Chapter 3 Pavement Patching and Repair

3-1 General

The roadway is defined as the area between the outer limits of side slopes or otherwise improved portion of a public highway ordinarily used for vehicular travel. A roadway surface is normally classified as flexible (consisting of asphaltic materials) or rigid (consisting of Portland Cement Concrete) pavement.

It is desirable that the roadway surface provide a safe, smooth driving surface with good skid resistance for the people we serve. Roadway distress such as alligator cracks, pumping, pushing, wheel rutting, raveling, frost heaves, and pot holing are defects that need to be addressed.

Maintenance of the state's roadways is the primary way that unwanted pavement distresses are reduced or eliminated. Preferably, the maintenance of pavement should be accomplished with minimum expense and the least possible traffic disruption. Maintenance of pavements is a necessary investment performed to prevent costly renovation or reconstruction.

Preventive maintenance is the most cost-effective way to extend pavement performance and minimize the need for future costly major repairs. Area maintenance staff are required to inspect each section of highway at least once a year to detect and schedule deficiency repairs prior to becoming a major problem.

The intent of this chapter is to communicate the benefits of pavement preservation in the life of a pavement and to identify pavement distress. It must be noted that proper documentation and communication is of greatest importance. This will be developed in greater detail as this chapter progresses.

3-2 Reference

Standard Specifications for Road, Bridge, and Municipal Construction M 41-10

Asphalt Institute

3-3 Resources

Headquarters Maintenance Office

Regional and Area Maintenance Offices/Crews

Regional Materials Office

Construction Manual M 41-01

Design Manual M 22-01

WSDOT *Pavement Policy*

Asphalt Institute Publications

- MS-4 *The Asphalt Handbook*
- MS-5 *Introduction to Asphalt*
- MS-8 *Asphalt Paving Manual*
- MS-14 *Asphalt Cold-Mix Manual*
- MS-15 *Drainage of Asphalt Pavement Structures*
- MS-16 *Asphalt in Pavement Maintenance*
- MS-17 *Asphalt Overlays for Highway and Street Rehabilitation*
- MS-19 *Basic Asphalt Emulsion Manual*

3-4 Communication

The Washington State Legislature provides biennial appropriations conforming to a specific, (LOS) Level of Service for roadway maintenance and operations activities. The maintenance area's roadway surface program needs to be managed to meet the LOS commitments.

In doing so, it is essential that each Region Maintenance Area work in combination with its Program Management, Materials, Design and Construction offices to ensure that Maintenance projects are coordinated with the work that these offices are planning and/or constructing in the Capital Program.

It is advised that written recommendations for pavement repairs be submitted to the Regional Maintenance Engineer. The Regional Maintenance Engineer will then share the region wide roadway surface maintenance program with the Regional Materials and Regional Construction Engineer. This allows better coordination between the maintenance and construction programs. As a result of this coordination reoccurring areas of pavement failure can be eliminated.

3-5 Integrated Pavement Preservation

Washington State has adopted an integrated approach to pavement preservation. Integrated pavement preservation looks at the overall pavement life-cycle and is a planned approach to pavement preservation and pavement maintenance. Because the terminology of preservation and maintenance can vary based on context, the following is how the FHWA defines the two:

> **Preservation:** Preservation consists of work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preservation activities generally do not add capacity or structural value but do restore the overall condition of the transportation facility.
>
> **Maintenance:** Maintenance describes work that is performed to maintain the condition of the transportation system or to respond to specific conditions or events that restore the highway system to a functional state of operation. Maintenance is a critical component of an agencies asset management plan that is comprised of both routine and preventive maintenance.

As well as structuring funds so they can be moved in a timely manner for planned maintenance, the success of this approach relies on decision making and timing of maintenance activities. Integrated Pavement Preservation consists of Preventive Preservation, to include Strategic and Emerging Maintenance, and Reactive Maintenance.

3-5.1 *Preventive Preservation*

Preventive Preservation is planned and coordinated maintenance that is typically performed early in a pavement life and is intended to extend pavement service life 1 to 6 years. Planning occurs between the Region Maintenance Superintendents, the Region Materials Engineer, the HQ Pavement Office, and Capital Program Development and Management (CPDM).

Preventive Preservation includes Strategic Preservation and Emerging Preservation.

The following is an example of a typical Strategic Preservation Maintenance (P1-M) schedule for a biennium.

Strategic Pavement Preservation & Maintenance (P1-M) Schedule - 21-23 Biennium				
Start	**End**	**Organization**	**Description of Work**	**Duration (Days)**
6/1/2019	8/15/2019	Region Program Development	Region Materials Review	75
8/16/2019	9/30/2019	Region Program Development	Provides proposed changes to WSPMS from the notes of Region Pavement Review	45
10/1/2019	10/31/2019	Region Maintenance	Region 21-23 pavement maintenance needs, including P1 and M2	30
11/1/2019	7/31/2020	Region Program Development Region Materials Lab	Develop 10-year P1 (Preservation) Plan (expect schedules to adjust)	273
7/31/2020	7/31/2020	Region Program Development	Publish the 2-year P1 Preservation Project List to Region Materials and Region Maintenance	0
8/1/2020	8/31/2020	Region Program Development Region Materials Lab	Develops the Region Strategic Preservation Maintenance List (P1-M and M2)	30
9/1/2020	10/31/2020	Region Materials Lab Region Maintenance	Conduct field reviews of the Region P1-M list and provide recommendations to HA Mats Lab for approval	60
11/1/2020	11/30/2020	HQ Materials Lab - Pavement Office	Review the P1-M List and provide comments/concurrence	29
12/1/2020	12/31/2020	HQ Materials Lab - Pavement Office Region Program Development Region Materials Lab Region Maintenance	Finalize the 21-23 P1-M List	30
12/1/2020	4/30/2021	Region Maintenance	Begin environmental review/ permitting process	150
1/1/2021	4/30/2021	Region Maintenance	Develop the P1-M cost estimates into HATS Feature Activities. HQ coordinates with HQ Mats Lab for WSPMS upload. Region Maintenance coordinates with Construction Traffic Control Office.	119
5/1/2021	5/31/2021	Region Program Delivery	Send WOA to CPDM	30
6/1/2021	6/30/2021	CPDM	Approves and setup the work order and groups	29
7/1/2021	6/30/2023	Region Maintenance	Executes the 21-23 P1-M List; begins reporting unit costs	729

It must be stated that there are limitations and parameters set for the funding of P1-M projects. These limitations can change and include, but are not limited to, average daily traffic (ADT), chip seals, ramps, and total dollars to be spent.

3-5.2 Strategic Preservation & Maintenance

This work is primarily completed early in the pavement life cycle to within 4 years before a planned (Capital Preservation) project. Strategic Preservation work may be completed under Contract or by Maintenance.

Examples of Strategic Maintenance for flexible pavements would include crack seal, mastic seal, chip seals, wheel path chip sealing. For rigid pavements, strategic preservation might include spall repair, corner break, and/or partial depth repairs.

3-5.3 Emerging Maintenance

This work is completed with M2 funding and performed by WSDOT Maintenance. The intent of this work should be to reduce the need for future Reactive Preservation and extend pavement life.

Emerging Maintenance work focuses on areas of pavement that are predicted to fail within a year if maintenance is not performed.

Emerging Maintenance work might include digouts, grader patching, and milling for flexible pavement as well as partial depth or full depth panel replacement for rigid pavement.

3-5.4 Reactive Maintenance

This work is completed using M2 funding and performed by WSDOT Maintenance.

Reactive Maintenance is unplanned, “emergent” and maintenance work that is done to correct immediate needs.

Since Reactive Maintenance is emergent and needs to be quickly addressed, the most typical technique is pothole patching where cold patch or possibly a grader patch is used to hold the pavement distress until a more effective treatment can be placed.

The easiest way to summarize pavement maintenance as it relates to maintenance activities is to say that this work mainly involves Emerging and Reactive Maintenance.

3-6 HATS

To properly document areas of pavement repair need and prepare for work to be completed, a system of mapping pavement distress for planned activities must be in place.

HATS is the program used to collect the needs of pavement maintenance and to estimate budgetary requirements. The data contained within HATS provides a complete record of planned activities which can be used to estimate the funding needed to complete identified maintenance program activities.

The other benefit of the HATS program is that it can be used to compare when and where a Capitol Preservation or P1 maintenance project is going to occur. By having clearly defined HATS information available, programming can occur as to whether emerging treatment will even be needed.

3-7 Pavement Distresses

Environment and traffic loading are the primary cause of pavement distress, but damage and deterioration of pavements can result from numerous other factors. For example, an overlay with poorly graded or inadequately fractured aggregate and low asphalt content may not have adequate particle interlock; thus cracking and oxidation may develop. Poor subgrade drainage, overweight loads, and accelerating or decelerating traffic are all potential sources of surface irregularities.

The WSDOT collects pavement condition data of the existing roadways using the Pavement Distress Identification Van. Distress measurement data is collected, processed, then analyzed and input within the Washington State Pavement Management System (WSPMS).

