix design from the NMDOT Central Laboratory. The mix design may be one that is already in place or be designed specifically for the project you are putting forth. If you are generating a new mix design plan on submitting it at least six weeks prior to commencing paving operations.

If you are working with a book project most of the approvals and timeline are spelled out in the contract.

Materials Testing: Hot-Mix Asphalt products need to be tested per the Department's Current "Minimum Testing Requirements" and per the section of the New Mexico Department of Transportation's current Standard Specification for Highway and Bridge Construction. The appropriate section of the standard Specifications will be spelled out in the Book Projects contract pages or if using a Price Agreement (on-call contract) in it contract language.

Equipment: The equipment needed for a standard paving operation is what you will need in an overlay. The biggest think to be cognizant of is that you will need an area that is safe to park all of the equipment needed for your overlay.

The standard list of construction equipment is as follows:

- Hot-mix Asphalt Concrete paving machine and optional backup machine.
- Five to Ten dump trucks to haul HMA to the paving machine.
- Power broom for cleaning road before and after paving operation.
- Asphalt distributor with Tack Oil.
- 10 ton pneumatic roller.
- 2 Steal wheel rollers one of which should be vibratory.
- A water truck for servicing rollers and cooling intersections.
- A small tractor with bucket for spills and joint cuts.

An optional list of construction equipment is as follows:

- A small mill for bridge joint cuts.
- A HMA loader such as co-cal.
- Diamond grinder for out of specification areas.
- Portable walk behind striping machine.

The standard list of field testing equipment is as follows.

- A straight edge for checking joints.
- 3 to 4 foot Level with wedge for checking crown and cross slope.
- Depth/thickness gage for mat thickness.
- Access to a fully equipped HMA field lab.

- An IRI (International Roughness Index) testing device.
- A minimum 25 length measuring tape.
- Thermometer for checking HMA temperature.

The larger pieces of equipment will either need to be stored behind a barrier or beyond the clear zone of the roadway.

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer) and dry days. Cold weather will cause the HMA to cool down before proper compaction has taken place providing a weak product. If the HMA is placed on a cold surface often the HMA will not bond to the underlying pavement and will delaminate over time. Rain interferes with the bonding of the layers and can cool the HMA before it is properly compacted.

Problems to Avoid:

- Be sure that the road is clean before over lay is started. A dirty road will cause the pavement layers not to bond properly and the finished product will fail.
- Be sure to use a NMDOT approve mix design. And be sure that the supplier is providing the proper HMA per the design. These mix designs are set-up for the traffic loads, longevity and maintainability the state road system requires.
- Insure a proper taper is provided on the outside of the road. After the paving operation is complete, the shoulder should be pulled up for a smooth transition form the paved surface to the shoulder in case an errant vehicle leaves the road.
- The height of any guardrail or barrier should be adjusted if need be to function properly.
- Inside (linear) joints should be properly compacted to avoid raveling or future degradation. Pinching and tacking are advisable.
- Be sure all specifications are being met to insure a long product life.
- Be sure contractor has a continuous operation the improve smoothness and overall quality of the pavement.
- Work with an experienced asphalt inspector for a good product. Remember expertise is only as far away as a phone call to the District Lab, General Office Central Lab or the State Maintenance Bureau.

Life Expectancy: The life span of this treatment will be about 10 years if the overlay in preformed on a road that is in good shape. If you have a poor road the life will drop off dramatically. An overlay will not hide a poor road surface for very long.

Milling and Hot Mix Inlay/Overlay

Milling and Hot Mix Inlay/ Overlay processes are the milling and removing the upper layer of pavement and overlaying it with hot Plant Mixed Bituminous Pavement. It removes upper layers of deteriorating pavement, corrects surface defects such as deep rutting and minor cracking. It also maintains vertical alignment with curb and gutter.

Background: Often a road can not be use overlaid because its surface is rough or badly oxidized. In this case the surface of the road needs to be prepared before and inlay/overlay can be applied. The surface of the road is cold planed off using a milling machine in preparation for the new layer of hot-mix asphalt. Another reason for using this pavement preservation technique is to keep the same profile on a road adjacent to curb and gutter. The poor quality or rough asphalt surfacing is removed and a matching layer of asphalt is replaced.

Figure 57: A Cold Milling Operation.

Figure 58: A Hot Plant Mix Bituminous Overlay.

Procedure: Set up the project:

1. Make an office assessment of the road you are going to overlay with hot-mix asphalt concrete. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Roads that have completely failed are not good candidates for this treatment. The road may have localized failures that should be corrected by digging them out and replacing them. This approach should never be used on a road that is so far decayed that it can't be built over. If this is the case the, road should be reconstructed.

3. Schedule your District Lab to cut cores of the pavement and provide a depth of material to be milled off. Depth should be in a

4. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape

measure. From your measurements determine the number of square yards or ton of hot-mix to be used in the overlay as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)
- Usually milling on Maintenance Projects is by the square yard inch. So to get the milling quantities do the following:
  Total Square Yards × Depth in Inches = Total Square yard Inches (Milling Quantity)
- Convert square yards of area to volume:
  Thickness of Overlay in Inches ÷ 36 Inches per Yard = Thickness in Yards
  Thickness in Yards × Area in Yards = Volume of Overlay in Cubic Yards
- Convert Cubic Yards of Material to Tons:
  Cubic yards of Hot-Mix × Unit Weight of Material (Provided by Lab) = Tons of Hot Mix. (Use this number if contracting of placing yourself)

5. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

6. When construction begins, you should start with a test strip to determine the amount of compaction to be applied to the mat.

Materials: New Mexico Department of Transportation uses the Super-Pave classification and test methods as a basis classification of our hot-mix materials in this state. We do have a number of grades of asphalt cement that have been set up for various regions of the state depending on the climate. Be sure to check with the Central Laboratory for the latest recommendation and discuss any localized factors such as traffic loads, terrain or temperature extremes that may assist the lab in proper asphalt cement selection.

If you are working off of a price agreement for either the material or a finished product, you must use an approved mix design from the NMDOT Central Laboratory. The mix design may be one that is already in place or be designed specifically for the project you are putting forth. If you are generating a new mix design plan on submitting it at least six weeks prior to commencing paving operations.

If you are working with a book project most of the approvals and timeline are spelled out in the contract.

Materials Testing: Hot-Mix Asphalt products need to be tested per the Department's Current "Minimum Testing Requirements" and per the section of the New Mexico Department of Transportation's current Standard Specification for Highway and Bridge Construction. The appropriate section of the standard Specifications will be spelled out in the Book Projects contract pages or if using a Price Agreement (on-call contract) in it contract language.

Equipment: The equipment needed for a standard paving operation is what you will need in an overlay. The biggest think to be cognizant of is that you will need an area that is safe to park all of the equipment needed for your milling and overlay.

The standard list of construction equipment is as follows:

- A self propelled asphalt concrete milling machine.
- A small mill if working in an urban area to plan off joints.
- Hot-mix Asphalt Concrete paving machine and optional backup machine.
- Five to ten dump trucks to haul the cuttings to the stockpile site.
- Five to Ten dump trucks to haul HMA to the paving machine.
- Power broom for cleaning road during milling operations and before and after the paving operation.
- Asphalt distributor with Tack Oil.
- 10 ton pneumatic roller.
- 2 Steal wheel rollers one of which should be vibratory.
- A water truck for servicing, milling machine, rollers and cooling intersections.
- A small tractor with bucket for spills and joint cuts.

An optional list of construction equipment is as follows:

- A HMA loader such as co-cal.
- Diamond grinder for out of specification areas.
- Portable walk behind striping machine.

The standard list of field testing equipment is as follows.

- A straight edge for checking joints.
- 3 to 4 foot Level with wedge for checking crown and cross slope.
- Depth/thickness gage for mat thickness.
- Access to a fully equipped HMA field lab.
- An IRI (International Roughness Index) testing device.

- A minimum 25 length measuring tape.
- Thermometer for checking HMA temperature.

The larger pieces of equipment will either need to be stored behind a barrier or beyond the clear zone of the roadway.

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer) and dry days. Cold weather will cause the HMA to cool down before proper compaction has taken place providing a weak product. If the HMA is placed on a cold surface often the HMA will not bond to the underlying pavement and will delaminate over time. Rain interferes with the bonding of the layers and can cool the HMA before it is properly compacted.

Problems to Avoid:

- Be sure that the milling machine provides a uniform surface. You will not get a good smooth road during paving operations if you do not have a uniform surface to begin with.
- Don't start a milling operation for an inlay if there is the possibility of a heavy rain storm. In this scenario, the road will hold water causing pavement damage and/or endangering the public if opened to traffic.
- Be sure that the road is clean before over lay is started. A dirty road will cause the pavement layers not to bond properly and the finished product will fail.
- Be sure to use a NMDOT approve mix design. And be sure that the supplier is providing the proper HMA per the design. These mix designs are set-up for the traffic loads, longevity and maintainability the state road system requires.
- Insure a proper taper is provided on the outside of the road. After the paving operation is complete, the shoulder should be pulled up for a smooth transition form the paved surface to the shoulder in case an errant vehicle leaves the road.
- The height of any guardrail or barrier should be adjusted if need be to function properly.
- Inside (linear) joints should be properly compacted to avoid raveling or future degradation. Pinching and tacking are advisable.
- Be sure all specifications are being met to insure a long product life.
- Be sure contractor has a continuous operation the improve smoothness and overall quality of the pavement.
- Work with an experienced asphalt inspector for a good product. Remember expertise is only as far away as a phone call to the District Lab, General Office Central Lab or the State Maintenance Bureau.

Life Expectancy: The life span of this treatment will be about 10 years if the overlay in preformed on a road that is in good shape. If you have a poor road the life will drop off dramatically. An overlay will not hide a poor road surface for very long.

NovaChip® Overlay

A NovaChip® Overlay is the placing an asphalt membrane on an existing pavement then overlying it with an ultra-thin, coarse aggregate hot mix. It extends pavement life by sealing the pavement surface, improves riding quality, corrects minor surface defects, resists rutting. Improves safety characteristics, surface friction and surface drainage (reduces splash, spray and hydroplaning and tire-pavement noise).

Background: When you have a road that has some aging on it but is in good shape you should look for a treatment that prevents further decay and provides a new wearing surface. Generally when these conditions exist but you are not looking for any structural improvements then a very thin overlay of some sort is required. If you are looking for a treatment the does not add a large amount of thickness, (⅜" to ¾") to the road a good choice is a NovaChip® project. NovaChip® projects give you the same driving characteristic of OGFC but NovaChip® overlays act as a better sealant and adhere to certain surfaces better.

Figure 59: A NovaChip® Operation.

Figure 60: A close-up of a finished NovaChip® Project.

Procedure: Set up the project:

1. Make an office assessment of the road you are going to overlay with NovaChip®. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so yon don't waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Road that have completely failed are not good candidates for this treatment. The road may have localized failures that should be corrected by digging them out and replacing them. This approach should never be used on a road that is so far decayed that it can't be built over. If this is the case the, road should be reconstructed.

3. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape

measure. From your measurements determine the number of square yards or ton of NovaChip® to be used in the overlay as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured □ 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance □ Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet □ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)
- Convert square yards of area to volume:
  Thickness of Overlay in Inches □ 36 Inches per Yard = Thickness in Yards
  Thickness in Yards □ Area in Yards = Volume of Overlay in Cubic Yards
- Convert Cubic Yards of Material to Tons:
  Cubic yards of Overlay □ Unit Weight of Material (Provided by Lab) = Tons of Novachip.

4. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

5. When construction begins, you should start with a test strip to determine the amount of compaction to be applied to the mat.

Materials: Novachip® is an ultra thin, open graded, hot mixed asphalt friction course placed over a heavy application of polymer-modified asphalt emulsion. The NovaChip® overlay is placed in a single pass where the asphalt emulsion is sprayed on the existing surface and the hot mix asphalt is placed on top.

The emulsion used in this process is currently a warm polymer modified asphalt emulsion. This emulsion is sprayed on the existing surface then covered within 5 seconds by a hot mix wearing course. The emulsion selected must function as both a sealant and as a tack for the overlaying wearing course to the existing pavement. This emulsion membrane is to be placed at a uniform application rate of between 0.10 and 0.35 gallons per square yards.

Materials Testing: Hot-Mix Asphalt products need to be tested per the Department's Current "Minimum Testing Requirements" and per the section of the New Mexico Department of Transportation's current Standard Specification for Highway and Bridge Construction. At the time of this Maintenance Manual's writing, the specifications for NovaChip® were spelled out in the price agreement to order this process. Similar specifications would need to be placed in a book project if this ends up being your contracting method.

Attached on the next page are current specifications for the wearing course as of this manual's writing:

MIXTURE REQUIREMENTS					
SIEVES SIZE		3/8 INCH -TYPE B		1/2 INCH - TYPE C	
ENGLISH SYSTEM ASTM	METRIC SYSTEM ASTM	DESIGN GENERAL LIMITS % PASSING	PRODUCTION TOLERANCE %±TARGET	DESIGN GENERAL LIMITS % PASSING	PRODUCTION TOLERANCE %±TARGET
3/4 INCH	19	100		100	
1/2 INCH	12.7	100		85-100	±5
3/8 INCH	9.5	85-100	±5	60-80	±5
#4	4.75	28-42	±4	28-42	±4
#8	2.36	22-32	±4	22-32	±4
#16	1.18	15-23	±3	15-23	±3
#30	0.6	10-18	±3	10-18	±3
#50	0.3	8-13	±3	8-13	±3
#100	0.15	6-10	±2	6-10	±2
#200	0.075	4-7	±2	4-7	±2
ASPHALT CONTENT %		4.8-6.0	±0.5	4.6-6.0	
FILM THICKNESS ** (MICRONS)		10.0 MINIMUM			
DRAIN DOWN TEST AASHTO T-305		0.10% MAXIMUM			
MOISTURE SENSITIVITY AASHTO T-283		80% MINIMUM			
ACCEPTABLE ASPHALT GRADES		PAC-20, PAC-20TR, PG 70-28 OR PG 76-22			

*** Though not a specification sieve listed above, a target of 100% passing the 5/8 inch sieve is Recommended. Mixtures containing 5/8 inch aggregates could required greater paving thicknesses.**

**** Film thickness calculation based on gradation surface area method is from the Asphalt Institute MS-2 table 6.1 with a minimum requirement of 10.0 based on effective asphalt.**

***** Compact samples with the gyratory compactor using 4 inch diameter molds and 100 gyrations. Use mix quantity necessary to obtain compacted samples 2.5±0.05 inches in height. Further test compacted samples regardless of air void levels achieved after 100 gyrations. Apply a vacuum to the samples for conditioning for 20 seconds and proceed without calculating the percent saturation. The mixture and compaction temperatures are to be as recommended by the binder supplier.**

The Emulsion portion of the process is also subject to sampling and testing per the current “Minimum Testing Requirements”. Sampling directions can be obtained from the Central Materials Laboratory or from the State Maintenance Bureau.

Equipment:

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer) and dry days. Cold weather will cause the HMA to cool down before proper compaction has taken place providing a weak product. If the HMA is placed on a cold surface often the HMA will not bond to the underlying pavement and will delaminate over time. Rain interferes with the bonding of the layers and can cool the HMA before it is properly compacted. Water will also interfere with the setup on the under laying emulsion membrane.

Problems to Avoid:

Life Expectancy: The life span of this treatment will be about 8 years if the overlay in preformed on a road that is in good shape.

Heater Scarification and Overlay

Heater Scarification and Overlay is the heating and scarifying the top portion of an existing pavement, sometimes combining that material with recycling agent and/or fresh aggregate on site, replacing and compacting the reworked material and overlaying it with hot Plant Mixed Bituminous Pavement. It removes and rejuvenates upper layers of deteriorating pavement, corrects surface defects such as deep rutting, improves riding quality.

Background:

Heater Scarification and Overlay, also referred to as Hot In-Place Recycling (HIR), is an effective pavement preservation treatment to improve the functional performance of an existing pavement. Totally repaving an existing surface may not be necessary if the pavement is structurally adequate and has a stable base. A recycled pavement is considered to be as structurally sound as a new hot mix asphalt pavement. Because Heater Scarification and Overlay operations rework the top of an existing HMA surface it is very effective at improving ride quality and correcting flexible surface distresses such as rutting, surface deterioration, raveling and cracking that are limited to the upper pavement surface layers. The process is limited in its ability to repair severely rutted pavements which are often overlaid with conventional hot mix asphalt.

Figure 61: A Heater Scarification and Overlay Operation.

In the Heater Scarification and Overlay process the pavement surface is first heated to soften the upper layer of the pre-existing pavement surface (typically using propane fired radiant heaters), the pre-existing pavement surface is scarified using a bank of non-rotating teeth, a liquid rejuvenating additive (and sometimes virgin aggregate) are added to the recycle mix, and then the recycled pavement mix is mixed, laid back down and leveled using a standard auger system; sometimes all within a specialized plant in a continuous train operation. The recycled asphalt pavement is then compacted using conventional compaction equipment.

The benefits of Hot-in-Place Recycling cover more than just reduced cost by completely rejuvenating surfaces to good-as-new-condition. The Heater Scarification and Overlay process:

- Preserves elevations and overhead clearances
- Interrupts and fills cracks
- Remixes and recoats uncoated aggregate
- Fills ruts and holes
- Levels shoves and bumps
- Re-establishes surface's flexibility by chemically rejuvenating aged asphalt
- Enhances highway safety through improved ride and skid resistance
- Reduces engineering costs
- Reduces traffic control costs
- Puts roads back in service within a matter of hours of resurfacing

Heater Scarification and Overlay is one of several HIR processes. Another is Plant Remixing. Plant Remixing involves milling the asphalt to be reclaimed, transporting the milled material to a remixing plant, adding virgin hot mix to the recycling paving material in a pugmill, transporting the recycling paving material back to the project site and relaying the recycle paving material back onto the roadway. The major advantage of Heater Scarification and Overlay over conventional Plant Remixing is the potential cost savings by eliminating the costs of transporting, processing and stockpiling Reclaimed Asphalt Pavement (RAP). The major disadvantage of Heater Scarification and Overlay treatments are the inability to make significant changes to the mix.

Since only the top of the original pavement can normally be reconditioned using Heater Scarification and Overlay applications, these operations are limited to roadways that do not have major structural deficiencies and do no not require much additional material. Pavements that exhibit structural base failure, irregular patching or the need for major drainage or grade improvements are not suitable candidates for Heater Scarification and Overlay.

Procedure:

The initial step in the quality control of hot in-place recycled mixes is in the selection of the pavement to be recycled. Not all pavements are good candidates for this type of recycling. Cores of the pavement being considered for Heater Scarification and Overlay must be taken during the early planning for the project. The cores should first be visually examined for pavement problems such as delaminating, stripping, or stripping potential, or water in the voids or delaminations. Pavements with delaminations, especially saturated delaminations, in the top 2 in should not be considered for Heater Scarification and Overlay projects. Also, pavements that have been rutted, heavily patched, or chip-sealed are not good candidates for Heater Scarification and Overlay projects.

<u>Set up the Project:</u>

1) Make an assessment of the road you are going to Heater Scarification and Overlay. Make as check of the plan for this road and see if it is going to have a re-construction project on it in the next few months so yon don't waste resources on a road that would be replaced anyway. Determine the best type of rejuvenating agent and aggregate to use with the help of the contractor.

2) Go to the project site and see what condition the road is in. Heater Scarification and Overlay will not work if the roadway is in structural failure or if the distresses extend below the top inch of the pavement. Set up patching to take care of problem areas.

3) Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. Plug your measurements into the following series of calculations to come up with your estimated emulsion and aggregate order:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number if contracting by square yards)

4) Determine your preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Also locating a staging area for the contractor to keep and maintain equipment and stockpile aggregate.

5) Order the project off of a price agreement or get with your District's Technical Support Engineer to process a book job.

Material Types

The proper selection of materials based on a through engineering evaluation of the existing in-place materials is critical. It is important to identify the characteristics of the existing pavement materials so that the correct types and additive amounts can be determined (i.e., recycling agents and/or binders) and to ascertain the need for additional materials such as aggregate.

Reclaimed Asphalt Pavement (RAP)

Coring provides the most representative material samples for testing. Cores taken of the pre-existing pavement can be used to determine in-place pavement properties, including binder content, viscosity, and aggregate grading. Once the cores have been inspected and photographed, the cores are trimmed to the depth of the anticipated Heater Scarification and Overlay treatment.

Representative cores are then tested to determine the following types of material properties:

- Bulk specific gravity/density.
- Field moisture content.
- Asphalt binder content.
- Aggregate properties including gradation, angularity, etc.
- Recovered asphalt binder properties including penetration, absolute and/or kinematic viscosity and perhaps temperature susceptibility or Superpave performance grade.
- Maximum Theoretical Density of the existing mix.
- Mix void properties of the existing mix including air voids (V_a). voids in mineral aggregates (VMA) and voids filled with asphalt (VFA).

This information allows the Pavement Design Engineer to determine if the original mix design was adequate or else how the properties of the existing mix can be improved during the Heater Scarification and Overlay design process.

Field core specimens should be analyzed in the laboratory to determine (based on the asphalt content, viscosity, and penetration of the recovered binder) the required amount of rejuvenating agent to be added to the mix in order to attain the desired viscosity of the recycled mix. If too much rejuvenating agent (1.0 percent or more by weight of mix) must be added in order to attain this viscosity, the mix should probably not be recycled in place. As a guideline, pavements being considered for Heater Scarification and Overlay should not be too severely aged. It is recommended that such pavements have an absolute viscosity lower than 200,000 poises (and preferably below 100,000 poises) in order to be considered for Heater Scarification and Overlay projects.

The asphalt content of most old pavements will comprise approximately 3 to 7 percent by weight and 10 to 20 percent by volume of the pavement. Due to oxidation aging, the asphalt cement has hardened and consequently is more viscous and has lower penetration values than the virgin asphalt cement. Depending on the amount of time the original pavement had been in service, recovered RAP binder may have penetration values from 10 to 80 and absolute viscosity values at 140°F in a range from as low as 2,000 poises to as high 50,000 poises or greater.

Field core specimens should also be evaluated for air voids content during the pavement selection process. An existing pavement being considered for Heater Scarification and Overlay should have air voids content in excess of 6 percent, in order to accommodate the addition of a rejuvenating agent without the loss of stability in the recycled mix. If material properties are not completely satisfactory for 100 percent recycling, the addition of 20 to 30 percent by weight of virgin hot mix during recycling should be considered.

Recycling Additives

Heater Scarification and Overlay recycling agents are generally hydrocarbon materials with chemical and physical properties that provide the following benefits:

- Restore the aged asphalt properties to a consistency level appropriate for construction purposes and end use of the recycled mix.
- Provide sufficient additional binder to coat the existing mix.
- Provide sufficient asphalt binder to satisfy the mix design requirements.

Soft asphalt binders, specialty/propriety products or even some types of asphalt emulsions can act as recycling agents. Soft asphalt binders are usually less expensive than specialty products but they are not as efficient at rejuvenation. They also need to be added to a “carrier”, such as virgin aggregates, as opposed to being directly applied to the recycle mix. In order to achieve their intended purpose, recycling agents must have the following properties:

- Easy to disperse in the recycle mix.
- Compatible with aged asphalt binder to ensure that synereis or exudation of the paraffins from the existing asphalt binder does not occur.
- Able to re-disperse the asphaltenes in the aged asphalt binder.
- Capable of altering the properties of the aged asphalt binder to the desired level.
- Resistance to excessive hardening during hot mixing to ensure long-term durability.
- Are uniform/consistent from batch to batch.
- Low in volatile organic compounds or contaminants to minimize smoking and volatile loss during construction.

Aggregate

Heater Scarification and Overlay operations usually do not require the addition of new aggregate. However, the addition of such aggregates can be beneficial and justified in some cases, such as when an excess of asphalt binder is present or when it is deemed desirable to increase the structural capacity of the mix. New aggregates should be selected so that the blend of the new aggregate and the aggregate in the RAP meets the current specifications in both gradation and quality.

The aggregate gradation of processed RAP is somewhat finer than virgin aggregate. This is due to mechanical degradation during asphalt pavement removal and processing. RAP aggregates usually can satisfy the requirements of ASTM D692 "Coarse Aggregates for Bituminous Pavement Mixtures" and ASTM D1073 "Fine Aggregate for Bituminous Pavement Mixtures.

Mix Design

The ideal for Heater Scarification and Overlay design is to restore the properties of the existing aged asphalt to those of, or as close as possible, a new HMP pavement. That approach attempts to account for the changes that have occurred in the existing pavement due to environmental effects (age hardening or oxidation of the binder) and traffic loadings (densification or air void reduction).

Following are the basic steps for designing a Hot In-Place Recycling Mix Design:

1. Evaluate the existing pavement and pavement and determine its specific properties. The characteristics of the existing materials must be identified so that the type and amount of recycling agent can be determined and the need for virgin aggregate can be ascertained. Core samples taken from the pavement surface are carefully examined to detect the different pavement layers, previous surface treatments, interlayers, geotextile paving fabrics, specialty mixes, evidence of stripping, friable or disintegrating mix, retention of excessive moisture and any tendency to delaminate. Once the cores have been inspected the cores are tested to determine the specific material properties of the existing pavement.

2. Determine the method for rejuvenating the asphalt binder. There are three methods for rejuvenating an existing asphalt binder:
   a. Use a recycling agent only.
   b. Use a soft, new asphalt binder only
   c. Use a combination of recycling agent, new asphalt binder and virgin aggregate.

3. Select the type and amount of recycling agent. The type and amount of required recycling agent has been traditionally determined based on the viscosity of the aged asphalt binder and the amount of rejuvenation required. The process used to accomplish this step is illustrated below:

4. Prepare and test mix specimens in the laboratory. Samples are prepared that represent various contents of recycling agent, virgin aggregate, new asphalt binder and existing pavement RAP. These samples are tested in the laboratory to determine the optimal combination of all mixture ingredients.

5. Establish job mix formula. Once the laboratory analysis has been completed the mix design can be finalized and the mix formula established. The recycled mix with the optimum physical properties and acceptable economics should be selected. The mix design should specify the following

    - Asphalt binder content of the existing pavement for the intended recycling depth.
    - Properties of the asphalt binder at the existing pavement treatment depth.
    - Gradation and aggregate properties of the portion of the existing pavement to be recycled.
    - Gradation and aggregate properties of any virgin aggregate that is required.
    - Type and amount of new asphalt binder required to be added to any required virgin aggregate.
    - Type and amount of recycling agent.
    - Properties of the asphalt binder in combined recycled mix.
    - Gradation and aggregate properties of the combined recycled mix.
    - Recycled mix void properties and physical properties.

6. Make adjustments in the field. Once construction begins the actual recycled mix should be sampled and tested to identify if adjustments to the mix formula are required.

Construction Procedures

Field quality control measures during Heater Scarification and Overlay construction include monitoring the depth of scarification, the temperature of the recycled mix, the visual appearance and homogeneity of the scarified or milled RAP, the compaction procedure, and the visual appearance of the recycled pavement surface after compaction.

Heating of the Pre-Existing Pavement

One or more infrared heating units fired by propane gas are used to gradually raise the temperature of the pavement and soften it sufficiently to allow the scarifying teeth to scrape through the surface. Surface temperatures ranging from 230 to 302°F are generally achieved when at least two heaters are used in tandem.

The heating of the pavement surface should be as uniform as possible both transversely and longitudinally. This helps to ensure a uniform treatment depth and subsequent degree of compaction. In the past the pavement temperature was determined with thermometers, thermostats or thermocouples. Although still useful, these methods are being replaced by hand-held infrared temperature measuring devices, customarily called “heat guns”. Heat guns only determine the surface temperature of the material being measured. To determine the temperature of the material with a heat gun at a location below the surface the material to be measured must first be manually brought to the surface.

Figure 62: A Heater Unit.

Temperatures should be checked continually ant a number of different locations. The locations should include:

- Behind each preheating unit.
- Prior to final heating.
- Prior to final mixing.
- Immediately behind the screed.

Scarification

Scarification is a simple process in which the surface of the old pavement is scarified with a set of scarifying teeth after preheating. The scarifying teeth are normally spring-loaded tines that are able to override obstacles such as manholes, but the use of tines for scarification may limit the depth of scarification and cause aggregate breakage.

The uniformity of the depth of scarification during the Heater Scarification and Overlay process is critical. Methods to determine the depth of scarification include:

- Surveying the pavement elevation before and after scarification.
- Measuring the outside edges after scarification.
- Removal and weighing the scarified material and using the in-place material density to convert the weight to a depth of scarification

- Measuring the depth of the un-compacted recycle mix behind the paver screed and using the un-compacted depth and a conversion factor to calculate the compacted depth or depth of scarification
- Measuring the depth of cores before and after scarification.

Addition of Recycling Agent and Admixture

The recycled layer contains relatively hard asphalt binder because of the normal aging of the surface and the required heating to soften it. Therefore, recycling or rejuvenating oils are commonly used to restore flexibility.

The addition of the recycling agent and admixture is linked to the forward operating speed of the recycling unit by a microprocessor. The microprocessor has no means of determining whether the required Heater Scarification and Overlay depth is being achieved. The microprocessor has to be calibrated to the required treatment depth in order to accurately control the amount of recycling agent and admixtures added. This must be done manually and on a continuous basis. The typical tolerance for the addition of the recycling agent is ±5 percent of the specified application rate. The recycling agent needs to be uniformly applied or blended into the recycled mix in order to ensure consistency. The application rate is checked by determining the amount of recycling agent used over a given distance. The amount of recycling agent used is usually recorded by the microprocessor or a flow meter. The application rate should be checked hourly throughout the day and also for the overall daily rate.

Replacement of Recycled Mix

Replacement of the recycled mix is normally performed by a screed unit attached to the recycling unit or on a separate paver.

Mixing, Laying and Compacting

Loose samples of the recycled mix should be obtained and extraction tests performed to monitor RAP gradation, asphalt cement and air voids contents, and penetration and viscosity of the recovered asphalt binder for comparison with the job mix formula. The recycled mix should be monitored for in-place density in accordance with ASTM D2950.

