Chip Seal Maintenance

Solutions for Bleeding and Flushed Pavement Surfaces

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This study summarizes the research directed at identifying maintenance solutions for bleeding and flushed pavements surfaced with a chip seal. Factors that contribute to bleeding and flushed chip seals pertain to aggregates, binders, traffic, environment, and construction. No better advice exists for dealing with bleeding and flushed chip seals than to avoid the problem from the outset by employing a preventive maintenance perspective. Bleeding is an immediate maintenance problem that must be addressed; corrective maintenance, or in some cases emergency maintenance, would be done. Basic approaches to treat bleeding include bridging over the live asphalt by applying aggregate of various types and gradations, cooling off the pavement surface by applying water with or without additives, and removing the bleeding asphalt and rebuilding the pavement seal. Flushing, in contrast to bleeding, is typically not a maintenance problem that must be addressed immediately. Basic approaches to treat flushed chip seals are to retexture the existing surface or to add a new textured surface over the flushed pavement. Three promising areas for further research and implementation relative to bleeding and flushing solutions include the uses of lime water, ultrahigh pressure water cutting, and the racked-in seal at intersections.

Expressed in the context of chip seal best practices, this study documents typical manifestations of bleeding and flushing, discovering the causes and underlying factors that contribute to the problem, and identifying cost-effective treatment approaches.

Three factors define its scope. First, the research intentionally focuses on the maintenance perspective to bleeding and flushing problems. Second, this report specifically focuses on chip seals. Bleeding and flushing issues for hot-mix asphaltic concrete pavements have been intentionally excluded from consideration. Third, the maintenance solutions discussed largely derive from experience with roads in the Texas Department of Transportation (DOT) system. Although Texas physiography is diverse, by virtue of its being located in the southern part of the United States, the discussion in this paper does not heavily go into issues of cold-weather maintenance.

METHOD

The research method consisted of gathering, synthesizing, and reconstituting observational data from literature, survey questionnaires, and field interviews. Research and reporting were accomplished in 2006 through five tasks stipulated in the research project statement.

Data gathering used a breadth and depth approach. The study began with a literature review (Task 1), international in scope. Task 2 consisted of interviewing persons knowledgeable about the bleeding and flushing problem. Brief interviews were conducted with chip seal experts throughout the United States, including academicians, representatives from other state DOTs, binder suppliers, pavement preservation experts, and industry contacts. This work provided a practical, national-level context for addressing the bleeding and flushing problem.

The research focus then shifted to an in-depth study of maintenance practices in Texas. In Task 3, face-to-face interviews were conducted with Texas DOT maintenance personnel to clarify the data and to gain additional, more subjective information not amenable to questionnaire responses. More than 120 Texas DOT personnel participated in on-site interviews, allowing for the capture of extensive construction and maintenance experience. In Task 4, results of the literature review and the statewide data-gathering efforts were tabulated, summarized, and synthesized. Task 5 constituted submittal of final project reports (*1, 2*).

FINDINGS

Maintenance Perspectives on Bleeding Versus Flushed Chip Seals

Bleeding and Flushing Mechanism

In a serviceable chip seal, binder performs its function of sealing the roadway surface against moisture infiltration and other environmental effects. However, the aggregate particles perform their function of creating a skid-resistant surface and keeping vehicle tires out of the asphalt. From a systems perspective, the asphalt binder protects the road, and the aggregate particles protect the binder. But for various reasons, the binder may migrate to the surface of the aggregate, filling the voids. This situation—inadequate voids between the aggregate particles—can manifest itself as either bleeding or flushing.

Bleeding and flushing are related in that both mechanisms describe a condition whereby asphalt binder rises above the surface of the chip seal aggregate. This probably explains why most pavement maintenance publications, both academic and operations oriented, treat the terms more or less interchangeably (*3–13*). However, one of the principal findings of this research is that maintenance perspectives on bleeding and flushing in chip seals differ. Thus, the terms should be differentiated.

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Bleeding Pavement

Roadway maintenance personnel describe bleeding as the rapid onset of live, excess asphalt on the pavement surface that rises above the chip seal aggregate. The appearance of the pavement surface goes from dull black to glossy, shiny, and glass-like. Traffic through a bleeding pavement makes a smacking sound, like driving through rain—sometimes called "singing."