Pavement distress is measured according to the *Pavement Surface Condition Rating Manual* (pdf 3.32 mb), however; the following are brief descriptions and examples of various pavement distress. It is always best to consult with your respective Region Materials Engineer if you are not sure about the type or cause of distress or the proper repair needed.

3-7.1 *Longitudinal Cracking*

A longitudinal crack runs approximately parallel to the roadway centerline. These are typically a result of traffic loading or HMA with inadequate asphalt content.

Exhibit 3-1 Longitudinal Cracking

This type of crack is usually a non-working crack that can be treated with a crack sealing material. It is highly recommended that these cracks are filled before getting to a width greater than a ½ inch to reduce sealant cost. Although this is the most cost-effective treatment option available, attempting to seal cracks that are greater than ¾ inch is challenging and a mastic material may be used if the cracks are larger than 1 inch.

3-7.2 *Transverse Cracking*

Transverse cracks run roughly perpendicular to the roadway centerline. They are usually caused by surface shrinkage caused by low temperatures, hardening of the asphalt, or cracks in underlying pavement layers such as PCC slabs. They may extend partially or fully across the roadway.

Exhibit 3-2 Transverse Cracking

Transverse cracks are most typically a working crack and sealing these cracks with a rubberized material is the most effective treatment option, although crack sealing with mastic material is an alternative if cracks are greater than 1 inch.

3-7.3 *Alligator Cracking*

The condition of alligator cracking is reached when irregular longitudinal cracks begin to interconnect to form a series of small blocks that resemble an alligator's skin. This distress is associated with traffic loading and is usually rooted in poor construction, poor drainage, subgrade failure, or the pavement may have just reached the end of its life. If neglected, full-depth distress can be observed when subgrade material is forced up through the surface leading to depressed pavement and an eventual pothole.

Exhibit 3-3 Alligator Cracking

If the alligator cracking isn't extensive, subgrade material isn't visible and signs of depressed pavement isn't present, a chip seal might be a possibility. The typical repair method, however; is to complete a partial-depth or full-depth patch. Full-depth cracking extends through the entire pavement structure, whereas partial-depth cracking goes through a portion of the pavement.

3-7.4 *Potholes*

Potholes are voids in the roadway surface where pieces of the pavement have become dislodged. Areas in which many potholes occur become suspect for fundamental problems such as inadequate drainage, pavement strength, or base/subgrade problems. Single or infrequent potholes may be the only pavement distress to occur in an area, and beyond the treatment of the individual pothole no other pavement repair work may be required. If potholes occur in a systematic or cyclic manner, these are typically a result of the construction process.

Exhibit 3-4 Potholes

Pothole repairs will generally be full-depth patches, but care should be taken to confirm that they are full-depth. The repair area will always need to extend beyond the limit of the visible distress to get to sound material. If repairs only include the affected area, reoccurring distresses typically result.

3-7.5 *Raveling and Pitting*

Raveling and pitting distresses are characterized by the loss or dislodgment of surface aggregate particles. This usually results from HMA that is designed with too little asphalt or overheating of the mix during manufacture. It can also occur by oxidized asphalt binder initiated by poor compaction, letting the mix get cold when paving, dirty aggregate, or paving too late in the construction season. The most important consideration with this distress is to perform repairs before a more serious condition develops, and prior to the onset of inclement weather because this pavement distress is a good indicator that pavement permeability is present. A pavement that is raveling must be sealed as soon as reasonably possible since unsealed pavements will continue to ravel, age, and harden much faster than normal resulting in difficult maintenance problems.

Exhibit 3-5 Raveling and Pitting

The best treatment option for a pavement that is raveling or pitting is to perform a fog seal to ensure the pavement has been sealed and thereby reduce the rapid deterioration usually exhibited from this distress. If raveling becomes severe a chip seal may be an effective alternative.

3-7.6 *Flushing*

Flushing (or bleeding) is free asphalt on the surface of the pavement indicated by a shiny, glass like surface. There are many causes such as too many fines in the mix, too few voids, too much asphalt in patches, underlying distress that is allowing moisture to strip the asphalt from the aggregate, or a chip seal that has lost its rock. It is inherent to unstable mixes and often results in other roadway surface distress, such as rutting, if not corrected.

Exhibit 3-6 Flushing

Removal and replacement of flushed or bleeding pavement areas is an expensive, but sometimes cost-effective method of repair. Another option is to perform a chip seal with minimal or no emulsion, but this approach necessitates proper prior planning. If repairs are not possible prior to a seasonally wet period, contact the regional traffic engineer to evaluate friction and the need for posting “Slippery When Wet” signs.

3-7.7 Rutting

Rutting is a surface depression within the wheel path and is a result of permanent deformation of the pavement or subgrade. This condition is normally caused by heavy loads on roads lacking sufficient strength to support the loading but can also occur because of HMA with too much binder in addition to studded tire use. Wheel ruts, if not repaired, can trap water and contribute to hydroplaning.

Exhibit 3-7 Rutting

There are a few options available to address this type of roadway distress. Rut filling with HMA is the most widely used, however; a second rut filling option is to utilize chip seal materials. Grinding of rutting can also occur but care must be taken to ensure this option will remove ruts until preservation occurs.

3-7.8 Sags and Humps

Sags and humps are localized depressions or elevated areas of the pavement that result from settlement, pavement shoving, displacement due to subgrade swelling, or displacement due to tree roots. The deficiency usually occurs in isolated areas of the roadway surface.

Exhibit 3-8 Sags and Humps

This distress typically results in full-depth repairs although a partial-depth patch or a micro-grind may be used depending on the cause of the distress.

3-8 Preventive Maintenance Techniques

Preventive maintenance programs started early in the life of a pavement (1-3 years) provide the protection needed to greatly improve service life. For aged pavements, surface treatments can greatly delay the costs of major reconstruction.

In recent years research has shown that applying the proper maintenance treatment can help to extend pavement service life when applied at the right time. Additionally, placing the appropriate treatment can also provide cost benefits if done when pavement distresses have not progressed too far in the pavement life. Please note that the Learning Center provides detailed training on many of the subjects included below and is resource that should be considered.

The following maintenance techniques are placed in the preferred order of a pavement life cycle which also corresponds to least costly to most costly. As an example, it is recommended that crack sealing take place earlier in the pavement service life, whereas HMA dig out patching should occur later, with an estimated cost that is nearly 12 times that of crack sealing. Of course, there may be instances when a more costly treatment is a better choice because of the amount of distress. For example, a chip seal may be more cost effective than crack sealing if the amount of cracking is high and if an HMA dig out is needed, it is the preferred method of repair.

3-9 Crack Sealing (or Pouring)

Crack sealing can extend the useful pavement life for several years. The purpose of crack sealing is to prevent water from entering the subgrade and causing damage, and to keep the edges of the cracks from raveling where top-down cracking is present. There are two widely used types of crack pouring material in highway maintenance, hot pour and cold pour. The two types use different techniques and equipment. The purpose of the two is the same, to minimize water entry and resulting damage.

Over-poured cracks can be a safety hazard to motorcycles. Overband (over-poured) crack pouring, especially on longitudinal cracks, can cause loss of control for motorcycles. The problem is compounded on curves or when the surface is wet. Cracks that are not over filled do not seem to cause a problem. Areas that have excessive crack pouring material from past practices should be addressed.

The supervisor needs to be aware of the nature, extent, and severity of the cracking problem and next scheduled contract for resurfacing. Filling cracks in an area scheduled for immediate reconstruction or resurfacing by contract is not recommended unless it is a part of the overall project.

Generally, alligator cracking or more general cracking can be repaired using chip seals. Serious cracking and settlement of the pavement may indicate the need for excavation to repair the subgrade before patching can be successful.

3-9.1 *Hot Pour Method*

This method utilizes blocks of crack pour material heated in specialized crack pouring machines. The most common type used within maintenance are trailer mounted, oil jacketed units. This method is often used by contractors and maintenance for crack sealing distressed areas that are not going to be removed and repaired prior to an overlay. It is a common method of sealing the joint between the edge of a PCC road surface and the asphalt shoulder. It works well for large volume work involving large cracks.

Often the cracks are routed out first. If not, they should be cleaned and dried with compressed air prior to pouring. Filling cracks with this method requires a large crew and specialized equipment.

Safety is a big concern in a hot crack pour operation. This material is extremely hot and can cause severe burns when loading the machine or applying the material.

3-9.2 *Cold Pour Method*

This method utilizes cold applied liquid material and does not require specialized equipment. This type of material is available in 5- to 50-gallon containers. It can be sanded lightly after application and opened to traffic. One person can apply it using the spout on the 5-gallon bucket it comes in.

Experience has shown that for maintenance purposes cold pour seems to prevent water entry into the subgrade as well as hot pour material. It also resists build up on bumps better than the hot material does.

Cold pour is excellent as tack for small asphalt patches and pothole repairs. It greatly simplifies the problems of tack storage, transporting, and application. A sealed five-gallon bucket can be carried easily by a pothole patching crew.

This material works well for hand pouring the cracks around an isolated bridge drain or catch basin if a piece of foam ‘backer rod’ is poked down into the crack before pouring to serve as a bottom for the material. It can also be poured against rubber expansion joints without melting the rubber joint.

