Chip Seal Certification

Session Guide

National Center for Pavement Preservation
Michigan State University

PREFACE

The Purpose of Certification

The intent of the certification process is to provide assurance to highway agencies that pavement professionals and pavement practitioners certified in specific treatments have successfully completed a recognized program and passed an examination designed to assess the knowledge required for providing high quality thin surface treatment construction. Recipients of a certification possess particular qualifications and have demonstrated their competence to ensure the successful placement of a designated thin surface treatment.

In recent years, pavement preservation treatments have assumed a critical role in safeguarding America's highway system from the detrimental effects of harsh environmental conditions and ever increasing traffic. Pavement preservation is a pillar of sound asset management and ensures that the overall condition of the road network can be sustained at a desired level. Therefore, the successful placement and performance of pavement preservation treatments is an essential foundation for the realization of long-term financial planning and the ability of agencies to achieve their pavement condition goals cost-effectively.

The Congressional Act cited as "Moving Ahead for Progress in the 21st Century Act", known as "MAP-21", established a set of national goals and a process for performance reporting. Part of the law contains provisions for pavement performance and development of asset management plans. Consequently, successful construction and performance reliability are critical for every agency responsible for the condition of pavements in their jurisdiction.

Benefits of Certification

Agency personnel certified in specific thin surface treatments will ensure that future investments in those treatments are properly designed, constructed, and perform as intended. Certification would give agency employees the knowledge necessary to monitor contractor performance.

Company personnel certified in their product will have the confidence to make proper day-to-day decisions and will ensure that good quality control is maintained throughout their projects. Company certification promotes a common understanding by all personnel of the processes involved in production and placement of their product.

Certified consultants become aware of the treatment processes and quality assurance practices to perform the duties and functions required by the client.

Certified Personnel

It is understood that project oversight is completely defined and managed by the agency, but the contractor is ultimately responsible for their product quality and workmanship. The value of certified personnel is to alleviate potential problems by:

a. Serving as on-site technical experts in the treatment.
b. Providing peer-to-peer training for other staff and workers.
c. Reviewing the Contractor's Quality Control Plan for the project, including material sources, test requirements, equipment requirements; and treatment mix design documents, if applicable.
d. Witnessing on-site calibration of placement equipment used for construction.
e. Responding to treatment issues that may arise in the field.

In addition to the concerns that can potentially arise on any project, safety is paramount. Safety in construction is not a matter to be taken lightly and needs to be foremost in every aspect of the project at all times. Construction materials, machinery, and handling techniques all come with their own dangers. Road user and worker safety and accessibility should be an integral and high-priority element of every project from planning through design and construction.

Work zone crashes involving vehicles or construction equipment often lead to fatalities and injuries. Work zones are inherently dangerous and are not places to cut corners or cheat on safety. Your life and the lives of others are in jeopardy, so pay attention and know what it takes to keep everyone safe.

SESSION 1: PROJECT SELECTION

1.1 **Overview** - The project selection process is challenging because it encompasses a wide range of pavement designs, paving materials, traffic loadings, topography, and subgrade support conditions. In addition, climatic conditions and existing drainage characteristics further complicate the selection process. There are three commonly used methodologies that should be considered in project selection. These are pavement management, field sampling and forensic investigation, and on-site review. Ideally all three methods should be used whenever possible, but this is seldom practical due to logistics and time.

1.2 **Pavement management** provides the tools necessary to capture the existing pavement condition and forecast future performance so that agencies can identify the optimal timing for treatment application. A robust pavement management system should allow an agency to integrate the operation and preservation of their road and highway network with their long-range delivery and planning objectives. Most pavement management systems are being used to make project selection decisions and they can easily identify reconstruction and rehabilitation candidates through pavement condition analysis. However, project level selections of individual candidates become much more difficult because of inherent constraints which limit the accuracy of the data being collected. This is because obsolete or insufficient data may have been used in the decision making process. Important condition data, such as raveling, flushing/bleeding, and pavement oxidation, is generally absent because it is difficult to collect and quantify. For these reasons, care should be taken to avoid project selection decisions for thin surface treatments based solely on the output of the pavement management system.

1.3 **Field sampling and forensic investigations** have been used to reduce the probability of premature pavement failures. Predicting pavement failure is difficult and normally begins with a thorough review and analysis of original construction records. Studies may employ non-destructive testing such as ground penetrating radar (GPR) and falling weight deflectometers (FWD) to determine the existing pavement structure. Field sampling such as coring and trenching are used to validate suspicions of weak pavement structures. Overall, whatever method is used, forensic investigations should begin early in the candidate selection process to allow the maximum opportunity to correct problems and avoid a premature failure.

1.4 **On-site pavement reviews** are generally made to identify and quantify existing distress. There are two classes and several types of distress associated with each type of pavement. Generally, pavement distress and failure may be structural and / or functional. Structural distress is associated with the pavement's inability to carry its design load. Functional distress is related to accessibility, ride quality (roughness), and safety issues (e.g., skid resistance, hydroplaning, etc.). Conversely, functionally distressed and / or failed pavements (e.g., very rough) may or may not exhibit any structural distress. Pavements exhibiting structural distress (e.g., severe alligator cracking) will also exhibit functional distress and eventually fail. Pavements with structural distress are not candidates for thin surface treatments. Each class of pavement distress (functional or structural) contains several distress types.

1.5 **Pavement distresses** should be identified using a minimum of four factors: location, type, severity, and extent or amount.

Distress Location – The location of each type of distress relative to the common location referencing system must be identified. In addition, for some distress types such as longitudinal cracks, slippage cracks, patches, and polished aggregate, the location of the distress across the pavement surface (e.g., inside or outside the wheel path) should also be observed and recorded.

Type - Distress type (such as transverse cracks, longitudinal cracks, rutting, etc.) should be identified and recorded. Some distress types are specific to certain pavement types. For example, rutting is associated only with flexible and composite pavements.

Severity - Most distress types can be found at various severity levels. Highway agencies typically categorize distress severity as low, medium, or high. Although these levels are somewhat subjective, they do describe distinct stages of distress progression that relate well to pavement preservation needs. Some agencies such as the Michigan Department of Transportation use additional severity levels. Regardless of the number of severity levels used by an agency, photographs of each severity level of each distress are an indispensable part of the distress identification process and training. The "how to measure" subsection (presented under each distress type in the next section) gives specific directions on how to measure the particular distress and the units of measurement.

Extent (Amount) - The amount or extent of each type of distress must also be observed and recorded. For some distress types such as transverse cracks, the amount expresses the number of occurrences. For others, such as longitudinal cracks and alligator cracks, the quantity is expressed by the extent either in linear feet or surface area.

1.6 **Structural Distress** – Pavements exhibiting significant structural distresses should not be considered for thin surface treatments. Isolated structural distresses need to be removed and patched.

Note: The extent of the distress should be marked out, cut with a diamond saw, and the failed material removed. Often all materials down to and including some subgrade must be replaced with new materials, compacted in 4-inch lifts, and capped with a compacted asphalt patch. The patch will require a tack coat along the edges of the repair area prior to placement and compaction of the new asphalt surface. The new asphalt patch should be slightly overfilled by 0.25 inch to allow for traffic compaction. The edges of the patched area should be sealed with a crack sealant.

Alligator Cracks are a series of interconnecting cracks caused by fatigue failure of the asphalt concrete (AC) surface (or stabilized base) under repeated traffic loading. The cracks start at the bottom of the asphalt layer and eventually propagate upward to the pavement surface.

Alligator cracks are a load-associated distress caused mainly by the pavement design (inadequate design of the asphalt layer thickness or under- estimating the traffic load and volume), or construction processes (relatively soft pavement layers and / or roadbed soil). Adverse environmental conditions (temperature and moisture) tend to accelerate the start and propagation of the cracks. As alligator cracks occur only in areas that are subjected to continual traffic loadings, they will not occur over the entire pavement unless the entire surface is subjected to traffic loading. Alligator type cracks that occur over the entire pavement surface, including those areas that are not subjected to traffic loading are more likely to be caused by movement in the roadbed soil due to frost-heave.

Alligator fatigue cracks are measured in square feet or square meters of surface area. The major difficulty in measuring this type of distress is that two or three severity levels often exist within one distressed area.

Pumping and Water Bleeding involve the ejection of water and fine materials under pressure through cracks under moving wheel loads. Pavement surface staining or the accumulation of fine material close to the crack is evidence of pumping. Water bleeding occurs when water accumulates in voids beneath the pavement surface and slowly seeps out of cracks or construction joints in the pavement surface.

Stripping is the loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward. Although not completely understood, some aggregates have an affinity for water rather than asphalt. These aggregates tend to be acidic and suffer from stripping after exposure to water. Over time, stripping leads to decreased structural support and failure. Thin surface seals tend to accelerate the stripping process, leading to rapid failure.

1.7 Combined Structural and Functional Distress – Often a distress first appears as a structural distress and later incorporates characteristics of a functional distress. The reverse progression can also occur when a functional distress deteriorates to a severity that impacts the structural integrity of the pavement. If addressed early in the distress cycle, thin surface treatments have proven to be highly effective in correcting the distress. Examples of these distresses include potholes, raveling, weathering, slippage cracks, swell, rutting, and block cracking.

Potholes are bowl shaped depressions of various sizes in the pavement surface that are caused by breaks in the pavement surface due to alligator or block cracking, localized disintegration of the pavement surface, and / or freeze thaw cycles accompanied by the presence of moisture and accelerated by the action of traffic. Potholes may be found anywhere along the pavement surface mainly in the wheel path. They are considered as structural and functional types of distress and are measured by depth and surface area in square feet.

Raveling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (raveling) and loss of asphalt binder (weathering). Eventually, such surface wearing propagates downward and weakens the pavement structure. These distresses are caused by three primary mechanisms:

1. Horizontal shear stress due to traffic,
2. Presence of water (which enters the pavement through interconnecting voids) and high hydrostatic pressure caused by traffic, and
3. Long term emissions from motor vehicles (hydrocarbons act as solvents to asphalt).

Raveling and weathering are considered as functional and structural types of distress.

Slippage cracks are crescent or half-moon shaped cracks generally having both ends pointing in the direction of traffic. This type of cracking is caused by a low strength asphalt mixture and a poor bond between the surface course and the next layer of the pavement structure. Slippage cracks occur when parts of the AC surface move laterally away from the rest of the surface due to induced lateral and shear stresses caused by traffic loadings. The cracks may be found along the pavement surface, generally in the wheel path. Slippage cracks are considered both functional and structural types of distress.

Swell is an upward bulge in the pavement surface typically accompanied by surface cracking. Swell is mainly caused by frost action or swell in the roadbed soil or by blow-up of the underlying PCC slab. Swell may be found anywhere along the pavement surface and is considered to be both a functional and structural distress type.

Rutting is a surface depression in the wheel paths. These ruts in the wheel paths may or may not occur with pavement uplift adjacent to the sides of the rut. In many instances, ruts are noticeable only after a rainfall, when the wheel paths are filled with water. Rutting is caused by inadequate compaction during construction, soft asphalt mix, softening of the materials beneath the pavement due to moisture infiltration, or studded tires. Rutting is considered to be both a functional and structural distress type.

Block cracking divides the asphalt surface into approximately rectangular pieces. The blocks range in size from approximately 1 to 100 square feet. Block cracking is caused mainly by shrinkage / hardening of the asphalt binder and daily temperature cycling that results in daily stress / strain cycling. The occurrence of block cracking usually indicates that the asphalt has hardened significantly. Block cracking is not a load associated distress although load can increase the severity of block cracking. Low tensile strength asphalt mixture also accelerates the initiation of block cracking. Wider and spalled cracks cause higher pavement roughness and lower structural integrity. Block cracking normally occurs over a large portion of the pavement area, but sometimes it may occur only in non-traffic areas. It is considered to be both a functional and structural distress type.

1.8 Functional Distresses - Are related to accessibility, ride quality, and safety issues and can usually be corrected by a thin surface treatment. In general, proactive treatment applications applied at varying times will result in varying costs and pavement performance. The benefits and costs of the treatment are tied to the condition and rate of deterioration of the pavement at the time the treatment was applied. Examples of functional distresses include bleeding, corrugation, depressions, longitudinal and traverse cracking, polished aggregate, and lane-shoulder drop off.

Bleeding is a film of bituminous material on the pavement surface, creating a shiny, glass like, reflective surface that usually becomes quite sticky. Since the bleeding process is not reversible during cold months, asphalt will accumulate on the surface. Bleeding is caused by an excessive amount of the asphalt cement in the mix and / or low air void content. High temperatures cause the asphalt to expand filling up the voids first and then flushing to the pavement surface. It should be recognized that traffic loads may cause increased densities (lower air voids) in the wheel path of the AC course, thereby enhancing asphalt bleeding.

Bleeding may occur anywhere on the pavement surface. If traffic loads are causing additional compaction (densification) of the asphalt course, then bleeding could be more severe in the wheel path than in any other location. Asphalt bleeding is considered a functional distress. Bleeding areas have lower friction (skid resistance), which is considered a safety hazard.

Corrugation is a form of plastic movement of the asphalt surface typified by ripples across the pavement surface. They occur in areas where vehicles accelerate (start) and / or decelerate (stop) and are more pronounced in the proximity of the wheel path. Corrugation may be caused by lack of stability of the asphalt mix, especially at high temperatures, excessive moisture in the roadbed soil, contamination of the asphalt mix, low air voids, high asphalt content, or a combination of the above causes.