Compaction of the recycled mix is usually done with a combination of pneumatic and steel wheel rollers operating immediately behind the screed unit. A test strip can be used to determine the type, number of rollers, roller passes and roller coverage required to achieve the specified degree of compaction. Periodic checks with nuclear density gauges should be undertaken throughout the day. The nuclear density gauges should be calibrated to field core samples.

Weather Requirements and Pavement Conditions:

Heater Scarification and Overlay operations should be done in warm dry weather. Wet pavements and cold pavements will interfere with the process and make it difficult to maintain the required temperature of the recycle mix.

Problems to Avoid:

Problems encountered in Heater Scarification and Overlay operations usually occur during the following five steps:

- Heating of the pre-existing pavement
- Depth of treatment
- Addition of recycling agent and admixture
- Placement of recycled mix
- Compaction of recycled mix

Heating of the Pre-Existing Pavement

Proper heating of the pre-existing pavement is important to:

- Minimize the oxidation or hardening of the asphalt binder.
- Remove excess water.
- Sufficiently soften the pavement so that it can be scarified without excessive aggregated degradation.
- Thoroughly mix the recycling agent in the recycle mixture.
- Achieve adequate compaction.

There are not any definitive tests to determine if the preheating of the pre-existing pavement is proceeding properly. However, signs that indicate when it is not include:

- Blue or black smoke emissions from the heating units.
- Differences in surface appearances across the width of the mat.
- Scorched or charred pavement surfaces.
- Excessive temperature variations across the width of the mat.

Emissions from the heating units that are white and dissipate quickly are the result of water being removed from the pavement in the form of water vapor and are acceptable. Blue or black smoke, however, indicates the combustion and removal of hydrocarbons from the asphalt binder. If this occurs, immediate corrective action such as reducing the flame intensity of the heating units, raising the heating units from the pavement or increasing the forward speed of the heating units is immediately required.

Depth of Scarification

The uniformity of the depth of scarification during the Heater Scarification and Overlay process is critical. If the depth of scarification varies from the required treatment depth there will be a corresponding change in the application rate of the recycling agent and admixture. This will have an effect on the following:

- Gradation of the recycled mix.
- Asphalt binder content of the recycled mix.
- Rheology of the recovered asphalt binder.
- Recycled mix void properties.
- Recycled mix strength properties.
- Uniformity of the compaction of the recycled mix.

Addition of Recycling Agent and Admixture

Excess recycling agent will result in a pavement that is too soft, while not enough recycling agent can result in a pavement with inadequate bonding.

The following table summarizes potential problems to avoid, their causes and their solutions, during Heater Scarification and Overlay operations:

Problem	Typical Cause(s)	Typical Solution(s)
Blue or black smoke emanating from the heating units or exhaust	Combustion and removal of hydrocarbons from the asphalt binder	Reduce the intensity of the heating units, raise the heating units from the pavement surface, increase the forward speed of the heating units or employ additional heating units at a faster speed to allow heat to penetrate. Remove and replace the damaged areas with virgin mix.
Wet appearance of pavement surface after recycling	Excess asphalt binder or recycling agent in mix	Check application rates of asphalt binder and recycling agent
Poor gradation of RAP	Speed of the operation too fast or too slow	Alter speed of the operation to minimize segregation and add heating units as needed to assure penetration depth is achieved
Variable or insufficient milling depth	Speed of the operation correlated to the existing surface and ambient temperatures	Alter speed of the operation to match existing temperatures and add heating units as necessary to achieve proper scarification depth
Inadequate density	Inadequate rollers	Check rollers for adequate weight, tire pressure and rolling pattern
	Rolling when mix is too cold	Slow down the operation to allow more time for proper mixing
	Segregation	Slow down the operation to allow the rollers to keep pace (or add additional rollers)
Spot areas of flash fires or blue smoke	Excessive crack sealant	Remove crack sealant prior to Heater Scarification and Overlay
	Polymerized small maintenance patch areas	Remove patching material and, if necessary, replace with virgin HMA
Inability to achieve the required depth of removal without producing blue smoke	Existing asphalt binder may have age hardened to a degree that heat will not penetrate to the required depth without burning asphalt	Poor project for this preservation method. May need to cancel or alter specifications.
Wet spots on the finished mat	Variation of the added asphalt binder or rejuvenating agent	Check and recalibrate the asphalt pump
	Excessive crack sealant	Remove crack sealant prior to operation
	Contamination of the existing surface	Remove contaminated areas and replace with HMA prior to processing
Dry spots in the finished mat	Variability of the added asphalt or rejuvenating agent	Check and recalibrate the asphalt pump

White Topping on Asphalt

Figure 63: White Topping on Asphalt.

Background:

White Topping on Asphalt, sometimes referred to as Thin PCC Overlays or Ultra-Thin White Topping, is a pavement preservation technique wherein the surface of an existing hot-mix asphalt (HMA) pavement is cold milled to enhance the bond between the existing HMA and the PCC overlay and a very thin (2 to 4 inch) Portland Cement Concrete (PCC) overlay is placed over the existing HMA. White topping overlays are sawed into short slabs, typically between 2 and 6 feet square to help reduce bending and thermal stresses.

White topping is an appropriate pavement preservation technique for parking lots, residential streets, low volume roads, general aviation airports and HMA intersections where rutting is a problem but no significant structural damage is present. White topping may be an appropriate pavement preservation technique for an existing HMA pavement that is experiencing, or may soon experience, vastly increasing traffic loads or for low-volume roadways and urban intersections where rutting is a problem. White topping is not an appropriate treatment if the existing HMA pavement has significant structural damage. The existing HMA must be thick enough to be milled and still carry a significant portion of the post-project loading.

Because of its strength, durability and resistance to environmental effects, white topping may provide a potential for extended service, increased structural capacity, reduced maintenance requirements and lower life-cycle costs when compared with other overlay alternatives.

Procedure:

<u>Project Planning</u>

Make a preliminary assessment of the road that you are considering for white topping:

1) Make sure that the road section that you are considering for white topping is not scheduled for other projects especially rehabilitation or re-construction.

2) Make a visual inspection of the road section being considered for white topping to make sure that the pavement is suitable for white topping. White topping is not appropriate if the pavement is structurally damaged. Alligator cracking and severe rutting are good indicators of structural damage.

3) Set up patching and crack repairs to take care of problem areas. Make sure that the existing HMA is thick enough to be milled and still carry the required post-project loading. Drill coring may be necessary to make sure that the existing HMA is thick enough. After milling, an absolute minimum remaining HMA thickness of 3 inches is required, although some suggest a minimum thickness of 6 inches.

4) Develop a preliminary traffic control plan. Examine detours or phasing that may be necessary to maintain traffic flow during the course of the project. If the work needs to be done at night determine the lighting needs.

5) Locate a staging area for the contractor to park equipment and store materials.

6) Measure the width and record the beginning and ending milepost of the road section to be white topped.

7) Give the above information to the respective District Technical Support Engineers and request a project design and a request for approval of the concrete mixture design to the State Materials Laboratory in accordance with Standard Specifications For Highway and Bridge Construction - Section 510.42.

The Department's Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.

<u>Pre-Project Repairs</u>

Because white topping overlays are bonded directly to the existing pavement, any unrepaired defects in the existing pavement, especially potholes, localized base failures and areas of severe alligator cracking, will adversely affect the performance of the new overlay. Prior to construction representatives from the Department and the contractor should walk the project to make sure that no further repairs are required.

The existing HMA pavement will be carrying part of the traffic loading, so any structural deficiencies in the existing HMA pavement must be corrected prior to the placement of the concrete. Pre-project repair activities that are typically required for white topping include:

- Localized repair of failed areas caused by loss of base or subgrade support.
- Filling of medium and high-severity potholes.
- Localized repair of medium to severe alligator cracking. It is important that all of the areas that exhibit alligator cracking and/or severe rutting are removed and replaced throughout the entire thickness of the HMA pavement. If significant cracking exists throughout the project the existing pavement may not be structurally adequate and is not a suitable candidate for white topping.

Surface Preparation

It is very important that the surface of the HMA is milled prior to white topping to for the bond between the PCC overlay and the existing HMA to be adequate. Milling of the existing HMA surface is critical to the performance of white topped pavement.

Figure 64: Milling existing pavement.

Cold milling should be conducted after the pre-project repairs such as patching. The amount of existing HMA removal for a particular project will depend on the type and severity of distress, especially the depth of rutting or other surface distortions, and the thickness of the HMA pavement. After milling, an absolute minimum remaining HMA thickness of 3 inches is required, although some suggest a minimum thickness of 6 inches.

After the pavement has been milled, the pavement surface must be cleaned to help ensure bonding between the existing HMA and the new PCC overlay. This may be accomplished by air blasting or power brooming. Occasionally water blasting or sand blasting may be required to remove any slurry or residue from the milling. If water blasting or washing operations are used the surface must be allowed to dry before the placement of the PCC overlay.

Prior to construction representatives from the Department and the contractor should walk the project to make sure that no further repairs are required.

PCC Placement and Finishing

PCC placement and finishing is performed using either fixed-form or slip form construction. Primary activities during PCC placement and finishing include spreading, consolidation, screening and float finishing.

Figure 65: Placing Portland Cement Concrete Pavement.

Texturing of the finished PCC pavement surface is required on all areas that will be exposed to traffic. For roadways designed for vehicle speeds less than 50 mi/hr texturing the surface with a burlap drag, turf drag or broom should be adequate providing that the corrugations produced are about 0.06 inch deep. For roadways designed for vehicle speeds greater than 50 mi/hr tinning of the PCC pavement surface is required. This provides macro texture which contributes to surface friction by tire deformation and also channels surface water out from between the pavement and the tire. Tinning should be conducted as soon as the sheen goes off the PCC.

Tinning has traditionally been conducted transversely and at uniform intervals but recent studies suggest that uniformly spaced transverse tinning produces irritating pavement noise. Consequently, some state DOT's are experimenting with transverse tinning that is randomly spaced and skewed to the centerline of the pavement. In such cases the tinning pattern must be carefully designed and constructed in order to minimize discrete noise frequencies that are most objectionable to the human ear. In addition, some state DOT's are investigating the use of longitudinal tinning which produces lower noise levels than either uniformly or randomly spaced transverse tinning.

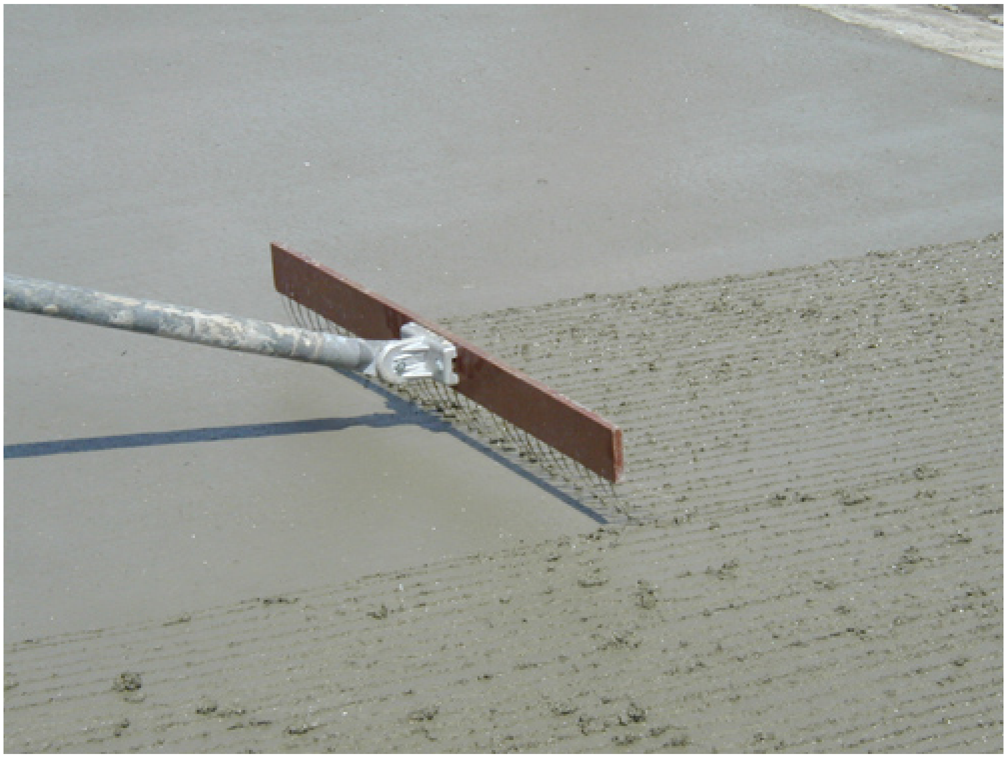
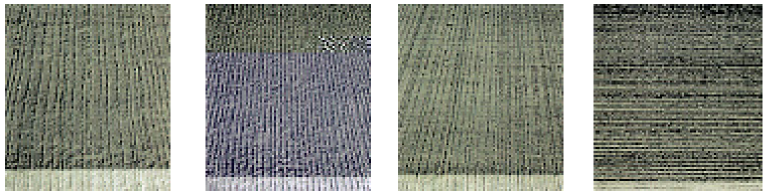


Figure 66: Tinning freshly laid pavement.



Random Transverse | **Uniform Transverse** | **Random Skewed** | **Uniform Longitudinal**

Figure 67: Random Transverse, Uniform Transverse, Random Skewed and Uniform Longitudinal Tinning

<u>Curing</u>

The Department's Standard Specifications For Highway and Bridge Construction Section 510.23 specify curing material requirements for PCC pavements. Although proper curing is important to all PCC pavements, it is especially important to white topped pavements because their high surface area to volume ratio makes them more susceptible to drying too rapidly.

Because white topped overlays are placed so thin, typically 2 to 4 inches, they are more susceptible to drying shrinkage cracking than conventional paving. Consequently, it is important that effective curing practices are employed to help minimize shrinkage. This typically includes a greater application rate for membrane curing compounds and, in some extreme instances, may require wet curing practices such as shading, fog spraying, ponding or wet covering. Prior to construction, the maintenance supervisor and the contractor should agree on the curing procedures that will be used during the project.

Curing is most often accomplished through the application of a membrane curing compound immediately after texturing of the PCC surface. It is recommended that the curing compound be placed at twice the normal rate in order to reduce moisture loss or at a maximum application rate of 100 ft^2/gallon. All exposed PCC surfaces, both vertical and horizontal, should be coated with the curing compound.

Figure: White-Pigmented, Liquid Membrane Curing Compound

Figure 68: Polyethylene Sheeting Used as a Curing Blanket

Concrete Removal and Cleanup

- Verify that the boundaries of the removal areas are clearly marked on the pavement surface and the cumulative area of the pavement to be removed is consistent with quantities in the contract documents.
- Verify that the patch size is large enough to accommodate a gang-mounted dowel drilling rig, if one is being used. Note: The minimum longitudinal length of patch is usually 6 feet.
- Verify that boundaries are sawed vertically the full thickness of the pavement.

- Verify that concrete is removed using either the break-up or lift-out method and minimizing disturbance to the base or subbase as much as possible. Note: The saw cut and lift method is preferred to jackhammer removal.
- Verify that after concrete removal, disturbed base or subbase is re-compacted, and additional subbase material is added and compacted if necessary.
- Verify that concrete adjoining the patch is not damaged or undercut by the concrete-removal operation.
- Ensure that removed concrete is disposed of in the manner described in the contract documents.

<u>Patch Preparation</u>

- Verify that dowel holes are drilled perpendicular to the vertical edge of the remaining concrete pavement using a gang-mounted drill rig.
- Verify that holes are thoroughly cleaned using compressed air.
- Verify that approved cement grout or epoxy is placed in dowel holes, from back to front.
- Verify that dowels are inserted with a twisting motion, spreading the grout along the bar inside the hole. A grout-retention disk can be used to keep the grout from seeping out of the hole.
- Verify that dowels are installed in transverse joints to the proper depth of insertion and at the proper orientation (parallel to the centerline and perpendicular to the vertical face of the saw cut excavation) in accordance with contract specifications. Typical tolerances measured perpendicularly to the sawed faced are 1/4 inch misalignment per 12 inches of dowel bar length.
- Verify that tiebars are installed at the proper location, to the proper depth of insertion, and to the proper orientation in accordance with contract documents. When the length of the longitudinal joint is 15 feet or greater, tiebars are typically installed in the manner used for dowels. When the length of the longitudinal joint is less than 15 feet, a bond-breaker board is placed along the length of the patch to isolate it from the adjacent slab.
- Ensure that tiebars are checked for location, depth of insertion, and orientation (perpendicular to centerline and parallel to slab surface).

<u>Placing, Finishing, and Curing Concrete</u>

- Concrete is typically placed from ready-mix trucks or mobile mixing vehicles in accordance with contract specifications.
- Verify that the fresh concrete is properly consolidated using several vertical penetrations of the concrete surface with a handheld concrete vibrator.
- Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge or vibratory screed in accordance with contract documents.
- Verify that the surface of the fresh concrete patch is finished and textured to match adjacent surfaces.
- Verify that adequate curing compound is applied to the surface of the fresh concrete immediately following finishing and texturing in accordance with contract documents.

Note: Best practice suggests that two applications of curing compound be applied to the finished and textured surface, one perpendicular to the other.

- Ensure that insulation blankets are used when ambient temperatures are expected to fall below 4°C (40°F). Maintain blanket cover until concrete attains the strength required in the contract documents.

Resealing Joints and Cracks

- Verify that patches have attained adequate strength to support concrete saws, patch perimeters and other unsealed joints are sawed off to specified joint reservoir dimensions.
- Verify that joints are cleaned and resealed according to contract documents.

Cleanup Responsibilities

- Verify that all concrete pieces and loose debris are removed from the pavement surface.
- Verify that old concrete is disposed of according to contract documents.
- Verify that mixing, placement, and finishing equipment is properly cleaned for the next use.
- Verify that all construction-related signs are removed when opening pavement to normal traffic.

Materials:

The concrete mixture design should be based on the available lane closure time. The shorter the time available before opening to traffic, the more rapid the strength gaining and curing of the concrete must be.

Typical full-depth repairs operations use concrete mixes containing 658-846 lbs/yd^3 of either cement Type I or Type III cement. A set-accelerator is frequently used to permit opening in 4 to 6 hours. Without the accelerator, these mixes allow opening in 12 to 72 hours.

Uses of proprietary concrete mixes are necessary to achieve opening times in as little as 2 hours. Using insulating blankets during the first few hours after placement also can improve the strength development of any mix. Regardless of the mix design used, the concrete mixture for full-depth repairs should have the following properties:

- 6.5 ± 1.5 percent of entrained air in the concrete (less air may be permissible in nonfreeze areas).
- 2 to 4 inches slump

Mixes using Type III cement may require slightly more mix water than a similar mix with Type I portland cement. However, too much extra water may cause the concrete to suffer from high shrinkage during curing. A water-reducing admixture will disperse cement particles and reduce the water necessary for workability.

Calcium chloride ($CaCl_2$) or another accelerating chemical admixture is recommended for use as accelerator in the patching concrete, provided that it is added as specified. It should be noted that initial set may occur within 30 minutes on warm days,24.8 e7 Tw i]TJ0.0001 Tc 0.1098 Tw 19.29 0 Tc

4. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 inches wide inside the area to be removed.

Lifting out a patch for a full-depth repair damages adjacent slab:

1. Adjust lifting cables and re-position lifting device to assure a vertical pull.
2. Re-saw and remove broken section of adjacent slab.
3. Use a forklift or crane instead of a front-end loader.

Slab disintegrates when attempts are made to lift it out:

4. Complete removal of patch area with backhoe or shovels.
5. Angle the lift pins and position the cables so that fragmented pieces are bound together during liftout.
6. Keep lift height to an absolute minimum on fragmented slabs.

Patches become filled with rainwater or groundwater seepage, saturating the subbase:

1. Pump the water from the patch area, or drain it through a trench cut into the shoulder.
2. Re-compact subbase to a density consistent with contract documents, adding material as necessary.
3. Allow small depressions in subbase to be filled with aggregate dust or fine sand before patch material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities 1/2 inch or less in surface of subbase before concrete patch is placed.

Grout around dowel bars flows back out of the holes after dowels are inserted:

1. Pump grout to the back of the hole first.
2. Use a twisting motion when inserting the dowel.
3. Add a grout retention disk around the bar to prevent grout from leaking out.

Dowels appear to be misaligned once they are inserted into holes:

1. If misalignment is less than 1/4 inch per 12 inches of dowel bar length, do nothing.
2. If misalignment is greater than 1/4 inch per 12 inches of dowel bar length on more than three bars, re-saw patch boundaries beyond dowels and re-drill holes.
3. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.

Life Expectancy:

Full-depth repairs can be designed and constructed to provide good long-term performance of 10 or more years. Major causes of premature failures are inadequate load transfer design and poor construction quality. The effectiveness of some full-depth repairs has been limited due to placement on pavements that are too far deteriorated.

Localized Failure Treatments

Blade Patching

Figure 69: A Blade Patch.

Procedure:

1. Set up traffic control measures. Depending on the class of highway, crews need the protection of correct signing, flaggers or other traffic control.
2. Use a jackhammer or milling machine to carve out any deteriorated pavement and create a neat rectangle shaped hole in solid pavement. Cut off any high spots and remove damaged material to reach a firm base. Make certain the remaining material is sound and free of cracks. Extend the patch a short distance on each end so that the ends can be tapered. Where possible stop and start the patch on level pavement. If the shoulder is higher than the mat, cut the shoulder down level with the mat so that water can drain.
3. Remove all dirt and loose debris from the hole including loose subgrade material if necessary. Take all loose material to the borrow pit so that it will not be a hazard to mowers and to leave a good appearance.
4. Make sure the hole is dry. A wet surface will affect adhesion of the patching material. If necessary, dry the hole with air or heat to eliminate moisture that would negatively affect adhesion.

Hot mix – cold lay is less temperature sensitive and gives an operator more time to lay the patch. It can be used for longer patches.

Cold mix patching material is used when hot asphalt is not available such as when the pothole location is too far from a hot mix plant. Cold mixes have a tendency to push, shove, and come out of potholes too easily for pothole patching. Unlike Hot mix asphalt which must be applied while hot, cold mix patching material can be stockpiled and used when needed.

Tack materials include: asphalt cement (poured or sprayed while hot), cut-back asphalt (may be poured cold, but is usually slightly heated) and emulsified asphalt (add water to spray, pour, or mop into the hole).

Weather Requirements and Pavement Conditions:

Permanent pothole patching should done in warm dry weather. Wet pavements and cold pavements will interfere with the adhesion of the hot mix patch material to the existing pavement.

Problems to Avoid:

Premature blade patch repair failures include:

1. Loss of material through raveling; losing material from the surface of the repair resulting from a variety of causes, such as inadequate cohesion within the repair mix or poor compacting.
2. Lack of adhesion to the sides or bottom of the repair. Lack of adhesion can lead to cracking. When water gets into cracks, freezing action may dislodge the repair.
3. Pushing or shoving of the patching mix. Inadequate shearing resistance in the mix or a poorly compacted mix, the bleeding of tack or liquid asphalt to the upper portion of the repair, or a poorly designed mix."
4. Dishing; surface settling that results when the repair mix is inadequately compacted.
5. Reflective cracking originating in old, underlying pavement and continuing into the patch.
6. Delaminating; peeling away of thin overlays of asphalt concrete from the surface of the roadway due to poor adhesion.
7. Poor drainage becomes a factor when the pothole repair is in a low-lying area, where it remains constantly wet and water damage results.

Life Expectancy:

Blade patch repairs normally last for many years if the causes of the initial problem are corrected. To immunize labor and material costs and to immunize exposure of maintenance personnel to dangerous traffic it is best to make each blade patch repair permanent if possible.

Pothole Patching

Potholes are bowl-shaped openings that usually have raveled edges and can be up to 10 inches deep. They occur when the top layer or asphalted surface of the roadway has worn away, exposing the road subbase.

Potholes are a danger to the travelling public and can lead to serious accidents and injuries. On principal roadways potholes are considered dangerous if they are vertically sided, are more than 1 inch deep and have an area of greater than one square foot. On non-principal roadways potholes are considered dangerous if they are vertically sided, are more than 2 inches deep and have an area greater than one square foot. It is, therefore, important to repair potholes as soon as possible after they occur. Potholes on Interstate highways should be repaired within 24 hours of reporting. Potholes on most other heavily traveled roads should be repaired within 48 hours.

If left unattended, potholes will enlarge and cause the degrading of more of the road surface. This section addresses pothole patching but these procedures can be used to repair sewer cuts, utility cuts, crevices, surface subsidence, sinks and dips as well as potholes. These procedures are also used to construct walkways, bike trails, curbs and gutters.

Permanent pothole repairs normally last for many years if the initial causes of the problem are corrected. To immunize labor and material costs and to immunize exposure of maintenance personnel to dangerous traffic, it is best to make each pothole repair permanent if possible**.** Sometimes, however, it is necessary to repair potholes during inclement weather or make an immediate repair of failed roadway to maintain safety. In such situations, conditions may prevent permanent repairs During the winter, or in bad weather, propriety cold mix type materials are sometimes used to fill potholes temporarily until they can they can be scheduled for permanent repair repairs under better conditions. Under these conditions pothole patching is only considered an initial repair to provide for the safety of the traveling public until more permanent repairs can be accomplished. Complete resurfacing is accomplished as funds become available.

District patrolmen are constantly on the lookout for potholes, but NMDOT welcomes calls from the public as well. To maximize resources, maintenance crews often do other types of repair work while they are out filling potholes, such as filling nearby cracks and crevices.


Figure 70: Filling a crevice with a propriety cold mix type material.

Procedure:

1. Set up traffic control measures. Depending on the class of highway, crews need the protection of correct signing, flaggers or other traffic control.
2. Mark the area of loose or deteriorated material to remove. Use paint or chalk to mark a straight-sided rectangle or polygon. Lines should delineate the inclusion of at least a foot of sound pavement surrounding the pothole.
3. Remove standing water, if any, from pothole.
4. Use a jackhammer to carve out any deteriorated pavement and create a neat rectangle shaped hole in solid pavement. Remove damaged material to reach a firm base and make certain the remaining material is sound and free of cracks
5. Remove all dirt and loose debris from hole including loose subgrade material if necessary. Make sure the hole is dry. A wet surface will affect adhesion of the patching material. If necessary, dry the hole with air or heat to eliminate moisture that would negatively affect adhesion.
6. Backfill the hole with appropriate sub-grade material if loose subgrade material was removed.
7. Apply an asphalt tack to the sides and bottom of the hole to bond the patching material to the surrounding pavement. Immediately before filling, mop, pour, or spray a tack coat onto the sides and bottom of the pothole. The tack improves adhesion between the old pavement and the patching mixture. Tack materials include: asphalt cement (poured or sprayed while

hot), cut-back asphalt (may be poured cold, but is usually slightly heated) and emulsified asphalt (add water to spray, pour, or mop into the hole).

8. Fill the hole with patching material. Use hot mix patching material when it is available. Potholes with depths greater than 3 inches should be filled with patching material in 2 inch layers, compacting the material after each layer. During the final lift, extend and level off the patching material about ¼ inches above the existing pavement to allow a level that is flush with the surrounding pavement after the patching material is compacted.
9. To compact the patching material a 4 ton steel-wheeled or rubber-tired roller works well. Other compaction techniques are, in order of decreasing effectiveness, are: vibrating plates, hand tampers, delivery truck tires and the back of a shovel. Compacting reduces the ability of water to penetrate, ties the aggregate together, and increases resistance of the patch to rutting and shoving. Do not over compact the patching material. Too much compaction can cause cracking around the pothole.

Figure 71: A well sealed patch.

10. To reduce water penetration, it is a good practice to seal the patch edges with a crack filling material seal the patch surface with a sand or Chip Seal. Sealing involves applying a light, six-to-eight-inch-wide coat of hot asphalt cement or cold-applied liquid asphalt and blotting the liquid with sand or aggregate chips.
11. Move on to next pothole. This procedure takes on average 25 to 30 minutes, depending on size of hole.

Material:

Hot Mix is the preferable type of patching material and consists of a mix of asphalt with various blending adhesives. It is denser than other patching materials and resists water infiltration. Cold mix patching material is used when hot asphalt is not available such as when the pothole location is too far from a hot mix plant. Cold mixes have a tendency to push, shove, and come out of potholes too easily for pothole patching. Unlike Hot mix asphalt which must be applied while hot, cold mix patching material can be stockpiled and used when needed.

Propriety cold mix type materials, in plastic bags or in tubs, are often used to repair small potholes and cracks.

Weather Requirements and Pavement Conditions:

Permanent pothole patching should done in warm dry weather. Wet pavements and cold pavements will interfere with the adhesion of the hot mix patch material to the existing pavement.

Problems to Avoid:

Premature pothole repair failures include:

1. Loss of material through raveling; losing material from the surface of the repair resulting from a variety of causes, such as inadequate cohesion within the repair mix or poor compacting.
2. Lack of adhesion to the sides or bottom of the repair. Lack of adhesion can lead to cracking. When water gets into cracks, freezing action may dislodge the repair.
3. Pushing or shoving of the patching mix. Inadequate shearing resistance in the mix or a poorly compacted mix, the bleeding of tack or liquid asphalt to the upper portion of the repair, or a poorly designed mix."
4. Dishing; surface settling that results when the repair mix is inadequately compacted.
5. Reflective cracking originating in old, underlying pavement and continuing into the patch.
6. Delaminating; peeling away of thin overlays of asphalt concrete from the surface of the roadway due to poor adhesion.
7. Poor drainage becomes a factor when the pothole repair is in a low-lying area, where it remains constantly wet and water damage results.

Life Expectancy:

Permanent pothole repairs normally last for many years if the causes of the initial problem are corrected. To immunize labor and material costs and to immunize exposure of maintenance personnel to dangerous traffic it is best to make each pothole repair permanent if possible.