3-10 Bituminous Surface Treatments

A bituminous surface treatment (BST) of flexible pavements utilize asphalt emulsions in the treatment process and are excellent methods for preventing the development of early pavement damage or distress. These treatments seal the pavement, retards the aging process and prevents the old pavement from further hardening.

3-10.1 *Fog Seals*

In instances of a pavement with very minor raveling, a fog seal may adequately seal the pavement and prevent further raveling. Fog Seals are very light applications of diluted, quick breaking asphalt emulsions. Some of the asphalt materials used for fog seals are: CSS-1 and STE-1 which are cationic (positively charged) emulsions, while HFE-100S-50% diluted is an Anionic (negatively charged) emulsion. These products may require cover material (¼”- 0) depending on the surface and application rate. The decision whether to use a cationic or anionic formulation should be based on knowledge of the charge of the existing materials used as part of the pavement. Understand that like charged materials repel each other and opposites attract. We want the materials to attract each other and make a tight bond. The Region Materials or the Headquarters Materials Lab should be consulted to assist in the determination.

Asphalt emulsions used for fog seals are usually diluted with water or other types of cut-backs as prescribed by the manufacturer. The Fog Seals are applied at the rate of 0.1 to 0.2 gallons (of diluted material) per square yard, depending on the texture and porosity of the old pavement. The application rate will be determined by the amount of emulsion the old pavement surface can absorb without becoming slippery. Traffic control may be required for up to two hours, depending on location and volume of traffic.

3-10.2 *Sand Seal*

Where more raveling has occurred, a sand seal may be needed to adequately seal the surface and provide a quality surface. A sand seal is an application of liquid or emulsified asphalt covered with fine aggregate. It is used to seal against air and water infiltration, or improve skid resistance. Applications are 0.1 to 0.2 gallons of CRS-2 or CMS-2 per square yard covered with ten pounds of ⅜-inch minus aggregate. Some regions have found ¼-inch minus to be better suited for sand seals.

3-10.3 *Aggregate (Chip) Seal*

An aggregate seal is a single spray application, usually of a liquid or emulsified asphalt. Immediately following is a single layer of aggregate of as uniform a gradation (size) as practicable. This type of seal reduces the infiltration of air and water into the mat and may be used to improve skid resistance of slippery pavements.

Chip seals are useful and can be applied in many different ways: Full lane width, wheel path, partial lane width, short longitudinal sections or for long sections.

A typical chip seal uses application rates for CRS-2P at .35 to .60 gallons/per square yard (typically 0.45 gal./s.y.) with 20 to 45 pounds of Crushed Cover Stone per square yard (typically 30 lb./s.y.). Look in the *Standard Specifications* Sections 5-02.3, 9-02.1, and 9-03.4 for specific information on Bituminous Surface Treatment and materials.

3-11 HMA Repair Methods

All flexible pavements require patching at some time during their service life. Surface patching should be performed to a standard that is appropriate to the resources available with the objective of retaining a smooth ride for as long as possible.

There are two principal methods of repairing HMA pavements. The first includes remove and replace (grind and inlay) which can be categorized as partial-depth and full-depth repairs. The second method is an HMA overlay and this technique covers defective roadway sections in order to seal, stabilize, and renew the defective area.

Since patching is one of the most expensive operations to perform, it is essential to develop work schedules that include desirable weather conditions, adequate staffing, and proper equipment.

3-11.1 *Partial-Depth Grind and Inlay*

Partial-Depth Grind and Inlay are used for making permanent repairs to the pavement. Defective pavement and unstable surfacing materials are removed to a depth of stable material that can typically be found only two-inches below the roadway surface. The milled area should extend into the good pavement surrounding the defective area by about 12 inches (1 foot). Cut the edges of the patch area vertically and in straight lines to provide a good line for compaction later.

After the defective pavement material is removed, clean the entire repair area to create a clean foundation for new HMA to be placed. Apply a tack coat of asphalt to the vertical and horizontal surfaces of the hole to assure a good bond and seal between old and new HMA material. New HMA should be placed in depths at least equal to the thickness of the adjacent HMA compacted in lifts of 1 to 3 inches.

For best results in a patch of this nature, back fill the hole with HMA Class ⅜ (preferred) or HMA Class ½ Inch material. The asphalt should be compacted in lifts of no more than 3 inches thick to obtain optimum patch life. Small patch projects can be compacted with a vibrating plate compactor, while a roller works best on large patches. During hot weather it might be advantageous having some water on hand to help cool the mix between lifts. Standing water should not be allowed on the mix between lifts.

After the intermediate lifts of the patch have been compacted sufficiently, the surface lift can be completed. Take special care to ensure that it is compacted to slightly above flush with the surrounding surface since some compaction will occur by traffic as the mix is further kneaded into place. The patch should be cool enough before traffic is allowed on it, so it will not leave marks in the surface. Deeper patches will require more time to cool and must be planned for accordingly.

3-11.2 *Full-Depth Dig Out*

Full-Depth Dig Outs are used for making permanent repairs to the pavement. Defective pavement and unstable surfacing materials are removed to a depth of stable material. Alligator cracking that is depressed greater than ½ inch is a good indication that pavement distress is full-depth and stable material might only be found at the subgrade. The excavated area should extend into the good pavement surrounding the defective area by about 12 inches (1 foot). Cut the edges of the patch area vertically and in straight lines to provide a good line for compaction later.

After defective pavement and/or base material is removed, level and compact the base material. This will make an adequate foundation for the new asphalt concrete material. Surfacing materials (gravel base, crushed surfacing) and pavement must always be replaced in depths at least equal to the original design or by additional depth of ACP compacted in lifts of 1 to 3 inches. Apply a tack coat of asphalt to the vertical sides of the hole to assure a good bond and seal between old and new pavements.

For best results in a patch of this nature, back fill the hole with a hot plant-mix material such as HMA Class ⅜ (preferred) or HMA Class ½ Inch. The asphalt should be compacted in lifts of no more than 3 inches thick to obtain optimum patch life. Small patch projects can be compacted with a vibrating plate compactor, while a roller works best on large patches. During hot weather it might be advantageous having some water on hand to help cool the mix between lifts. Standing water should not be allowed on the mix between lifts.

After the intermediate lifts of the patch have been compacted sufficiently, the surface lift can be completed. Take special care to ensure that it is compacted to be even and flush with the surrounding surface, so it provides a good riding surface. Some compaction will occur by traffic as the mix is further kneaded into place. The patch should be cool enough before traffic is allowed on it, so it will not leave marks in the surface. Deeper patches will require more time to cool and must be planned for accordingly.

3-11.3 *Potholes*

Potholes and localized failures should be repaired as soon as possible after they are reported. Asphalt pre-mix (cold mix) should be available throughout the year so any potholes that appear can be patched immediately. Fiber reinforced, and other specialized ‘winter mix’ have been found to be effective in many locations. Many times the use of a propane torch to dry the holes and heat the mix for good compaction is time well spent.

The use of an asphalt ‘tack’ is highly recommended. A higher success rate is normally achieved when the edges are squared up and tack is added to the edge of the pothole. If the lack of availability or storage of standard tack is a problem, try using one of the cold pour crack pouring materials. They are available in (5) gallon buckets with a pour spout. Many pothole patching crews use this as standard procedure.

Do not use sand, clay, or other temporary patching material to patch or “pad” potholes or frost boils. On today’s roads these methods usually cost more in the long run and often leave unsafe conditions for the traveling public. Asphalt pre-mix is the preferred method, even if it has to be replaced when final repairs are made.

For permanent pothole patching proceed as follows:

- Remove the defective material down to a stable base.
- Square off the edge of the hole vertically.
- Dry the hole as much as possible (fiber reinforced mix often does well in wet holes).
- Tack the hole if possible.
- Place and compact the mix.

Compaction is very important in making the repair permanent (heat applied to the mix is very beneficial to good compaction). If traffic is picking the fresh mix out of the hole try dusting the finished patch with some roadside dirt. Spend a little more time patching and compacting the pothole the first time. This will often keep you from returning to patch the same hole repeatedly. Permanent repairs are normally made with hot mix if available.

3-11.4 *HMA Overlay*

Overlay patches are generally applied when an area is too large to be economically repaired by hand with a small crew. The overlay patch with HMA also has the advantage of setting quickly. It does, however, commit a considerable investment in labor, equipment, and materials.

Typically, overlay patches are applied in areas of pavement failure or wear problems rather than areas with a base or subgrade problem. Ruts, raveling, pitting, minor cracking, and oxidation are typical failures where overlay can be effective in quickly and permanently restoring the surface. When addressing pavement rutting, mix should be placed in lifts when patching rutted areas in order to get uniform compaction. This method of compaction will help prevent the rut from reflecting into the finished patch. To obtain proper compaction in the wheel ruts, a rubber-tired (pneumatic) roller should be used. Steel wheel rollers will bridge the rut and very little compaction will occur. After the ruts are filled and if it is decided to overlay the entire lane, then a steel wheel roller would be used for compaction.