Depressions are localized pavement surface areas having elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are only noticeable after rain, when trapped water creates "birdbath" areas. Depressions can be caused by time-dependent settlement of the foundation soil or can be "built-in" during construction. Hence, depressions could be located anywhere along the pavement surface.

Longitudinal cracks are parallel to the pavement's centerline or traffic direction, whereas **transverse cracks** extend across the traffic lane or lanes. The two types of cracks are not caused by traffic loadings, although load and moisture accelerate their propagation. Longitudinal cracks may be caused by a poorly constructed paving lane joint, whereas longitudinal and transverse cracks may be caused by shrinkage of the asphalt pavement surface due to low temperatures or hardening of the asphalt binder, reflective cracking in the lower asphalt courses, segregation in the asphalt layer, or settlement of material in utility trenches.

Low temperatures cause high tensile strains in the pavement surface. Under these conditions, the cracks will start at the top (where temperature is colder) and propagate toward the bottom of the asphalt layer. Segregation lowers the tensile strength of the asphalt course, which increases the potential for top-down cracking. In contrast, reflective cracks or cracks due to settlement of the material in utility trenches start at the bottom of the asphalt layer and propagate upward.

Polished aggregate lowers the pavement’s skid resistance and occurs when aggregate is worn due to traffic. Polishing, which occurs mainly in the wheel paths, is caused by the presence of soft aggregates in the asphalt mixture combined with repeated traffic loadings.

Severity for polished aggregate is undefined. The degree of polishing can be determined by conducting skid resistance tests. Areas with polished aggregates are measured in square feet or square meters. Polished aggregate can be detected both by visual observation and tactilely, by running the fingers over the polished surface.

Lane-shoulder drop off is a difference in elevation between the traffic lane and the shoulder. If the shoulder is at a lower elevation than the adjacent traffic lane, it signifies settlement or pumping of the material from underneath the shoulder. If the shoulder is at higher elevation than the traffic lane, it signifies heaving of the shoulder due to frost action or swelling soils. Hence, lane-shoulder drop off is not caused by traffic loading and is a serious safety concern.

1.9 **Ride Quality** – Often ride quality is considered only a measure of comfort experienced by the driver and passenger, but it is also related to good braking and acceleration. Over time, poor ride quality can adversely affect driver safety, fuel efficiency, vehicle wear and tear, and pavement durability.

The International Roughness Index (IRI) provides an accepted method for judging the ride quality of roadway pavements. The lower the IRI value, the flatter the paved profile. For example, an IRI of 0.0 inch/mile relates to a perfectly flat profile. There exists no upper limit on IRI, but in practice, IRI values above 220 in/mi are poor-riding pavements. Ride is reported every 1/10 mile and should be computed in accordance with AASHTO Standard R43-07 on Standard Practice for Determination of International Roughness Index for Quantifying Roughness of Pavements.

In general, the pavement condition thresholds for ride quality (IRI) are:

Good	less than 95 inches/mile
Fair	95 to 170 inches/mile (*Note: in urban areas, the threshold is relaxed to 220 in/mi*)
Poor	greater than 170 inches/mile (*Note: in urban areas, greater than 220 in/mi*)

Pavements with unsatisfactory ride characteristics cannot be corrected with a thin surface treatment. If the ride is rough before a thin surface treatment it will remain rough after the treatment is applied.

In recent years, micro milling has become an accepted method of milling pavement due to its ability to improve ride quality. It is frequently used in combination with thin surface treatments to improve the unsatisfactory ride quality prior to treatment placement.

Micro milling should not be confused with standard milling or fine milling. Micro milling is limited to around one-inch in depth for a single pass and has a lower production rate than other types of milling. The finished pavement texture is smooth with good friction characteristics and a quiet riding surface. A forward operating speed of 20 to 30 feet per minute is common for a micro milling machine.

SESSION 2: MATERIALS

2.1 Introduction

The two main chip seal materials are binder and aggregate.

Chip seal material selection generally depends on climatic conditions, aggregate quality and compatibility with binder, product availability, and the experience with particular practices. Emulsified asphalt and cover aggregate make up the finished product.

The binder's function is to seal the existing pavement from the environment, provide interfacial bonds between the aggregate particles, and provide the adhesive which bonds the aggregate to the existing flexible pavement surface.

2.2 Aggregate Selection

The aggregates in a chip seal serve several functions. Cover aggregate should provide a good skid resistant surface while resisting polishing, abrasion, and disintegration caused by weathering.

Aggregate quality, which is important to the overall success of the chip seal program, involves a number of constructability requirements for the use of aggregates which are clean, durable, and abrasion-resistant. The cover aggregate, which is expected to transfer load to the underlying surface, should provide adequate skid resistance and should be durable against climatic effects and traffic wear.

The cost implications of using a higher grade aggregate in conjunction with the appropriate binder type should be carefully assessed, not on the myopic basis of first cost, but using life cycle cost analysis.

Another aggregate issue is ionic compatibility with the selected binder to ensure that good adhesion is developed between the rock and the binder. This is especially critical when using emulsified asphalts because they are routinely supplied in either anionic or cationic grades.

The aggregate’s role is to form the matrix of strength in the chip seal and as such, its properties are critical to success. Local sources are generally used but some other materials such as expanded clay (light weight aggregate) or slag may be used if they meet the required specification.

Aggregate physical properties include:

- Gradation or particle size distribution,
- Cleanliness or absence of deleterious materials,
- Hardness or abrasion resistance,
- Durability or soundness,

- Particle shape and surface texture, and
- Absorption characteristics.

Aggregates must be handled and stored in a manner that avoids contamination and minimizes degradation. Specific guidelines are as follows:

- Stockpile areas should be clean and stable to avoid contamination from the surrounding area,
- Stockpiles should be on free-draining grades to avoid moisture entrapment,
- Stockpiles of different aggregate sizes should be separated to prevent inter-mingling,
- Segregation or separation of a blended aggregate is the primary concern. Segregation, which is found mostly with coarse aggregates, may occur in the stockpile or upon handling if it gets too dry. Segregation may be avoided or minimized by not stockpiling in a conical shape. Acceptable stockpile shapes are either horizontal or radial. Making each end dump load a separate pile, each adjacent to the next, makes horizontal stockpiles. Radial stockpiles are made with a radial stacker, and
- Degradation of the aggregate by creating fines can be avoided by handling the stockpile as little as possible. In chip seal applications, re-screening may be useful in minimizing degradation.

For chip seals, the best performance is obtained when the aggregate has the following characteristics:

- Single-sized particles, if possible,
- Clean,
- Free of clay,
- Cubical (limited flat particles),
- Crushed faces,
- Compatible with the selected binder type,
- Surface damp for use with emulsions, but dry for use with hot binders.

Gradation and Size

Aggregate size, typically referred to as nominal top size, is the smallest sieve through which one hundred percent of the aggregate passes. The average of the smallest dimension of the aggregate is referred to as the Average Least Dimension (ALD).

The nominal size of aggregate is selected based on traffic, surface condition and type of chip seal. Larger aggregate particle sizes are generally more durable and less sensitive to variations in binder application rate. Additionally, as the binder material is meant to seal the surface, a larger sized aggregate will result in a thicker asphalt layer enhancing the quality of the seal. However, if not properly embedded and swept, larger aggregate can cause more damage to vehicles, immediately after application. Its coarser texture also results in a chip seal which produces more noise when traversed by vehicles.

The most common size for a single course chip seal is a ⅜" (10mm) chip. In addition, double course seals usually have a ½" (12.5 mm) initial aggregate application, followed by a second aggregate application of approximately half that nominal size.

Single-sized aggregate with less than one percent passing the No. 200 sieve is considered ideal. The amount of fines in the gradation affects the binder's ability to adhere to the aggregate. Poor quality aggregate can potentially increase the amount of fines every time the material is handled. Therefore, specifications should require clean and durable aggregate to reduce degradation during material movement and application.

Aggregate gradations should be determined by the ultimate use. Table 2-1 designates the gradations that achieve the best chip seal results.

Sieve Size T27	**Passing, %**			
	A	**B**	**C**	**D***
¾"	100			
½"	90-100	100		
3/8"	5-30	90-100	100	100
No. 4	0-10	5-30	90-100	0-65
No. 8		0-10	5-30	0-15
No. 16	0-2		0-10	0-10
No. 30		0-2		
No. 50			0-2	0-6
No. 200	0-1	0-1	0-1	0-3

*Gradation D should be limited to application of less than 500 AADT

Table 2-1 Recommended Gradations

Aggregate Shape

The shape of cover aggregate is crucial to the successful performance of a chip seal. Aggregate shape is typically characterized by angularity. As the orientation of the embedded chip is important, cubical aggregate shapes are preferred because traffic does not have a significant effect on the final orientation of aggregate. Cubical aggregates also tend to lock together and provide better long-term retention and stability. The quantity of flat particles in the aggregate can be determined by the Flakiness Index test. A low Flakiness Index indicates that all the particles are near to having a cubical shape. Under traffic, elongated and flat particles will lie on their flattest side and become covered within the binder. As a result, flatter aggregate is more susceptible to bleeding in the wheel paths. Since the orientation of cubical aggregate is not as susceptible to displacement by traffic, the opportunity for bleeding is reduced.

The angularity of the aggregate, a characteristic that can be measured by testing for percent fracture, determines a chip seal's propensity to damage by stopping or turning traffic. The specification should require that 75% of the aggregate particles have at least two fractured faces. Rounded aggregates, as indicated by low percent fracture, are susceptible to displacement by traffic because they provide the least interfacial area between the aggregate and binder. The roundness of the aggregate will determine how resistant the chip seal will be to turning and stopping movements.

Aggregate Toughness and Soundness

Resistance to abrasion, degradation, and polishing will ensure that the selected aggregate remains functional for the expected life span of the chip seal. It is important to use aggregates with good resistance to degradation and abrasion by using a common testing procedure known as the Los Angeles Abrasion Test (AASHTO T96, ASTM C131). Resistance to weathering and freeze-thaw degradation is generally measured by either magnesium sulphate loss or sodium sulphate loss (AASHTO T104, ASTM C88).

Aggregate fracture and abrasion resistance should be determined by the ultimate use. Table 2-2 identifies suitable limits for chip seal aggregates.

Property	Chip Seal Class*		
	I	II	III
Fracture, 1 Face,% min T335	70	85	95
Fracture, 2 Faces, % min T335	60	80	90
Los Angeles Abrasion, max. % loss, T 96	37	35	30
Flakiness Index, max. % FHL T 508	35	30	25

* Class I = ≤ 500 AADT, Class II = 501- 5000 AADT, Class III = > 5000 AADT

Table 2-2 Recommended Fractures and Abrasion Resistance

Aggregate Cleanliness

Dirty aggregates may cause adhesion problems in chip seals. Dust on the surface of the aggregate particles is one of the major causes of aggregate retention problems. Dust is defined as the percentage of fine material that passes the No. 200 sieve. To improve the quality of the material, the percentage of fines passing the No. 200 sieve should be specified as a maximum of one percent at the time of manufacture. Dusty and dirty aggregate ultimately lead to problems with aggregate retention because asphalt binders have difficulty bonding to dirty or dusty aggregate, causing the aggregate to be dislodged upon opening to traffic.

The aggregate should be sprayed with water a couple of days prior to the start of the project. Washing chip seal aggregate with clean, potable water prior to application may assist in removing fine particles that will prevent adhesion with the binder and surface damp chips will assist the binder in wetting the rock, thus increasing adhesion.

Aggregate Type

Major aggregate types include:

- Igneous rocks: Volcanic rocks formed from molten rock. Examples are granite and basalt.
- Sedimentary rocks: Rocks formed by the deposition of layers of material that are subsequently compressed. Examples include limestone, sandstone, and chert.
- Gravel: Formed from the breakdown of any natural rock. Usually found in rivers or waterways. An example is river gravel.
- Sands: Formed from the deterioration of any natural rock. Sands often contain clay or silt and should be washed.
- Lightweight: Formed by heating clay to around 2,200°F in a rotary kiln.   Another lightweight product is slag, a by-product of a metallurgical process derived from manufacturing tin, steel, or copper.

Often the lightweight synthetic aggregate ‘calcined bauxite” offers a high friction surface in high stress areas. Other lightweight aggregates carry the additional benefit of a significant reduction in windshield breakage, but are generally more expensive than natural aggregate and may have high water absorption.

Absorption

Chip seal aggregates that absorb asphalt, will require an increase in the effective application rate of the binder. Unless an increased binder adjustment is made, the chip seal is likely to ravel.

2.3 Binder Selection

Two main binder types are used for chip seal operations – asphalt cements and emulsified asphalts. Binder type varies according to the type of chip seal being used. Whatever binder is used, performance must achieve three conditions:

- The binder should not bleed when applied at the appropriate rate,
- Upon application, the binder needs to be fluid enough to uniformly cover the surface, yet viscous enough to not puddle or run off the pavement, and

- The binder should quickly develop adhesion to the aggregate and to the roadway surface.

Climate and weather play an extremely important role in chip seal binder selection in addition to surface temperature, aggregate, and climate of region during construction operations. One of the most important environmental factors that should be considered is the ambient air and pavement temperature. It is an accepted fact that ambient temperatures at the time of construction closely affect the quality of chip seal. In hot weather, bleeding can be prevented with binder selection directed towards the use of "harder", hot applied asphalts and emulsions. During construction at low ambient air temperatures, or with high humidity, or damp aggregate and pavement surfaces, emulsions are generally believed to be more successful than hot asphalts.