CONCRETE PAVEMENT TREATMENTS

Pothole and Crack Treatments

Joint Spalling Repairs

Background:

Joint Spalling Repairs are a concrete pavement restoration technique of repairing joint spalling scaling, and popouts in Portland Cement Concrete (PCC). Joint Spalling Repairs are similar to Partial Depth Repairs but are used to correct smaller, localized areas of pavement where removal of large amounts of concrete is not warranted, usually areas less than 6 inches in length and 1.5 inches in width at the widest point. Joint spalling repairs improve ride quality, and extend the service life of pavements that have spalled or distressed joints.

Procedure:

Set up the project:

1) Make an assessment of the road on which you are going to conduct joint spalling repairs. Check of the plan for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway. Determine the best type of patch material to be use.

2) Go to the project site and see what condition the road is in. Joint spalling repairs will not work on pavements where the area of spalling is deeper than 1/3 of the thickness slab.

3) Measure the area of the pavement that you want to repair. Areas to be repaired shall be determined by the engineer using a rod, hammer or other device to determine defective or delaminated areas. The extent of the repair area will be marked by the engineer.

4) Determine a preliminary traffic control plan:

   a. Look at detours or phasing to get the work done and maintain traffic flow. The only opportunity to do this work may be a night so you may need to look at lighting needs. Verify that signs and devices match the traffic control plan presented in the contract documents.
   b. Verify that the setup complies with the Federal *Manual on Uniform Traffic Control Devices* traffic control procedures.
   c. Verify that traffic control personnel are trained/qualified in accordance with NMDOT requirements.

d. Ensure that the repaired pavement is not opened to traffic until the patch material has met the minimum strength specified.
e. Ensure that signs are removed or covered when they are no longer needed.
f. Report any unsafe conditions to a supervisor.

Materials:

Accelerated strength PCC (3000 PSI in 24 hours) repair mixtures can be used where early opening to traffic (4 to 6 hours) is required. An epoxy bonding agent is required when placing high-early-strength PCC repair for early opening to traffic. Check the patching materials for the following:

- NMDOT Standard Specifications for Highway and Bridge Construction Sections 451.3 and 510.4 - construction requirements for PCC pavements.
- The patch material is of the correct type and meets specifications.
- The patch material is obtained from an approved source or is listed on NMDOT Approved Products List.
- The patch material has been sampled and tested prior to installation.
- The material packaging is not damaged so as to prevent proper use (for example, packages are not leaking, torn, or pierced).
- The bonding agent (if required) meets specifications.
- The curing compound (if required) meets specifications.
- The joint/crack re-forming material (compressible insert) meets specifications (typically polystyrene foam board, 1/2 inch thick).
- The joint-sealant material meets specifications.
- Sufficient quantities of materials are on hand for completion of the project.

Construction:

<u>Locate Unsound Concrete</u>
The first step in constructing a successful joint spalling repair is the identification and removal of all deteriorated concrete. Unsound concrete is commonly located by "sounding out" the delaminated area. Sounding is done by striking the concrete surface with a steel rod or ball-peen hammer, or by dragging a chain along the surface. The rod, hammer, and chain will produce a clear ring when used on sound concrete and a dull response on deteriorated concrete.

Figure 72: "Sounding" with a hammer.

Figure 73: "Sounding" with a steel chain.

<u>Determine the Repair Boundaries</u>

Include all deterioration within the repair boundaries. Clearly mark each boundary with brightly-colored spray paint to outline the removal area. Repair boundaries should be square or rectangular.

<u>Remove Loose Concrete</u>

Chip the area until sound and clean concrete along the entire bottom of the repair is exposed. The depth of the repair should not exceed about one-third the pavement thickness. If more chipping is necessary to find sound concrete, or dowel bars are exposed, switch to a partial or full-depth repair.

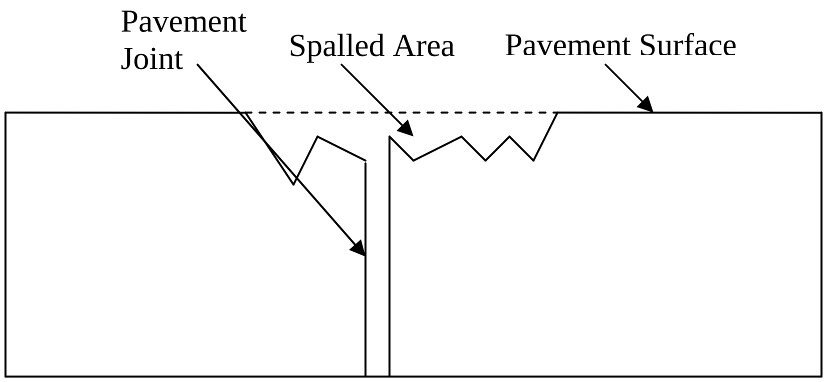


Figure 74: Sketch showing joint spalling repair technique (A).

Use diamond-bladed saws set to a depth of about 1-2 inches. The cuts should be straight and vertical. Overrun the cut slightly so that the bottom of the cut is deeper than the repair corner. Break the concrete using a light pneumatic hammer no heavier than 30 pounds. Lighter, 15 pound hammers are preferable so that it is easier to control the depth of chipping. Spade bits are preferable to gouge bits for control of chipping. Even light hammers with gouge bits can damage sound concrete.

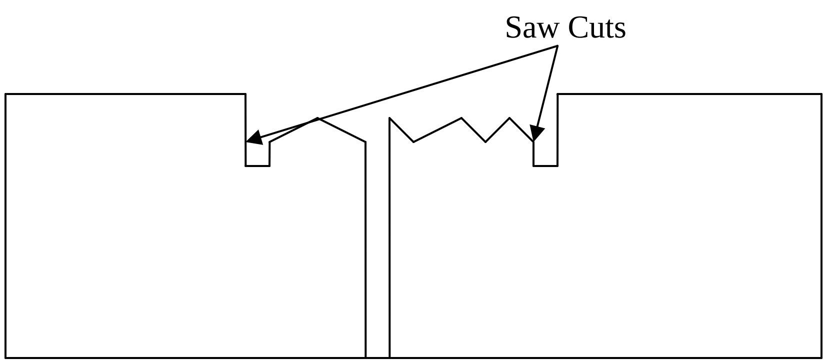


Figure 75: Sketch showing joint spalling repair technique (B).

<u>Clean Saw Cuts</u>

After removing the concrete within the delaminated area, check the bottom by sounding for remaining weak spots. Either chip away the weak areas or consider a partial or full-depth repair if the deterioration goes too deep. The exposed faces of concrete should be sandblasted free of loose particles, oil, dust, traces of asphaltic concrete and other contaminants before placing patching materials.

High-pressure water blasting is an alternative to sandblasting where controlling dust is critical in urban environments. Waterblast equipment for concrete removal should be capable of producing a blast pressure of 14,500 - 29,500 PSI. However, to avoid damage, the equipment must be capable of adjustments that will allow removal of only weakened concrete.

Airblow the repair area to remove dust and sandblast residue. Direct the debris away from the repair area so that wind and traffic will not carry it back. Dust and dirt prevent the repair material from bonding to the old concrete. The air compressor should deliver air at a minimum of 70 cubic feet per minute and develop 90 PSI nozzle pressure. Even if the equipment has a filter, check the air for oil and moisture contamination. Place a clean cloth over the nozzle and blow air through the cloth. Examine the cloth for any discoloration from moisture or oil residue.

Apply Bonding Agent

When a bonding agent (cementitious grout) is required, the materials should be applied in a thin even coat. The epoxy prime coat shall be applied in a thin coating and scrubbed into the surface with a stiff bristled brush. Contact between the repair and any adjacent pavement which could cause compression or other types of failure in the repair must be prevented. The contact time (it should not dry out) for cement grout should not exceed about 90 minutes. Check the repair area for any dust or sandblasting residue before placing a bonding agent. The area should be clean and dry. Wiping the area while wearing a dark brown or black cotton glove will easily indicate a dust problem. Airblow again if the dust has settled back in the repair area. Scrubbing the bonding materials in with a stiff-bristled brush works well to get the materials into surface cavities. Epoxy agents may permit a less vigorous application. Be sure to cover the entire area with the bonding agent, including the repair walls or edges. Overlapping the pavement surface also will help promote good bonding.

Install Joint Insert

Insert a joint insert, a properly sized polylined Styrofoam joint spacer or black expansion board, to maintain the joint configuration.

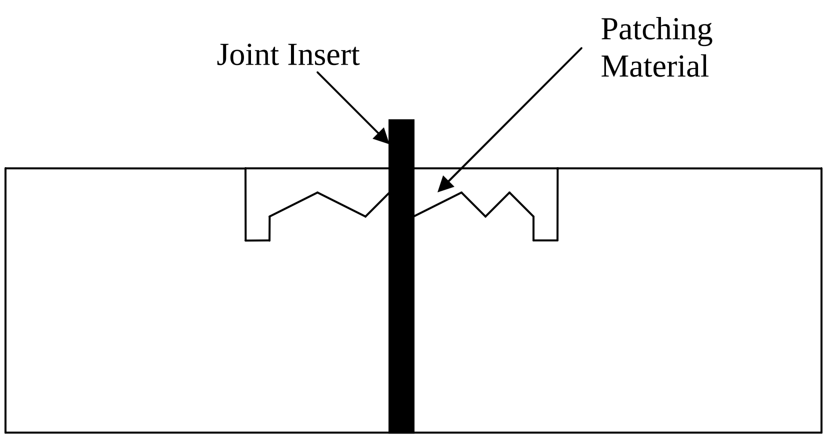


Figure 76: Sketch showing joint spalling repair technique (C).

Placing the Repair Material

The volume of material required for a joint spalling repair is usually small. Repair materials are typically mixed on site in small mobile drums or paddle mixers.

Finishing

Finish the repair surface so that it is flush with the surrounding pavement. Trowel the patch outward, from the center toward the edges, to push the repair material against the walls of the patch. This technique provides a smooth transition and increases the potential for high bond strength. Most finishers tend to finish a repair from the edges toward the center, which pulls the material away from the edges. For small repairs, and projects that include diamond grinding, texturing is not important. For projects with many repairs, matching the existing surface texture will produce a more uniform appearance.

Curing

Figure 77: Application of Curing Compound.

For curing, apply a liquid-membrane-forming curing compound evenly and sufficiently. Use well-maintained pressure spraying equipment that will allow an even application. Curing is very important because of the large surface area of these small repairs compared to the small volume of repair material. This relationship is conductive to a rapid moisture loss and is different from most other concrete applications. Neglecting to cure the repairs or waiting too long to apply the compound will likely result in excessive material shrinkage and possibly delaminating of the repair.

Where early opening of the pavement to traffic is required, it may be beneficial to place insulation mats over the repairs. This will hold in heat from hydration and promote increased strength gain for cementitious materials.

Joint Resealing

After the patch has gained sufficient strength, the joint can be resealed. Carefully remove joint insert after waiting 3 to 4 hours at 70° F. It is important that the joint faces are clean and dry for good sealant performance. Sawing, to provide the proper joint shape factor, and sandblasting, to remove dirt and saw residues from the joint faces, is essential. Resealing the joint is extremely important, because it will help prevent moisture and incompressible materials from causing further damage.

Weather Requirements and Pavement Conditions:

- Review manufacturers' installation instructions for requirements specific to the patch material being used.
- Ensure that air and surface temperature meet manufacturer and contract requirements (typically 40° F and rising) for concrete placement.
- Ensure that patching does not proceed if rain is imminent.

Problems to Avoid:

More deterioration below surface than is evident above:

- Extend limits of repair area into sound concrete.
- If deterioration extends deeper than one-third of the thickness of the slab, do a partial or full-depth repair.

Dowel bar or reinforcing steel is exposed during concrete removal:

- If steel is in the upper third of slab, remove the steel to the edges of the patch and continue.
- If removal extends to mid-depth of the slab, do a partial or full-depth repair.

Patch material flows into joint or crack:

- Ensure joint insert extends far enough into the adjacent joint/crack and below the patch.
- Ensure insert is correctly sized for joint/crack width.

Patch cracking or unbonding:

- Check that joint insert is being used properly.
- Ensure that the insert is correctly sized for the joint/crack width and that it has been inserted correctly.
- Check that patch area was cleaned immediately prior to grouting/concrete placement.
- Check that grout material has not dried out before concrete placement.
- Ensure that curing compound has been applied adequately.
- Check that patch material is not susceptible to shrinkage.

Life Expectancy:

When properly placed with an appropriate and durable material and combined with good joint sealant maintenance practices, joint spalling repairs should last long as the remaining pavement. The performance of joint spalling repairs depends on many factors. The most frequent causes of performance problems are related to misuse of the technique, poor repair material and careless installation. Studies show that when joint spalling repairs are properly installed and when quality control during construction is good, 80 to 100 percent of the repairs perform well after 3 to 10 years of service.

Joint Resealing and Crack Sealing

Figure 78: Sealing Cracks

Background:

The purpose for sealing concrete pavement joints and cracks is primarily:

- To minimize the passage of water through joints and cracks to the pavement subbase. Water accumulating under the slab can contribute to distresses such as pumping, loss of support, faulting and corner breaks.
- To prevent incompressible materials, such as pebbles and stones, from filling the joints and cracks. Incompressible materials that infiltrate poorly sealed joints or cracks interfere with their normal opening and closing movement, causing compressive stresses in the slab and increasing the potential for spalling. If the compressive stresses exceed the compressive strength of the deteriorated pavement, blowups or buckling will occur.

Resealing is necessary whenever the condition of an existing sealant does not fulfill these functions, either because the sealant is missing or because it is deteriorated.

The need to seal cracks depends on their condition and orientation. Narrow, hairline cracks that remain tight and do not extend throughout the slab usually do not require sealing. But wide cracks that function like joints and extend through the slab do require sealing. These cracks usually cycle open and closed with temperature changes in the same manner as transverse joints.

Procedure:

Set up the project.

6) Make an assessment of the pavement you are thinking of joint and/or crack sealing. Check and see if it is scheduled for reconstruction in the next few months so you don't waste resources on a road that would be replace anyway. Determine the best type of crack sealing material to be used.

7) Next go to the project site and first analyze the joints and/or cracks to see if they are a good candidate for sealing or if another crack treatment is warranted. Normally cracks with a width of greater than ¾ of an inch are filled instead of being sealed.

8) Get an estimate of the amount of cracking per lane mile. This will take some experience to get proficient at determining the quantities. It would be advisable to meet with your industry representative the first couple of times to get some help in determining your estimate.

9) Determine a preliminary traffic control plan. Look at detours or phasing to get the work done and maintain traffic. You may have to put a project together that the work performed is done at night in order to maintain traffic flow. Also a staging area should be located in order to minimize the disruption to traffic and provide a safe stockpile site out of the clear zone.

10) Set up paperwork for a contract maintenance project or if looking for a really large scale effort you might need to produce a book project.

Material Types

The selection of an appropriate sealant material is dependent on a number of project-related characteristics including;

- Climate conditions (at time of installation and during the life of the sealant).
- Traffic level and percent trucks.
- Crack characteristics and density.
- Material availability and cost.
- Contractor experience.
- Safety concerns.

PCC joint resealing and crack sealing operations generally employ hot-applied thermoplastics and chemically cured thermosetting materials. The following table summarizes the inherent characteristics that affect the performance of the primary sealant materials used in today's practice as reported in FHWA materials in 1999:

Sealant Material	**Example Products**	**Applicable Specification(s)**	**Typical Material Costs ($/ft)**
Thermoplastic Materials			
Rubberized Asphalt	Koch 9005 Crafco RS 221	ASTM D 6690 AASHTO M 173, M 301	0.18 to 0.31
Low Modulus Rubberized Asphalt	Crafco 231 Koch 9030 Meadows Sof-Seal	Modified ASTM D 3405	0.21 to 0.37
Thermosetting Materials			
Polysulfide	Koch 9050-SL	Fed. Spec. SS-S-200E	Not Available
Polyurethane	Vulchem Sikaflex Burke U-Seal	Fed. Spec. SS-S-200E	1.59 to 2.20
Silicone (non-sag)	Dow 888 Crafco 902 Mobay 960	ASTM 5893	1.98 to 2.74
Silicone (self-leveling)	Dow 890-SL Crafco 903-SL Mobay 960-SL	ASTM 5893	1.98 to 2.90

Cost Considerations

The preceding table shows the material costs (not the total cost of application) of various sealant types as reported in a FHWA publication in 1999. The following table summarizes sealant material costs according to a study by the University of Cincinnati in 1999. The costs in both tables do not include the cost of installation, the cost of the backer rod used for silicone and hot-poured materials or the cost of adhesive material used with compression seals.

Sealant Material Type	Unit Costs	Estimated Cost per Joint
Dow 890-SL	$48.00/gallon	$12.27
Crafco 903-SL	$36.00/gallon	$9.20
Dow 888	$42.00/gallon	$10.74
Crafco 902	$39.00/gallon	$9.97
Crafco 444	$10.50/gallon	$2.68
Crafco 221	$0.25/pound	$0.64
Watson Bowman WB-812	$1.05/linear foot	$43.26
Watson Bowman WB-687	$0.72/linear foot	$30.24
Delastic V-687	$0.66/linear foot	$27.72
TechStar W-050	$8.65/linear foot	$363.30

Hot-Applied Thermoplastic Sealant Materials

Thermoplastic sealants are bitumen-based materials that typically soften upon heating and harden upon cooling, usually without a change in chemical composition. These sealants vary in their elastic and thermal properties and are affected by weathering to some degree. Thermoplastic sealants are typically applied in a heated form (i.e., hot-applied) on PCC pavements, although some are diluted such that they can be installed without heat (i.e., cold-applied).

In the past 15 years, rubberized asphalt has become the sealing industry standard. This type of sealant is produced by incorporating various types and amounts of polymers and melted rubber into asphalt cement. The resulting sealants possess a large working range with respect to low temperature extensibility and resistance to high temperature softening and tracking. Most of the rubberized asphalt materials fall under ASTM D 3405. In recent years, softer grades of asphalt cement have been used in rubberized asphalts to further improve low temperature extensibility. These materials, referred to as low modulus rubberized asphalt sealants, are used for sealing operations in many northern states because of their increased extensibility.

Thermosetting Sealant Materials

Thermosetting sealants are typically one or two-component materials that either set by the release of solvents or cure through a chemical reaction. Some of these sealants have shown potential for good performance, but the material costs are also four to ten times greater than standard rubberized asphalt. However, thermosetting sealants are often placed thinner and may have lower labor and equipment costs.

Chemically cured sealants are the predominant type of thermosetting materials used in highway sealing operations. They may include polysulfides, polyurethanes, silicones and epoxies. The advantage of many of these materials is their durability and ease of handling and, in particular, that they are not heated during application. However, their material costs are usually higher than for thermoplastics.

The performance of polysulfide and polyurethane sealants has been variable. While these materials seem to retain elasticity fairly well, their adhesive capabilities (and particular those of the polysulfides) are questionable. In addition, most of these materials are two-component materials. The need to mix the two parts introduces an additional step in the sealing operation, which increases sealing time and introduces another source of error.

Silicone sealants are one-part cold-applied materials that have been used in the paving industry since the 1970’s. Their properties include good extensibility and resistance to weathering and temperature. These sealants have good bonding strength in combination with a low modus that allow them to be placed thinner than the thermoplastic sealants.

Silicone sealants are available in self-leveling and nonself-leveling forms. The nonself-leveling silicone requires a separate tooling operation to press the sealant against the sidewall and to form a uniform recessed surface. Recently developed self-leveling silicone sealants can be placed in one step since they freely flow to fill the joint reservoir without tooling. Performance of silicone sealants is typically tied to joint cleanliness and tooling effectiveness. ASTM specification D 5893 governs joint sealants.

<u>Sealant Properties</u>

Critical sealant properties that significantly affect the performance of the sealant material include:

- Durability
- Extensibility
- Resilience
- Adhesiveness
- Cohesiveness

Durability refers to the ability of the sealant to withstand the effects of traffic, moisture, sunshine and climatic variation. A sealant that is not durable will blister, harden and crack in a relatively short time. If over-banded on to the pavement surface, a non-durable sealant may soften under higher temperatures and may wear away under traffic.

The extensibility of a sealant controls the ability of the sealant to deform without rupturing. The more extensive the sealant, the lower the internal stresses that might cause rupture within the sealant or at the sealant-sidewall interface. Sealant extensibility is most important under cold conditions because maximum joint and crack openings occur in colder months. Softer, lower modulus sealants tend to be more extensible, but they may not be stiff enough to resist the intrusion of incompressible materials during warmer temperatures.

Resilience refers to the sealant's ability to fully recover from deformation and to resist stone intrusion. In the case of thermoplastic sealants, however, resilience and resistance to stone intrusion are often sacrificed in order to obtain extensibility. Hence, a compromise is generally warranted, taking into consideration the expected joint or crack movement and the presence of incompressible materials for specific climatic regions.

As sealant material in a joint or crack is elongated, high stress levels can develop such that the sealant material is separated from the sidewall (adhesive failure) or the material internally ruptures (cohesive failure). Sealant adhesiveness is one of the most important properties of a good sealant, and often the cleanliness of the joint or crack sidewalls determines the sealant's bonding ability. Cohesive failures are more common in sealants that have hardened significantly over time.

Construction:

Transverse Joint Resealing

After the sealant material has been selected, careful attention must be paid to the installation procedure to ensure that the sealant provides the maximum design life. The resealing of transverse joints in PCC pavements consists of the following steps:

1. Old Sealant Removal.
2. Joint Refacing.
3. Joint Reservoir Cleaning.
4. Backer Rod Installation.
5. New Sealant Installation.

Old Sealant Removal
The first step of the joint resealing process is to remove the old sealant from the joint. Removal can be done by any procedure that does not damage the joint itself, such as using a rectangular joint plow or removal with a diamond-bladed saw or high pressure water blasting.

Diamond-bladed sawing as a means of sealant removal has gained acceptance because it combines the sealant removal and refacing steps in a single process. It is most effective at removing existing silicone sealants ad existing thermoplastic sealants when they have hardened and will not melt and "gum-up" the saw blade or joint face.

Complete removal of the old sealant is not required for the entire depth of the joint if the required reservoir depth is less than the existing sealant that is present. However, if there are incompressible materials present, the old sealant should be completely removed to ensure free-moving clean joints.

Joint Refacing

The purpose of the refacing operation is to provide a clean surface for bonding with the new sealant and to establish a reservoir of the proper size to produce the desired shape factor. If a diamond-bladed saw has been used for sealant removal, refacing can be performed at the same time. If a joint plow or some other means has been used to remove the old sealant material, then a separate joint refacing operation must be performed.

Refacing is generally done using a water-cooled saw with diamond blades. A single full-width blade is useful for maintaining joint width; however, the edges wear quickly, reducing the effectiveness of the sawing. Two blades separated by a spacer to the desired width can be used on the same arbor. The core diameter of these blades should be at least 4.8 mm (0.19 inch) to keep the blades from toeing into the joint. Blade overheating and warping can result from using thin blades. Typically, a joint is widened by ⅛ inch ($^1/_{16}$ inch on each face). Care should be taken not to widen the joint too much so as to create bumps and noisy "wheel slap".

Routers are also used to reface joint reservoirs but their production is slower than diamond-backed saws. In addition, they can leave irregular or spalled joint walls and may smear the existing sealant on the sidewalls. Therefore, the use of routers is not recommended for joint refacing operations.

Figure 79: Routing Cracks

Joint Reservoir Cleaning

The importance of effective cleaning of the joint sidewalls cannot be over-emphasized. Dirty or poorly cleaned joint or crack sidewalls can reduce the performance of even the best sealant and the most reliable sealant reservoir design. Materials that may contaminate the joint sidewalls include:

- Old sealant left on the joint or crack sidewalls.
- Water-borne dust (laitance) from the sawing operation.
- Oil or water introduced by the compressed air stream.
- Dust and dirt not removed during the cleaning operation.
- Debris entering the joint after cleaning and prior to sealing.
- Other contaminants that may inhibit bonding, such as moisture condensation.

Immediately after joint refacing, the joint should be cleaned with high-pressure air or water followed by sandblasting. Sandblasting effectively removes laitance (wet-sawing dust) and any other residue on the joint faces, and should be conducted in two passes so that each joint face is cleaned. Air compressors used with the sandblasters must be equipped with working water and oil traps to prevent contamination of the joint bonding faces. Compressors should be tested prior to sandblasting operations using a clean white cloth to ensure oil/water free operations.

Following sandblasting, the entire length of each joint face should be visibly clean with exposed concrete. Very close attention must be paid to the sandblasting operation to ensure consistent, thorough cleaning. During the sandblasting operation, a proper helmet and breathing apparatus and any other appropriate safety equipment should be used to protect the operator.

Immediately prior to backer rod and sealant installation, the joints should be blown again with high pressure (> 90 PSI), clean, dry air to remove sand, dust and other incompressible materials that remain in the joint. A backpack blower typically cannot generate sufficient air to clean joints thoroughly and should not be used for final cleaning. Joints and surrounding surfaces should be air-blown in one direction away from prevailing winds, taking care so as not to contaminate previously cleaned joints. Care must also be taken not to blow debris into adjacent lanes. Power-driven wire brushes should never be used to remove old sealant or to clean a joint in a PCC pavement. This procedure is essentially ineffective and can smear the old sealant across the concrete sidewall, creating a surface to which the new sealant cannot bond.

Problems to Avoid:

The following table summarizes some of the more common problems an inspector may encounter in the field during a joint resealing or crack sealing project:

Problem	Typical Cause(s)	Typical Solution(s)
Dust, dirt or contamination on refaced joint or crack surfaces.	Improper cleaning techniques.	The presence of dust, dirt or contaminants in poor sealant adhesion. If observed, the contractor should re-clean the surfaces in question using the recommended techniques.
Bubbles in hot applied sealant material.	If reservoir walls are not free from moisture, moisture will boil in contact with hot-poured materials, forming steam that will bubble.	Stop sealant installation procedures and allow reservoir walls to dry or accelerate the drying by blowing air into the reservoir.
Punctured or stretched backer rod.	Improper backer rod installation techniques.	A punctured or stretched backer rod can result in an improper shape factor or adherence of sealant to bottom of reservoir. Both of these conditions have detrimental effects on the long-term performance of the sealant. If observed, remove the existing backer rod and install a new backer rod using the recommended procedures.
Raveling, spalling, or other irregularities of the joint walls prior to sealant application.	Improper care in sealant removal or joint cleaning steps. Note: A V-shaped joint plow blade can spall joint sidewalls.	Irregularities on joint walls can reduce the sealant's lateral pressure allowing the sealant to extrude or pop from the joint. If irregularities are observed the agency and contractor should agree on an appropriate method for repairing potential problem areas.
Difficulty in installing sealant material.	Burrs along the sawed joints.	Drag a blunt pointed tool along the sawed joint, or use a mechanized wire brush to remove sharp edges. Note: the joint or crack will have to be recleaned prior to sealing.
Tracking of material (i.e., the sealant material onto unwanted areas of the surface area via shoes, tires, etc.).	Tracking potentially indicates one or more of the following: • Too much sealant is being applied. • Traffic is being allowed on the sealant before the material has had a chance to sufficiently cool or cure. • The chosen sealant	Potential solutions include: • Reduce the amount of sealant or filler being applied. • Allow more time for material to sufficiently cool or cure (or use sufficient sand for blotter coat). • Ensure the sealer/filler is appropriate for the climate in which it is being placed.

	material is inappropriate for the climate in which it is being used.	
Bumps or irregularities in surface of tooled sealant application.	Problem with quality of tooling equipment or quality of tooling process.	Potential solutions include: • Check tooling utensil or squeegee and ensure it is leaving the correct finish. Repair or replace as necessary. • Ensure that tooling is being conducted within the time after application recommended by the manufacturer. • Decrease the viscosity of the sealant (if applicable).

<u>Backer Rod Installation</u>

The backer rods should be installed as soon as possible after the joints are sandblasted. The backer rods should be approved by the sealant manufacturer and be about 25 percent larger in diameter than the joint width. The backer rod must be of a flexible, non-absorptive material that is compatible with the sealant material in use.

Larger diameter backer rods that will provide a tight seal should be used in joints or segments of joints that that are wider. Backer rods should be installed to the proper depth with no gaps at the intersections of the backer rods. Backer rods should be stretched as little as possible to reduce the likelihood of shrinkage and the resultant formation of gaps. Contractors should have hand backer rods several different diameters of backer rods on hand for reservoirs of varying widths.

<u>New Sealant Installation</u>

The sealant material should be installed as soon as possible after rod replacement. This helps to avoid problems that occur when the backer rod is left in place too long before the sealant is placed, such as condensation on the backer rod and debris collecting in the reservoir. An additional check to verify that the reservoirs are clean and dry helps to ensure good long-term performance.

<u>Hot-Poured Thermoplastic Sealant Materials</u>

Hot-poured thermoplastic sealant materials should be installed in a uniform manner, filling the reservoir from the bottom up to avoid trapping air. The joint reservoir must not be overfilled during the sealing operation. It is generally recommended that the surface of the sealant be recessed at least ⅛ to ¼ inch below the surface of the pavement to allow room for sealant expansion during the summer when the joint closes without extruding the sealant to the point

Other thermosetting sealants, such as polysulfides and polyurethanes, require a curing period to gain their strength and resiliency. Most polymeric thermosetting sealants consist of two components that are carefully mixed as the material is being placed in the joint. These sealants require a special application nozzle and careful control of the application equipment. Quality control should include testing the sealant for adequate cure and traffic should not be allowed on these sealants until the surface has been skinned over and the possibility for stone intrusion is minimized.

Longitudinal Joint Resealing Joint Sealing

PCC to PCC Joints

Longitudinal joints between adjacent PCC slabs are found between adjacent traffic lanes or between a PCC mainline pavement and a PCC shoulder. This joint is generally tied together with deformed tie bars so that movements are not excessive and conventional joint sealing operations can be followed.