Application of any overlay patch requires a considerable degree of skill, coordination, and planning. All loose, broken asphalt should be removed and replaced. Any deep ruts, depressions, or humps should be repaired or pre-leveled in advance of the overlay so that the overlay may proceed efficiently. It is necessary to repair these areas prior to the overlay to provide an even platform for the new pavement. This is essential to proper compaction and consequently to pavement life. If, for instance, wheel path ruts are overlaid without pre leveling, the ruts will not get the same compaction from rolling that the thinner high spots will. Then traffic wheel loads will eventually compact the deeper new sections, causing ruts to reappear. All areas should be tacked before patching to ensure a good bond and minimize raveling in thin areas. The tack rate should be 0.4 to 1.4 gallon per square yard of applied tack (0.2 to 0.8 residual).

Be careful when repairing the roadway surface in an area of unpaved shoulders. Widening over thin gravel or dirt shoulders will usually lead to cracking and failure. This is because of the lack of sufficient top course material. If there is the need to widen the paved roadway, make sure the shoulder is prepared properly to support the anticipated loading.

3-11.5 *Spreader Box Patching*

On small paving jobs it is often convenient and economical to use a tow-behind paver, or spreader box. These pavers hook to the rear of the trucks that are hauling the mix. The asphalt is dumped directly in the hopper of the paver which places it on the roadway or base material.

As the towing vehicle moves ahead, the mix is struck off by an adjustable height blade (cutter bar or screed) and is surface-finished by the screed. Starting the paving at full depth requires setting the screed on blocks before filling the hopper. The hopper should be kept uniformly full during paving to ensure an even spread. An even towing speed is necessary to maintain a uniform spread thickness.

Spreader boxes vary greatly in size, operating controls, accessories, and capabilities. Working with them requires skill and experience. Manufacturers and construction equipment dealers can provide assistance in the operation and care of particular models.

Clean-up of equipment and tools after each day’s operation is essential to good patches. This is especially true of the spreader box. It must be kept free from the accumulation of cold asphalt. An environmentally approved release agent should be used for cleaning tools and equipment.

Spreader box patching with HMA material has the advantage of providing a smooth finished surface when the equipment is properly operated. Several people are required to operate a spreader box efficiently. Careful planning of the patching operation is very important to economical and cost-effective pavement maintenance. The spreader boxes can work well if surface irregularities are pre-leveled with equipment appropriate for the conditions. The entire surface should be tacked, both before pre leveling and before starting the spreader box patch.

Rolling of the hot plant-mix should begin immediately after placement of the mix. If the mix is allowed to cool below 185 degrees before rolling, adequate compaction will not be possible.

3-11.6 *Grader Patching*

Road graders are a useful pavement patching tool especially valuable for leveling to eliminate sharp depressions or sags in the pavement surface. These graders vary in size, model, and capabilities depending on their intended use.

One efficient way of blade patching is using two graders facing each other. This method is quicker than the single blade method and can help in getting the patch laid before the mix gets cold. It helps keep coarse mix away from the ends of the patches, making smoother approaches, and helps keep a straighter edge.

HMA patching with graders is frequently accomplished when it is not practical or economical to use other means. Graders can be used to lay a leveling course of pavement prior to placing finish courses with asphalt spreader boxes and are excellent for placing a leveling course to restore the roadway grade and shape when it cannot be done with a paver or spreader box.

All of the area to be blade patched should be tacked. Road graders with a long wheelbase and smooth-tread tires are often used for spreading hot plant-mix asphalt in leveling operations. The roller must follow the grader immediately after the mix is spread while it is still hot.

Graders are not efficient at carrying large quantities of material over long distances, so the dumping of asphalt should be carefully controlled for an efficient operation. A dump person should be utilized. Make as few passes as possible with the grader to reduce segregation of the material.

3-11.7 *Compacting Hot Mix Patches*

Compaction is among the most important phases of the operation. All asphalt concrete patches, small or large, must be compacted to consolidate the material. The properly compacted asphalt patch will be tough and dense and will stand up to the wear of traffic and weather much better than if compaction is inadequate. However you compact the mix, do it well; it is very important.

A 10 ton or larger steel-wheeled roller is valuable to an efficient asphalt patching operation. A lighter vibratory roller is a poor substitute, as it can slow the operation considerably. On larger paving projects, one roller may be used to do the breakdown rolling or initial compaction, with another used for the finish rolling.

The patching operation should match the speed of the roller train. If the patching crew outpaces the roller, it forces the rolling of mix that is too cold resulting in a poor-quality patch. The maximum temperature of mix from the plant is 350 degrees F and tarping trucks from the HMA plant is highly recommended to better retain heat. Do not compact HMA in vibratory mode when temperature is below 175 degrees F. Rolling mix that is too cold can cause it to crack. If the operation needs to move faster and the roller can’t keep up, add more rollers to the compaction train. Compacting mix that is too hot can cause pushing. Avoid stopping rollers or reversing direction on the hot mat. Do not turn on the mat while moving. Improper operation of rolling equipment can affect the quality and ride of the patch.

Rolling for compaction should begin as soon as the paving material is laid. The initial rolling or "breakdown" gives the highest percentage of compaction of any rolling phase. Consequently, it also offers the most potential for material displacement at the edges. It is important to make the initial breakdown pass at least 4 inches away from the edges of the mat. A subsequent pass will level this edge.

Intermediate rolling further compacts and seals the surface. Finish rolling removes any roller marks and other blemishes left by prior rolling.

Various roller types are used in asphalt compaction. Steel-wheeled, vibratory, and pneumatic tired are the types most commonly available. Steel wheeled and vibratory rollers are used for all three phases of asphalt rolling. Vibratory rollers should not be operated on thin lifts and so are not generally used in maintenance patching operations. Rubber-tired rollers are not normally used in maintenance operations with the exception of rut filling activities and chip seal applications.

All rollers used in asphalt paving or patching operations should be:

- In good operating condition.
- Used according to the manufacturer's recommendations.
- Capable of reversing direction without backlash.
- Able to operate at speeds low enough to avoid displacement of the hot asphalt.

Do not use rollers producing pickup, washboard, uneven compaction, or otherwise undesirable effects. Vibratory rollers under vibration should not exceed (3) mph. Steel-wheeled rollers should be limited to (4) mph and pneumatic tired rollers to (5) mph maximum. The drive wheel of the roller should always be pulling the roller to prevent displacement and pushing of the material. This is particularly important on steeper grades and in breakdown rolling passes.

3-11.8 *Effects of Traffic on a Patching Operation*

Timing is critical while doing hot asphalt mix patching. Flaggers for the operation must avoid delaying asphalt trucks and paving equipment while hot mix patching/paving as the mix temperature is critical to successfully completing the patch or paving operation.

Don't let traffic drive on any uncompact mix. A finished patch should be cool enough to hold your hand on before traffic is allowed to drive on at normal speeds. A pilot car offers a big advantage for multiple patches over an extended section of roadway. The use of a third flagger or traffic cones to keep traffic off the unfinished mix and away from the equipment is desirable. Traffic striping that is blacked out or covered should be remarked the same day with temporary striping (tape or paint products).

3-12 HMA Materials Information

Sources for additional pavement maintenance information.

3-13 Classes of Hot Mix Asphalt (HMA)

Exhibit 3-9 Mix Type in Patches

Mix Class	Size	
Class ½”	½”-0”	Mix should be used when placing multiple layers
Class ⅜”	⅜”-0”	Mix should be used when placing one or more layers

Exhibit 3-10 Asphalt Concrete Paving Quantities (Tons/100 linear ft)

	Depth of Mix (Compacted)					
Width (ft)	**1”**	**2”**	**3”**	**4”**	**5”**	**6”**
2	1.2	2.4	3.6	4.8	6.0	7.6
4	2.5	5.0	7.5	10.0	15.0	15.2
6	3.8	7.6	11.4	15.2	19.0	22.8
8	5.0	10.1	15.0	20.0	25.0	30.4
10	6.3	12.6	18.9	25.2	31.5	38.0
11	7.0	14.0	21.0	28.0	35.0	42.0
12	7.6	15.2	22.8	30.4	38.0	45.6
16	10.1	20.2	30.4	40.6	50.7	60.8
18	11.4	22.8	34.2	45.6	57.0	68.4
20	12.4	25.2	37.2	49.6	62.0	76.0
22	14.0	28.0	41.8	56.0	70.0	83.7
24	15.2	30.4	45.7	60.8	76.0	91.3

The following can be used to convert tons volume to tons:

Volume (cu.ft.) = Length (ft.) × Width (ft.) × Thickness (ft.) = cu.ft.

Pounds of HMA (lbs.) = Volume (cu.ft.) × 145 (lbs./cu.ft.) = lbs.

Tons of HMA = Pounds of HMA (lbs.) ÷ 2,000 (lbs. per ton) = tons

Example:

Volume (cu.ft.) = Length (20 ft.) × Width (12 ft.) × Thickness (0.20 ft.) = 48 cu.ft.

Pounds of HMA (lbs.) = Volume (48 cu.ft.) × 145 (lbs./cu.ft.) = 6,960 lbs.