One of the ways bleeding manifests itself is during the chip seal construction process when the pavement is first opened to traffic, before the binder has fully cured. The other typical manifestation results from heavy traffic drawing asphalt binder to the surface during extended periods of high temperatures. The key factor is that the asphalt binder is no longer in solid form. Bleeding asphalt sticks to aggregate and tires and causes tracking. When the bleeding pavement is left unattended, this can result in the chip seal aggregate rolling over and being picked up, especially for fresh seals. This can lead to pitting out or pulling up chunks of pavement—that is, "slinging" instead of singing—effectively ruining the seal (Figure 1). Functionally, bleeding is considered a failure and must be addressed through corrective, reactive, and in some cases, emergency, maintenance.

Flushed Pavement

In contrast to bleeding, flushing is typically not an immediate maintenance problem and may not be a maintenance problem at all. In a flushed chip seal, asphalt fills the voids in the aggregate mat and comes up flush with the top of rock, but the binder is not live; it is solid or semisolid. A flushed pavement is still holding its seal, so in a real sense, the chip seal is still performing at least one critical aspect of its function.

Progressive wearing down of aggregate is common during the typical life cycle of a properly constructed chip seal, giving rise to a flushed pavement surface. Depending on the degree of severity, flushed areas may be discolored or darker (low severity), experience a loss of surface texture (moderate severity), or have a shiny, glossy appearance showing tire marks in warm weather (high severity). The excess asphalt associated with flushed pavement frequently appears in the wheelpaths (Figure 2).

FIGURE 1 Pavement delamination—picking up of a chip seal—as result of bleeding.

FIGURE 2 Chip seal with flushing in wheelpaths.

The maintenance threshold for flushed pavements is a slick roadway surface with low skid resistance. Flushed areas become very slippery, especially in wet weather conditions, which is a safety concern. The condition becomes particularly severe when flushing coincides with rutting and water accumulation in the wheelpaths. Under high-traffic and high-temperature conditions, flushed pavements can track and bubble, eventually going to bleeding.

Factors That Contribute to Bleeding and Flushed Pavements

Factors that contribute to bleeding and flushed pavements include issues pertaining to aggregates, binders, traffic, environment, and construction. They are discussed as follows.

Aggregate Issues

When a chip seal loses its rock, flushing or bleeding, or both, will result. Aggregate issues include rock loss, application of too much rock, use of dirty rock, use of soft rock, and use of modified aggregate grades. In particular, loss of aggregate, also known as rock loss, or "shelling," ranks high as one of the major causes of flushing and bleeding for pavements with chip seals. Rock loss problems frequently occur when a chip seal is placed outside the established asphalt season, that is, the approved calendar period for chip seal construction, either late or early. Rock loss problems tend to happen when abnormally cool or cold temperatures (or rain and snow) occur during or after placement of a chip seal before the aggregate or asphalt bond has had a chance to fully develop.

Binder Issues

The development and appropriate use of polymer modified and other binders have improved chip seal performance due to their increased adhesion, toughness, and reduced temperature susceptibility. Binder issues relative to bleeding and flushing include binder selection, historically problematic binders, binder application rate, binder curing, and binder quality. Binder selection is a key consideration, as is the binder application rate. Softer binders used in relatively colder climates have been shown to cause more bleeding problems during hot summers in those areas. The use of any asphalt binder outside the recommended temperature conditions can lead to problems with bleeding, flushing, or rock loss. Also, the asphalt shot rates must be appropriate for the selected type and grade of binder and rock. If the asphalt rate is too light, it can lead to rock loss (shelling) and ultimately flushing. If the asphalt rate is too heavy, it can lead to bleeding or flushing, or both.

Traffic Issues

Certain types of traffic can press aggregate into the chip seal matrix or can result in aggregate being dislodged or rolled over, by shear stresses due to vehicle turning. Traffic considerations relative to bleeding and flushing include traffic volume, traffic type (heavy trucks), traffic movements (stop and go, turning, etc.), and intersections. Higher traffic volumes will cause flushing and bleeding to appear sooner than for roadways with lower traffic volumes. Starting, stopping (braking), turning, and slow-moving traffic tends to aggravate flushing and bleeding problems, especially at intersections. Heavy loads associated with truck traffic make bleeding and flushing worse because such traffic has a tendency to imbed, shove, and move the cover stone.