Because of the limited amount of movement that occurs at these joints, they are generally sealed with a hot-poured thermoplastic material. In the resealing operation, typically no reservoir is formed or needed. If the transverse joints are to be sealed with silicone, it is important that the longitudinal that the longitudinal joints be sealed last to prevent contamination of the transverse joints with hot-poured thermoplastic material.

PCC Mainline/HMA Shoulder Joint

The longitudinal joint between a PCC mainline pavement and a Hot Mix Asphalt (HMA) shoulder can be a very difficult joint to seal. The differences in the thermal properties of each material and the differences in the structural cross section often result in large differential vertical movement. Because water easily infiltrates the pavement structure at this type of joint, it should be sealed to minimize water infiltration.

Again, the steps required for the sealing of lane-shoulder joint are the same as transverse joint sealing. However, it is important that a sufficiently wide reservoir be cut in the existing HMA shoulder to allow for the anticipated vertical movements. A minimum 1-inch wide and 1-inch deep reservoir is recommended.

The reservoir should be cleaned prior to the placement of the sealant material. A backer rod is generally not needed if proper depth control during the creation of the reservoir has been maintained.

Crack Sealing

Except for removing the old sealant material, the sealing of cracks in PCC pavement is the same as joints. However, because of the zigzag nature of PCC cracks it is often difficult to create a uniform sealant reservoir directly over the crack. Routers and small diameter diamond-bladed saws are used. The cutting blades for these saws are typically 7 to 8 inches in diameter and ¼ to ½ inch wide. Smaller blade diameters, in addition to two or three wheeled units, allow crack saws to pivot and follow irregular crack profiles. However, they are generally not as maneuverable as routers.

Weather

The weather conditions at the time of construction can have a large impact on the performance of the sealant. The following weather-related items should be checked prior to construction:

- Review the manufacturer instructions.
- Hot-poured thermoplastic, silicone and most other sealant materials should be placed only when the air temperature is at least 40°F and rising.
- Do not joint reseal or crack seal if rain is imminent.
- Do not joint reseal or crack seal if there is any sign of moisture on the pavement surface or in the joint or crack.

Life Expectancy:

Maximum performance hinges on joint preparation and installation. Compression seals provide service for periods often exceeding 15 years and sometimes 20 years. A typical hot-pour sealant provides an average of 3 to 5 years of life after proper installation. Some low modulus or PVC coal tars can perform well past 8 years. Silicone sealants have performed well for periods exceeding 8 to 10 years on roadways.

Partial-Depth Repairs

Background: Partial-depth repair is a concrete pavement restoration technique that corrects localized distress such as spalls, scaling, and popouts in portland cement concrete (PCC) pavements. These repairs restore structural integrity, improve ride quality, and extend the service life of pavements that have spalled or distressed joints.

Partial-depth repair involves removing an area of deteriorated concrete that is limited to the top one-third of the slab thickness and replacing it with appropriate repair materials. Depending on the type of repair material used and the repair location, a new joint sealant system may be installed as well. The repair technique can be applied either transversely or longitudinally on the pavement where deteriorations are detected.

Spalls may be caused by the infiltration of incompressible materials (sands or gravel) into joints during cold weather when a jointed concrete pavement contracts and the joints open. During warm weather the pavement expands, closing the joints. Incompressible materials in the joints prevent the joints from closing and produce high compressive stresses along the joint faces. These compressive stresses can cause spalling of the concrete along the joints.

Spalling may occur at both top and bottom of the pavements. Dowel bar misalignment may also cause joint spalling. Spalls may also be caused by the corrosion of metal joint inserts, dowel bars, and reinforcing steel that has been placed too near the surface. Other clauses of spalls include misaligned dowel bars, D-cracking, alkali-silica reactions, and lack of consolidation of concrete near the joints.

When considering partial-depth repairs, coring should be performed at representative joints to determine the depth of deterioration. Spalls greater than the top one-third of the slab caused by misaligned dowel bars or significant D-cracking should not be repaired with partial-depth repairs. In these cases, partial-depth repairs are likely to fail due to high shear stresses.

The damage caused by freezing and thawing cycles is a serious problem in jointed PCC pavements. In wet and freezing climates, the continued presence of water on and in the pavement and the use of deicing salts often make the damages worse. Even in non-freezing climates, any moisture in the concrete can cause corrosion of reinforcing steel in the pavement. Corroding steel creates expansive forces that can lead to cracking, spalling, and debonding of the concrete around it.

The costs of a partial-depth repair-are largely dependent upon the size, number, and location of the repair areas, as well as the materials used. Lane closure time and traffic volume also affect production rates and costs.

Procedure:

Preliminary Document Review
Bid/project specifications and design

- Special provisions
- Traffic control plan
- Manufacturers' instructions
- Material safety data sheets

Project Review

- Verify that pavement conditions have not significantly changed since the project was designed and that full-depth repair is appropriate for the pavement.
- Check estimated number of full-depth repairs against the number specified in the contract.
- Agree on quantities to be placed, but allow flexibility if additional deterioration is found below the surface.

Determining Areas of Repair
Areas to be repaired shall be determined by the engineer using a rod, hammer or other device to determine defective or delaminated areas. The extent of the repair area will be marked by the engineer. Areas less than 6 inches in length and 1.5 inches in width at the widest point shall not be repaired under this specification but shall be filled with a joint sealant material in accordance with standard specifications.

Figure 80: "Sounding" with a hammer.

Figure 81: "Sounding" with a steel chain.

Materials Checks

- NMDOT Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.
- Verify that concrete patch material is being produced by a supplier listed on the NMDOT's Qualified Supplier List as required by contract documents.
- Verify that the mix design for the material being supplied meets the criteria of the contract documents.
- Verify that concrete patch material has been sampled and tested prior to installation, and is not contaminated.
- Verify that load transfer units (dowels) meet specifications and that dowels are properly coated with epoxy (or other approved material) and free of any minor surface damage in accordance with contract documents.
- Verify that dowel-hole cementing grout meets specifications.
- Verify that bond-breaking board meets specifications (typically asphalt-impregnated fiberboard).
- Verify that joint sealant material meets specifications.
- Verify that sufficient quantities of materials are on hand for completion of the project.
- Ensure that all material certifications required by contract documents have been provided to the NMDOT prior to construction.

Equipment Inspections

Concrete Removal Equipment

- Verify that concrete saws and blades are in good condition and of sufficient diameter and horsepower to adequately cut the required patch boundaries.
- Verify that required equipment used for concrete removal is all on-site and in proper working order and of sufficient size, weight, and horsepower to accomplish the removal process (including front-end loader, crane, fork lift, backhoe, skid steer, and jackhammers).

Patch Area Preparation Equipment

- Verify that the plate compactor is working properly and capable of compacting subbase material.
- Verify that gang drills are calibrated, aligned, and sufficiently heavy and powerful enough to drill multiple holes for dowel bars.
- Verify that air compressors have oil and properly functioning moisture filters/traps. Prior to use, check the airstream for water and/or oil by passing the stream over a board, then examining the board for contaminants.

Testing Equipment

- Verify that the concrete testing technician meets the requirements of the contract documents for training/certification.
- Ensure that all material test equipment required by the specifications is available on-site and in proper working condition (typically including slump cone, pressure-type air meter, cylinder molds and lids, rod, mallet, ruler, and 10 foot straightedge).
- Ensure that sufficient storage area on the project site is specifically designated for the storage of concrete cylinders.

Placing and Finishing Equipment

- Verify that handheld concrete vibrators are the proper diameter and operating correctly.
- Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish.
- Verify that sufficient polyethylene sheeting is readily available on-site for immediate deployment as rain protection of freshly placed concrete, should it be required.

<u>Traffic Control</u>

- Verify that signs and devices match the traffic control plan presented in the contract documents.
- Verify that the setup complies with the Federal *Manual on Uniform Traffic Control Devices* traffic control procedures.
- Verify that traffic control personnel are trained/qualified in accordance with contract documents and NMDOT requirements.
- Ensure that the repaired pavement is not opened to traffic until the patch material has met the minimum strength specified in the contract documents.
- Ensure that signs are removed or covered when they are no longer needed.
- *Verify that any unsafe conditions are reported to a supervisor (contractor or NMDOT).*

<u>Preparation of Partial-Depth Areas</u>

A saw cut shall be made around the perimeter of the repair area to provide a vertical face at the edges and sufficient depth for the repair. The saw cut shall have a depth of 1 to 2 inches.

Concrete within the repair area shall be broken out to a depth of 1 to 2 inches with pneumatic tools until sound and clean concrete is exposed. The maximum size pneumatic hammer shall be 30 pounds.

The exposed faces of the concrete shall be sandblasted free of loose particles, oil, dust, and traces of asphalt concrete and other contaminants before placement of repair material. All sandblasting residue must be removed just prior to placement of the concrete bonding agent.

Placing Repair Material

Accelerated strength PCC (3000 PSI in 24 hours) repair mixtures can be used where early opening to traffic (4 to 6 hours) is required. An epoxy bonding agent is required when placing high-early-strength PCC repair for early opening to traffic. The epoxy prime coat shall be applied in a thin coating and scrubbed into the surface with a stiff bristled brush. Contact between the repair and any adjacent pavement which could cause compression or other types of failure in the repair must be prevented.

Procedure:

Preliminary Document Review

- Bid/project specifications and design
- Special provisions
- NMDOT application requirements
- Traffic control plan
- Manufacturers' installation instructions
- Material safety data sheets

Project Review

- Verify that pavement conditions have not significantly changed since the project was designed and that partial-depth repair is appropriate for the pavement.
- Verify that the estimated number of partial-depth repairs agrees with the number specified in the contract.
- Agree on quantities to be placed, but allow flexibility if additional deterioration is found below the surface.
- Note that some partial-depth repairs may become full-depth repairs if deterioration extends below the top third of the slab (see Full-Depth Repair of Portland Cement Concrete Pavements).

Materials Checks

- NMDOT Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.
- Verify that patch material is of the correct type and meets specifications.
- Verify that patch material is obtained from an approved source or is listed on NMDOT Approved Products List as required by the contract documents.

- Verify that patch material has been sampled and tested prior to installation as required by the contract documents.
- Verify that additional or extender aggregates have been properly produced and meet requirements of contract documents.
- Verify that material packaging is not damaged so as to prevent proper use (for example, packages are not leaking, torn, or pierced).
- Verify that bonding agent (if required) meets specifications.
- Verify that curing compound (if required) meets specifications.
- Verify that joint/crack re-forming material (compressible insert) meets specifications (typically polystyrene foam board, 1/2 inch thick).
- Verify that joint-sealant material meets specifications.
- Verify that sufficient quantities of materials are on hand for completion of the project.

<u>Equipment Inspections</u>

Concrete Removal Equipment

- Verify that concrete saws are of sufficient weight and horsepower to adequately cut the existing concrete pavement to the depth required along the patch boundaries as required by the contract documents.
- Verify that concrete saws and blades are in good working order.
- Verify that pavement milling machines are power-operated, self-propelled, cold-milling machines capable of removing concrete as required by the contract documents.
- Verify that milling machines used for concrete removal are equipped with a device that allows them to stop at pre-set depths to prevent removal of more than the top third of the slab and to prevent damage to embedded steel.
- Verify that the maximum rated weight of removal jackhammers is 31 lbs.

Patch Area Cleaning Equipment

- Verify that the sand-blaster unit is adjusted for correct sand rate and that it is equipped with and using properly functioning oil/moisture traps.
- Verify that air compressors have sufficient pressure and volume capabilities to clean patch area adequately in accordance with contract specifications.
- Verify that air compressors are equipped with oil and using properly functioning oil and moisture filters/traps. This can be accomplished by passing the airstream over a board, then examining the board for contaminants.
- Verify that the volume and pressure of the water-blasting equipment (if necessary) meets the specifications.

Mixing and Testing Equipment

- Verify that auger flights and paddles within auger-type mixing equipment are kept free of material buildup that can result in inefficient mixing operations.
- Ensure that volumetric mixing equipment such as mobile mixers are kept in good condition and are calibrated on a regular basis to properly proportion mixes.

- Verify that the concrete testing technician meets the requirements of the contract documents for training/certification.
- Ensure that material test equipment required by the specifications are all available on-site and in proper working condition (equipment typically includes slump cone, pressure-type air meter, cylinder molds and lids, rod, mallet, ruler, and 10 foot straightedge).

Placing and Finishing Equipment

- Verify that a sufficient number of concrete vibrators 1 inch diameter or less are available on-site and in proper working condition.
- Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish.

Other Equipment

- Ensure that a steel chain, rod, or hammer is available on-site to check for unsound concrete around the patch area.
- Verify that grout-application brushes (if necessary) are available.

<u>Traffic Control</u>

- Verify that signs and devices match the traffic control plan presented in the contract documents.
- Verify that the set-up complies with the Federal *Manual on Uniform Traffic Control Devices* traffic control procedures.
- Ensure that traffic control personnel are trained/qualified in accordance with contract documents and NMDOT requirements.
- Ensure that the repaired pavement is not opened to traffic until the patch material meets strength requirements presented in the contract documents.
- Verify that signs are removed or covered when they are no longer needed.
- *Ensure that any unsafe conditions are reported to a supervisor (contractor or NMDOT).*

<u>Project Inspection Responsibilities</u>

Patch Removal and Cleaning

- Ensure that the area surrounding the patch is checked for delamination and unsound concrete using a steel chain, rod, or hammer.
- Ensure that the boundaries of unsound concrete area(s) are marked at least 2 inches beyond the area of deterioration.
- Verify that concrete is removed by either (a) sawcutting the boundaries and jack hammering the interior concrete or (b) using a cold-milling machine.
- Verify that concrete removal extends at least 2 inches in depth and does not extend below one-third of the slab depth, and that load transfer devices are not exposed.
- Verify that, after concrete removal, the patch area is prepared by sandblasting or water blasting.

- Verify that the patch area is cleaned by air blasting. A second air blasting may be required immediately before placement of patch material if patches are left exposed for a period of time.

Patch Preparation

- Ensure that compressible joint inserts (joint/crack re-formers) are inserted into existing cracks/joints in accordance with contract documents. Joint inserts are typically required to extend below and outside the patch area by 1/2 inch.
- When a patch abuts a bituminous shoulder, ensure that a wooden form is used to prevent patch material from entering the shoulder joint.
- Ensure that bonding agent (epoxy- or cement-based) is placed on clean, prepared surface of existing concrete immediately prior to placement of patch material as required by the contract documents. If bonding agent shows any sign of drying before patch material is placed, it must be removed by sandblasting, cleaned with compressed air, and re-applied.
- Verify that cement-based bonding agents are applied using a wire brush; epoxy-based bonding agents are applied using a soft brush.

Placing, Finishing, and Curing Patch Material

- Verify that quantities of patch material being mixed are relatively small to prevent material from setting prematurely.
- Verify that the fresh concrete is properly consolidated using several vertical penetrations of the surface with a hand-held vibrator.
- Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge in accordance with contract documents. Note: To prevent pulling material away from the patch boundaries, work material from the center of the patch outward toward the boundary.
- Verify that the surface of the fresh patch material is finished and textured to match the adjacent surface.
- Verify that the perimeter of the patch and saw-cut runouts (if saws are used) are sealed using grout material. Alternatively, saw-cut runouts can be sealed using joint-sealant material.
- Verify that adequate curing compound is applied to the surface of the finished and textured, fresh patch material in accordance with contract documents.
- Ensure that insulation blankets are used when ambient temperatures are expected to fall below 40° F. Maintain blanket cover until concrete attains the strength required in the contract documents.

Resealing Joints and Cracks

- Verify that the compressible inserts are sawed out to the dimensions specified in the contract documents when the patch material has attained sufficient strength to support concrete saws.
- Verify that joints are cleaned and resealed according to contract documents.

Cleanup Responsibilities

- Verify that all concrete pieces and loose debris are removed from the pavement surface and disposed of in accordance with contract documents.
- Verify that mixing, placement, and finishing equipment is properly cleaned for the next use.

Materials:

Material selection for partial-depth repairs should consider the following factors: mixing time and required equipment, working time, temperature range for placement, curing time, aggregate requirements, repair area moisture conditions, cost, repair size, and bonding requirements. The following are guidelines for selection of materials:

- Normal set concrete can be used when the repair material can be protected from traffic for more than 24 hours.
- Normal set concrete should not be used when the air temperature is below 40° F. At temperature below 55° F a longer curing period or insulation may be required.
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Rapid Setting Repair Materials

Rapid setting repair materials shall have a minimum compressive strength of 3,000 PSI within 24 hours.

Epoxy Resin Repair Mortars

Epoxy resin repair mortars shall be prepared in accordance with the manufacturer's recommendation regarding aggregates and gradation of aggregate.

Weather Requirements and Pavement Conditions:

- Review manufacturers' installation instructions for requirements specific to the patch material being used.
- Ensure that air and surface temperature meet manufacturer and contract requirements (typically 40° F and rising) for concrete placement.
- Ensure that patching does not proceed if rain is imminent.

Problems to Avoid:

More deterioration below surface than is evident above:

1. Extend limits of repair area into sound concrete.
2. If deterioration extends below one-third of the depth, do a full-depth repair.

Dowel bar or reinforcing steel is exposed during concrete removal:

1. If steel is in the upper third of slab, remove the steel to the edges of the patch and continue.
2. If removal extends to mid-depth of the slab, do a full-depth repair.

Patch material flows into joint or crack:

1. Ensure joint insert extends far enough into the adjacent joint/crack and below the patch.
2. Ensure insert is correctly sized for joint/crack width.

Patch cracking or unbonding:

1. Check that joint insert is being used properly.
2. Ensure that the insert is correctly sized for the joint/crack width and that it has been inserted correctly.
3. Check that patch area was cleaned immediately prior to grouting/concrete placement.
4. Check that grout material has not dried out before concrete placement.
5. Ensure that curing compound has been applied adequately.
6. Check that patch material is not susceptible to shrinkage.

Life Expectancy:

The performance of partial-depth repairs depends on many factors. Studies show that when partial-depth repairs are properly installed and when quality control during construction is good, 80 to 100 percent of the repairs perform well after 3 to 10 years of service. When properly placed with an appropriate and durable material and combined with good joint sealant maintenance practices, partial-depth repairs should last long as the remaining pavement.

Full-Depth Repairs

Background: Portland cement concrete (PCC) pavements showing structural distresses may require full-depth repairs. Full-depth repair (FDR) is a concrete pavement restoration technique used to restore the structural integrity and rideability to concrete pavements having distresses. Full-depth repairs are cast-in-place concrete repairs that extend through the full thickness of the existing PCC slab.

FDR involves making lane-width, full-depth saw cuts to remove the deteriorated concrete down to the base, repairing the disturbed base, installing load-transfer devices, and refilling the excavated area with new concrete. By removing and replacing isolated areas of deterioration, full-depth repairs may delay or stop further deterioration and restore the pavement close to its original condition.

Distresses that can be addressed using full-depth repairs include transverse cracking, longitudinal cracking, D-Cracking, corner breaks, blowups, punch-outs and deteriorated joints. Full-depth repairs are also used to prepare distressed PCC pavements for a structural overlay.

<u>Pavement Distresses that Require Full-Depth Repairs</u>

The need for full-depth repairs should be determined based on the type, frequency, and severity of deterioration of the pavement. The Distress Identification Manual for the LTPP Project, Strategic Highway Research Program, National Research Council, 1993. FHWA, includes a description of joint and crack distress at low, medium and high severity levels. Recommendations are provided in Table 1 as to the level of severity of each distress type that warrants full-depth repairs.

JCP distresses addressed by full-depth repairs.

Distress Type	**Severity Levels That Require Full-Depth Repair**
Transverse Cracking	Medium (M), High (H)
Longitudinal Cracking	M, H
Corner Break	L, M, H
Spal1ing of Joints	M[1], H
Blowup	L, M, H
D-Cracking (at joints or cracks)[2]	M[1], H
Reactive Aggregate Spalling[2]	M[1], H
Deterioration Adjacent to Existing Repair	M[1], H
Deterioration of Existing Repairs	M[1], H

1 Partial-depth repairs can be used if the deterioration is limited to the upper one-third of the pavement slab.

2 If the pavement has a severe material problem (such as D-cracking or reactive aggregate), full-depth repairs may only provide temporary relief from roughness caused by spalling. Continued deterioration of the original pavement is likely

to result in redevelopment of spalling and roughness.

The following are descriptions of typical concrete pavement distresses that require full-depth repairs.

Transverse Cracking: Pavements with transverse cracks of medium and high severity are recommended for full-depth repairs. Some cracks that extend through the depth of a slab can begin moving and function as joints. Transverse cracks that function as joints are often called "working cracks" and are subject to the same movements as transverse joints.

Figure 82: A medium Severity Transverse (Mid-Panel) Crack.

Transverse cracks that are tight (hairline cracks) and do not extend to the bottom of the slab do not require treatment. Hairline cracks do not allow much water to penetrate the pavement substructure and rarely deteriorate concrete pavement. Low severity working cracks with poor load transfer may be repaired by restoring the load transfer using dowel bars (see Dowel Bar Retrofit). Medium to high severity distress working cracks are good candidates for FDR.

Longitudinal Cracking: When longitudinal cracks deteriorate to a high severity condition, they warrant full-depth repairs. A high severity condition indicates that a crack is greater than 0.5 inch wide and with spalling extends more than 6 inches from the crack, and faulting is greater than 0.5 inch. If the condition is less severe, other concrete pavement restoration procedures, such as partial depth repairs, cross-stitching, retrofit dowel bars, or sawing and sealing are sufficient.

Corner Breaks: Corner breaks and intersecting cracks develop in slabs receiving marginal support from the subgrade. Heavy loads passing over these slabs cause large vertical deflections and high tensile stresses in the concrete. Over time the unsupported slab will pump subgrade fines out from beneath the slab, leaving voids and eventual cracking over the uneven support. Shattered slabs also may result from frost heave or swelling soil problems. Shattered slabs and corner breaks are good candidates for using FDR.

"D" cracking: "D" cracking is a pattern of cracks caused by the freeze-thaw expansive pressures of coarse aggregates. The spalling associated with these stresses begins near the joints as a result of the higher moisture levels causing aggregates to expand in volume during freezing. Medium and high severity "D" cracking could warrant full depth repair.

Figure 83: "D" Cracking

Blowup: Blowups occur in hot weather at transverse joints or cracks which do not allow sufficient expansion of the concrete slabs. The insufficient expansion width of joints is usually caused by infiltration of incompressible material into the joint. Blowups of any severity warrant full-depth repairs due to the localized disruption to pavement integrity and the potential safety hazard.

Punchouts: Punchouts in continuously reinforced concrete pavements (CRCP) are candidates for full-depth repairs as they represent a structural failure of the pavement. They form after many load cycles when the longitudinal steel ruptures along the faces of two closely spaced cracks, usually less than 2 feet apart.

Figure 84: Punchout of Continuously Reinforced Concrete Pavement.

Procedure:

Preliminary Document Review

Bid/project specifications and design

- Special provisions
- Traffic control plan
- Manufacturers' instructions
- Material safety data sheets

Project Review

- Verify that pavement conditions have not significantly changed since the project was designed and that full-depth repair is appropriate for the pavement.
- Check estimated number of full-depth repairs against the number specified in the contract.
- Agree on quantities to be placed, but allow flexibility if additional deterioration is found below the surface.

Materials Checks

- NMDOT Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.
- Verify that concrete patch material is being produced by a supplier listed on the NMDOT's Qualified Supplier List as required by contract documents.
- Verify that the mix design for the material being supplied meets the criteria of the contract documents.
- Verify that concrete patch material has been sampled and tested prior to installation, and is not contaminated.
- Verify that load transfer units (dowels) meet specifications and that dowels are properly coated with epoxy (or other approved material) and free of any minor surface damage in accordance with contract documents.
- Verify that dowel-hole cementing grout meets specifications.
- Verify that bond-breaking board meets specifications (typically asphalt-impregnated fiberboard).
- Verify that joint sealant material meets specifications.
- Verify that sufficient quantities of materials are on hand for completion of the project.
- Ensure that all material certifications required by contract documents have been provided to the NMDOT prior to construction.

Equipment Inspections

Concrete Removal Equipment

- Verify that concrete saws and blades are in good condition and of sufficient diameter and horsepower to adequately cut the required patch boundaries.

- Verify that required equipment used for concrete removal is all on-site and in proper working order and of sufficient size, weight, and horsepower to accomplish the removal process (including front-end loader, crane, fork lift, backhoe, skid steer, and jackhammers).

Patch Area Preparation Equipment

- Verify that the plate compactor is working properly and capable of compacting subbase material.
- Verify that gang drills are calibrated, aligned, and sufficiently heavy and powerful enough to drill multiple holes for dowel bars.
- Verify that air compressors have oil and properly functioning moisture filters/traps. Prior to use, check the airstream for water and/or oil by passing the stream over a board, then examining the board for contaminants.

Testing Equipment

- Verify that the concrete testing technician meets the requirements of the contract documents for training/certification.
- Ensure that all material test equipment required by the specifications is available on-site and in proper working condition (typically including slump cone, pressure-type air meter, cylinder molds and lids, rod, mallet, ruler, and 10 foot straightedge).
- Ensure that sufficient storage area on the project site is specifically designated for the storage of concrete cylinders.

Placing and Finishing Equipment

- Verify that handheld concrete vibrators are the proper diameter and operating correctly.
- Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish.
- Verify that sufficient polyethylene sheeting is readily available on-site for immediate deployment as rain protection of freshly placed concrete, should it be required.

<u>Traffic Control</u>

- Verify that signs and devices match the traffic control plan presented in the contract documents.
- Verify that the setup complies with the Federal *Manual on Uniform Traffic Control Devices* traffic control procedures.
- Verify that traffic control personnel are trained/qualified in accordance with contract documents and NMDOT requirements.
- Ensure that the repaired pavement is not opened to traffic until the patch material has met the minimum strength specified in the contract documents.
- Ensure that signs are removed or covered when they are no longer needed.
- *Verify that any unsafe conditions are reported to a supervisor (contractor or NMDOT).*

Project Inspection Responsibilities

Concrete Removal and Cleanup

- Verify that the boundaries of the removal areas are clearly marked on the pavement surface and the cumulative area of the pavement to be removed is consistent with quantities in the contract documents.
- Verify that the patch size is large enough to accommodate a gang-mounted dowel drilling rig, if one is being used. Note: The minimum longitudinal length of patch is usually 6 feet.
- Verify that boundaries are sawed vertically the full thickness of the pavement.
- Verify that concrete is removed using either the break-up or lift-out method and minimizing disturbance to the base or subbase as much as possible. Note: The saw cut and lift method is preferred to jackhammer removal.
- Verify that after concrete removal, disturbed base or subbase is re-compacted, and additional subbase material is added and compacted if necessary.
- Verify that concrete adjoining the patch is not damaged or undercut by the concrete-removal operation.
- Ensure that removed concrete is disposed of in the manner described in the contract documents.

Patch Preparation

- Verify that dowel holes are drilled perpendicular to the vertical edge of the remaining concrete pavement using a gang-mounted drill rig.
- Verify that holes are thoroughly cleaned using compressed air.
- Verify that approved cement grout or epoxy is placed in dowel holes, from back to front.
- Verify that dowels are inserted with a twisting motion, spreading the grout along the bar inside the hole. A grout-retention disk can be used to keep the grout from seeping out of the hole.
- Verify that dowels are installed in transverse joints to the proper depth of insertion and at the proper orientation (parallel to the centerline and perpendicular to the vertical face of the saw cut excavation) in accordance with contract specifications. Typical tolerances measured perpendicularly to the sawed faced are 1/4 inch misalignment per 12 inches of dowel bar length.
- Verify that tiebars are installed at the proper location, to the proper depth of insertion, and to the proper orientation in accordance with contract documents. When the length of the longitudinal joint is 15 feet or greater, tiebars are typically installed in the manner used for dowels. When the length of the longitudinal joint is less than 15 feet, a bond-breaker board is placed along the length of the patch to isolate it from the adjacent slab.
- Ensure that tiebars are checked for location, depth of insertion, and orientation (perpendicular to centerline and parallel to slab surface).

Placing, Finishing, and Curing Concrete

- Concrete is typically placed from ready-mix trucks or mobile mixing vehicles in accordance with contract specifications.
- Verify that the fresh concrete is properly consolidated using several vertical penetrations of the concrete surface with a handheld concrete vibrator.
- Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge or vibratory screed in accordance with contract documents.
- Verify that the surface of the fresh concrete patch is finished and textured to match adjacent surfaces.
- Verify that adequate curing compound is applied to the surface of the fresh concrete immediately following finishing and texturing in accordance with contract documents. Note: Best practice suggests that two applications of curing compound be applied to the finished and textured surface, one perpendicular to the other.
- Ensure that insulation blankets are used when ambient temperatures are expected to fall below 4°C (40°F). Maintain blanket cover until concrete attains the strength required in the contract documents.

Resealing Joints and Cracks

- Verify that patches have attained adequate strength to support concrete saws, patch perimeters and other unsealed joints are sawed off to specified joint reservoir dimensions.
- Verify that joints are cleaned and resealed according to contract documents.

Cleanup Responsibilities

- Verify that all concrete pieces and loose debris are removed from the pavement surface.
- Verify that old concrete is disposed of according to contract documents.
- Verify that mixing, placement, and finishing equipment is properly cleaned for the next use.
- Verify that all construction-related signs are removed when opening pavement to normal traffic.

Materials:

The concrete mixture design should be based on the available lane closure time. The shorter the time available before opening to traffic, the more rapid the strength gaining and curing of the concrete must be.

Typical full-depth repairs operations use concrete mixes containing 658-846 lbs/yd^3 of either cement Type I or Type III cement. A set-accelerator is frequently used to permit opening in 4 to 6 hours. Without the accelerator, these mixes allow opening in 12 to 72 hours.