Binders need to provide good adhesion and/or stickiness to adhere to the pavement surface and aggregate. Polymer modified emulsified asphalts usually contain either a styrene butadiene rubber (SBR) latex or a styrene butadiene styrene (SBS) polymer although other elastomeric polymers are sometimes used. Polymers improve stone retention during the early life of the treatment and increase the softening point of the binder after it has cured (i.e., the temperature at which the binder changes phase from being primarily solid to being primarily fluid).

Asphalt Emulsions

Asphalt emulsions are a convenient way of handling asphalt. Emulsified asphalts have three primary constituents: asphalt cement, an emulsifying agent, and water. The asphalt cement is suspended in the water with the help of an emulsifier agent.

Emulsions lie between solutions and suspensions. An asphalt emulsion is asphalt particles dispersed in water. It is not a solution because the oil and water are susceptible to separation. Water is the carrier of the asphalt and unless the system is chemically stabilized, emulsions may be subject to settlement or breaking prematurely. The oil is stabilized with an emulsifier to keep it dispersed. For this reason storage and handling are important issues. Over time, emulsions will become coarser and undergo property changes, so to avoid these problems, timely use is recommended and often required.

Anionic versus Cationic Emulsions:

Anionic emulsions have negatively charged droplets and cationic emulsions have droplets which carry a positive charge. Rapid-setting (RS) emulsions set quickly in contact with clean aggregates of low-surface area, such as in chip seals. Medium-setting (MS) emulsions set sufficiently slower and can be mixed with aggregates of low surface area, such as those used in open-graded mixes. Slow-Setting (SS) emulsions will mix with reactive aggregates of high surface area, and are often used in fog seals.

Generally, cationic emulsions outperform anionic emulsions on a chip seal project because they are less sensitive to weather, have inherent anti-stripping qualities, and are electrostatically compatible with more types of aggregate.

Figure 2-1 illustrates material compatibility in general terms along with the associated breaking process.

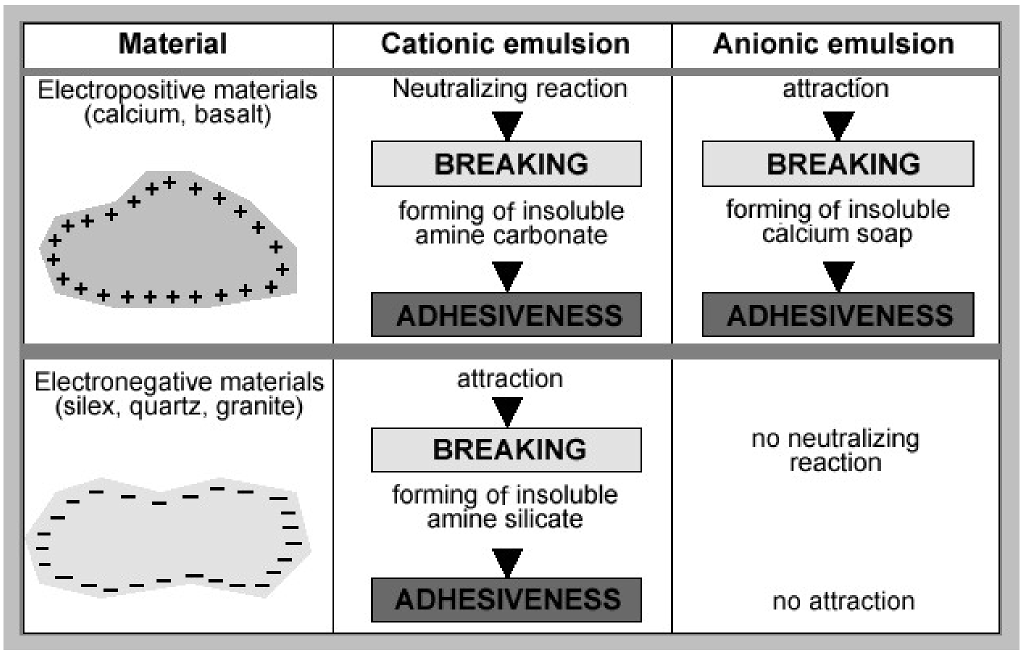

Figure 2-1 Material Compatibility and Reactivity of Emulsions

Cationic emulsions may be formulated for all application types and aggregates as illustrated in Figure 2-2. These emulsions are most useful for rapid setting chip seals because, when a cationic emulsion reacts with compatible aggregates, it creates a stronger adhesive bond. For the same reason, cationic emulsions are also less susceptible to cooler conditions and dampness than anionic emulsions.

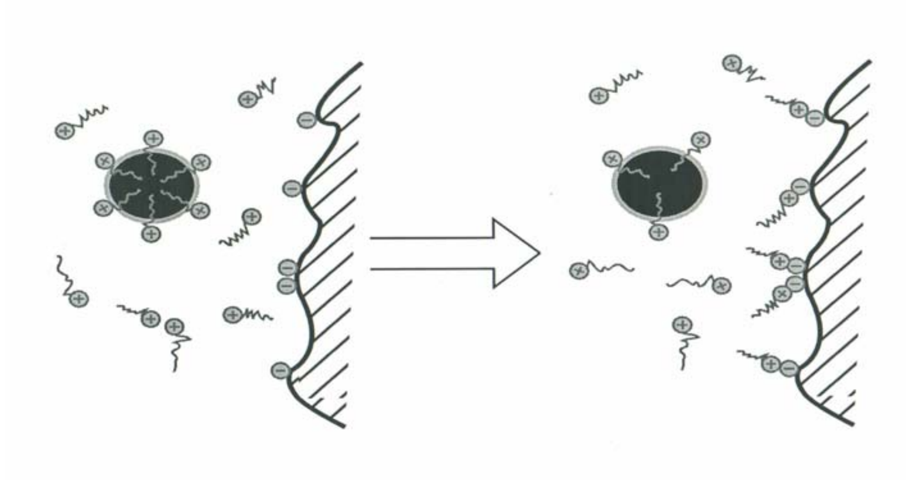

Figure 2-2 Cationic Emulsion Physio-Chemical Reaction with Aggregate

The curing process (illustrated in Figure 2-3) is the same for both types of emulsion (anionic and cationic), except the reaction mechanism for cationic emulsion pushes water away from the aggregate surface. Thus, cationic emulsions tend to cure faster.

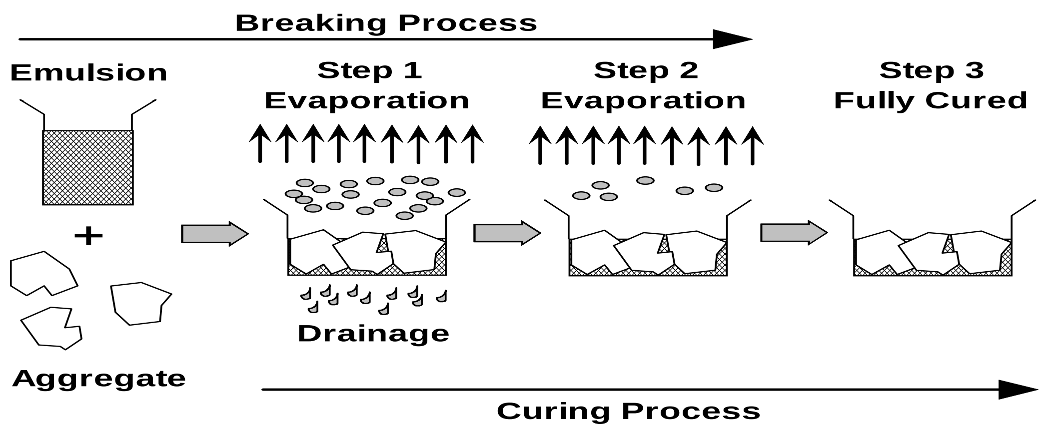

Figure 2-3 Emulsion Break and Cure Stages

High Float Emulsions

High float emulsions are those emulsions that pass the float test (AASHTO T-50, ASTM D-139). High float emulsions allow for a thicker residual asphalt film on the aggregate and this prevents runoff of the asphalt from the surface of the road. The wetting agents used in this type of binder penetrate the dust coating and provide a good bond with the aggregate particles. High float emulsions are designed to work in applications with excessively dirty or dusty aggregates. This type of binder can be used with aggregates having as much as five percent fine material passing the No.200 sieve.

Emulsion Application

Upon application of the asphalt emulsion to the pavement surface, the water evaporates, leaving behind the residual asphalt which bonds with the pavement and aggregate. One of the major concerns with using emulsions is the spreading time of the aggregate after the emulsion is applied. "Breaking" is used to describe the process by which the asphalt expels the water and dries to an integral film / layer on the aggregate. The phenomenon occurs when the water evaporates which is can be seen when the binder's color changes from brown to black. The aggregate chips must be applied and rolled <u>before</u> the emulsion "breaks". This emulsion-specific issue means that excessive delay in the application of the aggregate could jeopardize the ability of the rollers to properly embed the aggregate.

Recommended Temperatures and Handling

By following the rules, potential problems can be avoided:

- **Cold Temperatures**: Do not subject an asphalt emulsion to cold temperatures. When asphalt materials get cold, they shrink. In an emulsion, this means that the asphalt droplets get closer together. This has a number of important consequences. The material can flocculate and may coalesce which could cause the emulsion to settle out more quickly than desirable. For most emulsions, this happens if the temperature falls below 40°F.
- **Hot Temperatures**: Overheating an asphalt emulsion will lead to major problems. When water gets hot, its evaporation rate increases enormously. If the water evaporates, the droplets get closer together and can result in an emulsion reverting back to water and asphalt by the action of flocculation and coalescence. If any part of the emulsion gets hotter than 203°F, localized boiling may occur. When this happens, the droplets fuse back into asphalt. The risk of fusing necessitates the following precautions:
    1. Emulsions should only be heated gently and according to specifications,
    2. Use agitation while heating,
    3. Warm pumps before use,
    4. On bulk tanks in cold areas, use electrical heating if possible, and
    5. Do not use fire or a blowtorch to apply direct heat to emulsions.
- **Transporting:** Emulsions are generally stable enough to transport. However, a common problem arises when air enters the emulsion. Air can cause the emulsion to break in the bubbles of air; cationic

rapid set (CRS) emulsions are particularly prone to break in this way. These larger particles can “seed” the emulsion, causing settlement. Problems also arise when transport tanks are not clean. Mixing cationic and anionic emulsions can lead to breaking of the emulsion.

The points made for storing asphalt relate equally to the storage of an emulsion. When an emulsion is stored, it has a finite lifetime which is determined by its formulation, handling and storage.

2.4 Field Applications of Emulsion

For emulsions, cleanliness is very important. A sloppy operation will produce problems. When an emulsion comes in contact with air, it can begin to break. When a cationic emulsion comes into contact with metal, it can begin to break. Thus, if pump or spray bar nozzles are not properly cleaned after use, they will clog. If lines are left partially full of emulsion, they may clog. The higher the performance of the emulsion, the more critical it is to clean the equipment. Before any emulsion equipment is stored, it should be thoroughly cleaned. Specific guidelines include:

- Flush equipment including hoses thoroughly with WATER,
- Flush equipment and hoses with kerosene, NOT diesel fuel, distillate or other solvents. While these materials may dissolve asphalt, they are also incompatible with the emulsion and may cause the emulsion to break rather than be flushed away. *NEVER FLUSH INTO THE EMULSION TANK,* and always finish with a second flush using water,
- If a pump or line is already clogged with asphalt, apply gentle heat only at the blockage. Do not apply heat to the lines, as this will break the emulsion. Soak pumps with kerosene for an hour or more.

Rust, dirt, grass, or other foreign material should be kept out of the emulsion. This is especially important when working with cationic emulsions as they can break by reacting with foreign materials.

The main transport requirements are to ensure that correct pumping is performed and that pumps are warmed in cool climates. Clean tanks should be used or a switch-load process should be followed. With switch loading, materials are transported in tanks that last carried a compatible material and therefore, tanks need not be cleaned between materials. Always pump into clean tanks and always transport full containers.

Aggregate-Binder Compatibility

Adhesion between the aggregate and binder is governed by a number of variables, of which aggregate type is the most important. The adhesion between aggregate and binder depends on mechanical, chemical, and electrostatic properties such as aggregate dust, moisture content, and binder temperature. Different types of aggregate are better suited to certain binders as a result of electrostatic charges. Basically, the binder and aggregate must have opposite charges. If this does not occur, the binder will not form a strong bond with the aggregate, and it will ravel.

Emulsifiers may have a negative charge (anionic), a positive charge (cationic), or no charge (nonionic). Critical factors include emulsion pH, binder content, particle size / distribution, and compatibility with aggregates.

Before construction, it is essential to conduct laboratory testing to determine the compatibility between the aggregate and the binder. An anti-strip test, such as ASTM D1664 (AASHTO T-182) will assist in determining the compatibility between the aggregate and binder

2.5 Emulsified Asphalt Specifications

Current AASHTO designated standard specifications for emulsified asphalts are:

- M 140-14 for Emulsified Asphalt
- M 208-01 (2014) for Cationic Emulsified Asphalt
- M 316-14 for Polymer-Modified Emulsified Asphalt

Tests related to asphalt properties are listed below:

- M 320, Performance-Graded Asphalt Binder
- T 40, Sampling Bituminous Materials
- T 49, Penetration of Bituminous Materials
- T 50, Float Test for Bituminous Materials
- T 59, Emulsified Asphalts
- T 72, Saybolt Viscosity
- T 228, Specific Gravity of Semi-Solid Asphalt Materials
- T 301, Elastic Recovery Test of Asphalt Materials by Means of a Ductilometer

Emulsion tests:

- Binder content is best measured by the low-temperature evaporative technique (AASHTO PP72),
- Viscosity indicates the application properties (whether the emulsion can be pumped and sprayed) and whether it will remain where it is applied without running off. The viscosity of an emulsion is related to the binder content within the emulsion as shown in Figure 2-4.