Environmental Issues

The key environmental factors associated with flushed and bleeding pavements are high temperature, humidity, changing temperatures, and low temperatures. Temperature and humidity have a profound effect on flushing and bleeding. High temperatures—nearing 100°F (38°C) or higher—coupled with elevated humidity can turn flushed pavements into bleeding pavements. This is particularly the case where high temperatures persist for several consecutive days. Changing weather conditions can present special problems for chip seals. One example is a series of high temperature days followed by a cold snap or cooling rains. Such unstable weather patterns typically coincide with transition seasons at the beginning and end of the chip seal season, in the spring and fall.

Construction Issues

The dominant causes of flushed and bleeding pavements surfaced with a chip seal pertain to construction issues. Most of these causes are preventable with the proper application of the principles of pavement preservation (*14*). Construction issues relative to preventing and avoiding bleeding and flushed pavements include proper assessment of existing pavement conditions, use of good chip seal preparation techniques, treatment of rutting in wheel paths, attention to the special curing needs of new chip seals, use of fog seals to mitigate rock loss problems, and avoidance of poor construction practices.

Preventive Maintenance Approaches for Bleeding and Flushed Pavements

No better advice exists for dealing with bleeding and flushed pavements than to avoid the problem from the outset, during chip seal design and construction (*5*). As in medicine, so in maintenance, an ounce of prevention is worth a pound of cure. Three topics are key to a preventive maintenance mindset for reducing bleeding and flushing in chip seals. They are avoidance of known pitfalls and problem areas, judicious selection of binders, and centralized chip seal program management.

Potentially Avoidable Causes

Factors that result in bleeding and flushing (causes discussed in the previous section) fall along a spectrum relative to the extent to which they can be directly addressed in chip seal design and construction. On one end of the spectrum are unavoidable causes: factors that are simply inherent in the chip seal design and construction process and that cannot be changed. For example, traffic is what it is. The other end of the spectrum consists of purely avoidable causes. They include poor construction practices and improper selection of aggregate and binder; these causes have no place in quality chip seal construction and should be avoided. In between these two extremes are potentially avoidable causes: certain situations that seem to regularly accompany bleeding and flushing problems. Included are construction of chip seals during transition months at the beginning and end of the asphalt season, placing chip seals in excessively hot weather, not providing sufficient curing time before allowing the traveling public on the new roadway surface, and others. From a bleeding and flushing perspective, the goal is to design for unavoidable causes, avoid purely avoidable causes, and manage potentially avoidable causes.

Binder Selection

Unmodified asphalt cement binders were used before the advent of binders modified with latex, polymer, and crumb rubber. The use of modified binder has significantly reduced bleeding and flushing problems. The superior performance of these modified binders may be attributed to reduced temperature susceptibility, enhanced high-temperature properties, and improved aggregate-binder bonding effectiveness. Binder selection (both the type and application rate) is key to successful chip seal performance. The appropriate asphalt must be used in the appropriate season, for warm weather and cool weather. The use of any asphalt binder outside the recommended temperature conditions (or asphalt season) for that asphalt can lead to problems with bleeding, flushing, or rock loss.

Centralized Chip Seal Program Management

Inasmuch as chip-sealing involves both art and science, experience is the key to success. Successful chip seal construction occurs where roadway maintenance districts have a centralized chip seal program, together with an experienced and committed chip seal team that is dedicated to quality. This contrasts with the decentralized method where responsibility for chip sealing is a localized and part-time concern. The better approach is for roadway maintenance professionals who are properly supported by management to take ownership of the chip seal program. Such a centralized management approach—focused on planning, preparation, design, and inspection—consistently yields high-quality chip seals. Indirectly, this approach results in fewer problems with bleeding or flushing.

Maintenance Solutions for Bleeding Pavements

Apply Treatment

Bleeding is an immediate maintenance problem that must be addressed through corrective, reactive, or in some cases, emergency, maintenance. Maintenance forces employ several methods to treat bleeding chip seals, as shown in Table 1. The basic approaches are to (*a*) bridge over the live asphalt by applying aggregate of various types and gradations, (*b*) cool off the pavement surface by applying water with or without additives, or (*c*) remove the bleeding asphalt and rebuild the pavement seal.