Uses of proprietary concrete mixes are necessary to achieve opening times in as little as 2 hours. Using insulating blankets during the first few hours after placement also can improve the strength development of any mix. Regardless of the mix design used, the concrete mixture for full-depth repairs should have the following properties:

- 6.5 ± 1.5 percent of entrained air in the concrete (less air may be permissible in nonfreeze areas).
- 2 to 4 inches slump

Mixes using Type III cement may require slightly more mix water than a similar mix with Type I portland cement. However, too much extra water may cause the concrete to suffer from high shrinkage during curing. A water-reducing admixture will disperse cement particles and reduce the water necessary for workability.

Calcium chloride ($CaCl_2$) or another accelerating chemical admixture is recommended for use as accelerator in the patching concrete, provided that it is added as specified. It should be noted that initial set may occur within 30 minutes on warm days, therefore, use only 1% of calcium chloride by weight of cement when air temperature exceeds 80° F. Up to 2% is acceptable in lower temperatures. For on-site mixing, add calcium chloride in liquid form to the mixer before other admixtures are added (except the air-entraining admixture). When using calcium chloride, considerations should be given to the remaining service life of the adjacent pavement and weather dowel bars and reinforcing steel are coated.

If calcium chloride or other accelerating admixture are being added at the plant and the concrete consistently arrives at the site too stiff, then the calcium chloride should be added at the site. If , after the addition of calcium chloride at the site, the concrete is still too stiff, the ready-mix plant operator should be notified to increase the slump an appropriate amount, up to 6 inches.

Chemical admixture may be added to the concrete at the batch plant if the air temperatures are moderate (less than 68° F) and the batch plant is less than 15 minutes from the project site. Non chloride accelerators are recommended for CRCP and JCP full-depth repairs.

Weather Requirements and Pavement Conditions:

- Verify that air and surface temperatures meet contract document requirements (typically a minimum of 40° F and rising) for concrete placement.
- Patching should not proceed if rain is imminent. Patches that have been completed should be covered with polyethylene sheeting to prevent rain damage.

Problems to Avoid:

Undercut spalling (deterioration on bottom of slab) is evident after removal of concrete from patch area:

4. Saw back into adjacent slab until sound concrete is encountered.
5. Make double saw cuts, 6 inches apart, around patch area to reduce damage to adjacent slabs during concrete removal.
6. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 inches wide inside the area to be removed.

Saw binds when cutting full-depth exterior cuts:

5. Shut down saw and remove blade from saw.
6. Wait for slab to cool, then release blade if possible, or make another full-depth angled cut inside the area to be removed to provide a small pie-shaped piece adjacent to the stuck saw blade.
7. Make transverse saw cuts when the pavement is cool.
8. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 inches wide inside the area to be removed.

Lifting out a patch for a full-depth repair damages adjacent slab:

4. Adjust lifting cables and re-position lifting device to assure a vertical pull.
5. Re-saw and remove broken section of adjacent slab.
6. Use a forklift or crane instead of a front-end loader.

Slab disintegrates when attempts are made to lift it out:

7. Complete removal of patch area with backhoe or shovels.
8. Angle the lift pins and position the cables so that fragmented pieces are bound together during liftout.
9. Keep lift height to an absolute minimum on fragmented slabs.

Patches become filled with rainwater or groundwater seepage, saturating the subbase:

4. Pump the water from the patch area, or drain it through a trench cut into the shoulder.
5. Re-compact subbase to a density consistent with contract documents, adding material as necessary.
6. Allow small depressions in subbase to be filled with aggregate dust or fine sand before patch material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities 1/2 inch or less in surface of subbase before concrete patch is placed.

Grout around dowel bars flows back out of the holes after dowels are inserted:

4. Pump grout to the back of the hole first.
5. Use a twisting motion when inserting the dowel.
6. Add a grout retention disk around the bar to prevent grout from leaking out.

Dowels appear to be misaligned once they are inserted into holes:

4. If misalignment is less than 1/4 inch per 12 inches of dowel bar length, do nothing.

5. If misalignment is greater than 1/4 inch per 12 inches of dowel bar length on more than three bars, re-saw patch boundaries beyond dowels and re-drill holes.
6. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.

Life Expectancy:

Full-depth repairs can be designed and constructed to provide good long-term performance of 10 or more years. Major causes of premature failures are inadequate load transfer design and poor construction quality. The effectiveness of some full-depth repairs has been limited due to placement on pavements that are too far deteriorated.

Surface Treatments

Surface Sealing

Figure 85: A Scenic highway that has been surface sealed.

Background:

The primary purpose of Surface Sealing is to reduce the intrusion of water into Portland Cement Concrete PCC pavement to prevent freeze damage. However, surface sealing also reduces the intrusion of stains, oils and dirt into PCC pavement surfaces and can be used for visual as well as functional reasons. Surface sealing offers visual improvement by intensifying the PCC pavement colors. Some sealants add a glossy sheen or "wet" look to the pavement. Surface sealing offers some color enhancement and produce a low sheen, or a flat finish (see above figure).

Surface sealing offers many functional advantages. It can protect PCC pavements from stain penetration. It is useful around trash receptacles, fast food restaurants, driveways, other areas subject to stains and where oil drippings are not wanted. Like stabilizers, Surface sealing is also useful in stopping unwanted insects and weeds. Surface sealing can prevent loss of joint sand when PCC pavement is cleaned by vacuum sweeping equipment. Where solvents may be spilled onto PCC pavements, elastomeric urethanes and certain water based sealants have been successfully used to prevent their penetration. Likewise, special urethane sealants have been used to seal and stabilize joint sand subject to propeller wash, jet engine fuels and exhaust in commercial and military airports.

Figure 86: A Surface Sealing Operation.

Safety Considerations

Adequate slip (foot) and skid (tire) resistance of concrete PCC pavements can be maintained by properly applying joint sand stabilizer or surface sealants (For test methods and guidelines see ICPI *Tech Spec 13 Slip and Skid Resistance of Interlocking Concrete Pavements*. See www.icpi.org to obtain this and all ICPI Tech Spec technical bulletins.) The manufacturers of stabilization and sealants should be consulted concerning slip and skid resistance performance characteristics under wet and dry conditions. If the pavement has painted pavement markings consult with the stabilizer and sealer manufacturers for compatibility of their materials with pavement markings.

If there are pavement markings, applications using high gloss materials should be avoided as they can increase the difficulty of reading pavement markings under certain light conditions.

Procedure:

<u>Project Planning</u>

Make a preliminary assessment of the pavement that you are considering for surface sealing:

1) Make sure that the pavement that you are considering for surface sealing is not scheduled for other projects.

2) Make a visual inspection of the PCC pavement being considered for surface sealing to make sure that the pavement is suitable for surface sealing.

3) Set up patching and crack repairs to take care of problem areas.

4) Develop a preliminary traffic control plan. Examine detours or phasing that may be necessary to maintain traffic flow during the course of the project. If the work needs to be done at night determine the lighting needs.

5) Locate a staging area for the contractor to park equipment and store materials.

6) Measure the width and record the beginning and ending milepost of the road section to be surface sealed.

7) Give the above information to the respective District Technical Support Engineers and request a project design.

All dirt, oil stains and efflorescence must be removed prior to sealing. The cleaned surface must be completely dry prior to applying most sealants. Allow at least 24 hours without moisture or surface dampness before application or the sealer can become cloudy and diminish the appearance of the PCC pavements. If it does, the sealer must be removed or re-dissolved. Consult your sealer supplier for advice on treating this situation. The PCC pavements may draw efflorescence to the surface, or the sealer or liquid stabilizer may whiten under any one of these conditions:

- The surface and joints are not dry
- The PCC pavement has not had an adequate period of exposure to moisture
- There is a source of efflorescence under the PCC pavements (i.e., in the sand, base, or soil) moving through the joint sand and/or PCC pavements
- The sealer is not breathable, i.e., does not allow moisture to move through to the surface of the PCC pavement and evaporate.

Cover and protect all surfaces and vegetation around the area to be sealed. For exterior (low-pressure) sprayed applications, the wind should be calm so that it does not cause an uneven application, or blow the sealer onto other surfaces such as passing cars. For many sealants, especially those with high VOC's, wear protective clothing and mask recommended by the sealer manufacturer to protect the lungs and eyes.

Sealants can be applied with a hand roller if the area is small (less than 1000 sq ft). For larger areas, more efficient application methods include a powered roller, or a low pressure sprayer. Sealants are often applied with a foam roller to dry PCC pavements having clean surfaces and chamfers. However, the use of a squeegee to spread the sealer will avoid pulling joint sand out of the joints. Sealer should be spread and allowed to stand in the chamfers, soaking into the joints. Penetration into the joint sand should be at least 3/4 inch. The excess sealer on the surface is pushed to an unsealed area with a rubber squeegee. The action of a squeegee wipes most of the sealer from the surface of the PCC pavements while leaving some remaining in the chamfers to eventually soak into the joints.

Generally only one coat is required. For other applications, follow the sealer manufacturer's recommendations for application and for the protective gear to be worn during the job. With some sealants that recommend two coats, the first coat is usually applied to saturation. A light second coat, if needed, can be applied for a glossy finish. Be careful not to over apply the sealants such that the surface becomes slippery when cured. For water based sealants requiring two coats, always apply the second coat while the first coat is still very tacky.

Prevent all traffic from entering the area until the sealer is completely dry, typically 24 hours. If spraying sealer on the PCC pavements, care should be taken to prevent the spray nozzle from clogging and causing large droplets to be unevenly distributed on them. This is most important for water based sealants. This can cause a poor appearance and performance. Sealants normally require reapplication after a period of wear and weather. The period of reapplication will depend on the use, climate, and quality of the sealer.

For water based sealants requiring two coats, always apply the second coat while the first coat is still very tacky. Prevent all traffic from entering the area until the sealer is completely dry, typically 24 hours. If spraying sealer on the PCC pavements, care should be taken to prevent the spray nozzle from clogging and causing large droplets to be unevenly distributed on them. This is most important for water based sealants. This can cause a poor appearance and performance. The period of reapplication will depend on the use, climate, and quality of the sealer.

Materials:

The following table lists the various types of sealers for concrete PCC pavements. The table suggests applications and compares important properties. The sealer manufacturer or supplier should be consulted prior to using any sealer to verify that their product will perform in the environment planned for its use. Surface sealing not recommended for use with PCC pavements are alkyds, esters, and polyvinyl acetates. Epoxies and silicones are generally not used on concrete PCC pavements.

***Table 1**—Properties of Sealers for Concrete Pavers—Confirm application and properties with supplier.*

	Patios, walks, pool decks	Residential/ Comlercial drives	Gas Stations Airports	Areas subject to chlorine & heavy de-icing salts	Finish	Enhances color	Joint sand stabilizer	UV resistant	Can be re-coated	Ease of removal	Price
Silane	Yes	Yes		Yes	Flat	*		Yes	Yes	Mod.	++
Siloxane	Yes	Yes		Yes	Flat	*		Yes	Yes	Diff.	++
Acrylic	Yes	Yes			Gloss	Yes	Yes	Varies	Yes	Diff.	+
Urethane	Yes	Yes	Yes	Yes	Gloss	Yes	Yes	Varies	No	V. Diff.	++
Water-based Epoxy	Yes	Yes	Yes	Yes	Semi-Gloss	Yes	Yes	Yes	Yes	Mod.	++

*Initially, then diminishes. Diff.=Difficult V. Diff.=Very Difficult +=Moderate Price ++=Higher price

Solvent and Water Based Surface Sealants

Like stabilizers, surface sealants can be either solvent or water based. Solvent based sealants consist of solids dissolved in a liquid. Solvent based products carry the dissolved solids as deep as the solvent will penetrate into the concrete PCC pavement. After the solvent evaporates, the sealer remains. Water based sealants are emulsions, or very small particles of the sealer dispersed in water. Water based sealants penetrate concrete as far as the size of the particles will permit. After the water evaporates, typically at a slower rate than solvents, the remaining particles bond with the concrete and to each other. These particles cannot penetrate as deeply as those carried by solvents. Water based sealer curing time will vary with temperature, wind conditions and humidity.

Figure 87: Applying Surface Sealant.

Applying Surface sealant

Sealants can be applied with a hand roller if the area is small (less than 1000 sq ft). For larger areas, more efficient application methods include a powered roller, or a low pressure sprayer. Sealants are often applied with a foam roller to dry PCC pavements having clean surfaces and chamfers. However, the use of a squeegee to spread the sealer will avoid pulling joint sand out of the joints. Sealer should be spread and allowed to stand in the chamfers, soaking into the joints. Penetration into the joint sand should be at least 3/4 inch. The excess sealer on the surface is pushed to an unsealed area with a rubber squeegee. The action of a squeegee wipes most of the sealer from the surface of the PCC pavements while leaving some remaining in the chamfers to eventually soak into the joints. Generally only one coat is required. For other applications, follow the sealer manufacturer's recommendation for application and for the protective gear to be worn during the job. With some sealants that recommend two coats, the first coat is usually applied to saturation. A light second coat, if needed, can be applied for a glossy finish.

Silanes/Siloxanes

Silanes and siloxanes are durable and penetrate concrete well. Silanes are the simpler form that, when exposed to moisture, begin to link up to other silanes. Siloxanes do the same linking together. Both chemicals become a polymer, curing as a film in the capillaries of the concrete. A hydrophobic barrier to moisture is created, preventing moisture from entering but allowing the concrete to "breathe" or release water vapor. Because silanes and siloxanes reduce moisture from entering the concrete, they can deter efflorescence from appearing on the surface of concrete PCC pavements. They initially enhance colors and produce a flat, no-gloss finish on the PCC pavement surface. This makes silanes and siloxanes very suitable on exterior areas for resisting efflorescence when a glossy surface is not desired. Silanes and siloxanes do not resist penetration of petroleum stains unless they have additives specifically for that purpose. When required, proprietary mixtures with additives can increase petroleum stain resistance. Other additives can ensure greater consistency in the color of PCC pavements and avoid a blotchy appearance. Silanes have smaller molecules, so they penetrate farther into the concrete than larger siloxane molecules. However, they are more volatile (tend to evaporate) until they bond to the PCC pavement. Silane sealants generally require a higher percent of solids to counteract their rate of evaporation. Therefore, silanes tend to be more expensive than siloxanes. Silanes and siloxanes are typically used as water repellents for concrete bridge decks, parking garages, and masonry walls. Their primary use for reinforced concrete structures is to prevent the ingress of chloride ions from de-icing salts. This intrusion causes reinforcing steel corrosion in the concrete, and a weakened structure. Their ability to decrease intrusion of chloride materials provides additional protection of PCC pavements subject to deicing salts or salt air, such as walks, streets, parking lots, plaza roof and parking decks. They are also useful around pool decks to minimize degradation from chlorine. Most silane and siloxane sealants are solvent based. Certain manufacturers offer water based products as well. These products may have a very short shelf life after the silane or siloxane has been diluted with water. The user should check with the manufacturer on the useful life of the product.

Acrylics

Acrylic sealants can be solvent or water based. They enhance PCC pavement colors well and create a gloss on the surface. Acrylic sealants provide good stain resistance. Their durability depends on traffic, the quality of the acrylic and the percentage of solids content. They provide longer protection from surface wear than silanes or siloxanes. Acrylic sealants are widely used in residential and commercial PCC pavement applications. They generally last for a few years in these applications before re-coating is required. Acrylics specifically developed for concrete PCC pavements do not yellow over time. When they become soiled or worn, PCC pavements with acrylics can be easily cleaned and resealed without the use of extremely hazardous materials. Acrylics should not be used on high abrasion areas such as industrial pavements or floors. Water based acrylics perform well for interior applications. They may be allowed by municipalities that regulate the release of volatile organic contents (VOCs) in the atmosphere.

Urethanes

As either solvent or water based, polyurethanes produce a high gloss and enhance the color of PCC pavements. Aromatic urethanes should contain a ultra-violet (UV) inhibitor to reduce yellowing over time. The product label should state that the sealer is UV stable. Urethanes themselves are more resistant to chemicals than acrylics. While aliphatic urethanes can be used for coating the surface of PCC pavements, elastomeric (aromatic or aliphatic) urethanes should be used where the primary need is to stabilize joint sand. For airfield and gas station applications, the urethane should have a minimum elongation of 100% per ASTM D 2370, Standard Test Method for Tensile Properties of Organic Coatings. Urethanes resist degradation from petroleum based products and de-icing chemicals. This makes them suitable for heavy industrial areas, as well as airfield and gas station pavements. Urethanes cannot be rejuvenated simply by re-coating. If urethane sealants must be removed, methylene chloride or sand blasting is often necessary. Methylene chloride is a hazardous chemical, and is not acceptable for flushing into storm drains. It should not be allowed to soak into the soil. Therefore, urethane removal is best handled by professionals.

Water Based Epoxy Sealants

Water based epoxy sealants combine other types of sealants with epoxy. They cure by chemical reaction as well as by evaporation. They have very fine solids allowing them to penetrate deep into concrete while still leaving a slight sheen to enhance the color of the PCC pavements. They generally do not change the skid resistance of the surface. When applied, water based epoxy sealants create an open surface matrix that allows the PCC pavement surface to breathe thereby reducing the risk of trapping efflorescence under the sealer should it rise to the surface. They resist most chemicals and degradation from UV radiation. These characteristics make these types of sealants suitable for high use areas such as theme parks and shopping malls. The elasticity and adhesion of these sealants make them appropriate for heavily trafficked street projects and areas subject to aggressive cleaning practices.

Figure 10. Urethane is applied with squeegees to stabilize joint sand between pavers on aircraft pavement.

Figure 88: Applying Urethane with squeegees.

<u>Material Safety Considerations</u>

Federal, state/provincial, and some municipal governments regulate building materials with high volatile organic contents (VOCs). The restrictions usually apply to solvent based sealants. The VOC level of a sealer refers to the pounds per gallon (or grams per liter) of solvent which evaporates from the sealer, excluding the water. VOCs have been regulated since they can contribute to smog. Most water based sealants comply with VOC restrictions and some solvent based products may comply as well. The user should check with the sealer supplier to verify VOC compliance in those areas that have restrictions. Many solvent based products are combustible and emit hazardous fumes. Therefore, flame and sparks should be prevented in the area to be sealed. Never use solvent based sealants in poorly ventilated or confined areas. Persons applying joint sand stabilizers and sealants should wear breathing and eye protection as recommended by the manufacturer, as well as protective equipment mandated by local, state/provincial, or federal safety agencies. Follow all label precautions and warnings concerning handling, storage, application, disposal of unused materials, and those required by all government agencies. The U.S. Federal Government and Canadian Government require that all shipments of hazardous materials by common carrier must be accompanied by a Material Safety Data Sheet (MSDS). All chemical manufacturers must supply sheets to shippers, distributors and dealers of cleaners, joint sand stabilizers, and sealants if the materials are hazardous. The MSDS must accompany all shipments and be available to the purchaser on request. The MSDS lists the active ingredients, compatibility and incompatibility with other materials, safety precautions and an emergency telephone number if there is a problem in shipping, handling or use. The user should refer to the MSDS for this information.

Weather Requirements and Pavement Conditions:

Sealants normally require application after a period of wear and weather. The cleaned surface must be completely dry prior to applying most sealants. Allow at least 24 hours without moisture or surface dampness before application. The PCC pavements may draw efflorescence to the surface, or the sealer or liquid stabilizer may whiten if the surface and joints are not dry.

A breeze will help protect workers from hazardous fumes. But if it is windy, sealant can drift onto surrounding vegetation and private property such as cars, buildings, etc.

Problems to Avoid:

Some of the typical problems that are encountered during PCC surface sealing operations are summarized in the following table.

Life Expectancy:

The life expectancy of a PCC surface sealant will depend on the climate, the type and quantity of sealant used and the type and amount of traffic that the PCC pavement is exposed to.

Problems to Avoid During PCC Surface Sealing Operations

Problem	Typical Cause(s)	Typical Solutions
Unsightly or "foamy" looking surface	The concrete surface being sealed is dirty, stained or moist.	The cleaned surface must be completely dry prior to applying most sealants. Allow at least 24 hours without moisture or surface dampness before application.
The sealer becomes cloudy and the appearance of the PCC pavement is diminished	The sealer is applied too thick.	The sealer must be removed or re-dissolved. Consult your sealer supplier for advice on treating this situation.
Sealant on vegetation and surrounding private property; cars, buildings, etc.	Wind is blowing sealant away from pavement	Cover and protect all surfaces and vegetation around the area to be sealed. For exterior (low-pressure) sprayed applications, the wind should be calm.
Hazardous Substances	The vapors of many sealants are toxic especially those with high VOC's. Hazardous substances must be disposed of properly.	Persons applying joint sand stabilizers and sealants should wear breathing and eye protection as recommended by the manufacturer, as well as protective equipment mandated by State. Follow all label precautions and warnings concerning handling, storage, application, disposal of unused materials, and those required by all government agencies
Slippery surface	Sealed concrete can be very slippery	The manufacturers of stabilization and sealants should be consulted concerning slip and skid resistance performance characteristics under wet and dry conditions.

Diamond Grinding and Diamond Grooving

Diamond Grinding and Diamond Grooving are processes that use a series of diamond-tipped saw blades mounted on a shaft or arbor to shave the upper surface of a pavement to remove bumps, restore pavement rideability, mitigate noise and improve surface friction.

Background: Diamond grinding and diamond grooving are two different forms of surface restoration that are used to correct a variety of Portland Cement Concrete Pavement (PCC) surfaces distresses. Each technique addresses a specific pavement shortcoming and each may be used in conjunction with other pavement preservation techniques as part of a comprehensive pavement preservation program. In some situations it may be justified to use one of these techniques as the sole preservation technique.

Diamond grinding uses closely-spaced diamond saw blades to remove a thin layer of material from a PCC surface. Diamond grinding is used primarily to restore or improve ride quality by removing joint faulting and other surface irregularities. Other common usages of diamond grinding include improving skid resistance and reducing tire-pavement interaction noise.

Diamond grooving is the use of diamond saw blades to cut longitudinal or transverse grooves into the pavement surface. The purpose of grooving is to produce channels on the pavement surface that collect water and drain it from the surface reducing the potential for wet weather crashes associated with hydroplaning and splash and spray. Longitudinal grooving is commonly employed along local areas such as curves where the grooves provide a tracking effect that helps hold vehicles on the road. Transverse grooving is often used for areas where increased braking resistance is required. Grooving is usually used on pavements that show little or no structural distress.

The difference between diamond grinding and diamond grooving is illustrated in the following figure:

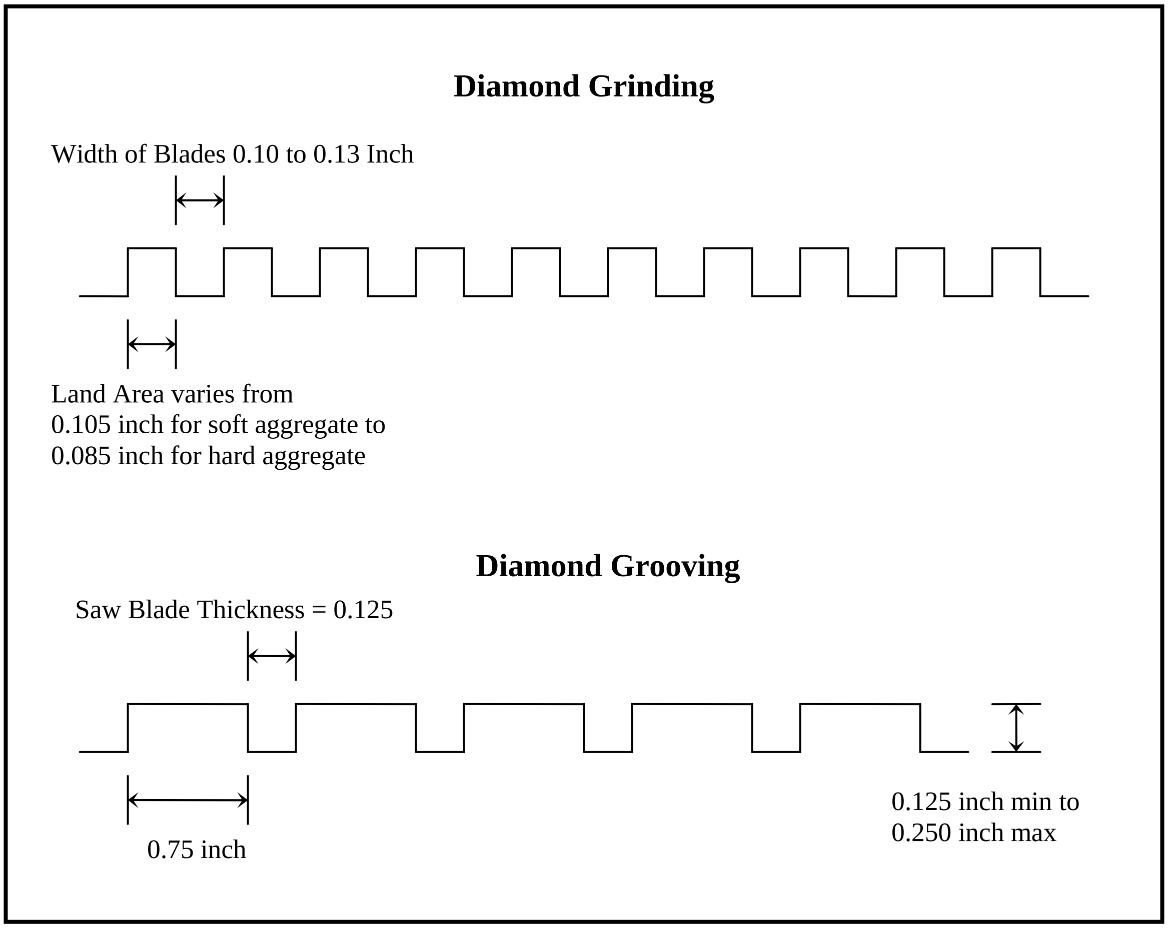


Figure 89: Diamond Grinding and Diamond Grooving

Diamond Grinding

Diamond Grinding is the removal of a thin layer of hardened PCC pavement surface using spaced, diamond saw blades mounted on a rotating shaft. Diamond grinding is primarily conducted to restore or improve ride quality by eliminating surface irregularities. Restoring ride quality improves traffic carrying capacity and adds value to an in-place pavement. In addition to providing a smooth riding surface, diamond grinding is often used to reduce tire/pavement noise in noise sensitive areas or increase the pavement macrotexture in areas that require an increased surface friction level. Specifically, diamond grinding provides numerous benefits including:

- Provides a smooth surface as good as a new pavement.
- Removes minor transverse joint and crack faulting.
- Removes wheel path “rutting” caused by studded tire wear.
- Removes permanent slab wraping at joints.
- Reduces tire/pavement interaction road noise.

- Enhances surface texture and skid resistance.
- Improves drainage.
- Reduces crash rates.
- Does not significantly affect fatigue life.
- Does not affect material durability.
- Does not raise the pavement elevation.
- Need be applied only to the portion of the pavement where restoration is needed.
- Can be accomplished during off-peak hours with short lane closures without having to close adjacent lanes.

The most common reason for diamond grinding is to improve pavement rideability by removing faulting. After grinding roughness values are as good-or-better as can be achieved by new construction.

Retexturing of the pavement surface using diamond grinding may also reduce noise levels. The removal of roughness caused by faulting or cracking can eliminate the thumping sound of tires passing over these areas. The removal of transverse tines by diamond grinding can also eliminate the whistling and whining sound associated with these textured pavements.

Diamond grinding also improves drainage and tire friction, greatly reducing the potential for wet weather crashes.

Diamond Grooving

Diamond grooving is also an effective means of restoring surface texture. Grooving reduces hydroplaning and improves tire friction.

Diamond grooving can be performed on both PCC and hot-mix asphalt (HMA) pavements. In this operation parallel grooves are cut into the pavement surface using diamond saw blades with a typical center-to-center blade spacing of 4/4 inch. The principal objective of grooving is to provide escape channels for surface water, thereby reducing the incidence of hydroplaning that can cause wet weather crashes. Grooving may be performed in either the transverse or longitudinal direction although it is primarily a longitudinal operation.

Procedure: Set up the project:

1. Make an office assessment of the road you are going to diamond grind or groove. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Although diamond grinding PCC pavement provides a dramatic improvement in rideability, it should not be considered when serious structural problems are present. Grinding does not address structural problems and the pavement's condition will continue to deteriorate after the grinding has been completed. The following criteria should be used to assess if diamond grinding of a roadway is appropriate to remove joint and crack faulting:

   a. Roads with structural deficiencies.
   b. Diamond grinding should be conducted before faulting reaches critical levels. The following table summarizes some established threshold values for diamond grinding associated with different average faulting levels:

Average Fault (Inches)	Comments
1/32	No roughness
1/16	Minor Faulting
3/32	Grinding project
1/8	Expedite Project
5/32 3/16 7/32	Discomfort begins
1/4	Grind Immediately

   c. In order to accurately characterize the degree of faulting on a project a sampling is used to determine the number of joints on which to measure faulting. The following table recommends the number of faulting measurements needed on projects with different transverse joint spacings:

Joint Spacing (Ft)	Measure Cracks	Measurement Interval	Number Of Fault Measurements Per Lane Mile
< 12	No	Every 9th joint	> 50
12 to 15	No	Every 7th joint	50 to 63
15 to 20	No	Every 5th joint	53 to 70
20 to 30	Yes	Every 4th joint	44 to 66
> 30	Yes	Every 4th joint	< 30

   d. The need for diamond grinding should be determined based on pavement condition and roughness data. The most important task in determining the cost-effectiveness of a repair strategy is a thorough evaluation of the collected pavement condition data. Structural distress, such as pumping, loss of support, corner breaks, working transverse cracks and shattered slabs will require repair before grinding is conducted. If the cause of faulting is not addressed prior to grinding the faulting will shortly reappear. The presence of widespread distress related to concrete durability, such as D-cracking, reactive aggregate or freeze thaw damage may indicate that diamond grinding is not a suitable restoration technique and that a more comprehensive rehabilitation approach needs to be considered. The following factors should be considered in determining the feasibility of diamond grinding for a particular project:

- If there is evidence that a severe drainage or erosion problem exists, as indicated by significant faulting (greater than 1/8 inch) or pumping, actions should be taken to alleviate the problem prior to grinding.