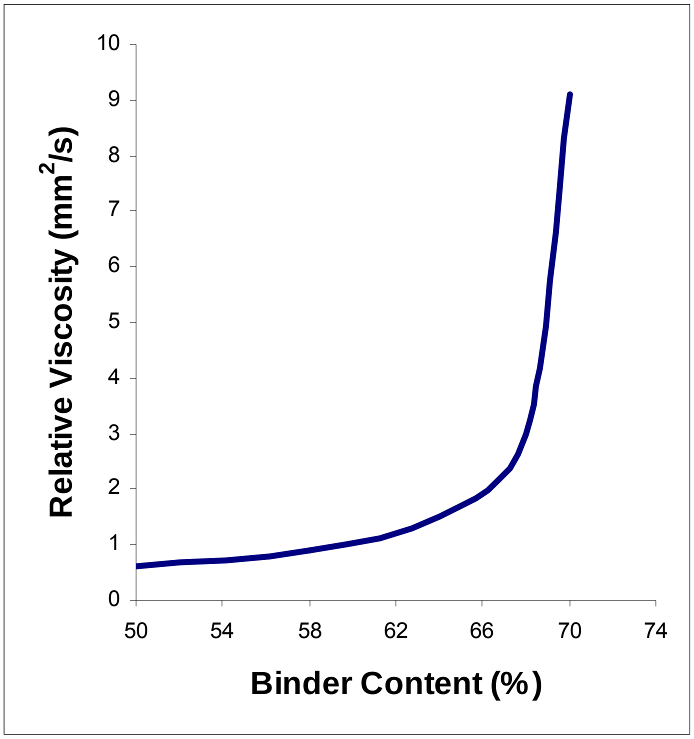

Figure 2-4 Relative Viscosity vs Binder Content

- Settlement and storage stability determine whether an emulsion can be stored without breaking in the storage container. Settlement is an indication that the emulsion could break in storage. Settlement is shown in Figure 2-5.

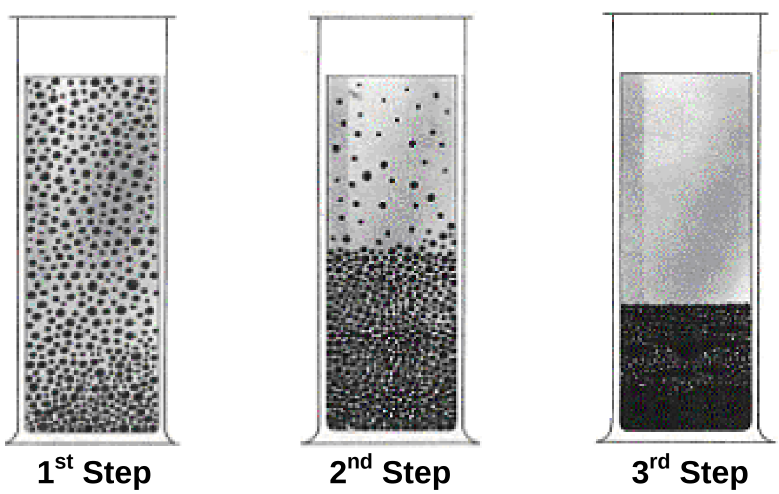

Figure 2-5 Settlement and Storage Stability Test

- Demulsibility is the measure of an emulsion's resistance to breaking and gives an idea of whether the emulsion is rapid or slow setting.
- The sieve test is a measurement of quality and stability of the emulsion. The retention of an excessive amount of asphalt particles on a sieve indicate that problems may occur in the handling and application of the material. In the sieve test, a representative sample of asphalt emulsion is poured through a No. 20 (850 μm) mesh sieve cloth. For anionic emulsions, the sieve and retained asphalt are rinsed with a mild sodium oleate solution then with distilled water. For cationic emulsions, distilled water only is used for rinsing. After rinsing, the sieve and asphalt are dried in an oven and the amount of retained asphalt is determined by weighing. The sieve test is shown in Figure 2-6.

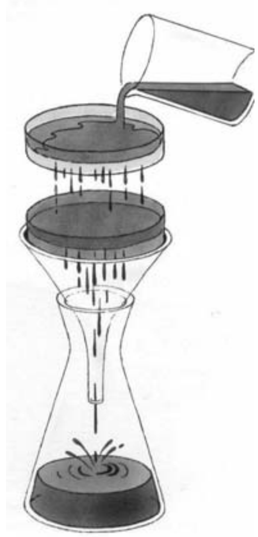

Figure 2-6 Sieve Test

2.6 Materials Selection Conclusions

The selection of chip seal materials is project-dependent, and the agency and contractor must fully understand not only the pavement and traffic conditions but also the climatic conditions under which the chip seal will be applied.

Materials in successful chip seals focus upon using:

1. A uniformly graded, high quality aggregate. Lightweight aggregate can be considered in areas where post-construction vehicle damage is a major concern.
2. Polymer-modified emulsified asphalts. The enhanced chip seal performance provides a significant benefit.

SESSION 3: DESIGN

3.1 Chip Seal Design Methods

Chip seal design practices largely fall into two fundamental categories: empirical design based on past experience and design based on some form of engineering algorithm.

A contemporary chip seal design process involves the determination of grade, type, and the application rate for a bituminous binder when given the aggregate size and type, surface condition of existing pavement, traffic volume, and actual type of seal being placed.

Today, there are two generally accepted chip seal design methods in use in North America: the Kearby method and the McLeod method. The McLeod method is most commonly used to design chip seals and assumes that 70% of the voids in the aggregate must be filled (i.e., 70% embedment).

The McLeod method also assumes the use of a cubical, single-sized aggregate. The main modification for graded aggregates is determining a median aggregate size (50% passing). The aggregate shape must also be examined; this is done by measuring the flakiness index. The average least dimension (ALD) can then be determined by Equation 3-1:

Equation 3-1

$$H = \frac{M}{1.139285 + 0.011506(FI)}$$

where: H = Average Least Dimension (ALD) (inches or mm)

M = Median Particle Size (inches or mm)

FI = Flakiness Index (percent)

ASTM C29 is used to measure the loose unit weight. This approximates the voids in the loose aggregate when it is dropped onto the pavement. The voids in this state are 50% for cubical, single-size aggregate and lower for graded aggregate. It is assumed that once rolled, a cubical aggregate will reduce its unit weight to a point where the voids content is 30% and finally to 20% once subjected to traffic. These assumptions are adjusted when using graded aggregates. Figures 3-1, 3-2, and 3-3 illustrate the average least dimension (ALD) concept, along with the effects of flakiness and void changes due to compaction.

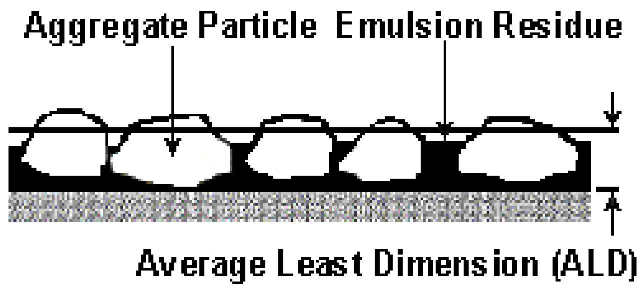

Figure 3-1 Illustration of ALD

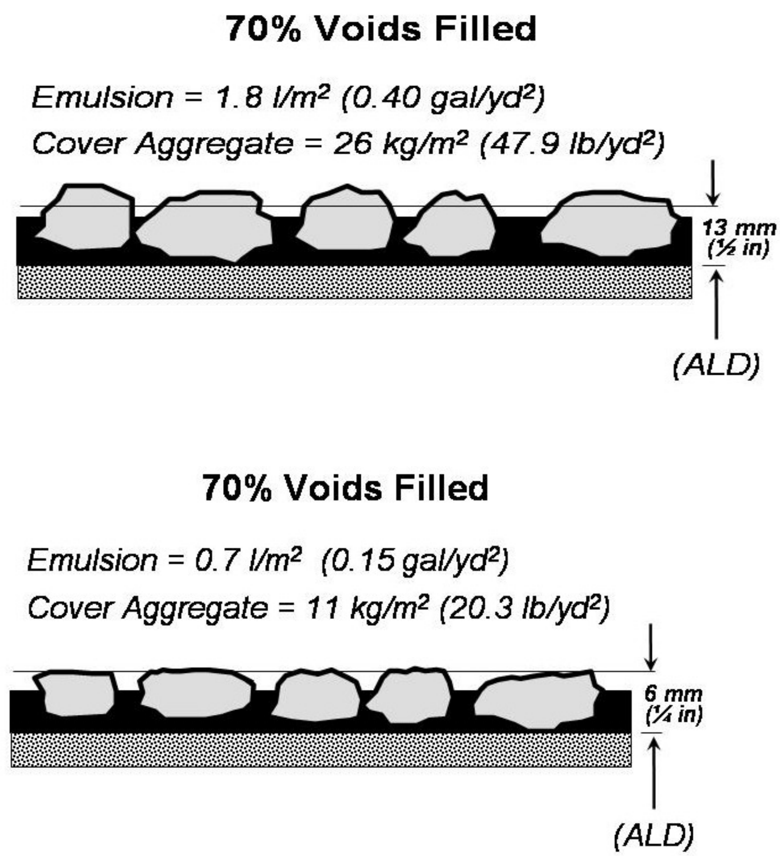

Figure 3-2 Illustrations of Flakiness of Aggregates

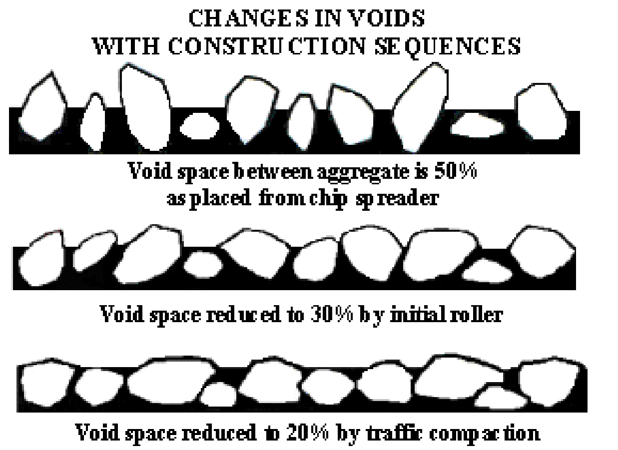

Figure 3-3 Effects of Compaction on Voids in Cubical Aggregate

Empirical Methods (Past Experience)
The main reason for this approach is the variable nature of existing asphalt pavement surfaces. Factors, such as transverse and longitudinal texture differences, affect the ultimate performance of a given chip seal and are in fact independent of the design parameters, thus creating a controversy as to whether a formal design procedure is really an exercise in pointless computation.

Agencies which predominantly use empirical methods are effectively basing their designs on the assumption that the chip seal contract merely specifies a base rate for binder and aggregate application, and thus, the "design" is mainly used to estimate the required quantities to be used during the bidding phase.

3.2 Chip Seal Design Practices

The selection of a pavement for a chip seal project is based on the structural soundness of the pavement and the types of distress that are present. Recognizing that a chip seal can best address only certain types of pavement distresses is paramount in project selection.

To accomplish the chip seal design in accordance with the formal methods, the engineer must first determine the following input characteristics:

- Surface texture,
- Traffic conditions: volume, speed, percent of trucks, etc.,
- Climatic and seasonal characteristics,
- Selection of chip seal type, and
- Selection of aggregate.

The above inputs then form a basis for determining an appropriate binder application rate.

Surface Texture Evaluation

Surface texture refers to the surface properties of the asphalt pavement surface. Surface texture is a measurement which influences the nominal size of aggregate used for the chip seal and thus, ultimately determines material application rates, skid resistance, and road noise.

Characterization of the pavement's surface texture is a critical step in the design process to select a binder application rate.

A suitable test procedure for determining the texture depth is a method called the Sand Patch Method, also known as the Sand Circle Test (ASTM E 965). This method is a procedure for determining pavement surface macro-texture through spreading a predetermined volume of sand or glass bead material on the pavement surface of a given area. Ensuing calculations of the volume of material that fills the surface voids determine the surface texture. The principle exemplified by this method is straightforward, the greater the texture depth, the greater the quantity of sand or glass beads that will be lost in the surface voids.

Also of importance is the significance of characterizing surface hardness, enabling selection of the chip seal's aggregate based on its expected embedment depth into the underlying pavement.

Traffic Conditions

Having a fundamental knowledge of local traffic volumes and conditions is essential for determining the appropriate binder design rate. When traffic volume is used as a chip seal design criterion, the percentage of heavy vehicles should be considered. This may be done by calculating ADT and then using an adjustment factor for heavy vehicles. Typically, higher traffic volumes reduce binder application rates. This is because the heavy traffic will continue to embed that aggregate into the underlying surface after the road is opened to traffic.

Additionally, areas where there is a lot of starting, stopping, and turning movements also deserve special consideration. These movements all serve to exert forces on the aggregate that cause it to roll, changing its position in the binder and often exposing the previously embedded surface which is covered in asphalt. This condition reduces the road's skid resistance and makes it prone to bleeding.

Climatic and Seasonal Characteristics

Emulsions are thought to be more appropriate than asphalt cements when done during warm weather construction when ambient temperatures are higher, as well as areas where the aggregate may be damp.