Tons of HMA = Pounds of HMA (6,960 lbs.) ÷ 2,000 (lbs. per ton) = 3.48 tons

3-14 Successful Chip Seal Projects

Chip seals are one of the more commonly used pavement preservation techniques used in Washington State. To improve the likelihood of a successful project and ensure longevity, it is important to understand the basics. The following will cover aspects related to pavement conditions, material selection, construction overview, pre-construction, and calibration.

3-15 Pavement Conditions

Prior to sealing, thoroughly examine the roadway surface. Then decide what kind of repair is needed based on the overall pavement condition. A chip seal does not add to the structural integrity of pavement. Therefore, the existing pavement must be structurally sound to obtain a long performance life from a chip seal repair. Existing pavements may have to be repaired; patched, crack sealed and then allowed to cure before a chip seal can be applied. Always clean the existing roadway surface before starting the chip seal process.

Since chip seals follow the original profile of the pavement, they do not correct surface irregularities. Chip seals are not typically used on pavements with more than ¾” of rutting because aggregates in the ruts cannot be fully compacted unless a pneumatic tired roller is used. Cleaning loose aggregate from the rut with a power broom will dislodge the aggregate from the non-rutted area. If the surface has light-to-moderate bleeding, the binder application rate should be reduced. Use of a chip seal on pavements with a high severity of bleeding should be avoided.

3-16 Chip Seal Material Selection

3-16.1 *Asphalts and Emulsions*

The two general types of asphalt for seal coating are liquid asphalt and emulsified asphalt. Emulsified asphalts are manufactured by suspending asphalt particles in water with the aid of an emulsifying agent. Asphalts for chip seals are listed in the *Standard Specification* Section 9-02.

3-16.2 *Common Types of Emulsions Used for Chip Seals*

CRS-2 (Cationic Rapid Set Emulsion) and CRS-2P (Polymer) are two of the most widely used emulsions. This emulsion will run into wheel ruts and down super elevated roadways if applied at rates above 0.4 gallons per square yard. CRS-2 provides a good seal on low volume highways.

CVRS-2P (Cationic Very Rapid Set Emulsion w/Polymer) is a rapid setting emulsion that binds the chips very fast and can be used on high volume roads. This material allows for sweeping of the roadway within an hour of application, thereby causing less windshield damage and increased safety for the travelling public.

HFRSP2/HFE-100S (High Float Rapid Set Polymer/High Float Emulsion) is used for chip seals. It is a rapid setting emulsion that binds the chips very fast and can be used on high volume roads. This product should not bleed under high pavement temperatures.

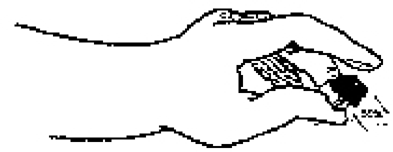
3-16.3 *Aggregate*

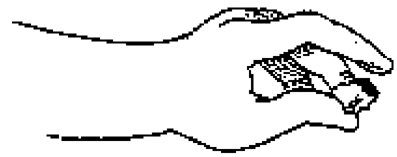
Aggregate for chip seals must conform to the requirements in the *Standard Specifications* Section 9-03.4 for grading and quality. However, aggregate availability may be a factor to consider if the chip seal is not intended to last a full cycle. The material must meet the requirements for grading and quality when placed in hauling vehicles for delivery to the roadway. During manufacture and placement into a temporary stockpile the exact point of acceptance will be determined by the Engineer or Area Superintendent. The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other contaminants. Crushed screenings must be substantially free from adherent coatings.

3-17 Chip Seal Construction Overview

3-17.1 *Application of Emulsion*

It is very important that the correct amount of emulsion be applied to the surface, as too much or too little asphalt will cause a slick roadway and flush the surface. If not enough asphalt is applied, the rock will ravel off leaving a surface rich in asphalt.





Many factors are used to determine the amount of asphalt to shoot, including the grade of asphalt, size of aggregate, condition of roadway surface, and traffic. After a rate of application is determined, a shot of asphalt should be put down, covered with aggregate, and rolled. A field check should be made by checking to see that the asphalt depth is approximately three-quarters of the way up on the firmly placed aggregate.

Any adjustment needed should be made in the asphalt application rate at this time. A field check should be performed periodically during the day to assure correct application rates are maintained throughout the entire project.

Rough and unsightly transverse joints can be avoided by starting and stopping the asphalt spread on building paper. The distributor, traveling at the correct speed for the desired application rate, starts spraying on the paper so that a full, uniform application of asphalt is applied to the exposed surface. The use of smaller, more absorptive aggregate at the ends has been successfully used instead of paper.

A longitudinal joint is usually unavoidable because traffic lanes must be maintained. If possible, longitudinal joints should be made along the centerline or center of lane of the pavement and never in the wheel tracks. To prevent aggregate from building up on the longitudinal joint, the edge of the aggregate spread should coincide with the edge of the full thickness of applied asphalt. This allows a width where asphalt is present in partial thickness, due to outside nozzle spray, that can be overlapped when asphalt is applied in the adjacent lanes.

3-17.2 *Spreading Aggregate*

Chip spreaders kick the aggregate backward or drop the aggregate straight down to reduce aggregate rollover and reduce the degree to which the aggregate picks up on vehicle tires after the section has been opened to traffic. The spreader is a variable width machine and calibrated on pounds per square yard. Dump trucks work in combination with the chip spreader to achieve a uniform application of aggregate.

All aggregate required for the planned spread should be on hand before starting. It should be dampened if necessary, as described in the section on Material Selection. When the distributor moves forward to spray asphalt, the aggregate spreader should follow immediately behind it. The asphalt must be covered as soon as possible, otherwise the cooling of the asphalt will prevent good adhesion between asphalt and aggregate. It is important that the aggregate be spread uniformly and at the proper rate of one rock thickness. Marking the length that each truckload of aggregate should cover aids in controlling distribution.

3-17.3 *Rolling*

Rolling seats the aggregate in the asphalt and promotes the bond necessary to resist traffic stresses. Pneumatic tired rollers should be used on all seal coat jobs to give uniform ground pressure over the entire area to achieve proper embedment of the aggregate in the asphalt binder. Steel wheeled rollers tend to compact only high spots and can fracture soft aggregates.

Rolling should begin immediately after the aggregate has been distributed and should continue until the aggregate is properly seated in the binder. Rolling should begin at the outer edge of the treatment and proceed in a longitudinal direction, working toward the center of the road. Each trip should overlap the previous trip by about one-half the width of the front wheels. As soon as the asphalt has a definite set or hardening, rolling should be discontinued, to prevent the bond between the surface and aggregate from being broken by the roller.

Rollers should be operated at slow speeds (4 to 6 mph) to set the rock, not displace it. The number of rollers required for a seal coat project depends on the length of the operation. It takes two to four passes of the roller to set the rock. These rollers should have tire pressures of (45) psi or more.

Loose aggregate should be swept along the longitudinal joint and from the uncovered lane prior to application of asphalt. Brooming loose aggregate on a completed sealed surface should be done as soon as practicable, and during the cool part of the day, to minimize flying rock problems.

Relying on traffic to seat the aggregate has been successful, if speed is controlled, but using rollers gives better control and improves the chances for success.

3-17.4 *Spreading of Fines or Choking - Optional*

The need for applying fines will vary with the types of emulsions used and application rates. Those rates must be closely monitored. The most common material used for choking is ¼” minus maintenance sand. In urban areas clean masonry sand can be used. Spreading these fines on a seal helps fill the voids, key the stone, reduces the chances of bleeding, and stops the squeezing and tracking of asphalt. The application of these fines prior to the roller, or after the roller depends on the types of emulsions used, and the location of the project. This material may also be applied to the chip seal when rolling of the coarse aggregate occurs and will help to reduce pick-up of coarse aggregate during construction. Fines application should not cover the coarse aggregate but merely fill the voids. The spreading of fines could be achieved by using a Hopper Sander with a mid-mount spinner. This vehicle may be placed before or after the rollers depending on the type of operation.

3-17.5 *Post-Seal Inspection*

The embedment of the aggregate into the asphalt should be checked a day or so after the construction of the seal coat. Remove several of the largest stones and determine if the 50 percent to 70 percent embedment has been obtained.

If an inadequate application of asphalt was applied, a fog seal can enrich and tie down the seal rock. A diluted CSS-1 (usually 50/50) is applied at the rate of 0.1 to 0.2 gallons per square yard of the dilution. (Application can vary depending on pavement texture, local conditions, and traffic). No cover aggregate is required; however, if a tighter seal is desired, a sand or ¼”- 0 cover may follow. Traffic should be controlled until the CSS-1 has cured.

3-18 Chip Seal Pre-Construction

3-18.1 *Weather*

The best time of year construct a chip seal is between May 15th and August 15th when the weather is dry during, and for some weeks after, placement. Specifications require the air temperature in the shade to be at least 60°F and rising before work begins and the road surface temperature shall not be more than 130°F. No matter what the temperature of the asphalt when sprayed, it will cool to the temperature of the pavement surface in one minute.

Never start a chip seal when the surface is wet or when it is threatening to rain. If the freshly placed chip seal gets wet, the combination of water and traffic will result in loss of the cover aggregate and will potentially cause damage to vehicles.