The method chosen often depends on the available materials, labor, and equipment at the time of treatment. Selection of the treatment approach must also consider the severity of the bleeding problem as well as many other factors, including environmental conditions (temperature and humidity), type of roadway, traffic levels and types, and specific locations on a roadway (curves, intersections, urban or rural environments).

In relative terms, the effectiveness of these solutions can be described as short term (a few days) to long term (1 or more years). The cost for these solutions, also relative, ranges from low (cents per square yard or square meter) to high (dollars per square yard or square meter). Assertions about the effectiveness and cost for each solution collectively reflect the experiences and perceptions of the Texas DOT maintenance personnel interviewed for this study. A brief discussion of each of these solutions follows. More information about these solutions is presented in the field handbook *Maintenance Solutions for Bleeding and Flushed Pavements* (*1*). The field handbook presents a more detailed discussion, including description, application, effectiveness, materials, procedure, helpful tips, and concerns.

FIGURE 3 Applying small-sized aggregate to treat bleeding chip seal.

Apply Layer of Small-Sized Aggregate

The application of small-sized aggregate [(Texas DOT Standard Specification Item 302: Grade 5, nominal size 0.19 in. (4.75 mm/No. 4 sieve)] (*15*) is the most commonly used maintenance solution for the treatment of bleeding chip seals in Texas.

Important to emphasize is that the application of small-sized aggregate for this solution does not introduce fines to the pavement surface. Small-sized aggregate is not fine aggregate (i.e., concrete sand), and it is clean, with less than 2% fines. Maintenance crews use the aggregate available to them, subject to local material availability and cost considerations. Given the choice, they do voice preferences. Typical selections are modified (single sized) gradation over standard gradation, hard rock over lightweight aggregate, and precoated over uncoated aggregate.

Maintenance forces and construction contractors use this option if there is enough free asphalt on the pavement surface to stick the rock. This method is typically used to treat light to moderate bleeding. The key with any aggregate remedy is to get the rock to adhere to the pavement surface, and the primary objective is to get the tires out of the asphalt (Figure 3).

Apply Layer of Larger-Sized Aggregate

The application of larger-sized aggregate [(Texas DOT Standard Specification Item 302: Grade 4 or Grade 3, nominal size of $\frac{1}{4}$ in. to $\frac{3}{8}$ in. (6.35 mm to 9.52 mm)] (*15*) is another solution for bleeding chip seals. Ideally, maintenance personnel will use the largest-sized rock practicable to remediate bleeding, the key question being whether enough free asphalt exists for the larger aggregate particles to adhere to the bleeding pavement surface. This solution is typically employed by construction contractors for treatment of severe bleeding that occurs during or shortly after chip seal con-

TABLE 1 Maintenance Solutions for Bleeding Chip Seal Pavement Surfaces

	Solution Type			Effectiveness			Cost		
Maintenance Solution for Bleeding Asphalt Pavement	Bridge Over	Cool Down	Remove Replace	Short Term	Mid-term	Long Term	Low	Medium	High
Apply layer of small size (Grade 5) aggregate	X			X	X			X	
Apply layer of larger size (Grade 4 or 3) aggregate	X				X	X		X	
Apply blotter material (coarse sand and stone screenings)	X			X			X	X	
Sandwich seal	X					X			X
Apply lime water		X		X	X		X		
Apply water		X		X			X		
Remove bleeding pavement surface and replace			X			X			X
Other methods	X	X		X			X		

struction. Here, the contractor applies the same rock that was used for the original chip seal, these original aggregate materials being still available (stockpiled) on site. The main concern in regard to the use of larger-sized aggregates is the potential for windshield damage.

Apply Blotter Material to Blot Excess Asphalt

Maintenance forces sometimes do not have access to their material of choice for treatment of a bleeding chip seal and are constrained to use whatever is on hand at the time. Some examples of these less-than-desirable materials include blow sand, ice chatt, bottom ash, and crushed stone screenings. These finer materials (particle size smaller than No. 4 sieve) are used as blotter materials to soak up excess asphalt from the bleeding pavement surface. This approach is problematic because a chip seal needs adequate voids between the rock particles to accommodate asphalt volume changes, and the introduction of fine aggregate materials can make a bleeding situation worse (*16*). Blotter materials are therefore viewed as providing temporary complaint relief when nothing else is available.