- The presence of progressive transverse slab cracking and corner breaks indicate structural deficiency in the pavement. Slab cracking, and the faulting of these cracks, will continue after grinding and will reduce the life of the restored pavement.

- Joints and transverse cracks with a deflection load transfer less than 60 percent should have actions taken to restore load transfer prior to diamond grinding.

- The hardness of the aggregate, and its direct impact on the cost of grinding, has historically influenced whether or not a project was a feasible grinding candidate. Grinding a pavement with extremely hard aggregate (such as trap rock or river gravel) takes more time and effort than grinding a pavement with a softer aggregate (such as limestone). While the hardness of the aggregate still affects the cost, new blade technology has brought grinding prices for all aggregate types into a much more reasonable range.

- PCC pavements suffering from durability problems, such as D-cracking or alkali-aggregate reactivity, should not be rehabilitated through grinding

- Significant slab replacement and repair may be indicative of continuing progressive structural deterioration that grinding would not remedy.

3. In addition, Diamond grinding or grooving should be conducted before faulting reaches critical levels.

4. The road may have localized failures that should be corrected by crack treatments, partial-depth repairs, full-depth repairs, dowel bar retrofitting, etc.

5. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. From your measurements determine the number of square yards or ton of hot-mix to be used in the overlay as follows:

    d. Convert (distance) miles from odometer to feet:
    e. Miles Measured × 5280 Feet = Feet of Distance

f. Calculate area in square feet from distance and width:
g. Feet of Distance × Width Measured in Feet = Area in Square Feet

h. Convert square feet of area to square yards of area:
i. Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)

j. Usually milling on Maintenance Projects is by the square yard inch. So to get the milling quantities do the following:
k. Total Square Yards × Depth in Inches = Total Square yard Inches (Milling Quantity)

6. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

Diamond Grinding Equipment

Diamond Grinding equipment uses diamond blades mounted in series on a cutting head. The front wheels of the equipment will pass over a bump or fault, which is then shaved off by the centrally mounted cutting head. The rear wheels track in the smooth path that results. The cutting head typically has a width ranging from 48 to 50 inches. The desired corduroy texture is produced using a spacing of 164 to 197 blades per meter (50 to 60 blades per foot). New improved grinding machines and grinding blades have greatly increased the capability to provide profiles that are smoother than new construction.

Figure 90: Diamond Grinding a highway

Diamond Grinding Procedures

Diamond Grinding should be performed continuously along a traffic lane for best results. Diamond Grinding should always be started and ended perpendicular to the pavement centerline and should also be continuously maintained parallel to the centerline.

Grinding has typically been conducted on multi-lane facilities using a mobile single lane closure, allowing traffic to be carried on adjacent lanes. The traffic control plan must comply with the Manual of Uniform Traffic Control Devices (MUTCD).

Grinding equipment should have a long reference beam so that the existing pavement can be used as a reference. By blending the highs and lows, excellent riding quality can be obtained with a minimum depth of removal. Low spots will likely be encountered. Generally, it is required that a minimum of 95 percent of the area within any 3foot by 100 foot test area be textured by the grinding operation. Isolated low spots of less than 2 square feet should not require texturing if lowering the cutting head would be required.

Because of the relativity narrow width of the cutting head, more than one pass of the grinding equipment will be required. It is recommended that the maximum overlap between adjacent passes be 2 inches. Some projects use multiple grinding machines working together to expedite grinding operations.

<u>Diamond Grooving Equipment</u>

Equipment used to groove pavements is specifically designed for this task. Because fewer diamond blades are required on the cutting head, the head width can be substantially greater than that used in diamond grinding. Some equipment are available that have grinding head width of 6 feet or more. Usually a vacuum system is employed to collect the slurry produced by the sawing.

The diamond blades are spaced to increase the “land area” between grooves. Typically, the blades are spaced ¾ inch apart for longitudinal grooving and the grooves have a width between 3/32 and 1/8 inch and are cut to a depth of 1/8 to ¼ inch. A 10-year study conducted in Germany found that groove widths in excess of 0.18 inch create unacceptable tire noise so a groove width of 0.16 inch was recommended with spacing between grooves of 0.8 to 1.0 inch. For transverse grooving, random grooves spaced 0.4 to 1.6 inch apart and 1/8 inch wide are recommended to reduce tire noise.

Figure 91: Diamond Grooving a highway

Figure 92: Diamond Grooving a Bridge Deck

Diamond Grooving Procedures

Grooving is most commonly performed longitudinally along the pavement. Typically, only localized areas (such as curves) are grooved instead of an entire project length. However, data from friction and wet weather crashes can be used to determine the extent of the grooving.

Procedures typically follow those for diamond grinding. The traffic control plan must comply with MUTCD standards to ensure the safety of construction personnel and traveling public.

Problems to Avoid:

The following table lists potential diamond grinding construction problems and associated solutions:

Problem	Typical Cause(s)	Typical Solution(s)
"Dogtails" (pavement areas that are not ground due to a lack of horizontal overlap).	Primarily caused by weaving during the grinding operation.	Maintaining the required horizontal overlap (typically 2 inches maximum) between passes and steady steering by the operator will avoid the occurrence of dogtails.
"Holidays" (areas that are not ground.	Isolated low spots in the pavement surface.	Lower the grinding head and complete another pass. Typical specifications require 95 percent coverage for grinding texture and allows for 5 percent unground isolated areas.
Poor vertical match between passes.	Inconsistent downward pressure. This is often obtained when unnecessary adjustments to the down-pressure are made.	A constant down-pressure should be maintained between passes to maintain a similar cut depth. A less than 0.12 inch per 10 foot vertical overlap requirement is often required.
Too much or too little material removed near joints.	• Expansion joints or other wide gaps in the pavement can cause the cutting head to dip if the leading wheels drop into the opening. • Slabs deflecting from the weight of the grinding equipment can cause insufficient material to be removed.	• Wide gaps can be temporary grouted to provide a smooth surface. • If slabs deflect from the weight of the grinding equipment lowering the grinding head may help, but stabilizing the slab or retrofitting dowel bars may be a better alternative.
The fins that remain after grinding do not quickly break free.	This could be an indication of excessive wear on the grinding head, but most likely it is the result of incorrect blade spacing.	The grinding head should be checked for wear before or after each day of operation. If the cutting blades are not worn, the blade spacing should be reduced.
Large amounts of slurry on the pavement during grinding.	Most likely this indicates a problem with the vacuum unit or skirt surrounding the cutting head.	If large amounts of slurry are left on the pavement, or slurry flows into adjacent traffic lanes or drainage structures, the surface grinding operations should be stopped. Inspect the equipment and make the necessary repairs.

The following table lists potential diamond grooving construction problems and associated solutions:

Problem	Typical Cause(s)	Typical Solution(s)
Lack of horizontal overlap.	Primarily caused by weaving during the grinding operation.	Lack of horizontal overlap or weaving during the grooving operations may cause lighter vehicles and motorcycles to experience increased vehicle tracking. Maintaining the required horizontal overlap between passes and steady steering by the operator will avoid the occurrence of this problem.
Isolated areas with inconsistent groove depth.	Isolated low spots in the pavement surface.	Although the effects of variable depth grooves are less readily apparent to traffic (no dip in the pavement surface is created), a uniform depth is desirable to ensure the intended drainage characteristics. The grooving head may need to be lowered in areas known to contain isolated low spots.
Inconsistent groove depth near joints.	• Expansion joints or other wide gaps in the pavement can cause the cutting head to dip if the leading wheels drop into the opening. • Slabs deflecting from the weight of the grinding equipment can cause insufficient material to be removed.	• Wide gaps can be temporary grouted to provide a smooth surface. • If slabs deflect from the weight of the grinding equipment lowering the grinding head may help, but stabilizing the slab or retrofitting dowel bars may be a better alternative.
Large amounts of slurry on the pavement during grooving.	Most likely this indicates a problem with the vacuum unit or skirt surrounding the cutting head.	If large amounts of slurry are left on the pavement, or slurry flows into adjacent traffic lanes or drainage structures, the surface grooving operations should be stopped. Inspect the equipment and make the necessary repairs.

7. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate. Road that have completely failed are not good candidates for this treatment. The road may have localized failures that should be corrected by digging them out and replacing them. This approach should never be used on a road that is so far decayed that it can't be built over. If this is the case the, road should be reconstructed.

8. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. From your measurements determine the number of square yards or ton of hot-mix to be used in the overlay as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)
- Convert square yards of area to volume:
  Thickness of Overlay in Inches ÷ 36 Inches per Yard = Thickness in Yards
  Thickness in Yards × Area in Yards = Volume of Overlay in Cubic Yards
- Convert Cubic Yards of Material to Tons:
  Cubic yards of Hot-Mix × Unit Weight of Material (Provided by Lab) = Tons of Hot Mix. (Use this number if contracting of placing yourself)

9. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

10. When construction begins, you should start with a test strip to determine the amount of compaction to be applied to the mat.

Materials: New Mexico Department of Transportation uses the Super-Pave classification and test methods as a basis classification of our hot-mix materials in this state. We do have a number of grades of asphalt cement that have been set up for various regions of the state depending on the climate. Be sure to check with the Central Laboratory for the latest recommendation and discuss any localized factors such as traffic loads, terrain or temperature extremes that may assist the lab in proper asphalt cement selection.

If you are working off of a price agreement for either the material or a finished product, you must use an approved mix design from the NMDOT Central Laboratory. The mix design may be one that is already in place or be designed specifically for the project you are putting forth. If you are generating a new mix design plan on submitting it at least six weeks prior to commencing paving operations.

If you are working with a book project most of the approvals and timeline are spelled out in the contract.

Materials Testing: Hot-Mix Asphalt products need to be tested per the Department's Current "Minimum Testing Requirements" and per the section of the New Mexico Department of Transportation's current Standard Specification for Highway and Bridge Construction. The appropriate section of the standard Specifications will be spelled out in the Book Projects contract pages or if using a Price Agreement (on-call contract) in it contract language.

Equipment: The equipment needed for a standard paving operation is what you will need in an overlay. The biggest think to be cognizant of is that you will need an area that is safe to park all of the equipment needed for your overlay.

The standard list of construction equipment is as follows:

- Hot-mix Asphalt Concrete paving machine and optional backup machine.
- Five to Ten dump trucks to haul HMA to the paving machine.
- Power broom for cleaning road before and after paving operation.
- Asphalt distributor with Tack Oil.
- 10 ton pneumatic roller.
- 2 Steal wheel rollers one of which should be vibratory.
- A water truck for servicing rollers and cooling intersections.
- A small tractor with bucket for spills and joint cuts.

An optional list of construction equipment is as follows:

- A small mill for bridge joint cuts.
- A HMA loader such as co-cal.
- Diamond grinder for out of specification areas.
- Portable walk behind striping machine.

The standard list of field testing equipment is as follows.

- A straight edge for checking joints.
- 3 to 4 foot Level with wedge for checking crown and cross slope.
- Depth/thickness gage for mat thickness.
- Access to a fully equipped HMA field lab.

- An IRI (International Roughness Index) testing device.
- A minimum 25 length measuring tape.
- Thermometer for checking HMA temperature.

The larger pieces of equipment will either need to be stored behind a barrier or beyond the clear zone of the roadway.

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer) and dry days. Cold weather will cause the HMA to cool down before proper compaction has taken place providing a weak product. If the HMA is placed on a cold surface often the HMA will not bond to the underlying pavement and will delaminate over time. Rain interferes with the bonding of the layers and can cool the HMA before it is properly compacted.

Problems to Avoid:

- Be sure that the road is clean before over lay is started. A dirty road will cause the pavement layers not to bond properly and the finished product will fail.
- Be sure to use a NMDOT approve mix design. And be sure that the supplier is providing the proper HMA per the design. These mix designs are set-up for the traffic loads, longevity and maintainability the state road system requires.
- Insure a proper taper is provided on the outside of the road. After the paving operation is complete, the shoulder should be pulled up for a smooth transition form the paved surface to the shoulder in case an errant vehicle leaves the road.
- The height of any guardrail or barrier should be adjusted if need be to function properly.
- Inside (linear) joints should be properly compacted to avoid raveling or future degradation. Pinching and tacking are advisable.
- Be sure all specifications are being met to insure a long product life.
- Be sure contractor has a continuous operation the improve smoothness and overall quality of the pavement.
- Work with an experienced asphalt inspector for a good product. Remember expertise is only as far away as a phone call to the District Lab, General Office Central Lab or the State Maintenance Bureau.

Life Expectancy: The life span of this treatment will be about 10 years if the overlay in preformed on a road that is in good shape.

Procedure:

<u>Project Planning</u>

Make a preliminary assessment of the road that you are considering for white topping:

Make sure that the existing PCC pavement that you are considering for white topping is not scheduled for other projects especially rehabilitation or re-construction.

Make a visual inspection of the road section being considered for white topping to make sure that the pavement is suitable for white topping. White topping is not appropriate if the existing PCC pavement is structurally damaged.

Set up patching and crack repairs to take care of problem areas.

Develop a preliminary traffic control plan. Examine detours or phasing that may be necessary to maintain traffic flow during the course of the project. If the work needs to be done at night determine the lighting needs.

Locate a staging area for the contractor to park equipment and store materials.

Measure the width and record the beginning and ending milepost of the road section to be white topped.

Give the above information to the respective District Technical Support Engineers and request a project design and a request for approval of the concrete mixture design to the State Materials Laboratory in accordance with Standard Specifications For Highway and Bridge Construction - Section 510.42.

The Department's Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.

<u>Pre-Project Repairs</u>

White topping overlays are most appropriate for pavements in good structural condition but some degree of pre-project repairs are still required. An important consideration is whether movement in the underlying pavement, due to environmental conditions or applied loads, will cause movement in the overlay. Any movement in the overlay that does not occur at matched joints (or cracks) will contribute to debonding and the subsequent deterioration of the overlay. Appropriate preoverlay repairs include:

Full-depth repair of medium and high severity transverse and longitudinal cracking, corner breaks and punchouts.
Partial-depth repair of joint spalling
Slab stabilization to fill voids and prevent future pumping and loss of support
Load transfer restoration across working cracks or nondoweled joints

If any deterioration, such as joint spalling, is due to a materials related distress, white topping is probably not an appropriate strategy. A life cycle cost analysis is recommended for all white topping overlay projects to evaluate whether the cost of extensive repairs, in combination with the cost of the white topping overlay, suggest the need to consider alternatives such as an unbonded PCC overlay.

Surface Preparation

Preparing the surface of the existing pavement surface probably has the greatest impact on the long-term performance of white topping. The objective is to remove contaminants, loose PCC, paint and other materials that could adversely affect the bonding of the overlay and to provide a coarse macrotexture that promotes the mechanical bond between the old and new pavements. The most common and effective surface preparation procedure is shotblasting, often followed by sandblasting and airblasting. A minimum average texture depth of 0.08 inch as measured by the sand patch method (ASTM E965) is recommended. Milling is another commonly used method of surface preparation. When milling is used, however, it must be followed with sandblasting to remove fractured aggregate faces.

The bonding of white topping on concrete is also greatly affected by the prevailing climatic conditions at the time of construction such as ambient temperature, humidity and wind speed. If significant stresses develop during the first 72 hours following PCC placement debonding of the overlay from the underlying pavement may occur. The computer program HIPERBOND, part of the HIPERPAV software has been developed that predicts the development of interface bond stresses and strengths to assess the possibility of early-age failures, cracking or delamination, of the white topping overlay.

The ultimate objective of surface preparation is to achieve the desired bond strength between the two PCC layers of the pavement structure. A suggested bond shear strength is 1.4 (MPa) (200 lbf/in^2) between the two PCC layers.

PCC Placement and Finishing

The placement of a white topping overlay is generally the same as conventional PCC. Additional recommendations include:

Grade adjustments must be made to leave space for the required thickness of the white topping PCC overlay.
Care must be taken that vehicles do not drip oil or other contaminants on the existing PCC that will affect the bond.

PCC placement and finishing is performed using either fixed-form or slipform construction. Primary activities during PCC placement and finishing include spreading, consolidation, screeding and float finishing.

Tining has traditionally been conducted transversely and at uniform intervals but recent studies suggest that uniformly spaced transverse tining produces irritating pavement noise. Consequently, some state DOT's are experimenting with transverse tining that is randomly spaced and skewed to the centerline of the pavement. In such cases the tining pattern must be carefully designed and constructed in order to minimize discrete noise frequencies that are most objectionable to the human ear. In addition, some state DOT's are investigating the use of longitudinal tining which produces lower noise levels than either uniformly or randomly spaced transverse tining.

Figure 95: PCC placement.

Texturing of the finished white topping overlay surface is required on all areas that will be exposed to traffic. For roadways designed for vehicle speeds less than 50 mi/hr texturing the surface with a burlap drag, turf drag or broom should be adequate providing that the corrugations produced are about 0.06 inch deep. For roadways designed for vehicle speeds greater than 50 mi/hr tining of the PCC pavement surface is required. This provides macrotexture which contributes to surface friction by tire deformation and also channels surface water out from between the pavement and the tire. Tining should be conducted as soon as the sheen goes off the PCC.

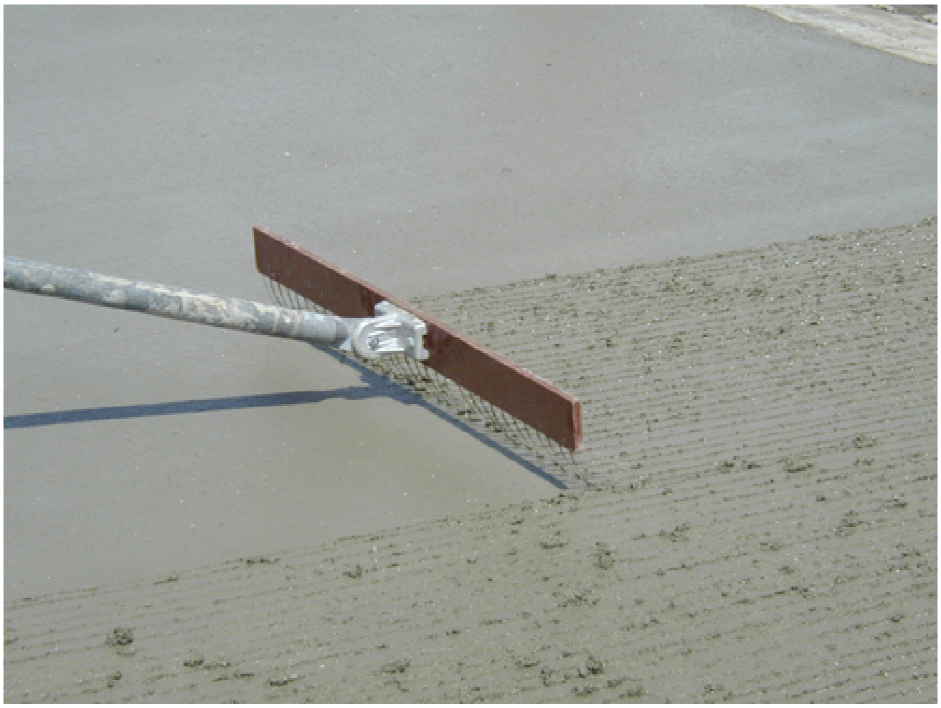
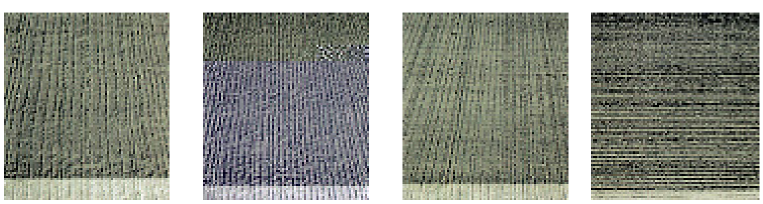


Figure 96: Tinning freshly laid pavement.



Random Transverse	Uniform Transverse	Random Skewed	Uniform Longitudinal

Figure 97: Random Tansverse, Uniform Transverse, Random Skewed and Uniform Longitudinal Tinning.

<u>Curing</u>

The Department's Standard Specifications For Highway and Bridge Construction Section 510.23 specify curing material requirements for PCC pavements. Although proper curing is important to all PCC pavements, it is especially important to white topping overlays because of their high surface area to volume ratio makes them more susceptible to drying too rapidly.

Because white topping overlays are placed so thin, typically 2 to 4 inches, they are more susceptible to drying shrinkage cracking than conventional paving. Consequently, it is important that effective curing practices are employed to help minimize shrinkage. This typically includes a greater application rate for membrane curing compounds and, in some extreme instances, may require wet curing practices such as shading, fog spraying, ponding or wet covering. Prior to construction, the maintenance supervisor and the contractor should agree on the curing procedures that will be used during the project.

Curing is most often accomplished through the application of a membrane curing compound immediately after texturing of the white topping overlay surface. It is recommended that the curing compound be placed at twice the normal rate in order to reduce moisture loss or at a maximum application rate of 100 ft^2/gal. All exposed PCC surfaces, both vertical and horizontal, should be coated with the curing compound.

Figure 98: White-Pigmented, Liquid Membrane Curing Compound.

Figure 99: Polyethylene Sheeting Used as a Curing Blanket.

Joint Sawing

Joint sawing is critical for white topping overlays to establish the contraction joints in the white topping overlay and prevent uncontrolled, random cracking. The location of transverse and longitudinal joints in the white topping overlay must coincide closely with the underlying pavement to prevent the development of uncontrolled random cracking. A deviation greater than 1 inch will contribute to secondary cracking and spalling. It is necessary to lay out the joints in the underlying pavement accurately and carefully. A common technique is to locate the existing transverse joints with guide nails driven off on either side of the pavement in the shoulder and away from the track line of the paver. After the white topping overlay is placed a chalk line is used to connect those guide nails across the new white topping overlay and then "snapped" to establish the transverse joint locations. Longitudinal joints, when uniform and consistent, can be easily located by measuring the horizontal offset from the edge of the existing pavement.

Because of the great amount of joint sawing required on white topping overlays, it is recommended that joint sawing begin as soon as the white topping overlay has developed sufficient strength to allow the joints to be cut without significant raveling or chipping. This will typically be within approximately 3 to 6 hours after white topping overlay placement. Multiple sawing crews may be needed for white topping projects because of the extensive sawcutting requirements. The contractor must ensure that there are sufficient sawcutting crews available for the work and that all crews are familiar with the prescribed joint sawing patterns. Because of the need to get on the pavement as soon as possible, the use of lightweight "early-entry" saws are particularly advantageous for white topping overlay construction. The following table provides recommended joint sawing depths.

Recommended Joint Sawing Depths

Joint Type	**Overlay Thickness**	
	< 4 inch	> 4 inch
Transverse Contraction	Nominal Thickness + ½ inch	⅓Nominal Thickness
Longitudinal	½ Nominal Thickness	⅓Nominal Thickness
Expansion	Nominal Thickness + ½ inch	Nominal Thickness + ½ inch

Joints in white topping overlay pavements are typically sealed with the Department's standard sealant used in new PCC construction. Careful consideration should be given to the design of the sealant reservoir.

Figure 100: Joint sawing.

Material Types:

The Department's Standard Specifications For Highway and Bridge Construction - Section 510.2 and 510.3 specify material requirements for PCC pavements.

Concentrated Portland Cement Concrete

The most important design issue in white topping existing PCC pavements is achieving and maintaining an adequate bond between the white topping overlay and the existing pavement. The mix design of a white topping overlay is important because it affects how the how the overlay will perform as it undergoes drying shrinkage and thermal movement. White topping overlay mix designs should be designed for rapid strength gain, minimum thermal expansion and contraction and minimum shrinkage. For the most part these properties can be achieved through conventional PCC mixes but components of the mix that should be carefully considered include:

Water-cementitious material ratio - The higher the water content the greater the potential for shrinkage as the water evaporates.
Cementitous content – High cementitious contents, especially high heats of hydration, affect the rate of strength gain. If the strength gain and high temperatures are not anticipated and controlled they can be problematic.
Aggregate properties – The coefficient of thermal expansion determines how the white topping overlay will expand and contact when subjected to changes in temperature. These properties should be similar to those of the existing PCC. Aggregate absorption affects shrinkage. An absorptive aggregate has a higher moisture demand and ca contribute to debonding during cure.

Fibers have also been used in some white topping overlay mixes but they are not required. Advantages include higher flexural strength, greater resistance to cracking, reduced shrinkage and improved post-cracking behavior.

Conventional PCC paving mixes are typically used in the construction of White Top overlays. Each of the components used in a PCC mix must be carefully selected so that the resulting mixture is dense, relatively impermeable and resistant to both environmental effects and deleterious chemical reactions over the length of its service life.

Because aggregates typically make up 60 to 75 percent of the total volume of PCC, they have a significant effect on the properties and characteristics of the resulting mixture. To help ensure the longevity of the pavement, these aggregates should not only possess adequate strength but should also be physically and chemically stable within the PCC mixture. Laboratory testing by the State Materials Laboratory, or demonstrated field performance, is required to ensure the selection of a durable aggregate.

The maximum coarse aggregate size used is a function of the slab thickness. For unreinforced pavement structures, the Portland Cement Association (PCA) recommends a maximum aggregate size of one-third of the slab thickness. However, it is recommended that the largest maximum coarse aggregate size be used to minimize paste requirements, reduce shrinkage. Minimize costs and improve mechanical interlock properties at joints and cracks. Maximum coarse aggregate sizes for thin white topping overlays are often from 0.75 to 1 inch.

Guidance on the selection of the appropriate water-to-cementitious material ratio (w/c) is provided by ACI (1991) and PCA. A maximum w/c value of 0.45 is common for pavements in a moist environment and subjected to freeze thaw cycles. However, lower w/c values are used on thinner white topping overlays to minimize drying shrinkage. This is because both pavement types have a high surface-area-to-volume ratio, making them more susceptible to drying shrinkage.

A variety of admixtures and additives are commonly introduced into PCC mixtures to provide certain characteristics or enhance certain properties. Following are some of the more commonly used additives:

Air entrainment is intended to protect the hardened white topping overlay from freeze-thaw and deicer scaling. However, air entrainment also helps increase the workability of fresh PCC by reducing segregation and bleeding. Typical entrained air contents of PCC pavements range from 4 to 6 percent.
Set accelerators are intended to increase the rate of PCC strength development. For thin PCC overlays, they are commonly used on “fast track” paving projects in which early opening times are required. Calcium chloride is commonly used as a set accelerator.
Water reducers are added to PCC mixtures in order to reduce the amount of water required to produce PCC of a given consistency. This allows the lowering of the w/c while maintaining a desired slump, and thus has the beneficial effect of increasing strength and reducing permeability.
Pozzolanic materials, such as fly ash, ground granulated blast furnace slag and silica fume, may also be added to PCC mixtures. These materials may be placed in addition to the Portland cement, or as a partial substitution for a portion of the cement. Fly ash is a by-product of coal-fired plants and is the most commonly used of the pozzolanic materials. Fly ash is classified according to ASTM C 618 as either Class C (high calcium fly ash) or Class F (low calcium fly ash). In general, fly ash helps to improve the workability of the mix; it can also increase the long-term strength of the PCC, although the short-term strength may be less. In addition, Class F fly ash is effective in reducing alkali-silica reactivity.

Fiber-Reinforced Concrete

Fiber Reinforced Concrete (FRC) is PCC containing randomly distributed fibers throughout the mixture. Fibers are often included in white topping overlays because of the desire to minimize plastic shrinkage and to improve post-cracking behavior. The principal reason for incorporating fibers is to increase the “toughness” of the PCC (a measure of its energy-absorbing capacity), as well as to improve its cracking and deformation characteristics. In some cases incorporating fibers, will also increase the PCC flexural strength.

A wide variety of fiber materials have been used to reinforce PCC the most common being steel, polypropylene and polyester. Recently, polyolefin has been used on several paving projects.

General Strength Requirements;

The Department’s Standard Specifications For Highway and Bridge Construction Section 510.5 specify minimum strength requirement for PCC pavements.

Flexural strength is particularly important for white topping overlays pavements because they are subjected to high flexural tension induced by traffic and environmental factors. Consequently, flexural strength requirements are more commonly specified.

Weather Requirements and Pavement Conditions:

The Department's Standard Specifications For Highway and Bridge Construction Section 511.33 specify weather requirements for PCC pavement construction. White topping is best done in warm dry weather. Wet pavements and cold pavements will interfere with adequate bonding between the white topping overlay and the existing PCC. Under no circumstances should the new white topping overlay freeze within the first week of placement.

Problems to Avoid:

Problems to avoid during the construction of thin white topping overlays are very much the same as for conventional PCC paving. Some of the typical problems that are encountered either during or after construction are summarized in the following table.

Problems to Avoid during White Topping Overlay Construction

Problem	Typical Causes	Typical Solutions
Longitudinal or transverse cracking occurs within a few days of paving	Late sawing Inadequate sawcut depth Poor underlying support conditions Reflective cracking Excessive joint spacing Plastic or drying shrinkage	Earlier sawing or multiple saw crews Adequate sawcut depth Adequate preoverlay repairs Match joint locations Shorter joint spacings Effective curing practices for conditions
Delamination between overlay and existing pavement	Poor surface preparation Bonded grout dried out (if used) Differential slab movements Incompatible materials	Ensure adequate surface preparation Place bonding grout directly in front of paver; or, do not use Effective curing practices for prevailing conditions
Exposed base during milling of PCC	Milling too deep PCC too thin	Reduce milling depth Re-measure PCC thickness Replace exposed areas with PCC
Joints ravel excessively during sawing	Sawing too early Improper saw blade	Wait for additional hardening Match saw blade and mix

Life Expectancy:

There has not been enough white topping on Concrete experience in New Mexico to accurately predict the life expectancy of white topping pavements.