3-18.2 *Traffic Control*

Traffic control is important and must be maintained throughout the work area. High speed traffic over a fresh seal coat displaces aggregate, causing bleeding of asphalt. Traffic should be allowed only in the lane not being sealed. When work is completed, traffic speed should be maintained at less than 35 mph, or the legal speed if under 35 mph, until the asphalt sets. Warning signs, flag persons, and pilot cars are essential for traffic control. Route trucks hauling aggregate to the aggregate spreader in a direction opposite of the seal coat operation. This prevents loaded trucks being turned on freshly placed seal coat.

Some emulsions such as High Floats may require up to 24 hours of traffic control or until the first sweeping occurs. This is in areas of high-volume traffic or areas where vehicle weight exceeds the normal load range.

3-18.3 *Equipment*

Before any work begins, examine all equipment to ensure it is in good working condition. Check spreader boxes or aggregate spreaders to see they are in proper working order. The roller operator should make sure that each tire on the roller is equally inflated to correct pressure and that controls for steering, starting, and stopping operate smoothly. All tires should be the same size and the water spray and scraper system must be checked to ensure material does not bond to the tires.

3-18.4 *Distributor*

New distributors use a ground speed control sensor and computer to regulate material application rates. Set the computer to the desired rate and the application will be correct even if the vehicle speed varies.

Older distributors are equipped with hydrostatic drive systems. The hydrostatic drive consists of a variable output pump driven by the truck power take off (P.T.O.). This in turn drives the distributor asphalt pump with a hydrostatic motor. Once the correct ratio between ground speed and pump flow rate is established for a given transmission setting, the truck ground speed may be varied without affecting the application rate. The operator needs a dry run to establish correct ratio between pump flow rate and ground speed.

Determine the correct ground speed (F.P.M.) and pump flow rate (G.P.M.) for the desire spray bar length (FT.) and application rate (GAL/SQ.YD.). Follow the correct operation procedures set up in your distributor manual for calibration.

3-18.5 *Nozzle Size*

The spray bar and nozzles are an important part of the distributor. The proper quantity of asphalt must be spread uniformly on the road surface through the spray nozzles. To achieve good results, correctly sized nozzles must be selected for the job conditions. For example: if nozzles are too large for the desired application, pulsation of the spray may occur, resulting in uneven longitudinal spreading of the asphalt.

Each equipment manufacturer has specific recommendations for the size of spray nozzles to be used for different applications. Use the manufacturer’s recommendation when choosing the correct nozzle size. All nozzles selected for use at any one time should have the same size opening.

3-18.6 *Proper Pressure*

The spray bar must have a constant, uniform pressure along its entire length for equal output from all nozzles. Be sure the spray bar and nozzles are CLEAN.

Although several methods are used to maintain pressure, distributors use gear-type pumps to deliver asphalt to the spray bar. Pressure is governed by variable pump speed on some distributors and by constant pump speed and a pressure relief valve on others. Each application should be checked, as recommended by the manufacturer.

The correct pump speed or pressure are critical to the proper application of the asphalt. Too low a pressure will result in a non-uniform discharge/streaking of material from the individual nozzles. Too high a pressure, in addition to atomizing the asphalt, will distort the spray fan.

When a metering system is used, the manufacturer supplies the distributor with charts for finding the proper pump speed for each application rate.

When a pressure relief valve is used, the pump runs at a constant speed and the pressure is automatically held in the spray bar. The manufacturer supplies charts for determining the discharge in gallons per minute for each size nozzle, the proper truck speeds for various application rates, and the corrections for temperature-viscosity variations. The following is general information related to how many gallons of emulsion (emulsified asphalt) might be required per 100 linear feet.

Exhibit 3-11 Gallons of Emulsified Asphalt Required Per 100 linear Feet: Various Widths and Rates

Gals. per Sq. Yd.	Width (feet)														
	1	2	6	7	8	9	10	11	12	14	16	18	20	24	24
0.10	1.1	2.2	6.7	7.8	8.9	10.0	11.1	12.2	13.3	15.6	17.8	20.0	22.2	24.4	26.7
0.15	1.7	3.3	10.0	11.7	13.3	15.0	16.7	18.3	20.0	23.3	26.7	30.0	33.3	36.7	40.0
0.20	2.2	4.4	13.3	15.6	17.8	20.0	22.2	24.4	26.7	31.1	35.6	40.0	44.4	48.9	53.3
0.25	2.8	5.6	16.7	19.4	22.2	25.0	27.8	30.6	33.3	38.9	44.4	50.0	55.6	61.1	66.7
0.30	3.3	6.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	46.7	53.3	60.0	66.7	73.3	80.0
0.35	3.9	7.8	23.3	27.2	31.1	35.0	38.9	42.8	46.7	54.4	62.2	70.0	77.8	85.5	93.3
0.40	4.4	8.9	26.7	31.1	35.6	40.0	44.4	48.9	53.3	62.2	71.1	80.0	88.9	97.8	107.
0.45	5.0	10.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	70.0	80.0	90.0	100.	110.	120.
0.50	5.6	11.1	33.0	38.9	44.4	50.0	55.5	61.1	66.7	77.8	88.9	100.	111.	122.	133.
0.55	6.1	12.2	36.7	42.8	48.9	55.0	61.1	67.2	73.3	85.5	97.8	110.	122.	134.	147.
0.60	6.7	13.3	40.0	46.7	53.3	60.0	66.7	73.3	80.0	93.3	107.	120.	133.	147.	160.
0.65	7.2	14.4	43.3	50.6	57.8	65.0	72.2	79.4	86.7	101.	115.	130.	144.	159.	173.
0.70	7.8	15.6	46.7	54.4	62.2	70.0	77.8	85.5	93.3	109.	124.	140.	156.	171.	187.
0.75	8.3	16.7	50.0	58.3	66.7	75.0	83.3	91.7	100.	117.	133.	150.	167.	183.	200.
0.80	8.9	17.8	53.3	62.2	71.1	80.0	88.9	97.8	107.	124.	142.	160.	178.	196.	213.
0.85	9.4	18.9	56.7	66.1	75.5	85.0	94.4	104.	113.	132.	151.	170.	189.	208.	227.
0.90	10.0	20.0	60.0	70.0	80.0	90.0	100.	110.	120.	140.	160.	180.	200.	220.	240.
0.95	10.6	21.1	63.3	73.9	84.4	95.0	106.	116.	127.	148.	169.	190.	211.	232.	253.
1.00	11.1	22.2	66.7	77.8	88.9	100.	111.	122.	133.	156.	178.	200.	222.	244.	267.
1.10	12.2	24.4	73.3	85.5	97.8	110.	122.	134.	147.	171.	196.	220.	244.	269.	293.
1.20	13.3	26.7	80.0	93.3	107.	120.	133.	147.	160.	187.	213.	240.	267.	293.	320.
1.25	13.9	27.8	83.3	97.2	111.	125.	139.	153.	167.	198.	222.	250.	278.	306.	333.
1.30	14.4	28.9	86.7	101.	116.	130.	144.	159.	173.	202.	230.	260.	288.	318.	347.
1.40	15.6	31.1	93.3	109.	124.	140.	156.	171.	187.	218.	249.	280.	311.	342.	373.
1.50	16.7	33.3	100.	117.	133.	150.	164.	183.	200.	233.	267.	300.	333.	367.	400.
1.75	19.4	38.9	117.	136.	156.	175.	194.	214.	233.	272.	311.	350.	389.	427.	467.
2.00	22.2	44.4	133.	156.	178.	200.	222.	244.	267.	311.	356.	400.	444.	489.	533.
2.25	25.0	50.0	150.	175.	200.	225.	250.	275.	300.	350.	400.	450.	500.	550.	600.
2.50	27.8	55.6	167.	194.	222.	250.	278.	306.	333.	389.	444.	500.	556.	611.	667.
2.75	30.6	61.1	183.	214.	244.	275.	305.	336.	367.	428.	489.	550.	611.	672.	733.
3.00	33.3	66.7	200.	233.	267.	300.	333.	367.	400.	467.	533.	600.	667.	733.	800.

Note:

Formula used for calculation:

Where:

Q = Quantity of asphalt required, in gallons per 100 ft (l/m)

R = Rate of application in gallons per sq. yd. (l/m^2)

W = Width of application, in feet (m)

For metric conversion factors see pages 6-A and 6-B Metric formula for calculation: Q = LWR where L = length in metres.

3-18.7 *Proper Nozzle Angle*

Adjust nozzle opening angles so the spray fans will not interfere with each other. The nozzle angle will vary according to the make of the distributor. The angle recommended by the Asphalt Institute, measured from the spray bar axis, is 15 to 30 degrees.

Manufacturers furnish special wrenches for setting the angle of the nozzles. The use of these wrenches is recommended, as it is extremely difficult to obtain a uniform spread with visually set nozzles. All nozzles should be set at the same angle except for the cut-off nozzle (end nozzle). Manufacturers make a nozzle with ½ spray pattern for this purpose.

At the time the angle of the nozzles is set, the edges of the nozzle openings should be inspected to see that they are not damaged. A nicked or otherwise damaged edge will produce a distorted fan of asphalt.