The designer must also specify the temperature ranges and weather conditions in which chip seal construction is permitted. Finally, the need to apply all types of chip seals in the warmest, driest weather possible cannot be overemphasized. All of the seal types protect the pavement from environmental deterioration and traffic wear.

Single Chip Seal

A single course chip seal is the most common type of seal. It is constructed from a single application of binder followed by a single application of graded aggregate. Single course chip seals are selected for normal situations where no special considerations would indicate that a special type of seal is warranted. The chip seals are used to provide new skid resistant wearing surfaces, arrest raveling, and seal minor cracks. Figure 3-4 shows a single chip seal application.

Figure 3-4 Single Chip Seal

Double and Triple Chip Seals

A double or triple chip seal is a built-up seal consisting of multiple applications of binder and aggregate. These seals are constructed by spraying an application of binder, spreading a layer of uniformly graded aggregate, rolling the aggregate for embedment, then repeating the procedure by applying an additional application of binder, spreading another layer of aggregate (approximately half the average least dimension of the base coat aggregate), and rolling. Sweeping should always be done between applications. This process may be repeated, as necessary, to build up a pavement's edges. Multiple course chip seals are used where a harder wearing and longer lasting surface treatment is needed. They have less traffic noise, provide additional waterproofing, and are more robust seals in comparison with a single chip seal. Multiple course chip seals are used in high stress situations, such as areas with a high percentage of truck traffic or on steep grades. Figure 3-5 illustrates a double chip seal application.

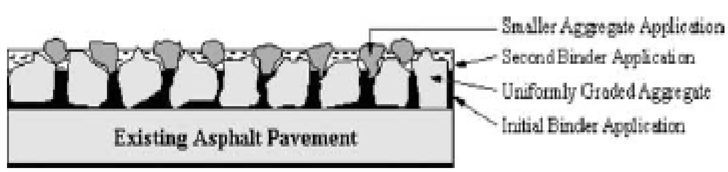

Figure 3-5 Double Chip Seal

The design of multiple course chip seals is based on the same concepts as the single chip seal. First, a design is performed for each layer as if it were the only layer in the system. Next, the following three additional rules are applied: 1) the maximum nominal top size of each succeeding layer of cover aggregate should be no more than half the size of the previous layer's aggregate; 2) no allowance is made for wastage; and 3) except for the first application, no correction is made for the underlying surface texture. The amount of binder determined for each layer of aggregate are added together to calculate the total binder requirement. For two-layer (double) chip seals, 40% of the total binder requirement is applied for the first layer of aggregate and the remaining 60% is applied for the second layer.

Aggregate Selection

The selection of the specific aggregate essentially establishes the thickness of the chip seal as this type of surface treatment is intended to be literally one stone thick. The most common nominal sizes range between ⅜ inch (9.5mm) and ½ inch (12.7mm). As the nominal aggregate size increases, the surface texture becomes coarser with a resultant increase in road noise and ride roughness. Additionally, the potential for windshield damage due to dislodged pieces of aggregate increases as the size of the aggregate increases. For the best success the following desirable characteristics of aggregate include:

- Particle size: ⅜ inch,
- Overall gradation: Single-sized,
- Particle shape: Cubical,
- Cleanliness: Less than one percent passing the No. 200 sieve,
- Toughness (resistance to abrasion): Abrasion below 30%.

The aggregate essentially protects the binder and the designer should use life cycle cost analysis rather than simple comparative pricing to determine if a high quality aggregate is economically justified.

The voids in loose aggregate may be calculated using Equation 3-2:

Equation 3-1 $$V = 1 - \left[\frac{W}{62.4G}\right]$$

where:

V = Voids as a Fraction of the Aggregate Volume

W = Loose Unit Weight of the Aggregate (in ASTM C 29) (lb/ft³)

G = Bulk Specific Gravity of the Aggregate (usually determined from local information or measured)

For projects in areas maintained by snowplows, the binder content is calculated using both the median particle size and the ALD. The average of these two results is used as the starting application rate in these areas.

Calculation of the design aggregate application rate is based on determining the amount of aggregate needed to create an even, single layer of chips on the pavement surface. The amount of cover aggregate required can be determined using Equation 3-3:

Equation 3-2 $$C = 46.8(1 - 0.4(V))(H)(G)(E)$$

where:

C = Cover Aggregate Application Rate (lb/yd²)

V = Voids as a Fraction of the Loose Aggregate Volume

H = ALD – (See Equation 3-1)

G = Bulk Specific Gravity

E = Wastage Factor for Traffic Whip Off (1 + fraction wasted)

Equation 3-1 is used to calculate H (average least dimension) and Equation 3-2 is used to calculate V (voids in loose aggregate). The bulk specific gravity of coarse and fine aggregates, G, can be determined using the ASTM C 127 and C 128 methods, respectively. The wastage factor (E) is to account for whip-off and handling and is normally estimated by the designer based on experience with local conditions. While other design methods are available, Equation 3-3 provides a good starting point and covers most situations. It requires the user to consider the attributes of the pavement surface being sealed and the conditions to which it will be subjected, both of which are very important.

Binder Application Rate

The previously outlined design methodologies all determine a basic binder application rate which typically depends on the average least dimension of the aggregate and type of chip seal being used. Intuitively, larger sized aggregates require additional binder to achieve the optimum embedment. There are different schools of thought with regard to embedment. One approach is to seek to achieve approximately 50% embedment after rolling and thus leave room for traffic to "finish" the process by further embedding the aggregate after the newly chip sealed road is opened. This approach strives to avoid bleeding in the wheel paths by leaving room for the additional embedment during the chip seal's service life. *The major disadvantage of this approach is that the aggregate outside the* *wheel paths is prone to be dislodged by traffic movements across the lane's width*.

The other school of thought is to achieve an embedment of up to 70% after rolling (embedding) across the entire road width. This approach will adjust the binder application rate based on the measured or perceived surface hardness and account for this in the design. This school is on guard against aggregate loss and may leave the road in a condition where it is prone to bleeding if the design calculations do not exactly match the existing surface.

The design binder application rate is calculated after considering a number of correction factions or allowances to the basic binder application rate. Typical adjustments are based on traffic characteristics, surface texture, aggregate absorption characteristics, and surface hardness. Typically, binder application rates are reduced where large or heavy traffic volumes are expected to considerably reorient and embed the aggregate after final rolling. The binder application rate may also be adjusted depending on the existing pavement surface texture. It is necessary to increase the application rate on pocked, porous, or oxidized surfaces because such textures will absorb more binder. In contrast, it is necessary to decrease the binder application rate on surfaces that are exhibiting susceptibility to bleeding, or are not pocked, porous or oxidized. Surface hardness, as measured by the ball penetration test or a penetrometer, characterizes the likely depth of aggregate embedment into the underlying pavement.

For chemically modified crumb rubber asphalt (CMCRA) the typical binder application rates of 0.55 - 0.65 gal/yd^2 are used. For asphalt rubber seals, the binder application rate is significantly higher compared with the base application level calculated for an unmodified binder. The higher binder rates are possible due to the higher viscosity of these binders.

In chip seal design, the residual binder application rate is the most important factor affecting seal performance. Enough binder must be present to hold the aggregate in place, but not so much that the binder fills, or is forced by traffic action to cover the aggregate. The proper amount of binder ensures that the desired surface texture is maintained. Chip seal design is not like hot mix asphalt design, in that film thickness is not as applicable of a concept. Binder application rates are determined based on the average least dimension of the aggregate, as well as other aggregate properties such as shape, density, absorption and gradation. The optimum binder content also depends on how much binder flows into existing voids in the pavement, and how much binder is already present at or near the pavement surface.

Most design methods calculate the specific requirements for each job by considering the required corrections in addition to the basic application rate (Equation 4 shows the rate designed to result in 70 percent embedment). One method for estimating the binder content is to use Equation 3-4:

Equation 3-3

$$B = \frac{[(2.244)(H)(T)(V) + S + A]}{R}$$

where:

B = Binder Application Rate (gal/yd^2)

H = Average Least Dimension (ALD) (inches) – (See Equation 3-1)

T = Traffic Factor – (See Table 3-1)

V = Voids in Loose Aggregate (decimal percent) – (See Equation 3-2)

S = Surface Condition Factor (gal/yd^2) – (See Table 3-2)

A = Aggregate Absorption Factor (gal/yd^2) – (If necessary)

R = Residual Asphalt Content of Binder (Decimal percent)

Vehicles / Day	0-100	101-500	501-1,000	1,001-2,000	>2,000
Correction Factor	0.85	0.75	0.70	0.65	0.60

Table 3-1 Traffic Factors

EXISTING PAVEMENT	CORRECTION (l/m^2)
Black, flushed asphalt	-0.04 to -0.27 (Depending on severity)
Smooth, non-porous or smooth	0.00
Slightly porous and oxidized or matte	+0.14
Slightly pocked, porous, and oxidized	+0.27
Badly pocked, porous, and oxidized	+0.40

Table 3-2 Correction Factors Associated with Existing Road Conditions

Aggregate will absorb some of the binder when applied to the pavement. It is important to correct for aggregate absorption. Aggregate such as granites, quartzite, basalts, trap rocks do not need a correction factor. Limestone and gravels should use the absorption correction factor of 0.02 gal/yd^2.

3.3 Chip Seal Design Conclusions

First, the selection of the binder is a very important decision and should be made after considering all the factors under which the chip seal is expected to perform. After all, the primary purpose of a chip seal is to prevent water intrusion into the underlying pavement structure; and the asphalt layer formed by the binder is the mechanism that performs this vital function.

The previously explained design methods are all based on the assumption that chip seal design requires the use of uniformly graded aggregate spread one-stone thick in a uniform manner. The application rates of all methods appear to be based on residual binder, and each method has a procedure for dealing with adjustments due to factoring the loss of binder to absorption by the underlying pavement surface and the aggregate being used. Contemporary design practices need to determine binder application rates based on surface characterization, absorption factors, traffic conditions, climate considerations, aggregate selection, and type of chip seal being constructed. Another important observation was that all the design methods had an aggregate embedment objective of between 50 to 70 percent of the seal's depth.

SESSION 4: EQUIPMENT

4.1 Introduction

Major equipment types used on a chip seal project will include: asphalt distributors, aggregate (chip) spreaders, rollers, dump trucks, and sweepers or vacuums.

4.2 Asphalt Binder Distributor

The asphalt binder distributor is the primary piece of equipment in the chip seal process. Its function is to uniformly apply the binder over the surface at the designed rate. Typically, spray distributors (boot trucks) are truck mounted, but trailer units have also been used. A distributor should have a heating, circulation, and pumping system, with a spray bar, and all controls necessary to guarantee proper application.

Further review of a distributor necessitates particular attention to the distributor components, production characteristics, controls, calibration, and spraying operations. The binder distributor has gone through some significant technological advances, such as parallel spray bars (also called wheel path bars) that enable variable spray rates across the lane. Particular attention should be paid to the binder distributor, especially on the use of variable nozzles and multiple spray bars.

Distributor Components

- Insulated asphalt tank,
- Heating system and circulation pump,
- Spray bar and nozzles,
- Distributor controls and gauges.

Insulated Tank

The binder distributor's tank must be capable of efficiently storing the binder at temperatures that allow the heated binder to remain consistent with the appropriate viscosity for spraying operations and within the design specifications. Most of the asphalt binder distributor tanks used for chip seal work hold from 1,000 to 4,000 gallons of liquefied asphalt. They should be equipped with baffles to prevent pressure surges due to the asphalt sloshing in the tank upon starting and stopping.

Heating System and Circulation Pump

Depending upon the make and size of the binder distributor, either one or two burners are used. These burners are supported at the rear of the tank, and positioned with a configuration that directs the flames into the insulated tank's flues. A constant volume circulation pump maintains a pressurized system so that the binder can be uniformly heated. The circulation pump must also spray at a constant volumetric rate for the entire length of the spray bar for each application. In addition, the pump enables the distributor operator to load the tank with binder from a storage tank.

Spray Bar and Nozzles

Figure 4-1 features a typical binder distributor spray bar. Many different bar widths are available, from 12 feet wide to spray bars as wide as 24 feet.

Figure 4-1 Distributor Spray Bar

Spray bars connect a series of evenly spaced nozzles along their length. Nozzles are manufactured with different sized openings to permit delivery at different volumetric rates from the same pump pressure. The nozzles control the spray pattern of bituminous binder shot from the distributor.

Appropriate selection of nozzles is critical to achieving a consistent and accurate spray pattern. Nozzles with larger openings need to be considered for more viscous asphalts such as crumb rubber binders. One may be able to modify the spray bar on the asphalt distributor so that it has smaller nozzles in the wheel paths, a practice which results in more binder in the non-traffic areas than in the traffic areas. The nozzles are installed in the spray bar so that the fan-shaped spray is at the proper angle to the axis of the spray bar. The angle varies from one manufacturer to the next. Figure 4-2 illustrates this angle which ranges from 15 to 30 degrees, depending upon the manufacturer. All nozzles must be set at the same angle to avoid distortion of the spray pattern.