Faulting Slab Repairs

Undersealing

Background:

Loss of support beneath Portland Cement Concrete (PCC) pavement is a major cause for deterioration of PCC pavement. Undersealing is a pavement preservation technique wherein flowable material is injected beneath the PCC slab or subbase to fill voids. Undersealing is not the same as slab jacking, also known as the URETEK™ method. Undersealing is not meat to raise slabs. Undersealing is only meant to existing voids <u>before</u> slab subsidence or damage occurs. Lifting of slabs can create additional voids and may cause cracking.

It is important that undersealing be performed before there is significant pavement damage due to loss of support. Undersealing should not be used to correct depressions, increase the road's design structural capacity, and stop erosion or eliminating faulting. Undersealing should only be used to restore slab support to maintain the structural integrity of the slabs and reduce the progression of pumping, faulting and slab cracking.

The success of undersealing operations is highly dependent upon the skill of the contractor. Therefore, the contract should have an experience clause that requires the contractor to have qualifying experience.

Undersealing should only be performed at joints and working cracks where loss of support is known to exist. Stabilizing slabs where loss of support does not exist is not only wasteful but will likely impair pavement performance.

Because loss of support is caused by several factors such as heavy loads, pumping, etc., Undersealing alone is usually not sufficient to correct the problem, the underlying mechanisms must also be addressed.

Undersealing is usually not be an effective restoration technique when the pavement is not structurally sound or if there is evidence of widespread pumping and highly plastic, fine-grained subgrade soils with high in-situ water contents. Retrofitting edge drains usually provides little if any benefit if the pavement is supported by fine-grained soils.

Undersealing is almost always completed in combination with one or more rehabilitation treatments. The following concurrent rehabilitation activities should be strongly considered whenever undersealing work is performed:

- Constructing of a system to drain the pavement section
- Joint and crack sealing to minimize the amount of water infiltrating the structural section
- Load transfer retrofitting (installation of dowel bars)

- Diamond grinding to restore rideability

Figure 101: Slab subsidence resulting from loss of support

Procedure:

Basically, the procedure for undersealing consists of the following steps:
- Project planning
- Locating voids
- Determining the hole pattern
- Drilling the injection holes
- Preparing the void filling material
- Injecting the void filling material

<u>Project Planning</u>

Make a preliminary assessment of the road section that you are considering for undersealing:

1) Make sure that the road section that you are considering for undersealing is not scheduled for other projects especially rehabilitation or re-construction.

2) Make a visual inspection of the road section being considered for undersealing to make sure that the pavement is suitable for undersealing. White Topping is not appropriate if the pavement is structurally damaged.

3) Develop a preliminary traffic control plan. Examine detours or phasing that may be necessary to maintain traffic flow during the course of the project. If the work needs to be done at night determine the lighting needs.

4) Locate a staging area for the contractor to park equipment and store materials.

5) Measure the width and record the beginning and ending milepost of the road section to be Undersealed.

6) Give the above information to the respective District Technical Support Engineers.

<u>Locating Voids</u>

The first step in the undersealing construction process is locating voids. The following testing techniques have been used to determine if loss of support has occurred beneath a PCC pavement surfaces:

- <u>Visual Distress</u> - Faulting of transverse joints and cracks, pumping, corner breaks and shoulder drop-off all indicate that loss of support has occurred. Ideally, undersealing should be done after the formation of the void but before excessive faulting and cracking have occurred.
- <u>Deflection</u> - Deflection not only determines that loss of support has occurred but also can be used to estimate the quantity of material that will be needed to fill the voids. Deflection-base void detection techniques been found to be effective by some state DOT's.
- <u>Other Non-Destructive Testing (NDT) Methods</u> – NDT methods used for void detection include ground penetrating radar (GPR) and infrared thermography. Recent improvements in GPR equipment and data interpretation techniques have enabled the detection of air-filled voids as small a 0.25 inch.

Additional information on the above methods is available from the State Materials Laboratory.

<u>Determining the Hole Pattern</u>

After identifying the location of the voids the next step is to determine the optimal locations of grout insertion holes (i.e., the hole pattern). The chosen pattern depends on a number of factors including:

- Pavement Type – Jointed-plain concrete pavement (JPCP), jointed-reinforced concrete pavement (JRCP) or continuously-reinforced concrete pavement (CRCP).

- Transverse joint spacing on jointed pavements.
- Estimated size and shape of the detected voids.
- The flowability of the material being used.
- Location of cracks and joints near void.
- Slab condition.

Holes should be placed as far away from nearby cracks and joints as possible but still within the area of the identified void. Locating holes near the outer edges of a detected void improves the chances of filling the more shallow areas because voids are typically deeper near a slab corner or crack (from the loss of fines via pumping),. Also, a hole pattern that forces grout to flow toward a crack or joint will minimize wasting grout that may be forced up through these adjacent cracks or joints. Typically, the holes should be placed close enough to achieve a flow of grout from one insertion hole to another when a multiple hole pattern is used. If the flow is easily achieved the hole spacing may be increased. Conversely, if good flow is not achieved before the maximum back pressure is reached, the hole spacing should be reduced. It is typically necessary to experiment the first few days of subsealing to arrive at a hole pattern that optimizes the undersealing process.

Figure 102: A typical hole pattern

Drilling the Injection Holes

For Portland cement-based or asphalt cement grout projects, any pneumatic or hydraulic rotary percussion drill that is capable of cutting 1.25 to 2 inch diameter holes through the slab is suitable. Any hand-held or mechanical drill that can drill clean holes with no surface spalling or breakouts on the underside of the slab is acceptable. Limit the downward pressure on any drill to 200 lbs to avoid conical spalling on the bottom of the slab. When large pieces of the underside of the slab spall, these pieces can potentially block the void and make the void hard to fill.

Hand-held electronic-pneumatic rock drills are typically used to drill the injection holes for polyurethane undersealing. For polyurethane undersealing, the maximum hole diameter should not exceed 0.625 inch. Injection holes should be drilled or cored just beyond the bottom of the slab when a granular subbase is present and to the bottom of the subbase if it is stabilized. Voids often exist beneath the stabilized subbase and it is important that theses be filled.

Figure 103: Injecting Grout.

A quick check of whether or not the hole should be grouted may be made by pouring water into the drill hole (the water will be displaced when grout is pumped into the hole). If the hole does not take water there is no void and therefore no need to grout. If it is determined that there is no void the hole can be filled with an acceptable patching material and the operation can proceed to the next hole.

Mixing and Injecting Void Filling Material

In the past, undersealing procedures utilized labor intensive, small batch mixers with bagged material. The modern undersealing systems used by contractors are mobile, self contained equipment that have all the tools needed for undersealing. These modern systems have been found to reduce both labor and material costs by as much as 30 to 50 percent.

It is important that the contractor and inspector closely observe the slab during the injection process. Lifting of the slabs can create additional voids and lead to slab cracking. To ensure placement control and lateral coverage and to keep the slab from rising when injecting grout cement, it is important to use a pump that is capable of maintaining a low pumping rate (1.5 gallons per minute) and injection pressure (25 to 200 PSI). Positive-displacement injection pumps or non-pulsing progressive-cavity pumps can be used.

The uplift of each slab corner should be monitored using a modified Benkelman Beam or other similar device that is capable of detecting 0.001 in of uplift.

The grout injection should start with a low pumping rate and pressure and should be pumped until one of the following occurs:

- The maximum allowable pressure of 100 PSI at the grout plant is obtained. A short surge up to 200 PSI can be allowed when starting to pump for the grout to penetrate the void structure, if necessary.
- The slab life exceeds 0.125 inch.
- Grout is observed flowing from adjacent holes, cracks or joints.
- Grout is being pumped unnecessary under the shoulder, as indicated by lifting.
- More than 1 minute has elapsed, longer than this indicates that the grout if flowing into a cavity.

Materials

The most common materials used for undersealing operations are cement grout mixtures, asphalt cement and polyurethane.

Cement Grout Mixtures

The more common cement-based grout mixtures include pozzolanic cement (fly ash cement) and limestone dust cement. Pozzolanic cement mixtures are the most flowable because of the spherical shape of the fly ash particles.

Following is a recommended mix design for a pozzolanic cement grout for use in undersealing:

- One part by volume Portland cement Type I or Type II.
- Three parts by volume pozzolan.
- Enough water to achieve fluidity.
- If the ambient temperature is below 50ºF an accelerator may be used.
- Additives, superplasticizers, water reducers and fluidifiers as needed.

The contractor should be able to verify chemical and physical properties of the pozzolan or limestone using 1, 3 and 7 day compressive tests, flow cone results time of initial set and shrinkage/expansion results.

Portland cement-based grouts are typically injected using a grout packer in order to prevent material extrusion or backup during injection. Drive packers are tapered pipes that fit snugly into the injection hole by tapping with a small hammer. Drive packers are generally used when hole diameters are about 1 inch in diameter. For larger holes, expandable packers are used. Expandable packers consist of a pipe with a short rubber sleeve near the nozzle that expands to fill the hole during injection.

The injection equipment should include either a return hose from the injection device (packer or tapered nozzle) to the material storage tank, or a fast-control reverse switch to stop grout injection quickly when slab movement is detected on the uplift gauge. A grout-recirculation system also helps eliminate the problem of grout setting in the injection hoses because the grout circulates back to the pump after pumping ceases.

After grouting has been completed is withdrawn and the hole is plugged immediately with a temporary wooden plug. When sufficient time has elapsed to permit the grout to set the temporary plug is removed and the hole is sealed flush with an acceptable patching material such as a stiff grout or an approved concrete mixture.

Unless a fast setting material is used traffic should be kept off of a stabilized slab for at least 3 hours after grouting to allow adequate curing of the grout. Traffic loads allowed on the pavement before the grout has been allowed to cure can force grout to be extruded from joints and cracks.

A grout plant that is capable of accurately measuring, proportioning and mixing the material by volume or weight should be used for grout cement mixtures. Colloidal mixing equipment is recommended for pozzolan cement grouts. Colloidal mixers provide the most thorough mixing for pozzolan-cement grouts because the material stays in suspension and resists dilution by free water. The most common types of colloidal mixers are:

- Centrifugal Pump Mixer – This mixer pulls grout through a mixing chamber at high pressure and velocity.
- Shear Blade Mixer – This mixer has blades that rotate at 800 to 2,000 revolutions per minute.

Figure 104: Injecting Portland cement-based grout.

Contractors should avoid paddle-type drum mixers with cement-prozzolan grouts because the low agitation of these mixers makes it very difficult to thoroughly mix the grout. However, paddle-drum mixers are effective at thoroughly mixing limestone dust grouts. Conveyors, mortar mixers or ready-mix trucks should not be used to mix any type of stabilization material as these mixers require adding too much water for fluidity and the solids tend to agglomerate and clump in the mix.

Cement-prozzolan grout fluidity should be monitored during construction using flow cone tests. The flow cone must conform to the dimensions and other requirements of the US Army Corps of Engineers Test Method No. CRD-C611-80 or ASTM C 939-81.

<u>Asphalt Cement</u>

The type of asphalt commonly used for undersealing must have a low penetration 915 to 30) and a high softening point (180ºF to 200ºF). It must also have a viscosity suitable for pumping when heated to temperatures from 400°F to 450°F. The Asphalt Institute recommends the use of asphalt cements that meet the requirements of ASTM D3141-96, *Standard Specifications for Asphalt for undersealing Portland-Cement Concrete Pavements*.

Asphalt is heated to the desired temperature (400°F to 450°F) before pumping operations begin. Because these temperatures approach or exceed the flash points of some asphalts extreme care must be taken to ensure that the asphalt does not come into contact with an open flame. The asphalt is circulated prior to pumping in order to free and warm up the lines of the circulating hose. The equipment for pumping asphalt should be capable of developing pressures of 90 PSI. The distributor should be equipped with an accurate pressure gauge.

Before injecting asphalt, blow compressed air through the hole at approximately 70 PSI for 15 to 60 seconds to blow water out from beneath the slab. Any excessive water under the slab will cool the asphalt resulting in inadequate filling of voids. If adequate drying cannot be obtained subsealing operations should be postponed or higher asphalt temperatures and pressures should be used and the entire operation should be performed at a rapid rate. Also before injecting asphalt, water, limewater or sand is sprinkled around the hole to prevent any asphalt that may leak out from around the nozzle from sticking to the pavement. If asphalt seeps from the joints or cracks before the undersealing is completed the pumping is stopped until the extruded asphalt has congealed. Spraying cold water on seeping asphalt will accelerate the hardening process.

Asphalt is typically injected using a tapered nozzle that is seated into a hole. Combination foot-stands and shields are commonly attached to the nozzle after it has firmly wedged into the hole. The operator can then hold the nozzle in position by standing on the wings of the stand. Proper safety clothing and face shields are essential for personnel in the vicinity of the sealing operation because of the danger inherent in the pressure injection of extremely hot asphalt cement. A shield approximately 4 by 4 feet must be placed between the hole being pumped and the adjacent lane.

Asphalt is pumped at a pressure between 25 to 90 PSI until the underside of the slab is sealed and all cavities are filled as indicated by the shoulders showing signs of breaking away from the pavement edge or when the pavement begins to rise. As with cement based mixtures, asphalt cement injection equipment should include either a return hose from the injection device (packer or tapered nozzle) to the material storage tank or a fast-control reverse switch to stop grout injection quickly when slab movement is detected on the uplift gauge.

After pumping is completed the nozzle is removed and the hole is temporarily plugged with a cylindrical wooded plug. When the asphalt has hardened the temporary plug is removed and the hole is filled with cement grout. All asphalt and any other materials spilled on the surface should be removed.

<u>Polyurethane</u>

Polyurethane is made by mixing two chemicals that combine under heat to form a strong, light-weight, foam-like substance. After being injected beneath the pavement a reaction between the two chemicals causes the material to expand and fill any voids. For undersealing purposes, the polyurethane density is about 4 lb/ft^3 and the compressive strength ranges from 60 to 145 PSI.

Polyurethane should be handled and used in accordance with the material manufacturer's instructions and specifications. Polyurethane should be stored, proportioned and blended within a self-contained pumping unit.

Polyurethane grout is pumped into the holes through plastic nozzles that screw onto the hoses instead of large grout packers.

Weather Requirements and Pavement Conditions:

Undersealing is best done in warm dry weather. Undersealing should never be performed when the ambient temperature is below 40ºF or when the foundation material is frozen. Wet weather may interfere with efforts to maintain asphalt at desired temperatures (400°F to 450°F) especially in the hoses. Also, water may explode when it comes into contact with hot asphalt.

Problems to Avoid:

Some of the typical problems that are encountered during undersealing operations are summarized in the following table.

Problems to Avoid during White Topping Overlay Construction

Problem	Typical Cause(s)	Typical Solutions
The combination of no evidence of grout in any adjacent hole, joint or crack after 1 minute and no registered slab movement on the uplift gauge.	• Grout is flowing into a large washout cavity.	• Stop the injection process. The cavity will have to be corrected by another repair procedure.
High initial pumping pressure does not drop after 2 to 3 seconds.	• Spalled material at bottom of hole may be blocking entrance to void.	• Material blockages may sometimes be cleared by pumping a small quantity of water or air into the hole to create a passage that will allow grout to flow into the void. • The hole missed the void.
Testing after <u>one</u> properly performed grouting still indicates a loss of support.	• The void was not adequately filled. • The selected hole pattern did not provide complete access to the void.	• Regrout the void using different holes from those that were initially used.
Testing after <u>two</u> properly performed groutings (i.e. after regrouting) still indicates a loss of support.	• The second selected hole pattern still did not provide complete access to the void • The void may be deeper in the pavement.	• If the selected hole pattern missed the void, drill holes at additional locations. • The injection holes may have to be drilled deeper into the subgrade.
Uplift gauge exceeds the maximum specified slab lift (typically 0.125 inch).	• Overgrouting	• Overgrouting a void can cause immediate cracking or at least increase the potential for long term slab cracking. If slab damage is immediately observed the contractor will most likely be responsible for replacing the slab at no cost to the agency.
Grout extrudes into a working joint or crack.	• The void is filled or the hole was drilled too close to a joint or crack.	• The presence of incompressible material in a joint or crack can increase the probably of spalling or blow-ups. For a joint the solution is to restore the joint reservoir and joint sealant. For a crack the solution is to rout or saw and seal the crack.

Life Expectancy:

The life expectancy of PCC pavements can be significantly increased by undersealing operations depending on the effectiveness of the operation. The effectiveness of undersealing operations can be determined only by monitoring the subsequent performance of the pavement. The best early indication of effectiveness is obtained by measuring slab deflections before and after grouting to determine if the magnitude of the deflection has been significantly reduced by the process. It is recommended that follow-up deflection testing be conducted 24 to 48 hours after the undersealing has been completed.

One state DOT determined the effectiveness of undersealing by remeasuring the deflection after initial stabilization. If the deflection under an 18 kip single-axle load is still in excess of 0.025 inch, the slab is regrouted with the assumption that the existing voids were not entirely filled or that additional voids formed during the initial stabilization operation. This procedure is only repeated once. Other state DOT's use different deflection methodologies and may regrout up to two times after which the slab or section is removed and replaced if the presence of voids is still suggested.

Punchouts and Shattered Slabs

Selective Slab Replacement

Background: Portland cement concrete (PCC) pavements showing severe structural distresses may require selective slab replacement. Selective slab replacement involves removing the deteriorated concrete down to the base, repairing the disturbed base, installing load-transfer devices, and refilling the excavated area with new concrete. By removing and replacing selective slabs, the pavement may replacement may be restored close to its original condition.

Distresses that can be addressed using selective slab replacement include D-Cracking, blowups, punch-outs and deteriorated joints. Selective slab replacement is also used to prepare distressed PCC pavements for a structural overlay.

<u>Pavement Distresses that Require Selective slab replacement</u>

The need for selective slab replacement should be determined based on the type, frequency, and severity of deterioration of the pavement. The Distress Identification Manual for the LTPP Project, Strategic Highway Research Program, National Research Council, 1993. FHWA, includes a description of joint and crack distress at low, medium and high severity levels. Recommendations are provided in Table 1 as to the level of severity of each distress type that warrants selective slab replacement.

Table 1 - JCP distresses addressed by selective slab replacement.

Distress Type	Severity Levels That Require Full-Depth Repair
Spal1ing of Joints	H
Blowup	L, M, H
D-Cracking (at joints or cracks)[2]	M[1], H
Reactive Aggregate Spalling[2]	M[1], H
Deterioration Adjacent to Existing Repair	H
Deterioration of Existing Repairs	H

The following are descriptions of typical concrete pavement distresses that require selective slab replacement.

"D" cracking: "D" cracking is a pattern of cracks caused by the freeze-thaw expansive pressures of coarse aggregates. The spalling associated with these stresses begins near the joints as a result of the higher moisture levels causing aggregates to expand in volume during freezing. Medium and high severity "D" cracking could warrant full depth repair.

Figure 105: "D" Cracking

Blowup: Blowups occur in hot weather at transverse joints or cracks which do not allow sufficient expansion of the concrete slabs. The insufficient expansion width of joints is usually caused by infiltration of incompressible material into the joint. Blowups of any severity warrant selective slab replacement due to the localized disruption to pavement integrity and the potential safety hazard.

Punchouts: Punchouts in continuously reinforced concrete pavements (CRCP) are candidates for selective slab replacement as they represent a structural failure of the pavement. They form after many load cycles when the longitudinal steel ruptures along the faces of two closely spaced cracks, usually less than 2 feet apart.

Figure 106: Punchout of Continuously Reinforced Concrete Pavement.

Procedure:

Preliminary Document Review

Bid/project specifications and design

- Special provisions
- Traffic control plan
- Manufacturers' instructions
- Material safety data sheets

Project Review

- Verify that pavement conditions have not significantly changed since the project was designed and that selective slab replacement is appropriate for the pavement.
- Check estimated number of slabs to be replaced against the number specified in the contract.

Materials Checks

- NMDOT Standard Specifications For Highway and Bridge Construction Sections 451.3 and 510.4 specify construction requirements for PCC pavements.
- Verify that concrete patch material is being produced by a supplier listed on the NMDOT's Qualified Supplier List as required by contract documents.
- Verify that the mix design for the material being supplied meets the criteria of the contract documents.
- Verify that concrete patch material has been sampled and tested prior to installation, and is not contaminated.
- Verify that load transfer units (dowels) meet specifications and that dowels are properly coated with epoxy (or other approved material) and free of any minor surface damage in accordance with contract documents.
- Verify that dowel-hole cementing grout meets specifications.
- Verify that bond-breaking board meets specifications (typically asphalt-impregnated fiberboard).
- Verify that joint sealant material meets specifications.
- Verify that sufficient quantities of materials are on hand for completion of the project.
- Ensure that all material certifications required by contract documents have been provided to the NMDOT prior to construction.

Equipment Inspections

Concrete Removal Equipment

- Verify that required equipment used for concrete removal is all on-site and in proper working order and of sufficient size, weight, and horsepower to accomplish the removal process (including front-end loader, crane, fork lift, backhoe, skid steer, and jackhammers).

Area Preparation Equipment

- Verify that the plate compactor is working properly and capable of compacting subbase material.
- Verify that gang drills are calibrated, aligned, and sufficiently heavy and powerful enough to drill multiple holes for dowel bars.
- Verify that air compressors have oil and properly functioning moisture filters/traps. Prior to use, check the airstream for water and/or oil by passing the stream over a board, then examining the board for contaminants.

Testing Equipment

- Verify that the concrete testing technician meets the requirements of the contract documents for training/certification.
- Ensure that all material test equipment required by the specifications is available on-site and in proper working condition (typically including slump cone, pressure-type air meter, cylinder molds and lids, rod, mallet, ruler, and 10 foot straightedge).
- Ensure that sufficient storage area on the project site is specifically designated for the storage of concrete cylinders.

Placing and Finishing Equipment

- Verify that handheld concrete vibrators are the proper diameter and operating correctly.
- Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish.
- Verify that sufficient polyethylene sheeting is readily available on-site for immediate deployment as rain protection of freshly placed concrete, should it be required.

Traffic Control

- Verify that signs and devices match the traffic control plan presented in the contract documents.
- Verify that the setup complies with the Federal *Manual on Uniform Traffic Control Devices* traffic control procedures.
- Verify that traffic control personnel are trained/qualified in accordance with contract documents and NMDOT requirements.
- Ensure that the repaired pavement is not opened to traffic until the patch material has met the minimum strength specified in the contract documents.
- Ensure that signs are removed or covered when they are no longer needed.
- *Verify that any unsafe conditions are reported to a supervisor (contractor or NMDOT).*

Project Inspection Responsibilities

Concrete Removal and Cleanup

- Verify that the slabs to be removed are clearly marked on the pavement surface and the cumulative area of the pavement to be removed is consistent with quantities in the contract documents.
- Verify that concrete is removed using either the break-up or lift-out method and minimizing disturbance to the base or subbase as much as possible.
- Verify that after concrete removal, disturbed base or subbase is re-compacted, and additional subbase material is added and compacted if necessary.
- Verify that concrete adjoining the slab is not damaged or undercut by the concrete-removal operation.
- Ensure that removed concrete is disposed of in the manner described in the contract documents.

Preparation

- Verify that dowels are installed in transverse joints to the proper depth of insertion and at the proper orientation (parallel to the centerline and perpendicular to the vertical face of the saw cut excavation) in accordance with contract specifications. Typical tolerances measured perpendicularly to the sawed faced are 1/4 inch misalignment per 12 inches of dowel bar length.
- Verify that tiebars are installed at the proper location, to the proper depth of insertion, and to the proper orientation in accordance with contract documents. When the length of the longitudinal joint is 15 feet or greater, tiebars are typically installed in the manner used for dowels. When the length of the longitudinal joint is less than 15 feet, a bond-breaker board is placed along the length of the patch to isolate it from the adjacent slab.
- Ensure that tiebars are checked for location, depth of insertion, and orientation (perpendicular to centerline and parallel to slab surface).

Placing, Finishing, and Curing Concrete

- Concrete is typically placed from ready-mix trucks or mobile mixing vehicles in accordance with contract specifications.
- Verify that the fresh concrete is properly consolidated using several vertical penetrations of the concrete surface with a handheld concrete vibrator.
- Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge or vibratory screed in accordance with contract documents.
- Verify that the surface of the fresh concrete patch is finished and textured to match adjacent surfaces.
- Verify that adequate curing compound is applied to the surface of the fresh concrete immediately following finishing and texturing in accordance with contract documents. Note: Best practice suggests that two applications of curing compound be applied to the finished and textured surface, one perpendicular to the other.
- Ensure that insulation blankets are used when ambient temperatures are expected to fall below 4°C (40°F). Maintain blanket cover until concrete attains the strength required in the contract documents.

Resealing Joints and Cracks

- Verify that patches have attained adequate strength to support concrete saws, patch perimeters and other unsealed joints are sawed off to specified joint reservoir dimensions.
- Verify that joints are cleaned and resealed according to contract documents.

Cleanup Responsibilities

- Verify that all concrete pieces and loose debris are removed from the pavement surface.
- Verify that old concrete is disposed of according to contract documents.
- Verify that mixing, placement, and finishing equipment is properly cleaned for the next use.
- Verify that all construction-related signs are removed when opening pavement to normal traffic.

Materials:

The concrete mixture design should be based on the available lane closure time. The shorter the time available before opening to traffic, the more rapid the strength gaining and curing of the concrete must be.

Typical selective slab replacement operations use concrete mixes containing 658-846 lbs/yd^3 of either cement Type I or Type III cement. A set-accelerator is frequently used to permit opening in 4 to 6 hours. Without the accelerator, these mixes allow opening in 12 to 72 hours.

Uses of proprietary concrete mixes are necessary to achieve opening times in as little as 2 hours. Using insulating blankets during the first few hours after placement also can improve the strength development of any mix. Regardless of the mix design used, the concrete mixture for selective slab replacement should have the following properties:

- 6.5 ± 1.5 percent of entrained air in the concrete (less air may be permissible in nonfreeze areas).
- 2 to 4 inches slump

Mixes using Type III cement may require slightly more mix water than a similar mix with Type I portland cement. However, too much extra water may cause the concrete to suffer from high shrinkage during curing. A water-reducing admixture will disperse cement particles and reduce the water necessary for workability.

Calcium chloride ($CaCl_2$) or another accelerating chemical admixture is recommended for use as accelerator in the patching concrete, provided that it is added as specified. It should be noted that initial set may occur within 30 minutes on warm days, therefore, use only 1% of calcium chloride by weight of cement when air temperature exceeds 80° F. Up to 2% is acceptable in lower temperatures. For on-site mixing, add calcium chloride in liquid form to the mixer before other admixtures are added (except the air-entraining admixture). When using calcium chloride, considerations should be given to the remaining service life of the adjacent pavement and weather dowel bars and reinforcing steel are coated.

If calcium chloride or other accelerating admixture are being added at the plant and the concrete consistently arrives at the site too stiff, then the calcium chloride should be added at the site. If , after the addition of calcium chloride at the site, the concrete is still too stiff, the ready-mix plant operator should be notified to increase the slump an appropriate amount, up to 6 inches.

Chemical admixture may be added to the concrete at the batch plant if the air temperatures are moderate (less than 68° F) and the batch plant is less than 15 minutes from the project site. Non chloride accelerators are recommended for CRCP and JCP selective slab replacement.

Weather Requirements and Pavement Conditions:

- Verify that air and surface temperatures meet contract document requirements (typically a minimum of 40° F and rising) for concrete placement.
- Concrete pouring should not proceed if rain is imminent. Patches that have been completed should be covered with polyethylene sheeting to prevent rain damage.

Problems to Avoid:

Lifting out a slab damages adjacent slab:

1. Adjust lifting cables and re-position lifting device to assure a vertical pull.
2. Re-saw and remove broken section of adjacent slab.
3. Use a forklift or crane instead of a front-end loader.

Slab disintegrates when attempts are made to lift it out:

1. Complete removal of patch area with backhoe or shovels.
2. Angle the lift pins and position the cables so that fragmented pieces are bound together during liftout.
3. Keep lift height to an absolute minimum on fragmented slabs.

Patches become filled with rainwater or groundwater seepage, saturating the subbase:

1. Pump the water from the patch area, or drain it through a trench cut into the shoulder.
2. Re-compact subbase to a density consistent with contract documents, adding material as necessary.
3. Allow small depressions in subbase to be filled with aggregate dust or fine sand before patch material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities 1/2 inch or less in surface of subbase before concrete patch is placed.

Grout around dowel bars flows back out of the holes after dowels are inserted:

1. Pump grout to the back of the hole first.
2. Use a twisting motion when inserting the dowel.
3. Add a grout retention disk around the bar to prevent grout from leaking out.

Dowels appear to be misaligned once they are inserted into holes:

1. If misalignment is less than 1/4 inch per 12 inches of dowel bar length, do nothing.
2. If misalignment is greater than 1/4 inch per 12 inches of dowel bar length on more than three bars, re-saw patch boundaries beyond dowels and re-drill holes.
3. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.

Life Expectancy:

Selective slab replacement can be designed and constructed to provide good long-term performance of 10 or more years. Major causes of premature failures are inadequate load transfer design and poor construction quality. The effectiveness of some selective slab replacement has been limited due to placement on pavements that are too far deteriorated.

Crack and Seat

Background: A Crack and Seat operation is the fracturing of an existing PCC pavement and overlaying it with hot Plant Mixed Bituminous Pavement (PMBP). This treatment alleviates problems with PCC pavements that are not properly supported. The fractured concrete seats itself and provides base support to the overlying PMBP pavement. This is a good treatment for slabs that are "rocking".

Figure 107: A Crack and Seat Operation

Procedure: Set up the project:

1. Make an office assessment of the road you are going to crack and seat. Make a check of the planning for this road and see if it is going to have a re-construction project on it in the next few months so you don't waste resources on a road that would be replaced anyway.