3-18.8 *Spray Bar Height*

The height of the spray bar above the pavement surface is probably the most important adjustment to assure uniformity of asphalt spread. Correct height must be maintained during the entire application. If the spray bar is too low or too high, streaking will result.

The preset height above the pavement surface should not vary more than ½ inch. The bar will not stay within this tolerance, however, unless the manufacturer or the contractor takes steps to ensure that it does. As the asphalt leaves the spray bar, the load lightens and the springs raise the distributor, resulting in an uneven application, and should be monitored throughout the day.

Excess vertical movement of the spray bar can be corrected in several ways. After the bar height is adjusted with a full load in the tank, the frame of the distributor can be tied down to the axle during the spreading runs. If it is a truck-mounted distributor and has an adjustable type spray bar, mechanical controls can be supplied by the manufacturer to maintain the proper height, regardless of the deflection in the springs. On trailer-mounted distributors, bar height control is not necessary because of the small deflection of trailer springs. In any event, the height of the bar should be checked after each run and any necessary adjustment made at that time.

Triple Coverage – This is where any point on the roadway surface will receive overlapping spray from the two adjoining nozzles.

- **4-Inch Nozzle** – Best results with 4-inch nozzle spacing will come from an exact triple coverage of the spray fans. A simple test procedure assures the proper height setting of a spray bar with 4-inch nozzle spacing. One can determine by visual inspection whether or not an exact single coverage of asphalt is being applied. To begin, the second and third, fifth and sixth, eighth and ninth, etc., nozzles are closed, using the center section of the bar only. The distributor is then operated at the correct pump speed/pressure with the spray bar height changed not more than ½-inch at a time until the proper height is obtained. When an even single coverage of asphalt, heated to the proper spraying viscosity, is applied to the surface, it will give a uniform triple coverage with all nozzles operating.
- **6-inch Nozzle** – The height of bar necessary to give a triple coverage will frequently cause wind distortion of the spray fans, resulting in non-uniform application. A double coverage is therefore recommended for 6-inch nozzle spacing.

Double Coverage – This involves the same procedure as above except that every other nozzle is left open; the remaining ones are shut off. If the distributor has already been checked for double coverage, increasing the spray bar height by 50 percent will give triple coverage.

3-18.9 Streaking Will Occur

- If the asphalt is too cold.
- When the viscosity of the asphalt is too high.
- If the snivies are not at the same angle.
- When the bar is too high.
- When the bar is too low.
- When the bar pressure is too high it cuts furrows because the snivies are too small and/or there is too much pump pressure.
- When the bar varies in height from a full to an empty distributor, blocking or locking against the overload springs will reduce or eliminate this variance in height.
- When the bar is too long and/or the snivy openings are too large for the pump capacity, this results in narrow and fluttering fans. Smaller snivies and/or higher pump capacity will correct this.
- If the pump pressure is too low it will create narrower spray fans and fluttering.
- If the distributor tank is allowed to run completely empty, an irregular pattern of misses and fluttering will occur across the bar. For this reason, the shot should be terminated while approximately 100 gallons are left in the distributor.

3-18.10 Cleaning

Cleaning of the distributor should take place in an area determined by its characteristics that are protective of the environment. For example: areas near waterways or with high seasonal water tables would not be necessarily suitable. These cleaning areas may require all fluids to flow through an oil water separator and all tank and bar cleaning agents to be barreled and labeled for disposal. No discharging or blowing your distributor bars in the ditch line, upon the right of ways or on private property is allowed, this could result in a serious violation.

3-18.11 Checking the Bitumeter

A bitumeter consists of a rubber-tired wheel, mounted on a retractable frame, with a cable leading to a circular dial in the cab of the vehicle. The dial registers the rate of travel in feet per minute and the total distance of each trip in feet. At least one manufacturer furnishes a dial that registers the application rate in gallons per square yard in addition to travel in feet per minute.

Check the bitumeter regularly to ensure accurate registering of speed when the distributor is spraying asphalt. To verify the bitumeter, 500 feet to 1,000 feet is accurately marked off on a straight and level length of road. The distributor is driven at constant speed over this length and the trip is timed with a stopwatch. The speed in feet per minute is calculated and compared with the bitumeter dial reading recorded during the run. This procedure is repeated for several other speeds, bracketing the speed to be used for spraying.

Errors found at the various speeds are tabulated or plotted on a graph so they can be readily applied when using the distributor. The bitumeter, when used, must be kept clean to ensure accurate registering of the truck speed. A build-up of asphalt on the wheel will produce an error.

3-19 Calibration Procedures

3-19.1 *Distributor Calibrations*

Step 1 – Calculate how much material is in the holding tank. The following methods work to calibrate an older distributor and calculate the application rate.

- **Method 1** – Determine the number of gallons in the distributor. This can be done by several methods. The first and most accurate is to weigh the distributor before loading and after loading. Subtract the weights and divide by the pounds per gallon the emulsion weighs. This equals the total gallons.
- **Method 2** – Find a level spot (the distributor tank must be level). Use a dip stick to dip the tank. Measure the number of inches covered with asphalt. After you know the size of the tank, you can calculate the number of gallons in the tank.
- **Method 3** – Use the meter on the distributor tank. This is a good method for checking the above calculations but is **not recommended** for calibrating purposes.

Methods 1 and 2 are recommended for Measuring Distributor Tank (MDT) equipment prior to the start of the project.

Step 2 – Apply asphalt to a known distance (minimum 200 feet) and established width.

Step 3 – Determine the total square yards covered with emulsion. This can be done by doing the following calculation:

$$\frac{\text{Length Traveled (feet)} \times \text{Width Covered (feet)}}{9} = \text{Square Yards}$$

Step 4 – Determine the number of gallons remaining on the distributor and use Method 1 or Method 2 explained in Step 1.

Step 5 – Subtract the total gallons on the distributor originally from the total gallons left on after applying asphalt. This will give the gallons used.

Step 6 – Divide the total gallons used by the total square yards covered:

$$\frac{\text{Total Gallons}}{\text{Total Square Yard}} = \text{Gallons/Square Yard}$$

Step 7 – To check your application rate on the project, follow the same steps except use Method 3 outlined in Step 1 to determine the number of gallons on the distributor.

3-19.2 *Chip Spreader Calibration*

The following is a step-by-step procedure on how to calibrate your chip spreader and calculate the application rate.

1. Construct a one square yard shallow box or tarp, with shallow and narrow sides.
2. Place the box/tarp in the middle of the roadway a minimum of 50 feet in front of the chip spreader.
3. Get the chip spreader up to speed and apply chips over the top of the box/tarp.
4. Remove the box/tarp with the chips from the road.
5. Find an accurate materials scale. If in the field, the scale must be leveled and checked.

6. Place the chips from the box/tarp in a small bucket and weigh the bucket with the chips.
7. Empty the chips out and weigh the empty bucket.
8. Subtract the weight of the empty bucket from the weight of the bucket with the chips.
9. Since you had a one-square yard box/tarp, the weight from Step 8 is your pounds per square yard of chips.
10. Repeat the process at two to three gears and two to three RPM or speeds. You can then develop a chart.

Exhibit 3-12 Tons of Aggregate Required Per Mile for Various Widths and Rates

Spread Rate	Spread Width (In Feet)						
	8	9	10	12	16	18	20
lb/yd^2	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile	Tons Per Mile
5	12	13	15	18	23	26	29
10	23	26	29	35	47	53	59
15	35	40	44	53	70	79	88
20	47	53	59	70	94	106	117
25	59	66	73	88	117	132	147
30	70	79	68	106	141	158	176
35	82	92	103	123	164	185	205
40	94	106	117	141	188	211	235
45	106	119	132	158	211	238	264
50	117	132	147	176	235	264	293
60	141	158	176	211	282	317	352
75	176	198	220	264	352	396	440
100	235	264	293	352	469	528	587
150	352	396	440	528	704	792	880
200	469	528	587	704	939	1056	1173
250	587	660	733	880	1173	1320	1467
300	704	792	880	1056	1408	1584	1760

Note: The aggregate weight may vary a couple of pounds if the chips are wet.

3-19.3 *DOs and DO NOTs of Seal Coating*

- **Do** turn spray nozzles so that fans are at proper angle to spray bar, so sprays do not touch or merge.
- **Do** check bar height at start of each shot to determine ground-to-nozzle distance over entire length of the spray bar.
- **Do** check spraying pressure so as to give constant uniform spray. Pressure too high will cause spray to fog and distort, pressure too low will cause spray to sag with heavy edges and pronounced longitudinal streaking.
- **Do** heat asphalt to upper part of spraying temperature range to eliminate heavy edge that is characteristic of all fan type sprays.
- **Do** keep spray bars in proper working order by regular cleaning and inspecting of strainers. Clean spray bars after each day's operation.
- **Do** keep aggregate stockpiles clean and free of contaminates.