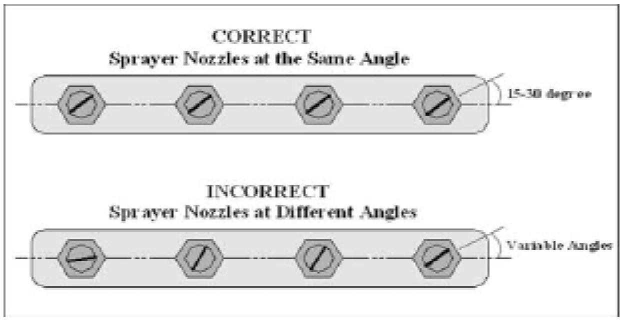

Figure 4-2 Spray Bar Nozzle Alignment

The spray bar and nozzles are designed to provide an appropriate fan width to ensure uniform transverse distribution, without any corrugation or streaking. Chip seal projects require triple lap coverage as shown in Figure 4-3. The advantage of triple lapping is that it ensures a uniform distribution of binder across the shot width and that no areas are missed. However, to do so, the spray bar must be adjusted to the correct height or the spray pattern will become distorted. A spray bar with a positive shutoff called a "cut-off valve," will avert problems with nozzle dribbling. This is particularly important on the end nozzles which might also be equipped with a deflector to develop a sharp edge on each side of the shot.

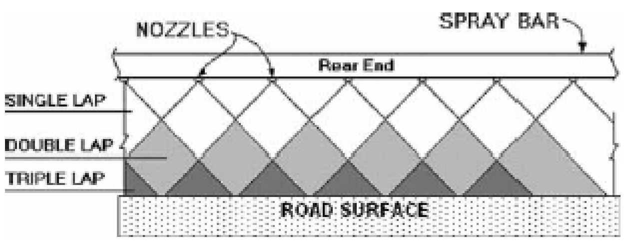

Figure 4-3 Spraying Lap Coverage

Binder Distributor Controls and Gauges

Typical controls and gauges include tachometers, volume measuring devices, pressure gauges, and a thermometer. In addition, all distributors should require ground speed control which regulates the pressure of the material to compensate for the speed of the vehicle. Newer distributors have computerized controls that allow the operator to make accurate rate adjustments, adjust the spray bar height and width, and even shut-off individual spray bar sections from the cab.

4.3 Distributor Calibration and Adjustment Checks – The following steps are necessary to prepare the distributor(s) prior to the project.

1. Check the distributor spray bar's transverse alignment to ensure it is closely perpendicular to the centerline of the pavement.

2. Blow air through the spray nozzles to ensure that there are no blockages. Each nozzle opening (orifice) can wear over an extended period of time, and if not changed it will not deliver the desired rate of asphalt emulsion. There are many types of nozzles and each type has a specific application. Follow the nozzle manufacturer's recommendation for proper nozzle selection.

3. Check and if necessary, adjust the nozzle angles to ensure that they spray at an angle of from 15 to 30 degrees from the spray bar axis. Often, the outer-most nozzles will be turned in to give a sharp edge with no over spray.

4. Check the distributor spray bar height. The height is usually set so that a triple overlap is obtained. This adjustment process is accomplished by shutting off the appropriate nozzles to determine where the spray pattern contacts the pavement. Every two nozzles should be turned off for every one that is left on for a triple lap application. The distributor operator should spray emulsion onto the pavement surface for a short distance and observe where the left open nozzles hit the pavement. Emulsion overlaps indicate the bar is too high and a gap indicates the bar is too low.

5. Check the asphalt emulsion temperature to ensure it is in the appropriate range for proper application. Chip seal emulsion should be between 105°F and 185°F. It is best to follow the manufacturer's product temperature recommendation.

6. Calibrate the binder distributor by spraying a pre-weighed area of roofing felt and subtracting the initial weight from that of the sprayed felt, then dividing the difference by the area of the felt. This is the responsibility of the contractor and the inspector should verify that the distributor is spraying the binder at the correct application rate.

7. Ensure that an adequate supply of binder is available for the day's operation.

4.4 Aggregate Spreader and Calibration Adjustments

A self-propelled aggregate spreader is equipped with a receiving hopper in the rear, belt conveyors to carry the aggregate to the spreading hopper, and a spreading hopper with adjustable discharge gates to apply an even, uniform layer of aggregate across the full width of the sprayed binder. These spreaders can be equipped with variable width spreading hoppers that will hydraulically extend to adjust to changing binder widths, such as a shoulder widening. Most manufacturers offer chip spreaders equipped with computerized controls that allow the gates to open and close hydraulically, to compensate for the speed of the spreader. This ensures a constant application rate, regardless of travel speed. Some models also come equipped with a vibratory hopper that further improves the uniformity of the discharge.

Chip spreaders must be able to spread an even coating of aggregate one chip particle thick over the entire binder sprayed surface. Figure 4-4 shows a typical chip spreader.

Figure 4-4   Aggregate Spreader

Before applying aggregate on a project, the following steps should be taken:

1. Ensure that all gates in the spreader open correctly.

2. Calibrate the spreader by spreading chips over a pre-weighed mat and subtract the initial weight from that of the mat with chips spread onto it. Then, divide the net weight of the stone by the area of the mat (suggest having the carpet 1 yard wide). Although this is the responsibility of the contractor, the inspector should verify that the spreader is applying the aggregate at the correct application rate.

3. Ensure that the spreader applies the aggregate in an even layer, one chip deep.

4. Ensure that the spreader is not leaving piles of aggregate or is not spreading an excessively thick layer, which can result in the aggregate being crushed under rollers or by traffic, compromising the final chip seal. An excessively thick layer of aggregate can also result in a lever and wedge effect, which compromises the quality of the chip seal as well. (See Figure 4-5.)

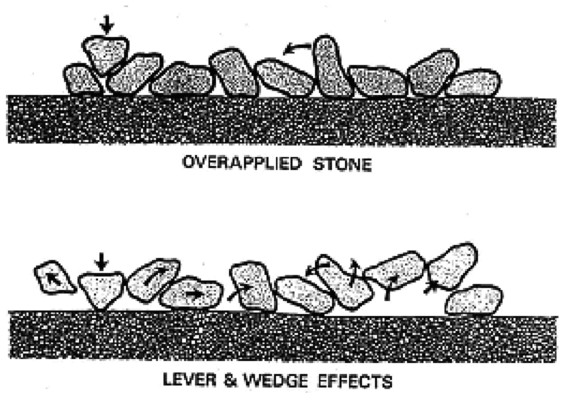

Figure 4-5 Lever and Wedge Effect

5. Ensure that an adequate supply of aggregate is available before applying the binder.

4.5 Dump Trucks

A sufficient number of dump trucks should be available to avoid any interruption in the supply of chips to the aggregate spreader. The dump trucks used on nearly all chip seal projects have tandem axles. Tandem-axles are preferred because their increased capacity requires fewer hook ups, resulting in less chance for spillage and a more efficient operation.

The dump trucks used for transporting the aggregate need to be compatible with the aggregate spreader, meaning that their hitches must match and that the dump bed will not damage the aggregate spreader's receiving hopper. Compatibility of the dump truck's bed is essential to ensure that aggregate is not spilled between the aggregate spreader and the dump truck, as illustrated in Figure 4-6. Dump trucks are sometimes equipped with aprons to ensure that the aggregate is effectively dumped into the aggregate spreader's hopper.

Figure 4-6 – Proper Connection

Tires on the trucks should be examined for binder pick up which could severely damage the mat. Tires should be cleaned and sanded. Trucks should not drive on the new surface unnecessarily and should never brake sharply. When driving on the fresh mat, wheel paths should be staggered to assist in embedding the aggregate uniformly. When pulling away from the spreader, trucks should move smoothly and slowly to prevent wheel spin and mat damage. Trucks should not be allowed to lose or dump chips when pulling away from the chip spreader. No sharp turning movements or high speeds should be allowed on a newly constructed chip seal.

4.6 Pneumatic Rollers

For all practical purposes, pneumatic (rubber-tired) rollers are being universally utilized in chip seal construction. Pneumatic rollers exploit the machine's weight per unit area of surface contact to provide the forces needed to embed the aggregate firmly in the binder. Pneumatic rollers are capable of ballast loading, either with water or sand, which allows the weight of the machine to be varied from 6 to 8 tons to achieve the specified minimum contact pressure of 80 lbs/in^2. The alignment of the axles is such that the rear axle tires, when inflated to the proper pressure, can compact the voids untouched by the front-axle tire, shown in Figure 4-7. All tires shall be as supplied by the roller manufacturer.

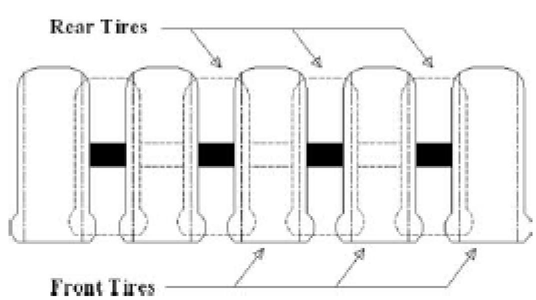

Figure 4-7 Pneumatic Roller Tire Configuration

4.7 Sweeping Equipment

There are two main sweeping tasks on a chip seal project: cleaning the existing road surface of dust and foreign materials, and removing excess aggregate from constructed chip seals. Three types of sweeping equipment are typically used in chip seal construction: rotary (kick) brooms, pick-up sweepers, and vacuum brooms.

Cleaning the existing road surface is done using rotary (kick) brooms or mobile pick-up brooms with nylon or steel bristles. Steel bristles are more successful in removing foreign materials from the existing pavement surface prior to placing the chip seal, but should never be used to broom a new chip sealed surface. The bristles should not be worn, and should be operated in such a manner that thoroughly removes dust and road debris. Figure 4-8 shows a rotary (kick) cleaning operation.

Figure 4-8 Brooming Process, Shown on a Shoulder Seal

Rotary (Kick) Brooms
Rotary brooms, also referred to as kick brooms, are sometimes employed to remove the excess aggregate from the surface of the chip seal. The downward pressure must be kept at a minimum to avoid dislodging the embedded particles. Plastic bristles must be used on a new chip seal because they are less likely to do damage than steel bristles.

The concern with rotary broom is that they can generate a dusty environment and create an air pollution problem. In addition, aggregate wastage that is swept to the side of the road can migrate back onto the driving lanes by either rain or vehicles exiting onto the shoulder.

Mobile Pick-up and Vacuum Sweepers
Mobile pick-up and vacuum sweepers are similar in that they both “remove” the aggregate from the roadway. While both sweepers have hoppers to store the removed aggregate, the manner in which they remove the aggregate makes them different.

Mobile pickup sweepers are generally used wherever dust must be minimized and it is desirable to remove all excess aggregate from the project site. A mobile pick-up sweeper has components that sweep the aggregate to a bristle broom which deposits the material into a hopper. Mobile pick-up sweepers are particularly useful in urban areas for removing accumulated aggregate from gutters or along the edges of the roadway.

Vacuum sweepers remove the excess aggregate through suction only. A vacuum sweeper is shown in Figure 4-9. The lack of contact with the seal's surface minimizes damage and is the preferred method for removing loose aggregate.

Figure 4-9 Vacuum Sweeper

Equipment Conclusions:

- All nozzles on the distributor’s spray bar must be set at the same angle to avoid distortion of the spray pattern. The angle is 15 – 30 degrees depending on the manufacturer.
- The distributor’s spray bar height is adjusted to obtain triple overlap coverage from the nozzles. Drilling patterns or “corn rows” are a result of not having the spray bar adjusted to the proper height.
- The distributor and aggregate spreader must be calibrated prior to beginning a project.
- A minimum of three (3) self-propelled pneumatic-tired rollers should be used on chip seal projects.
- Pneumatic-tired rollers must weigh 6 to 8 tons and have a minimum tire contact pressure of 80 lbs/in^2.
- Plastic bristles should be used for sweeping to reduce aggregate dislodgement.
- Vacuum sweepers minimize damage to a new chip seal.

SESSION 5: CONSTRUCTION

5.1 Introduction

Each phase of construction can impact the overall quality and service life of the chip seal. Important factors include weather conditions, surface preparation, traffic control, binder and aggregate placement, rolling, sweeping, and finishing.

5.2 Project Pre-planning

A project's success depends on the effort expended in pre-planning. Addressing the equipment and manpower needs is an important first step in the planning process. Sufficient time should be spent finding an appropriate staging area as close as possible to the job site.

Safety must be of paramount importance. Roadway work zones are hazardous both for motorists who drive through the complex array of signs, barrels, and lane changes and for workers. The operation of work zones needs to be carefully planned well in advance of the chip seal application.

Equipment

The equipment must be thoroughly maintained and checked to ensure it can operate without breakdown or malfunction. In cases where a breakdown or malfunction unexpectedly happens, once repaired it should operate without further problems for the remainder of the project.

Staging Area

The stockpile site and staging area should contain the following elements:

- A clean and well-drained pad for the aggregate stockpile,
- Space for an emulsion tanker, and
- Space for truck loading and maneuvering.

5.3 Surface Preparation and Traffic Control

Preparation of the surface is critical to the performance of the chip seal. The existing pavement surface should have a uniform texture, smooth ride, and few (if any) minor defects. A non-uniform texture can be corrected by retexturing the surface.

Isolated Failures and Cracks

Areas of the pavement exhibiting isolated structural failures (such as potholes and deteriorated patches) should be addressed by the removal and repair of the failed area. These repairs must be completed well in advance of the chip seal operation. Ideally, patches should be completed 6 months before chip sealing. In heavily patched areas, a light fog seal will assist the contractor in maintaining a uniform binder application rate throughout the project. Finally, the prepared surface must be clean, dry, and free of any loose material before constructing the chip seal.

Avoid the use of cold mix for patching prior to applying the chip seal. Other repairs may consist of surface leveling (HMA scratch course) or crack sealing. Ideally, crack sealing should be completed 3 months prior to chip sealing. Failure to address the deformations and surface cracks may affect the chip seal performance and cause further maintenance problems at a later date. Pavements that require numerous repairs are not suitable candidates for chip sealing.