Apply Sandwich Seal

The sandwich seal is a two-course chip seal where aggregate is spread on an existing binder-rich surface before the application of a single-course chip seal. It is very much like a standard two-course chip seal, except that the first application of binder is omitted (*16*). Coarse stone is placed directly on the road with no binder underneath it. While the sandwich seal directly addresses the mechanisms associated with bleeding, this method has seen limited use within Texas DOT. The most common application has been as a type of strip seal to correct moderate to severe bleeding and minor rutting in the wheelpaths. This seal is suited for treatment of chronic bleeding pavements. The sandwich seal is not considered a maintenance seal in that it is typically not done by maintenance personnel.

Apply Lime Water to Cool and Crust over Bleeding

The application of hydrated lime mixed with water is one of the most commonly used maintenance solutions for the treatment of bleeding asphalt pavements in Texas. Customary practice is to mix lime water using a portable 1,000-gal water tank unit that slides into the back of a dump truck. The tank unit comes with an agitator pump to keep the lime in suspension, and the lime water is applied to the bleeding pavement surface using a spray bar.

This method is typically used to treat light to moderate bleeding on roadways that do not experience extremely high volumes of traffic. Construction contractors and maintenance crews both use this method; they like it because it is quick and inexpensive and because it is a fast-moving operation. A typical application is on freshly placed chip seals to control bleeding and to minimize the chances of the chip seal being picked up.

No standard specification exists for the lime water method, so considerable variation exists in treatment practices. The application of lime water is generally viewed as a short-term solution to bleeding asphalt pavements; it buys some time. Maintenance crews indicate that treatment effectiveness can range from as little as 2 to 4 h to as much as 3 to 5 days.

Some binders might not be amenable to treatment with lime water (*17*). Intuition suggests that certain emulsions would fall in this category, especially on a fresh seal, since emulsion is a water-based product. One of the disadvantages of this treatment is that lime water puts a white film on the pavement and kills the reflectability of pavement markings and striping. Lime also is corrosive to paint. If the public is allowed to drive through wet lime slurry, this might result in claims that lime has splattered people's vehicles and damaged the paint. Because lime water is caustic, splashing creates a safety concern.

Apply Water to Cool Pavement Surface

Water (not mixed with lime or other additives) is sometimes spray-applied to cool off bleeding chip seals. Construction contractors and maintenance crews both use this method. The typical application is as an emergency, stop-gap treatment to arrest bleeding on a freshly placed chip seal, to minimize the chances of the chip seal being picked up. Water is considered a temporary measure to cool the pavement and to buy some time when other treatment methods or materials are unavailable.

Remove Bleeding Pavement Surface and Replace with New Chip Seal

When a fresh chip seal is heavily damaged, it can be removed and replaced with a new seal. This option is used only in the event of total failure of a chip seal. The problem seal is usually removed (scraped off) by a blade. This is not considered a maintenance seal in that it is not done by maintenance personnel. The new chip seal is usually applied by a contractor in the case of bleeding or failure during new construction. This treatment method is considered a long-term solution to bleeding pavement surfaces. The cause of bleeding should be determined before applying the new chip seal.

Other Solutions

Maintenance forces have infrequently used various other methods to treat bleeding chip seal surfaces. Examples include (*a*) powdered lime that is dry applied to a bleeding chip seal; (*b*) application of dry portland cement to treat smaller areas of bleeding; (*c*) use of brine water, a byproduct of the oil field; and (*d*) application of very clean, hot aggregate that is rolled into the bleeding pavement surface with a steel wheel roller.

Maintenance Solutions for Flushed Pavements

Treatment

Flushed asphalt pavement, in contrast to bleeding pavement, is typically not a maintenance problem that must be addressed immediately. Maintenance forces have employed a variety of methods to treat flushed chip seals (Table 2). The basic approaches are to (*a*) retexture the existing flushed pavement surface or (*b*) add a new textured surface over the flushed pavement. The method chosen often depends upon economics as well as the availability of materials, labor and equipment at the time of treatment.