- **Do** clean out tank thoroughly when changing asphalts from emulsified to cutback asphalts or from cationic to anionic emulsions.
- **Do** keep equipment on the same side of the roadway that the sealing operation is on, so traffic flow is not impeded.
- **Do** cover shot as soon as possible and roll immediately to ensure a good bond.
- **Do not** use worn nozzles or ones that have mechanical imperfections.
- **Do not** heat asphalt material above maximum temperature range, which would cause spray patterns of the fans to be uneven.
- **Do not** use asphalts that are too cold. Material will be too viscous and cause narrow spray fan, and materials will not flow together.
- **Do not** try to seal a wet or dirty road surface.
- **Do not** try to seal coat if air or road surface is too cold. Don't seal when windy.
- **Do not** make shots too long before applying aggregate.
- **Do not** turn equipment on a fresh patch.

3-20 Blade Mixed Asphalt Mix

Blade mixing of asphalt cold mixes is an economical and versatile method of producing material for construction or repair of highway pavement. High production rates are possible with a comparatively low expenditure, and entirely satisfactory pavements can be achieved with blade mixed cold asphalt. However, proper attention must be devoted to ensuring uniform quantities of aggregates, uniform aggregate gradation, and correct, uniformly applied quantities of asphalt are combined into the final mix design.

A wide variety of aggregates ranging from well graded crushed rock to silty sands can be mixed satisfactorily by cold blade methods. The optimum results will be obtained by using a uniformly graded manufactured aggregate with a maximum particle size of ½ inch or less and not more than 10 percent passing the No. 200 sieve.

Emulsified or cutback asphalts may be used in the production of cold mixes. Up to 3 percent surface moisture may be required on aggregates for successful mixing with emulsified asphalts and subsequent compacting of the mixture. The surface moisture of aggregates should be as low as possible if cutback asphalts are used.

Well graded mixes are made using an asphalt with a fairly slow rate of curing such as MC, SC, SS, or CSS. Open graded mixes are made with a faster curing asphalt such as MC or CMS, or RC if it is to be spread and compacted immediately. Asphalt cold mixes which are to be made and placed into stockpile for future use are made with an MC or SC asphalt of 250 or 800 grade.

Prior to beginning the mixing operation, a permanent base pad must be prepared at the site upon which the cold mix will be made. The pad should be reasonably level, 3 to 4 feet wider than the distributor spray bar and must be surfaced with compacted hot or cold asphalt mix. The length of the pad can vary depending upon conditions but should be approximately 400 feet if possible.

The cold mix is made in batches, the size of which will depend upon the capacity of the distributor and the desired asphalt content. For a uniform manufactured aggregate of ½ inch minus gradation, with a desired asphalt content of 5 percent and using a 1,000 gallon distributor, the batch size will be approximately 60 cubic yards.

Using a truck and tail gate or chip spreader, a layer of aggregate the width of the distributor spray bar is uniformly placed upon the length of the base pad at a rate of approximately 50 pounds per square yard. Heated asphalt is then shot over the layer of aggregate at a rate calibrated to yield the desired asphalt content. The amount of asphalt required will depend on the gradation of the aggregate and will normally range from 4 to 7 percent by weight of the completed mix. Successive layers of aggregate and shots of asphalt are placed one on top of the other until the batch is completed.

Mixing is accomplished by turning and blending the mixture with a grader. If several batches are being produced for stockpiling and production is a factor, the mixing is more efficiently accomplished by using two blades working in opposite directions. Well graded mixes will require a relatively greater mixing effort to coat all of the particles evenly than will be required for open graded mixes. Mixing should continue until a thoroughly uniform mixture is produced. The completed mix is then windrowed and picked up by a front-end loader and placed into stockpile.

Stockpiled mixes made with MC or SC cutback asphalts should be allowed to cure out for a period of time before the mix is used. Cure time varies depending on weather conditions but will normally be approximately two weeks.

3-21 Handling Emulsified Asphalts

The Asphalt Institute Fourth Edition of MS-19 titled *Basic Asphalt Emulsion Manual* is a great source of for best handling practices. Please refer to this manual for additional information.

3-22 Maintenance of Rigid Pavements

Rigid pavements are generally referred to as Portland Cement Concrete Pavement (PCCP) or Concrete Pavement. PCCP should be patched with Portland Cement Concrete. Prepare and apply patching materials according to the manufacturer instructions. If recommended by the patching material manufacturer, use a bonding agent.

The PCCP surface to be repaired should have all loose material removed down to solid material. A jackhammer or similar equipment may be necessary to remove some of the material in the area to be patched. The area to be repaired needs to be squared by concrete sawing, then sand blasted, cleaned and dried. Any operation that creates concrete dust that becomes airborne is a safety concern. Ensure appropriate PPE and methods are in place and can be found within Chapter 8 of the *Safety Procedures and Guidelines Manual* M 75-01.42.

Delamination occurs when a thin layer of surface concrete has lost bond with the underlying concrete. The area around the patch should be checked for delamination. Tapping on the surface with a hammer and listening for a hollow sound is one way to find the delaminated areas. Jack hammer operation can cause or exacerbate delamination. It is important for the operator to take care to avoid contacting the steel reinforcing with the jack hammer operation.

If reinforcing steel is encountered, remove or neutralize all rust. Coat exposed reinforcing steel with a WSDOT approved product to prevent rust from reoccurring. Then proceed with patching the area.

Traffic should be kept off the new patch as specified by the manufacturer, until it gains sufficient strength to support traffic.

3-23 Portland Cement Concrete Pavement Crack Pouring

Joints in Portland Cement Concrete Pavements (PCCP) compensate for thermal movements of the pavement. Properly sealed joints and cracks in concrete pavements prevent water from entering into and weakening the underlying base and subgrade materials. Properly sealed joints also prevent incompressible materials such as dirt and gravel from penetrating into joints, which then restricts thermal joint movements. Materials that restrict the natural expansion of the pavement joints can cause diagonal slab cracking, slab blowups, or tipping and spalling.

PCCP joints and cracks should be checked before the wet season to make sure they are sealed to prevent entry of damaging water.

Even fine cracks in steel reinforced slabs can be serious. They can allow water or chlorides to reach the steel causing corrosion and serious damage.

PCCP crack pouring is most effective when the pavement is cold and has contracted and opened the cracks. Don't pour cracks when the pavement temperature is below 45 degrees. Always use WSDOT approved crack sealant material.

Cracks must be cleaned out before pouring. A typical method is to clean and dry with compressed air prior to pouring. Foam backer rod can be used in larger cracks to keep the sealant in the top 1 inch of the crack reducing unnecessary use of sealing product.

Safety is a big concern in any hot pour operation. This material is extremely hot and can cause severe burns when loading the machine or applying the material.

3-24 Portland Cement Concrete Panel Replacement

Panel replacement and spall repairs are the concrete panel repair methods most often used by WSDOT. The intent of panel replacement is to remove and replace concrete panels that have deteriorated to a point where they have already failed or will fail prior to the preservation project.

3-24.1 *Full or Partial Panel Replacement*

Sometimes it is more economical to remove only the distressed portion of the panel. Reducing panel size decreases the cross sectional area of the panel available to resist loads which can result in premature cracking. To ensure good performance, the following criteria should be used when determining whether to use full or partial panel replacement (also see *Standard Specification* Section 5-01.3(4)):

- All full panel and partial panel replacements need to extend the full width of the existing panel.
- The remaining portion of the panel should be free of distress with the exception of minor spalling.
- The minimum length of a partial panel replacement is 6 feet.
- The minimum length of the portion of the panel to remain is 6 feet.
- Replace the entire panel if the above criteria cannot be met.

3-24.2 *Adjacent Panels*

When there are multiple panel replacements the intermediate dowel bars can be installed using dowel bar baskets. This is less time consuming than drilling into existing panels to install dowel bars. When a single cracked panel falls between two panels that are being replaced in the same lane, it should be considered for replacement.

3-24.3 *Non-Working Joints*

All concrete pavement cracks due to shrinkage as new concrete cures or due to loading during the concrete's life. Occasionally a crack does not form at a sawcut location leading to a non-working joint. A key to identifying a non-working joint is that there is no movement between the two sides of the joint. The joint will be uniform in width, cannot open and close due to temperature change and will not have any elevation difference between the two sides of the joint. If unsure if a joint is working or non-working, treat it as a working joint.

3-24.4 *Skewed Joints*

When replacing panels with skewed joints, the new joints can either be constructed with the same skew or they can be constructed perpendicular to the direction of travel (same as our current practice). If the joints are constructed perpendicular, they need to intersect the adjacent panel or panels at the existing transverse joint. Note that this situation will only occur when two or more adjacent panels are replaced in the same lane.

3-24.5 *Random Panel Spacing and Panels Longer than 17 feet*

For panels with random spacing the minimum size for partial panel replacement requires full panel replacement of the shorter panels. The longer panels are more susceptible to shrinkage cracking when being replaced and need to be broken up into two equal length panels. Dowel bars will be needed for the transverse joints to reduce the likelihood of transverse shrinkage cracking. Unusually long panels may occasionally be encountered within sections of standard PCCP. These should also be reduced into smaller panels using the criteria above if they are replaced.

3-24.6 *Sympathy Cracks*

Sympathy cracks form when joints intersect to form a T. If a T intersection is necessary, the panels should be isolated from each other by installing form core board, roofing paper or other material between the panels. The isolation material should extend a minimum of 2 feet each side of the joint.