Existing Structures

Normally, it is not necessary to cover concrete curbs, gutters or sidewalks because the end nozzle on the distributor spray bar can be adjusted or aligned to avoid spraying binder on them.

Cover utility castings (manholes, gate valve covers, catch basins, sensors, etc.) to prevent coating with the binder. Suitable covering includes plywood disks, Kraft paper, roofing felt or other approved materials. Always remove the protective coverings before opening the road to traffic. Protective coverings are shown in Figures 5-1 & 5-2.

Figure 5-1 Protecting catch basin

Figure 5-2 Protecting castings

Raised Pavement Markings and Delineators

Existing pavement markings and delineators should be removed from the road surface prior to applying the chip seal. If it is necessary to keep raised pavement markings in place, then they should be covered to prevent the binder from adhering to the markings. Failure to protect the markings properly will require follow-up cleaning of the markers which can diminish their visibility or reflectivity. Avoid using tape to cover markings, because the adhesive will adhere to the marker surface and will require follow-up cleaning. Also, the thickness of the finished chip seal will affect the visibility and reflectivity of markings. For these reasons, it is best to remove pavement markers prior to placing a chip seal.

Water-based paint markings normally do not require removal from roadways prior to chip sealing. However, it has been found they may require removal if heavy or multiple layers exist on the pavement. Some markings, such as thermal plastic and epoxy, do not allow the binder to adhere well to the surface.

Placing Temporary Pavement Markers
Place temporary pavement markers (reflective or non-reflective) on the road surface, after the road has been cleaned and before binder placement begins to provide visible lane delineations for traffic.

Temporary pavement markers designed for hot-applied asphalt cement binders can also be used for emulsion binders. However, the temporary pavement markers designed for emulsions are not designed for use with hot-applied asphalt cement binders. High material temperatures at which hot-applied asphalt cement binders are applied require the use of high temperature temporary pavement markers. Markers that are designed for use with emulsions will soften when exposed to high temperatures.

Yellow and white temporary (reflective) pavement markers are available to match the color of the existing delineation. For example, the yellow temporary pavement markers are used for the centerline and the white temporary pavement markers are used for lane delineation and some pavement markings (e.g., limit lines, crosswalks). Also, temporary (non-reflective) pavement markers are available to identify the location of specific markings for replacement.

Temporary pavement markers (reflective and non-reflective) come with or without covers (one or two plastic covers). The purpose of the plastic covers is to protect the reflective strip and the vertical portion of the temporary pavement marker from being covered during binder application.

Chip seals that require the subsequent application of a fog seal will need a double-cover temporary pavement marker. The first cover is removed after the application of the chip seal and before traffic control is removed from the roadway, to provide delineation for the motorists. The second cover is then removed after the application of the fog seal and before the traffic control is removed from the roadway.

Traffic Control Plans
The signs, devices and traffic controllers (flaggers) used must match the traffic control plan. The work zone must conform to the agency's requirements. All workers must have all required safety equipment and clothing.

Adequate traffic control is essential and should conform to the requirements of the Manual of Uniform Traffic Control Devices (MUTCD), Part 6. During and after chip seal construction, pilot cars are recommended for use. After construction, they should remain in place for 2 to 24 hours to ensure that traffic speed is limited to approximately 20 mph and to channel traffic into a variety of wheel paths. Opening to traffic should be delayed until cooler times of the day and after a final sweeping removes excess aggregate from the completed work.

Cleaning the Pavement Surface Prior to Construction
A clean and dry surface is critical for the binder to bond to the pavement. Pavement surfaces should be swept immediately before applying the binder. Sweeping is done with a mechanical or vacuum sweeper. If a mechanical sweeper is used, two or three sweeping passes are typically needed.

If the patched areas are generally more porous than the rest of the pavement, a tack coat may be required prior to sealing. Known shaded areas that seldom get sunlight (e.g., under bridge decks) may also need a tack coat to prevent aggregate loss.

Regardless of the method used, the prepared road surface should be free of loose particles, broken asphalt pieces, dirt and all other extraneous material prior to chip sealing.

5.4 Weather

Ideally, the weather during a chip seal project should be sunny, warm, low humidity, with a light breeze. However, few days exhibit ideal conditions, and instead, contractors are restricted to working within the minimum and maximum weather conditions. Thus, a contractor must closely examine the current and forecasted weather prior to constructing a chip seal.

Ambient Temperature
Ambient air temperature should be at least 50°F and rising for emulsions. Temperatures above 100°F can adversely impact the pavement surface temperature.

Pavement Surface Temperature
The pavement surface temperature should at least be 70°F and no more than 130°F. Excessively high pavement temperatures inhibit the binder’s ability to hold the aggregate in place. If the ambient temperature will reach or exceed 100°F on the day of application, the pavement temperature could approach or exceed 185°F, which is too hot to apply an emulsion chip seal.

For hot-applied asphalt cement binders, pavement temperatures can as low as 40°F, but rising.

It is important to adhere to all temperature limitations during application. This holds true for all areas where the chip seal will be applied, including those areas in the sun and shade. Failure to have the necessary minimum temperature in shaded areas will also weaken the bonding of the materials, as shown in Figure 5-3.

Figure 5-3 Resulting Impact of Temperature Variations

Wind
Wind can accelerate the break of the emulsified asphalt and also distort spray patterns when applying the binder. Excessive wind may cause the emulsion spray to be diverted and compromise the uniformity of the application rate, usually resulting in excessive aggregate loss.

Rain
Chip seals should not be applied during any precipitation or when rain is threatened. Chip seals should not be applied when inclement weather is predicted immediately before, during or after placement that could increase the potential for chip seal failure. Rainfall is a major cause of most chip seal failures, as shown in Figure 5-4.

Figure 5-4 Chip Seal exposed to rain within 24-hours of placement

Chip seals should not be applied to wet surfaces, regardless of the cause (rain, irrigation, etc). Wet pavement will affect the bonding of the binder to the pavement surface. Such consequences are shown in Figure 5-5.

Figure 5-5 Irrigation damage to new chip seal

Humidity
High humidity (>50%) will require more time for the emulsion to break and will slow the cure. However, cationic emulsions are less likely to be adversely affected by higher humidity levels.

5.5 Distributor Truck Spraying Operation

Before spraying emulsified asphalt or hot-applied asphalt cement, several important checks must be made on the distributor truck.

- Confirm calibration of the distributor truck,
- Verify the distributor's application rate of the binder,
- Check the spray bar's height and alignment,
- Review the distributor's spray bar coverage and nozzle adjustments,
- Blow out the nozzles,
- Ensure the temperature gage works correctly and binder is at the proper temperature, and
- Verify that the safety warning systems are in working order.

Visual checks should be made throughout the spraying process to ensure that the spray bars are clean and are spraying even fans. There should be no visible streaking of binder on the pavement surface. If streaking occurs, the operation should be stopped to recheck for proper functioning of the spray bar as well as the binder temperature.

Distributor Production Characteristics
Production rate is determined by the distributor's capacity to apply the binder. Other equipment should be matched to the distributor.

Care should be taken with the distributor that the application of binder is maintained within 100 feet of the aggregate spreader at all times. A rule of thumb is never more than a maximum time lag of one minute between the distributor and aggregate spreader.

Distributor Coverage and Alignment
After approximately 15 to 30 minutes of binder application, stop the distributor truck and inspect the sprayed areas to ensure the binder is not moving laterally (running off from where binder was applied). If the binder was formulated correctly, there should not be lateral movement in any area, including steep hills and super-elevations such as shown in Figure 5-6. If lateral movement is occurring, it compromises the adherence of the aggregate and causes chip loss.

Figure 5-6 Binder Runoff

Nozzles
Regularly monitor the distributor truck spray bar for potential problems, which may include clogged or dripping nozzles (when shut off). The spray bar nozzles shall produce a uniform triple lap application fan spray, and the shutoff shall be instantaneous, with no dripping.

Binder Temperature
Read the binder temperature gauge(s) on each distributor truck and confirm the binder temperature is within the recommended range. (Binder outside the specified temperature range can affect uniform application of the binder).

Distributor Measurements
Read the gauge on each distributor truck that indicates the remaining quantity of binder inside the truck. Measure the volume of emulsified asphalt in the distributor using the dipstick supplied with the distributor. Compare the volume in the distributor before and after a minimum of 500 gallons of binder is applied and divide this value by the area over which the emulsified asphalt was applied. The actual rate applied should be within ±5% of the target rate determined from the chip seal design.

Construction Joints
Seamless transverse construction joints at the start and end of spraying should be obtained by beginning and ending chip seal passes on roofing felt or Kraft paper. This ensures that the transverse joints are clean and sharp.

When beginning a new application of chip seal abutting previously placed chip seal, a transverse felt or paper joint shall be used so excess asphalt and chips are not placed at the joint. The transverse paper joint shall be formed by placing a 36-inch wide piece of felt or paper on top of the previously applied chip seal. The edge of the paper should align with the joint that will be formed when the previously placed chip seal meets the newly applied chip seal. The asphalt distributor shall begin applying asphalt emulsion by starting the application on top of the felt or paper. As the distributor moves forward and over the joint the paper shall be removed.

Figure 5-7 illustrates the layout of felt paper at the end of a project lane.

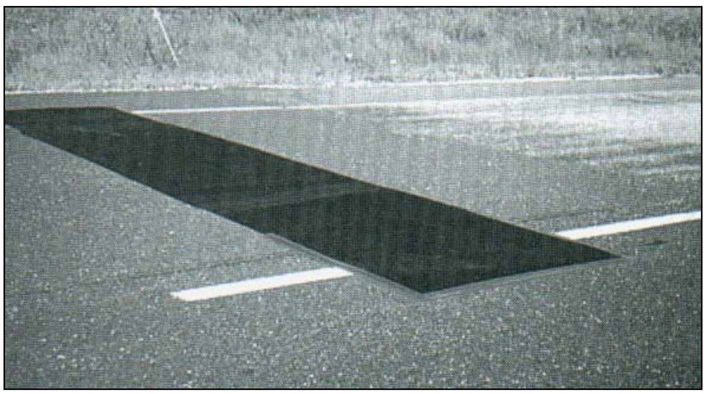

Figure 5-7 Start and Stop Passes on Roofing Felt (Transverse Joints)

The longitudinal construction joint for a single course chip seal must coincide with the painted lane line or at the outside edge of the shoulder. With a double course chip seal, the longitudinal construction joint for the first course shall overlap the painted lane line by 6 inches and for the second course, shall coincide with the original lane line location.

Constructing a longitudinal joint is made with an overlap, but the joint should correspond to a lane boundary rather than falling within a lane. In this process, a wet edge (i.e., one without an application of aggregate) of 3 to 6 inches is left to be overlapped by the adjacent run. The chip distributor then covers the whole run to the pavement's edge. There should be no overlapping layers of aggregate at the longitudinal construction joint for a single application chip seal.

Safety
Check that each distributor truck's audio warning (back-up horn) and visual warning (strobe or flasher) are working properly.

5.6 Aggregate Spreading

Before spreading aggregate, several important steps need to be checked on the chip spreader.

- Confirm the calibration of the chip spreader,
- Verify the chip spreader's aggregate application rate,
- Ensure there are sufficient dump trucks on the projects to maintain a continuous supply of aggregate to the chip spreader,
- Verify that the safety warning systems are in working order.

Confirm Chip Spreader Calibration
Prior to construction, evaluate the lateral spread uniformity by visually observing the flow of aggregate as it exits the spreader box. Stop the spreader and adjust the gate openings if any non-uniformity is observed. Then, if a coarse adjustment is needed, adjust the appropriate gates and determine the flow of aggregate using ASTM D5624, "Determining the Transverse Aggregate Spread Rate for Surface Treatment Applications". Adjustment of the spreader shall be completed when the actual spread rate matches the target design spread rate by ±10%. The longitudinal spread rate shall be measured using the same procedure by placing measuring pads directly in front of the spreader at 500 foot intervals for 1,500 feet.

Verify Application Rate
The flow of aggregate through the chip spreader should be checked in addition the spreading operation. Ensure that the aggregate does not roll or bounce when applied. If a wave of binder forms in front of the blanket of aggregate, the binder application may be too heavy. The scalping screen should also be checked for a build-up of contaminants. If contamination is found, it may be necessary to re-screen the stockpile. The spread pattern should be even without ripples or streaks. If ripples or streaks occur, the spreading gates may need to be lowered and the machine slowed down.

Sequence of Operation
A good operating guideline is to run the spreader no more than 100 feet behind the distributor truck. The speed of the spreader shall be restricted to avoid aggregate particles from rolling, and starting and stopping of the spreader should be minimized. The edges of the aggregate applications shall be sharply defined.

There should be two or three loaded trucks in the queue behind the spreader. Trucks can also achieve some aggregate compaction by staggering their wheel paths. The first chip spreading pass is usually done against traffic to allow good centerline match up and to accommodate and minimize truck movements on the fresh oil.

Excess Aggregate
Aggregate application rates should not result in uncovered binder or excess loose chips. Binder should not adhere to truck tires, the aggregate spreader, or rollers. Aggregate needs to be placed on the binder only. Proper aggregate placement will result in one stone thickness in depth. Evidence of excess aggregate generally means the chip spreader needs adjustment or recalibration.

Excess aggregate is generally the result of an improperly calibrated spreader, which can ruin the job and cause vehicle damage. The excess aggregate (wastage) should always be less than 10% of the design quantity. Previously used aggregates recovered from sweeping must never be returned to the stockpile or the spreader for reuse.