TABLE 2 Maintenance Solutions for Flushed Chip Seal Pavement Surfaces

Maintenance Solution for Flushed Asphalt Pavement	Solution Type: Add New Textured Surface	Solution Type: Retexture Existing Pavement	Effectiveness: Short Term	Effectiveness: Mid-term	Effectiveness: Long Term	Cost: Low	Cost: Medium	Cost: High
Cold milling to remove flushed asphalt		X		X		X	X	
Apply new seal coat	X				X		X	
Microsurfacing	X				X		X	X
Thin asphaltic concrete overlay	X			X	X		X	X
Ultra high pressure water cutting		X		X			X	X
Other solutions	X	X		X	X	X	X	X

In relative terms, the effectiveness of these solutions can be described as short term (a few days) to long term (one or more years). The cost for these solutions, also relative, ranges from low (cents per square yard and square meter) to high (dollars per square yard and square meter). Assertions about the effectiveness and cost for each solution collectively reflect the experiences and perceptions of the Texas DOT maintenance personnel interviewed for this study. A brief discussion of each of these solutions follows, with more complete information provided in the field handbook (*1*).

Cold Milling to Remove Flushed Asphalt With and Without Replacement

Cold milling is the controlled removal of the surface of the existing pavement to the desired depth, with specially designed milling equipment (Figure 4). Milling is done either to prepare the surface to receive overlays (by removing rutting, flushing, and surface irregularities), to restore the pavement cross slopes and profile, or to reestablish the pavement's surface friction characteristics. The typical application is where rutting has occurred in the wheelpaths, water accumulates during rains, and skid resistance and hydroplaning are a concern. Milling is also used quite often at intersections where heavy starting and stopping movements have caused rippled, bumped, and otherwise rough pavement surfaces.

FIGURE 4 Cold milling to retexture flushed pavement in wheelpaths.

New Chip Seal

A new chip seal may be applied over a flushed pavement surface to arrest flushing and restore skid resistance, as long as the surface is not too heavily flushed (*18*). The ideal application for this option is to treat the wheelpaths of a flushed pavement where there is also minor rutting and loss of skid resistance. On a much larger scale, this type of treatment is used to treat aged, flushed pavements where the flushing occurs due to aggregate wear and abrasion; this would be a full-width repair. This treatment method seals the roadway surface and improves skid resistance. It is considered a long-term solution to flushed pavement surfaces.

Microsurfacing

Microsurfacing is a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives. Microsurfacing is used on a limited basis to remediate problems associated with minor rutting, flushed pavement, ride quality, and skid resistance, or a combination of these problems. Selection of the microsurfacing method typically focuses on correcting problems associated with rutting in the wheelpaths and providing improved macrotexture and skid resistance on a roadway. Flushing problems are often addressed as a byproduct of this treatment. Microsurfacing is not typically used in itself to correct a flushed pavement problem, nor is it used to mitigate bleeding.

Thin Asphaltic Concrete Overlay

Maintenance forces use blade level-up techniques to create thin asphaltic concrete overlays, to remediate chronic problems with flushed pavement, typically in association with repair of rutting, patches, and other pavement defects. Thin overlays are also sometimes constructed using asphalt laydown machines. This is usually done in conjunction with chip seal preparation work in advance of chip seal operations.

Ultrahigh-Pressure Watercutting

The ultrahigh-pressure (UHP) watercutting is an emerging technology, currently used in Australia and New Zealand and being considered for implementation in the United States, that holds promise for treatment of flushed pavements (*19, 20*). The UHP watercutter machine combines both watercutting and road cleaning technologies in a single process to simultaneously remove excess binder and contaminants from pavement surfaces, and to retexture aggregate surfaces, improving road surface macrotexture and aggregate microtexture. This treatment can be used in advance of sealing operations to treat asphalt-rich patches, flushed areas, and to create a uniform surface texture for a subsequent (new) chip seal. UHP watercutting is less suitable for treating thin surfaces which may be easily damaged or dislodged.

Other Solutions

Maintenance forces infrequently use various other methods to treat flushed pavement surfaces. They include (*a*) the use of grooved motor grader mold boards in order to score the pavement surface; (*b*) preheating the pavement surface and rolling in hot aggregate; and (*c*) use of slurry seals, similar to microsurfacing, to form an impervious thin textured surface over an existing pavement.