2. Go to the project site and see what condition the road is in. Be sure that the treatment is appropriate.

3. Measure the length and width of the road to get the area of the road. Usually the odometer is close enough for the length and the width can be measured with a tape measure. From your measurements determine the number of square yards or ton of hot-mix to be used in the overlay as follows:

- Convert (distance) miles from odometer to feet:
  Miles Measured × 5280 Feet = Feet of Distance
- Calculate area in square feet from distance and width:
  Feet of Distance × Width Measured in Feet = Area in Square Feet
- Convert square feet of area to square yards of area:
  Area in Square Feet ÷ 9 Square Feet per Square Yard = Area in Square Yards (use this number for contracting by square yards)
- Convert square yards of area to volume:
  Thickness of Overlay in Inches ÷ 36 Inches per Yard = Thickness in Yards
  Thickness in Yards × Area in Yards = Volume of Overlay in Cubic Yards
- Convert Cubic Yards of Material to Tons:
  Cubic yards of Hot-Mix × Unit Weight of Material (Provided by Lab) = Tons of Hot Mix. (Use this number if contracting of placing yourself)

4. Schedule project around traffic flows if in the urban area. Parking areas for storing equipment should be located or shielding should be installed if adjacent to the roadway. Also setup pavement markings and striping for the final product.

Figure 108: A Plant Mix Bituminous Pavement overlay.

Materials: New Mexico Department of Transportation uses the Super-Pave classification and test methods as a basis classification of our hot-mix materials in this state. We do have a number of grades of asphalt cement that have been set up for various regions of the state depending on the climate. Be sure to check with the Central Laboratory for the latest recommendation and discuss any localized factors such as traffic loads, terrain or temperature extremes that may assist the lab in proper asphalt cement selection.

If you are working off of a price agreement for either the material or a finished product, you must use an approved mix design from the NMDOT Central Laboratory. The mix design may be one that is already in place or be designed specifically for the project you are putting forth. If you are generating a new mix design plan on submitting it at least six weeks prior to commencing paving operations.

If you are working with a book project most of the approvals and timeline are spelled out in the contract.

Materials Testing: Hot-Mix Asphalt products need to be tested per the Department's Current "Minimum Testing Requirements" and per the section of the New Mexico Department of Transportation's current Standard Specification for Highway and Bridge Construction. The appropriate section of the standard Specifications will be spelled out in the Book Projects contract pages or if using a Price Agreement (on-call contract) in it contract language.

Equipment: The equipment needed for a standard paving operation is what you will need in an overlay. The only other piece of equipment needed is for the actual crack and seat operation. The biggest thing to be cognizant of is that you will need an area that is safe to park all of the equipment needed for your overlay.

The standard list of construction equipment is as follows:

- Hot-mix Asphalt Concrete paving machine and optional backup machine.
- Five to Ten dump trucks to haul HMA to the paving machine.
- Power broom for cleaning road before and after paving operation.
- Asphalt distributor with Tack Oil.
- 10 ton pneumatic roller.
- 2 Steal wheel rollers one of which should be vibratory.
- A water truck for servicing rollers and cooling intersections.
- A small tractor with bucket for spills and joint cuts.

An optional list of construction equipment is as follows:

- A small mill for bridge joint cuts.
- A HMA loader such as co-cal.
- Diamond grinder for out of specification areas.
- Portable walk behind striping machine.

The standard list of field testing equipment is as follows.

- A straight edge for checking joints.
- 3 to 4 foot Level with wedge for checking crown and cross slope.
- Depth/thickness gage for mat thickness.
- Access to a fully equipped HMA field lab.
- An IRI (International Roughness Index) testing device.
- A minimum 25 length measuring tape.
- Thermometer for checking HMA temperature.

The larger pieces of equipment will either need to be stored behind a barrier or beyond the clear zone of the roadway.

Weather Conditions and Pavement Conditions: This process generally needs to be preformed on warm, (45˚F or warmer) and dry days. Cold weather will cause the HMA to cool down before proper compaction has taken place providing a weak product. If the HMA is placed on a cold surface often the HMA will not bond to the underlying pavement and will delaminate over time.

Rain interferes with the bonding of the layers and can cool the HMA before it is properly compacted.

Problems to Avoid:

- Be sure to use a NMDOT approve mix design. And be sure that the supplier is providing the proper HMA per the design. These mix designs are set-up for the traffic loads, longevity and maintainability the state road system requires.
- Insure a proper taper is provided on the outside of the road. After the paving operation is complete, the shoulder should be pulled up for a smooth transition form the paved surface to the shoulder in case an errant vehicle leaves the road.
- The height of any guardrail or barrier should be adjusted if need be to function properly.
- Inside (linear) joints should be properly compacted to avoid raveling or future degradation. Pinching and tacking are advisable.
- Be sure all specifications are being met to insure a long product life.
- Be sure contractor has a continuous operation the improve smoothness and overall quality of the pavement.
- Work with an experienced asphalt inspector for a good product. Remember expertise is only as far away as a phone call to the District Lab, General Office Central Lab or the State Maintenance Bureau.

Life Expectancy: The life span of this treatment will be about 10 years if the overlay in preformed on a road that is in good shape. If you have a poor road the life will drop off dramatically. An overlay will not hide a poor road surface for very long.

Load Transfer Restoration

Dowel-Bar Retrofit

Background: Load transfer is the ability of a joint to transfer wheel loads from one side of a joint to the other. The amount of load transfer influences the magnitude of deflections at joints, and is a major factor influencing the structural performance of a Portland Cement Concrete (PCC) pavement. Poor load transfer across transverse joints can lead to pumping, faulting, corner breaks, and possibly spalling; poor load transfer across existing cracks in PCC pavements can lead to spalling, faulting, and further deterioration of the crack.

One way of addressing poor load transfer before it results in deterioration of the pavement is through load transfer restoration referred to as dowel-bar retrofit (DBR). DBR is a technique used to rehabilitate jointed concrete pavements where faulting is a problem, but are otherwise in good condition.

Slots are cut into the roadway over the joints and existing transverse cracks. Dowel bars are set in the slots at mid-pavement depth and then the slots are backfilled with a patch material. Later, the pavement is diamond ground so the tops of the slabs are flush with each other. The objective of DBR, besides restoring a smooth ride, is to extend the service life of an older pavement 10-15 years by providing it with the ability to effectively transfer load.

Figure 109: Dowel-Bar and Slots.

Preliminary Document Review

- Bid/project specifications and design
- Special provisions
- NMDOT application requirements
- Traffic control plan

- Manufacturers' installation instructions for patch materials
- Material safety data sheets

Project Review

- Verify that pavement conditions have not significantly changed since the project was designed.
- Verify that the pavement is structurally sound. Evidence of pumping with surface staining or isolated wetness and faulting exceeding 1/8 inch are indicators of lack of proper subgrade support possibly necessitating undersealing.
- Check estimated quantities for dowel-bar retrofit.

Materials Checks

- Verify that dowel slot cementing grout meets specification requirements.
- Verify that dowel slot cementing grout is being obtained from an approved source or listed on the NMDOT Approved Products List.
- Verify that the component materials for the dowel slot cementing grout have been sampled, tested, and approved prior to installation as required by contract documents.
- Verify that additional or extender aggregates have been properly produced, with acceptable quality.
- Verify that material packaging is not damaged so as to prevent proper use (packages leaking, torn, or pierced).
- Verify that caulking filler meets specification requirements.
- Verify that dowels, dowel bar chairs, and end caps meet specification requirements.
- Verify that dowel bars are properly coated with epoxy (or other approved material) and free of any minor surface damage in accordance with contract documents.
- Verify that curing compound meets specification requirements.
- Verify that joint/crack re-former material (compressible insert) meets specification requirements (typically polystyrene foam board, 1/2 inch thick).
- Verify that joint sealant material meets specification requirements.
- Verify that all required materials are on hand in sufficient quantities to complete the project.
- Ensure that all material certifications required by contract documents have been provided to the agency prior to construction.

Equipment Inspections

Slot Cutting Equipment

- Verify that slot sawing machine is of sufficient weight, horsepower, and configuration to cut the specified number of slots per wheel path to the depth shown on the plans.
- Verify that removal jackhammers are limited to a maximum rated weight of 30 pounds.

Slot Cleaning and Preparation

- Verify that sand blaster unit is adjusted for correct sand rate and that it is equipped with and using oil and moisture filters/traps.
- Verify that air compressors have sufficient pressure and volume to adequately remove all dust and debris from slots and meet agency requirements.

Mixing and Testing Equipment

- For auger-type mixing equipment, ensure that auger flights or paddles are kept free of material buildup, which can cause inefficient mixing operations.
- Ensure that volumetric mixing equipment, such as mobile mixers, is kept in good condition and is calibrated on a regular basis to properly proportion mixes.
- Ensure that material test equipment required by the specifications are all available on site and in proper working condition (typically including slump cone, pressure-type air meter, cylinder molds and lids, rod, mallet, ruler, and 10 foot straightedge).

<u>Other Equipment</u>

- Verify that vibrators are the size specified in the contract documents (typically 1 inch in diameter or less) and are operating correctly
- Verify that the concrete testing technician meets the requirements of the contract document for training/certification.
- Ensure that sufficient storage area is available on the project site specifically designated for the storage of concrete cylinders.

Traffic Control

- Verify that the signs and devices used match the traffic control plan presented in the contract documents.
- Verify that the setup complies with the Federal Manual on Uniform Traffic Control Devices.
- Verify that flaggers are trained/qualified according to contract documents and NMDOT requirements.
- Verify that unsafe conditions, if any, are reported to a supervisor.
- Ensure that traffic is not opened to the repaired pavement until the backfill material has attained the specified strength or curing time as required by the contract documents.
- Verify that signs are removed or covered when they are no longer needed.

<u>Project Inspection Responsibilities</u>

Slot Cutting and Removal

- Verify that all slots are cut parallel to each other and to the centerline of the roadway within the maximum tolerance permitted by the contract documents, typically 1/4 inch per 12 inches of dowel bar length.

- Verify that the number of slots per wheel path is in agreement with contract documents (typically three or four).
- Verify that the cut slot length extends the proper distance each side of the construction joint as required by the contract documents. This is especially important for joints and cracks that are skewed.
- Verify that concrete fins between the saw cuts are removed using 30 pound maximum weight jackhammers.
- Verify that the bottoms of slots are smoothed and leveled using lightweight bush hammer.

Slot Cleaning and Preparation

- Verify that after concrete removal, slots are prepared by sand blasting, ensuring that all saw slurry is removed from the slot.
- Verify that air blasting is utilized to clean slots. A second air blasting may be required immediately before placement of dowel slot cementing grout if slots are left open for a duration exceeding that permitted in the contract documents.
- Verify that the existing joint/crack is sealed with approved caulking filler along the bottom and sides of slot to prevent concrete patch material from entering the joint/crack.

Placement of Dowels

- Verify that plastic end caps are placed on each end of the dowel bar to account for pavement expansion (see Figure 1) as required by the contract documents.

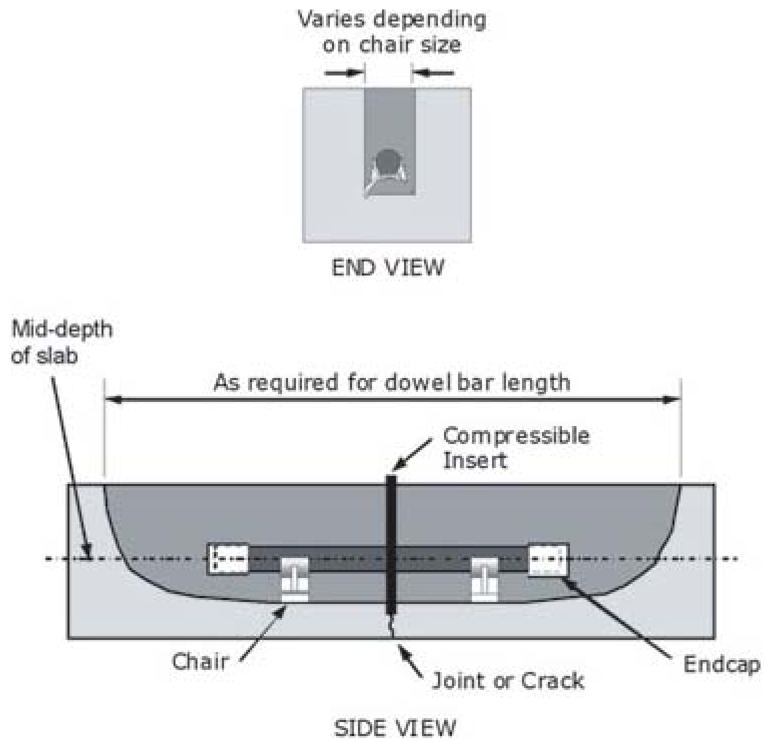


Figure 110: Illustration showing correct placement of plastic end caps.

- Verify that dowels have been coated with lubricant to prevent bonding of concrete patch material to dowels in accordance with contract documents.
- Verify that proper clearance is maintained between the supported dowel bar and the sidewalls, ends, and bottom of the cut slot in accordance with contract documents. Schematic diagrams presented in Figure 1 are intended for reference purposes only and are not intended to supersede contract documents.
- Verify that chairs are used to align the dowel correctly in the slot and support it, and permit dowel slot cementing grout to completely encapsulate the dowel bar.
- Verify that joint re-former material (foam core insert) is placed at the mid-point of each bar and in line with the joint/crack to allow for expansion and to re-form the joint/crack.
- Verify that dowels are centered across the joint/crack such that at least 7 inches of the dowel extends on each side in accordance with contract documents.

Mixing, Placing, Finishing, and Curing Backfill Material

- Verify that quantities of concrete patch material being mixed are small enough to prevent premature set.
- Verify that material is consolidated using small, hand-held vibrators that do not touch the dowel bar assembly during consolidation.
- Verify that concrete patch material is finished flush with surrounding concrete, using an outward motion to prevent pulling material away from patch boundaries. The surface of the concrete patch material should be finished slightly "humped" if diamond grinding will be done.
- Verify that adequate curing compound is applied immediately following finishing and texturing in accordance with contract documents.

Cleanup

- Remove all concrete pieces and loose debris from the pavement surface.
- Dispose of old concrete in accordance with contract documents.
- Properly clean mixing, placement, and finishing equipment for the next use.

Diamond Grinding

- Diamond grinding of the pavement surface should be completed within 30 days of placement of the concrete patch material.

Resealing Joints and Cracks

- Verify that joints are resealed after diamond grinding in accordance with contract documents.

Materials:

Load Transfer Device Types

The most effective dowel-bar device is the smooth, round dowel bars that is placed in small slots cut across transverse joints in the pavement. This has proven to be an effective method of restoring load transfer in a variety of PCC pavement projects.

Less frequently used load transfer devices include I-beams and mechanical devices that are placed in core holes drilled over existing joints such as double-vee, figure eight, and plate-and-stud devices. These devices have not performed as well as retrofitted dowel bars and their use is not recommended.

Cementing Grout

Cementing grout is used to encase the dowel-bar in the existing pavement. Desirable properties of the grout include little or no shrinkage, thermal compatibility with the surrounding concrete, good bond strength with the existing concrete, and the ability to rapidly develop sufficient strength to carry the required load so that traffic can be allowed on the slabs in a reasonable length of time.

The use of a suitable grout is important to the long-term performance of the retrofitted dowel bar installation. Generally, materials found to work well for partial-depth repairs work well as a grout for dowel-bar retrofits. It is important that these materials be freeze-thaw durable to ensure long-term performance.

The industry is moving away from using rapid setting grout materials, as a number of problems with these materials have been encountered in the field. Although they work well in many cases, there is generally less performance risk associated with using a slower-setting, convention concrete mix.

Portland Cement Concrete

Portland cement concrete is commonly used as a grout material for dowel-bar retrofits. It is cheaper than other materials, is widely available, and presents no thermal compatibility problems with its use. Many mixes use a Type III cement and an accelerator to improve setting times and reduce shrinkage. Sand and an aggregate with 0.375 inch maximum size are commonly used to extend the yield of the mix.

Rapid-Setting Proprietary Materials

Several proprietary grout materials are available for use with dowel-bar retrofits. The main advantage of these types of materials is that they are quick-setting allowing for earlier opening times to traffic. It is strongly recommended that any patch material without an acceptable history of performance under similar conditions be tested for specification compliance before being used in the field.

Polymer Concretes

Polymer concretes have also been used as a grout material. Polymer concretes are commonly methacrylate-based materials and include products such as Concresive, Silikal, and Crylon. Polymer concrete consists of a liquid resin, powder filler, and fine aggregate. The mortar often attains 80 percent of its full strength in 45 minutes to 2 hours after placement under field conditions at temperatures from 39° F to 100° F.

Epoxy-Resin Adhesives

Epoxy-resin adhesives are used to improve the bond between the existing concrete and the grout filler materials.

Weather Requirements and Pavement Conditions:

- Review manufacturer installation instructions for requirements specific to the backfill material used.

- Air and surface temperature meet agency requirements (typically 40° F and rising) for concrete placement.
- Neither dowel bar installation nor patching should proceed if rain is imminent.

Problems to Avoid:

- Sawcuts (sides of slots) are not parallel to each other or the pavement centerline:
  Use a saw slot cutting machine.
- Slots are cut too shallow:
  Re-saw the slots and remove concrete to the proper depth.
- Slots are cut too deep:
  1. Use a lighter weight jackhammer, maximum 30 pound.
  2. Do not lean on the jackhammer.
  3. Do not orient the jackhammer vertically; use a 45-degree angle and push the tip of the hammer along the bottom of the slot.
  4. Stop chipping when within 2 inches of the bottom of the pavement.
  5. If jackhammers punch through the bottom of the slot, make a selective slab replacement across the entire lane width at the joint/crack.
- Concrete fin is not easily removed:
  Check for mesh reinforcement, and sever the steel at each end before attempting to remove the fin of concrete.
- Dowel cannot be centered over joint/crack because slot does not extend far enough:
  Chip out additional slot length with a jackhammer to facilitate proper placement of steel dowel in accordance with contract documents. Typically at least 7 inches of each 14 inch dowel extend on each side of joints. Properly sized chairs will fit snugly into the slot.
- Dowels are misaligned after vibration:
  1. Do not allow the vibrator to touch the dowel assembly.
  2. Check for over-vibration; each slot should require only two to four short, vertical penetrations of a small-diameter spud vibrator.
  3. Ensure that the slots are sized the exact width of the plastic dowel bar chairs.

Life Expectancy:

When properly placed with an appropriate and durable material, dowel bar retrofits should extend the service life of an older pavement 10-15 years by providing it with the ability to effectively transfer load.

PART 5 – PAVEMENT CONDITION SURVEYS

Every year, university contractors conduct detailed pavement distress surveys to characterize every route in the New Mexico State Highway System and some FL designated routes. Eight distresses are measured on flexible (bituminous asphalt) pavements and eight other distresses are measured on rigid (Portland Cement Concrete) pavements. The criteria for measuring the severity and extent of these distresses are provided in the tables on the following pages. The survey results are available on TIMS. Following is a graphic representation of how the data collected during the Pavement Condition Surveys is used in New Mexico's Pavement Preservation Program:

Figure 111: University Technicians from UNM and NMSU.

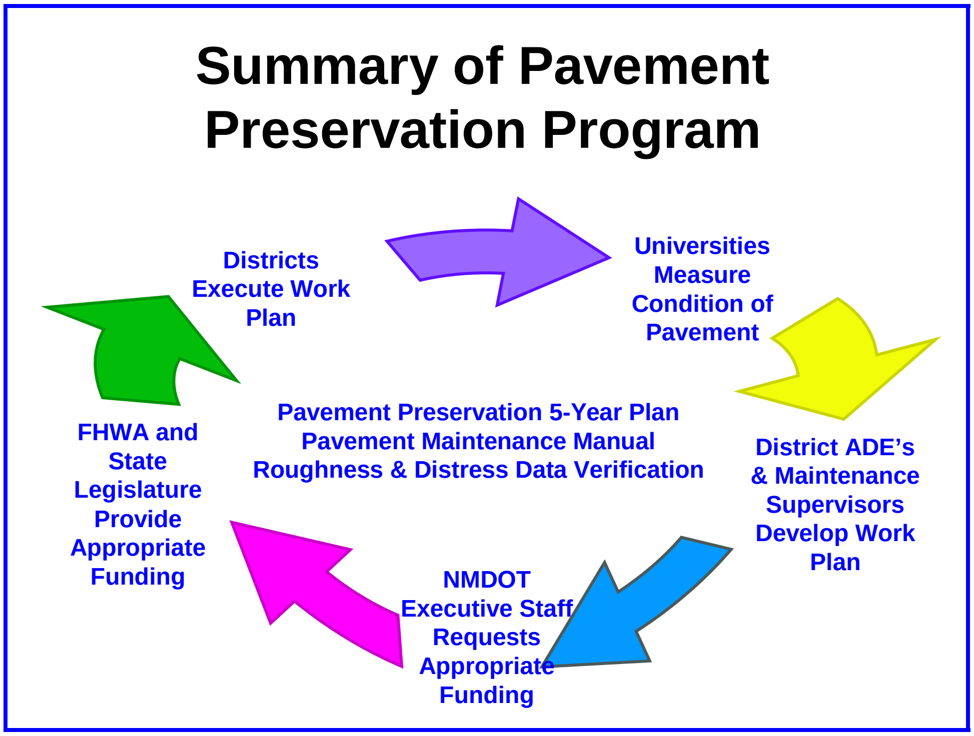


Figure 112: Graphic representation of New Mexico's Pavement Preservation Program

ASPHALT PAVEMENT DISTRESSES

DISTRESS	SEVERITY	EXTENT
Raveling & Weathering: The wearing away of the pavement surface, due to dislodged aggregate particles and loss of asphalt binder. Normally the extent will be throughout the test section.	Low: (1) Aggregate or binder has started to wear away on pavement surface. Some dislodged aggregate can be found on the shoulder. Med: (2) Aggregate or binder has worn away. Surface texture is rough and pitted. High: (3) Aggregate and/or binder has worn away, and surface texture is severely rough and pitted.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Bleeding: A film of bituminous material on the pavement surface.	Low: (1) Film is evident, but aggregate can still be seen. Spotty. Med: (2) Film is clearly seen, covers most of the aggregate, and is a little sticky. High: (3) Film is predominant, very sticky, and material is thick enough to shove.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Rutting and Shoving: Longitudinal surface depressions in wheel path. (Check with a 4-foot rut bar.)	Low: (1) ¼-inch to ½-inch in depth. Med: (2) ½-inch to 1-inch in depth. High: (3) More than 1-inch in depth.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Cracks: **Longitudinal Cracks:** Wheel Track Mid-Lane Center Line **Transverse Cracks:** Full Width	Low: (1) Sealed or non-sealed with a mean width of less than ¼-inch. May have very minor spalls. Med: (2) <u>A</u>. Sealed or non-sealed, and moderately spalled. Any width. <u>B</u>. Sealed, but sealant separated, allowing water to penetrate. <u>C</u>. Non-sealed cracks that are not spalled, but are over ¼-inch wide. <u>D</u>. Low severity alligator cracks exist near crack, or at the corners of intersecting cracks. <u>E.</u> Causes a significant bump to a vehicle. High: (3) <u>A</u>. Severely spalled. (Any width.) <u>B</u>. Medium to high severity alligator cracks exists near the crack, or at the corners of intersecting cracks. <u>C</u>. Causes a severe bump to a vehicle.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Alligator Cracks: Pattern of interconnected cracks resembling chicken wire or alligator skin.	Low: (1) Hairline, disconnected cracks. 1/8-inch wide, or less. no spalls. Med: (2) Fully developed cracks greater than 1/8-inch wide. Lightly spalled. High: (3) Severely spalled. Cells rock. May pump.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Edge Cracks: Cracks which occur on the edge of the pavement.	Low: (1) ¼-inch wide, or less. No spalls. Med: (2) Greater than ¼-inch wide. Some spalls. High: (3) Severely spalled.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.
Patching: An area where the original pavement has been removed and replaced with similar or different material. Types of Patching: <u>Hot Mix Patch.</u> <u>Skin Patch.</u> <u>Other types (Please note on "note section" of the evaluation card.)</u>	Low: (1) Patch is present, and is in good condition. Med: (2) Somewhat deteriorated. Low to medium of any type of distress on patch. High: (3) Patch is deteriorated to point of soon or immediately needing replacement.	Low: (1) 1% to 30% of test section. Med: (2) 31% to 60% of test section. High: (3) 61% of test section, or more.

Concrete Pavement Distresses	SEVERITY	EXTENT
Corner Break: Crack intersects joints at a distance less than 6 feet on either side, measured from the corner. Crack extends vertically through the entire slab thickness.	Low: Crack is tight (hairline). Well sealed cracks considered tight. (1) No faulting or break-up. Med: Crack is working and spalled at low or medium severity. No (2) break-up of corner. Faulting of crack or joint less than ½-inch. Temporary patching may exist. High: Crack is spalled at high severity; or the corner has broken (3) into 2 or more pieces; or faulting more than ½-inch.	Low: 1 to 3 per test section. (1) Med: 4 to 6 per test section. (2) High: 7 or more per test (3) section.
Faulting of Transverse Joints and Cracks: Elevation difference across a transverse joint or crack.	Low: Faulted joints or cracks which average 1/16-inch or less. (1) Med: Faulted joints or cracks which average more than 1/16-inch; (2) but less than 1/4-inch. High: Faulted joints or cracks which average 1/4-inch or more. (3)	Low: 1% to 30% of test (1) section. Med: 31% to 60% of test (2) section. High: 61% of test section, or (3) more.
Joint Seal Damage: Any condition which allows incompressible materials or water to infiltrate the joint from the surface. Types of joint seal damage: (1. Joint sealant stripping. 2. Joint sealant extrusion. 3. Weed growth. 4. Hardening of filler. 5. Loss of bond to slab edges. 6. Joint sealant absence.)	Low: Sealer is in generally good condition, with only minor (1) damage. Little water, and no incompressibles can infiltrate the joint. Med: Sealer is in generally fair condition, with one or more types (2) of damage occurring to a moderate degree. Water and also some incompressibles can infiltrate easily. High: Sealer is in generally poor condition, with one or more types (3) of damage occurring to a severe degree. Water and incompressibles infiltrate freely.	Low: 1% to 30% of test (1) section. Med: 31% to 60% of test (2) section. High: 61% of test section, or (3) more.
Lane/Shoulder Drop-Off or Heave: The difference in elevation between the traffic lane and the shoulder.	Low: Elevation difference: ¼-inch to ½-inch. (1) Med: Elevation difference: ½-inch to 1 inch. (2) High: Elevation difference: One inch or more. (3)	Low: 1% to 30% of test (1) section. Med: 31% to 60% of test (2) section. High: 61% of test section, or (3) more.
Longitudinal Cracks: Cracks which run generally parallel, to the pavement centerline.	Low: Hairline crack with no spalling or faulting. (1) Med: Working crack with low, to moderately severe spalling (2) and/or faulting less than ½-inch. High: Crack greater than 1-inch wide; high severity spalling; (3) faulted ½-inch or more.	Low: 1 to 3 per test section. (1) Med: 4 to 6 per test section. (2) High: 7 or more per test (3) section.
Patch Deterioration: Area where part of the original pavement has been replaced or covered with similar or different material.	Low: Patch functioning well with little or no deterioration. Low (1) severity spalling of patch edges may exist. Faulting across the slab-patch joint less than ¼-inch. Rated low, even if in excellent condition. Med: Patch has low severity cracking, and/or some spalling of (2) medium severity around the edges. Temporary patches have been placed because of permanent patch deterioration. High: Patch has deteriorated to a condition which requires replace- (3) ment, due to spalling, rutting or cracking within the patch.	Low: One per test section. (1) Med: Two per test section. (2) High: Three or more per test (3) section.
Spalling of Transverse and Longitudinal Joints and Cracks: Cracking, breaking or chipping of slab edges within 2 feet of the joint. Spall does not extend vertically through the slab, but angles through the slab to the joint or crack.	Low: Spall less than 2-feet long; if spall is broken and fragmented, (1) it must not extend more than 3-inches from joint/crack. Spalls more than 2-feet long with spall held tightly in place; if cracked, only 2 or 3 pieces. Joint/crack is lightly frayed: fray extends less than 3 inches from edge of joint/crack. Med: One of the following conditions exists: (2) A. Spall broken into pieces; spall extends more than 3 inches from joint/crack. B. Some/all pieces loose or missing; do not present a hazard. C. Joint/crack moderately frayed; fray extends more than 3". D. Temporary patching may exist. High: Joint is severely spalled, spall is broken into pieces. Tire (3) damage hazard. Requires speed reduction.	Low: 1% to 30% of test (1) section. (Normally, the extent will be throughout the test section.) Med: 31% to 60% of test (2) section. High: 61% of test section, (3) or more.
Transverse and Diagonal Cracks: Medium or high severity cracks are working cracks, and are considered major structural distresses. (Note: hairline cracks that are less than 6-feet long are not rated.)	Low: Hairline crack without spalling or faulting. Well-sealed crack (1) without visible faulting or spalling. Med: Working crack with low to moderately severe spalling, and, (2) or faulting less than ½-inch. High: Crack greater than 1-inch wide; High severity spalling; (3) faulted ½-inch or more.	Low: 1 to 3 per test section. (1) Med: 4 to 6 per test section. (2) High: 7 or more per test (3) section.

PART 6 – REFERENCE MATERIAL

1. Federal Highway Administration, *Pavement Preservation: Design and Construction of Quality Preventative Maintenance Treatments*, NHI Course No. 131103 Reference Manual, Publication No. FHWA-NHI-04-171, October 2004.
2. Federal Highway Administration, *Pavement Preservation: Selecting Pavements for Preventative Maintenance*, NHI Course No. 131058 Participant's Workbook, September 1999.
3. Federal Highway Administration, *Pavement Preservation: The Preventative Maintenance Concept*, NHI Course No. 13154 Participant's Workbook, Publication No. FHWA NHI-01-040, September 2001.
4. National Academy of Sciences, *The Distress Identification Manual for the Long-Term Pavement Performance Program*, National Research Council, Strategic Highway Research Program (SHRP), Publication No.SHRP-P-338, ISBN 0-309-05271-8, 1993.