Surface Damp Aggregate
Provide uniformly moistened aggregates, which are damp at the time of placement. Excessively wet aggregate in a chip seal operation will cause delays in production which increases cost and damages the completed chip seal. Allowing the placement of wet aggregate can re-emulsify the emulsion and compromise its ability to bond.

5.7 Rolling

Aggregate needs to be rolled to:

1. Orient particles to their least dimension,
2. Embed particles into the binder, and
3. Achieve aggregate mechanical interlock.

The reason for rolling chip seals is to orient the aggregate and achieve the desired aggregate embedment depth. Rolling achieves this by redistributing the aggregate and seating it into an interlocking mosaic within the binder. Traffic compaction will aid in finalizing the process. To realize proper embedment and orientation, particular attention must be paid to the elapsed time between when the aggregate is spread and when it is first rolled. Rolling should be expedited in hotter weather to ensure proper embedment of the aggregate before the emulsified asphalt begins to break. Selection of pneumatic tired rollers and determining the project’s rolling requirements, including the rolling patterns and number of rollers, are critical for a successful chip seal. Steel or vibratory steel rollers are not recommended because they can crush the aggregate.

Any minor irregularities should be corrected with a drag broom or hand rake before rolling.

Number of Rollers
All projects should have a minimum of three (3) self-propelled pneumatic-tired rollers to provide proper embedment and orientation to the aggregate. High production projects may require additional rollers to achieve rolling before the emulsified asphalt breaks.

Position the rollers in echelon so the entire width of the pavement lane is covered in one pass of the rollers. The total compacting width of each pneumatic-tired roller should not exceed 5 feet. Rollers should never be further than 500 feet behind the aggregate spreader.

The first pass of the rollers should occur as soon as possible but never longer than two minutes after applying the aggregate. The rolling pattern is always in a longitudinal direction at a speed limited to no more than 5 mph to avoid aggregate displacement.

Three complete roller passes of the aggregate chips is necessary and critical for orientation and embedment. One pass is defined as the roller moving over the aggregates in either direction. Ensure the rolling is completed quickly enough to embed the aggregate, before the emulsified asphalt breaks and no longer than 15 minutes.

Contact Pressure
The pneumatic rollers have the capability of ballast loading, either with water or sand, which allows the weight of the machine to be varied from 6 to 8 tons to achieve the specified minimum contact pressure of 80 lbs/in^2.

Each roller should be weighed prior to beginning the project at a certified weight scale to insure the roller meets the weight requirements. A certified weight ticket should confirm the weight for each roller.

Time of Rolling
Aggregate must be rolled while the binder is still hot to achieve proper embedment. Aggregates must be rolled before the emulsion breaks (while still brown – before turning black.) Rule of thumb: The first roller pass should occur just before the binder breaks.

Safety
Each roller should be equipped with an audio warning (back-up horn) and a visual warning system (strobe or flasher).

5.8 Sweeping

Excess cover aggregate should be removed from the pavement surface by sweeping within 3 hours of placement, but in unique conditions, never later than the morning after placement. Exercise care not to disturb aggregate that has set. Re-sweeping is necessary prior to opening to unrestricted traffic

Often, sweeping can be done within 1 to 2 hours after rolling. Sweeping should begin as soon as the aggregate begins to adhere to the binder. If chip sealing is performed in extremely high atmospheric temperatures, sweeping should be delayed until the coolest part of the day.

5.9 Protecting the Surface

Traffic should not be allowed onto the fresh chip seal before sweeping. Once the lane is opened to traffic, speeds should be controlled with a pilot vehicle so the imbedded aggregate is not displaced.

The pilot vehicle should be used during construction and until the driving lanes and shoulders have been swept free of loose aggregate. The vehicle should be identified by a "PILOT CAR FOLLOW ME" sign on the rear of the vehicle. The speed of the pilot vehicle should be limited to 35 mph, or slower if precautionary measures are needed to safeguard the public and employees.

Driving a consistent speed is the key component in helping to keep the queue of vehicles safely spaced together and avoiding undesirable speed increases from motorists trying to catch up to the vehicle queue or falling behind and not understanding the expectations of where and how fast to drive through the work zone.

The pilot vehicle should be required to have an operating amber beacon or strobe light and the name of the contractor or contracting agency prominently displayed.

5.10 Fog Sealing

Fog seal the surface of the completed chip seal after sweeping and before placing the permanent pavement markings, but not sooner than 24 hours after final rolling. Ideally, fog sealing should be applied within 1 to 3 days of final sweeping.

The fog seal is an emulsified asphalt designated SS-1h or CSS-1h. The fog seal emulsified asphalt shall be diluted prior to application such that the residue of the diluted emulsion is not less than 28 percent. The diluting of the emulsified asphalt should be performed by the emulsion manufacturer/supplier. Performance problems typically arise when the emulsion is not diluted by the supplier.

Diluted emulsified asphalt should be initially applied at an application rate of 0.06 - 0.12 gal/yd^2. Determining the optimal application is achieved by constructing a 100 foot test strip for fog sealing. Adjust the application rate as necessary to assure that a uniform application of the fog seal emulsion is applied without streaking. Apply the fog seal to minimize the amount of overspray and do not allow traffic on the fog seal until it has cured.

The fog seal will usually cure within 2 hours under dry conditions and temperatures above 60°F. Interim pavement markings can be placed after the fog seal cures. The permanent pavement markings should not be placed for three days after placing the fog seal for water-borne pavement marking or ten days for other types.

Sequencing the Work
The chip seal should always be constructed so that adjacent lane(s) are sealed on the same day. If the adjacent lane cannot be sealed the same day, sweep all loose chips from the unsealed lane before traffic is allowed on the surface without a pilot vehicle.

5.11 Construction Conclusions

Chip seal errors are very hard to correct – the contractor must “get it right” the first time. Below are a few tips for success:

- The chip seal ambient air temperature range is above 50°F and below 110°F. The pavement surface temperature range should be between 70°F and 130°F.
- Aggregate should be applied within 1 minute following application of emulsion, and the aggregate spreader should never be more than 100 feet behind the distributor truck.
- A chip seal project should have a minimum number of 3 rollers fully operational.
- Rolling should follow as closely as possible, but never greater than 500 feet behind the spreader.
- Aggregate wastage should never exceed the design quantity by more than 10%.
- Traffic should not be allowed onto the fresh chip seal before sweeping and initially, a pilot vehicle should be used to control vehicle speeds.
- The distributor and chip spreader should be calibrated regularly.

SESSION 6: QUALITY ASSURANCE

6.1 Introduction

Quality assurance includes everything in the process that is necessary to make the product perform in the way it was intended. Quality assurance consists of taking the proper steps at the right time to ensure that a project is being implemented in the right way. When a process does not work satisfactorily, corrective actions need to be applied. Such corrective actions should be known and planned before starting the project.

A quality assurance program complies with the Code of Federal Regulations Title 23, Section 637 (23 CFR 637) required for any federal-aid highway construction project.

Quality assurance incorporates three critical aspects: quality control by the contractor, quality acceptance by the agency, and independent assurance. In addition, the AASHTO Implementation Manual for Quality Assurance outlines the use of qualified laboratories, qualified personnel, and a framework for conflict resolution.

6.2 Contractor Quality Control

Quality control means making sure things are done according to the plans, specifications, and permit requirements. It is critically important to a successful project and should be adhered to throughout a project from conception and design to construction.

The Contractor is responsible for all process control sampling and testing. This also includes providing inspection, and exercising management control to ensure that all project work conforms to the contract requirements. In addition, the Contractor is responsible for maintaining complete testing and inspection records and making them available to the agency.

Ideally, quality control is achieved by developing a company culture which encourages quality and is embraced by everyone in the organization. At minimum, the contractor must develop a quality control plan to define and document the following processes.

1. ***Quality Control Testing*** – List the materials to be tested, tests to be conducted, the location of sampling, and the frequency of testing. Establish a detailed testing schedule based on production and a means to insure its accomplishment.

2. ***Inspection/Control Procedures*** – Address each of the following subjects in each phase of construction.

a. ***Preparatory phase***.
   i. Establish a procedure to ensure that materials comply with contract requirements and all submittals, including certifications that are delivered to the owner.
   ii. Identify a procedure to ensure that equipment is capable of complying with the contract requirements.

b. *Start-up phase*.
   i. Institute a procedure for reviewing contract requirements with personnel who will perform the work.
   ii. Establish standards of workmanship.

c. *Production phase*.
   i. Create inspection procedures for use during construction to identify and correct deficiencies and a feedback loop to prevent repeated deficiencies.

d. *Description of records*.
   i. List the project records to be maintained.

e. *Personnel qualifications*.
   i. Document the names, certifying authority, and relevant experience of all personnel directly responsible for inspection and testing.

f. *Subcontractors.*
   i. If a subcontractor is to perform work on the project, detail how the subcontractor will interface with the contractor.

A company's documented Quality Control Plan generally should comprise three to six pages with an additional two to four pages of detailed information about the pavement preservation treatment and pre- or post-treatments, if appropriate. Pre-treatments may include vegetation removal, crack filling, tacking, etc. Post-treatments may include fog sealing, blotting, applying a de-tack solution, etc.

6.3 Quality Acceptance by the Agency

For a quality assurance program to meet the requirements of 23 CFR 637, construction inspection must be performed as part of the acceptance program. *(Section 637.203 identifies construction inspection as a component of the state's acceptance program.)* Therefore, the agency is responsible for the acceptance function on its construction projects regardless of the contracting mechanism used. The agency's verification of sampling, testing, and inspection provides a quality assessment completely independent of the contractor's quality control process.

Quality acceptance includes inspecting the materials upon delivery and placement and inspecting the workmanship and quality of the finished product. This includes performing acceptance sampling, testing, and measurement activities to ensure the product's quality.

All incoming materials need documentary evidence that they conform to specified quality and contractual requirements before they are used on the project. The documentation is a necessity that verifies that the materials have met specific requirements.

6.4 Independent Assurance

Only tests that are used in the acceptance decision need to be covered by an Independent Assurance (IA) program. The IA program may comprise several actions such as: periodic observation of the test procedure, regular calibration of the test equipment, and the periodic testing of personnel proficiency. Both written and practical examinations may be used to determine the qualifications of those personnel performing the test.

Different laboratories could be responsible for performing the IA tests for state DOT and contractor personnel. The state could use the project approach for contractor personnel and the system approach for state personnel.

6.5 Qualified Laboratories

Agencies that chose not to use the contractor’s results in an acceptance decision must have an accredited central laboratory. State DOTs comply with the AASHTO Accreditation Program (AAP). AAP is a voluntary program that is available to all testing laboratories including government, commercial, university, and research facilities. The AASHTO Materials Reference Laboratory (AMRL) provides administrative coordination and technical support for AAP.

AMRL-accredited laboratories demonstrate that their testing services are of the highest quality and conform to specific national and international standards. An AMRL-accredited laboratory has been subjected to rigorous on-site, third party assessments and has demonstrated that the laboratory’s technical staff and the testing apparatus associated with each test achieved the highest standards. Each assessment includes a thorough review of the laboratory’s quality management system, including records of technician training, equipment calibration, and checks.

6.6 Qualified Personnel

The FHWA has a long history of encouraging qualification of all highway construction technicians, including construction inspection personnel. An example of FHWA's support of qualification programs for technicians is the AASHTO TSP•2 Oversight Panel’s recent commitment to advance pavement preservation certification.

6.7 Chip Seal Quality Assurance Program

Implementing a quality assurance program is critical to the success of a chip seal project. Any step skipped in the process, significantly increases the risk of failure or a reduced service life of the chip seal.

Contractor Quality Control Plan – should include the following procedures:

A. <u>Chip Seal Aggregate</u>

I. Stockpile - gradation testing rate is a minimum of one per day, or one per 1,500 tons, whichever is greater. If the material is hauled from the production site to a temporary stockpile, test at the temporary stockpile.
II. Construction - samples taken from the hopper of the chip spreader are tested for gradation. The testing rate for gradation is a minimum of one per day, or one per 1,500 tons, whichever is greater.

B. <u>Emulsified Asphalt</u>

I. Only emulsified asphalt from certified or approved source is allowed for use. Include the supplier name, plant location, emulsion grade, and batch number on all reports.

II. Provide material certification and quality control test results for each batch of emulsified asphalt used on the project.

III. Verify the application rate of the emulsified asphalt by dividing the volume of emulsified asphalt used by the area chip sealed each day. Allowable variation is ± 5% of the application rate adjusted from the design quantity.

Quality Acceptance by the Agency – should include taking random samples and performing acceptance tests.

A. <u>Chip Seal Aggregate</u>

I. Construction - take sample from the chip spreader hopper once per day. Samples will be stored and tested for gradation at the discretion of the Agency. If the results vary from the project requirements, a price reduction will be applied.

II. Price Reduction – are levied for gradations failing to comply with project specification.
   a. Reduce contract bid price for chip seals 2 percent for each 1 percent passing outside of the requirements for any sieve, except the 75 µm (# 200) sieve.
   b. Reduce contract bid price 2 percent price reduction for each 0.1 percent outside of the requirements of the 75 µm (# 200) sieve.
   c. All failing results will be added together. The deductions apply to the specification range only. If any gradations fall outside of the quality control range but within specifications, stop construction and require a new design.

B. <u>Emulsified Asphalt</u>

I. Tankers – take a sample from every tanker supplying the distributor on the project.

II. Testing – emulsions must be in accordance with AASHTO Standard Specification M 140-14 for Emulsified Asphalt, or M 208-01 (2014) for Cationic Emulsified Asphalt, or M 316-14 for Polymer-Modified Emulsified Asphalt.