Maintenance Solutions for Intersections

Maintenance Treatment Strategy

Intersections can be especially problematic for bleeding and flushing. Chip seals have limitations in their ability to resist the effects of abusive traffic maneuvers at high-stress traffic areas such as intersections, median openings, and turn lanes. Turning and braking of heavy vehicles can cause aggregate to roll, leading to loss of aggregate and bleeding of the seal. Concentrations of heavy traffic at intersections may cause aggregate embedment, leading to flushing of the binder.

Maintenance forces have employed a variety of methods to treat bleeding and flushed asphalt pavements at these high-stress traffic areas. The basic approaches are to retexture the existing pavement by microsurfacing or a racked-in seal, or to replace the high-stress pavement area with a more durable pavement material, such as hot-mix asphalt or portland cement concrete. Of these solutions, the racked-in seal is very compatible with typical roadway maintenance activity for chip seals and may prove to be a promising alternative for treatment of bleeding and flushing at intersections. A brief discussion of that approach follows.

Racked-in Seal

The racked-in seal is a variation to the single course chip seal. It consists of one heavy layer of binder followed by two layers of cover aggregate. The second layer of aggregate, or scatter coat, is smaller than (one-third to one-half size) the first layer. The smaller aggregate fills the voids and displaces the binder further upward on the larger stone, thereby mechanically locking the larger aggregate in position and producing a stable matrix. The racked-in seal has been proposed for use in Texas at high-stress areas, for example, heavily trafficked intersections that otherwise would be sealed with a single chip seal. It is frequently used in association with asphalt emulsion binders.

The purpose behind the racked-in seal is to provide a stronger chip seal treatment. The scatter coat aggregate is intended to prevent the chip seal rock from sliding, rolling over, or scrubbing off the underlying pavement. This analogy is to that of billiards, in which a rack holds cue balls in a tight pattern. The racked-in seal has been used in Canada, countries in Europe and in Asia, Australia, and New Zealand on roadways where traffic is heavy or fast, or both (*16, 21*). The racked-in seal has been introduced in Texas only recently and has seen limited application on system roadways.

CONCLUSIONS

This paper presents maintenance solutions for bleeding and flushed pavements surfaced with a chip seal. One of the principal findings of this research is that maintenance perspectives on bleeding and flushing in chip seals differ, and the terms should be differentiated. The main factors that contribute to bleeding and flushed pavements include issues pertaining to aggregates, binders, traffic, environment, and construction. No better advice exists for dealing with bleeding and flushed pavements than to avoid the problem from the outset.

Bleeding asphalt pavement is an immediate maintenance problem that must be addressed using corrective or, in some cases, emergency maintenance. Maintenance forces employ several methods to treat bleeding chip seals. Basic approaches are to bridge over the live asphalt by applying aggregate of various gradations, to cool off the pavement surface by applying water with or without additives, or to remove the bleeding asphalt and rebuild the pavement seal. Flushed pavement, by contrast, is typically not a maintenance problem that must be addressed immediately. The maintenance thresholds that call for treatment of a flushed pavement include a slippery pavement surface, low skid resistance, and rutting and water accumulation in the wheelpaths. The approaches that maintenance forces employ to treat flushed asphalt pavements are to retexture the existing pavement surface or to add a new textured surface over the flushed pavement.

Intersections can be especially problematic. The approaches to treat bleeding and flushed pavements at intersections are to retexture the existing pavement surface or to replace the chip seal with a new, more durable, pavement material.

RECOMMENDATIONS

The research findings suggest three promising areas for further research and implementation relative to solutions for bleeding and flushing. They are the use of lime water, UHP watercutting, and racked-in seal.

The research interviews show that application of hydrated lime mixed with water is one of the most commonly used maintenance solutions for the treatment of bleeding asphalt pavements in Texas. However, the lime water process is not understood well, and no definitive procedures exist for lime water application. Research is needed to explore how and why lime water works, as well as developing standard procedures for its use. UHP watercutting technology is currently being used in New Zealand and Australia to restore texture to chip-sealed road surfaces that are slick with excess asphalt binder. Implementation research to evaluate the use of the UHP watercutter for U.S. roadway applications may introduce a helpful tool for treatment of flushed chip seals.

Another promising area for further study in the aggregate family of bleeding solutions is the racked-in seal. The racked-in seal seems to be an economical alternative to using hot-mix asphaltic concrete or portland cement concrete overlays at intersections where traditional chip seals are not adequate. Research is needed to optimize the racked-in seal procedure.

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