# PAVEMENT DESIGN & MAINTENANCE


ئامادەکردنی ئەندازیاری شارستانی

بەختیار عبدالله نادر

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بەروار     ٢٠١٣/٣/٥

# PAVEMENT

The pavement soil is seldom strong enough to support repeated application of wheel loads without significant deformation. It is therefore necessary to interpose between the wheel and the soil , a structure of supplement the natural strength of the soil foundation. This struture is called **pavement.**
There is two type of pavement construction:

١- **FLEXIBLE ( OR ASPHALT ) PAVEMENT**

٢- **RIGID PAVEMENT**

**Asphalt mixture:**
Is a mixture from different material , course aggregate , filler , asphalt , and usually called asphalt concrete because of similaring in the mixture with concrete.
Mixes of these different materials also has special properties.
Bituminous mixes are strong, flexible, water proof, comfortable and economical. They are capable of taking heavy load of traffic and aircraft's .

**Pavement Layers and Materials**
A typical flexible (or asphalt) pavement consists of surface, base course, and subbase built over compacted subgrade (natural soil) as shown in Figure.١. In some cases, the subbase layer is not used, whereas in a small number of cases both base and subbase are omitted.
The surface layer is made of hot-mix asphalt (HMA) (also called asphalt concrete). The material for the base course is typically unstabilized aggregates. The aggregate base could also be stabilized with asphalt, portland cement, or another stabilizing agent.
The subbase is mostly a local aggregate material.
Also,the top of the subgrade is sometimes stabilized with either cement or lime.
Unlike rigid pavement, when the traffic load is applied on top of the surface layer a localized deformation occurs under the load, while the load is distributed in a manner as shown in Figure.٢. It can be seen that the load is distributed on a small area at the surface. As the depth increases, the same load is distributed over a larger area. Therefore, the highest stress occurs at the surface and the stress decreases as the depth increases.
. Thus, the highest quality material needs to be at the surface and as the depth increases lower quality materials can be used.
When the load is removed the pavement layers rebound. A very small amount of deformation, however, could stay permanently which could accumulate over many load repetitions causing rutting in the wheel path.
The name, flexible pavement, is used because of the localized deformation and the rebounce that happens every time the traffic load is applied and removed.
The required thickness of each layer of the flexible pavement varies widely depending on the Materials used, magnitude and number of repetitions traffic load, environmental conditions, and the desired service life of the pavement.
These factors are generally considered in the design process so that the pavement would last for the required designed life without excessive distresses. In most cases, the surface layer varies from ١ to ١٠ in., which could include a number of overlays. The base layer typically varies from ٤ to ١٢ in. and the subbase varies from ٦ to ٢٠ in**.**

**Failures in the construction of an asphalt pavement may be attributed to**;
• Insufficient or improperly compacted base
• Poor drainage
• Over-compaction or under-compaction of asphalt
• Asphalt is not at optimum temperature when applied

**A good asphalt pavement seldom wears out, it is destroyed by external factors**

• Water
- penetrates asphalt
- destroys base

• Sunlight (oxidation)
- breaks down the liquid asphalt that holds the aggregate together
- causes raveling and shrinking cracks
- invites water

• Petroleum spills
-gas and oil spots soften the asphalt

## Pavement Distresses and Performance

Common Pavement Distresses

Different types of distress can occur in asphalt pavement. These distresses could be developed due to traffic load repetitions, temperature, moisture, aging, construction practice, or combinations. The common types of distresses in flexible pavements are described in detail by NRC (١٩٩٣), and are discussed below.

Fatigue Cracking

Fatigue cracks are a series of longitudinal and interconnected cracks caused by the repeated applications of wheel loads. This type of cracking generally starts as short longitudinal cracks in the wheel path and progress to an alligator cracking pattern (interconnected cracks) as shown in Figure ٣.

This type of cracking happens because of the repeated bending action of the HMA layer when the load is applied. This generates tensile stresses that eventually create cracks at the bottom of the asphalt layer.

Cracks gradually propagate to the top of the layer and later progress and interconnect. This type of distress will eventually lead to a loss of the structural integrity of pavement system. Recent studies have demonstrated that a less common fatigue cracking may initiate from the top of the pavement surface and propagates downward (top-down cracking). This type of fatigue is not as well defined from a mechanical viewpoint as the more classical “bottom-up” fatigue. It is hypothesized that critical tensile and shear stresses develop at the surface and cause extremely large contact pressures at the tyre edges-pavement interface, coupled with highly aged (stiff) surface layer and these are responsible factors for this kind of cracking .

. Top-down cracking first shows up as relatively long longitudinal cracks adjacent to the tyres within the wheel paths.

Rutting

Rutting is defined as permanent deformation in the wheel path as shown in Figure ٤. Rutting can occur due to: (a) unstable HMA, (b) densification of HMA, (c) deep settlement in the subgrade as demonstrated in Figure ٥.. Rutting due to: (a) Unstable asphalt concrete, (b) Densification of asphalt concrete, and (c) Deep settlement.

Unstable HMA can occur because of one or more of different reasons such as too much asphalt binder , too soft asphalt binder, rounded aggregate particles, smooth aggregate texture, or too many fines in the HMA mix. Densification of HMA can occur because of the poor compaction during construction .Deep settlement can happen because of poor drainage or weak subgrade.

Roughness

Roughness is defined as the irregularities in the pavement profile which causes uncomfortable, unsafe, and uneconomical riding. Roughness affects the dynamics of moving vehicles, increasing the wear on vehicle parts and the handling of vehicles. Thus, road roughness has an appreciable impact on vehicle operating costs and the safety, comfort, and speed of travel. It also increases the dynamic loading imposed by vehicles on the surface, accelerating the deterioration of the pavement structure.

Thermal Cracking

As the temperature decreases the HMA material contracts. Since the material is restrained from movement due to the friction with the underlying material, tensile stresses develop within the HAM material. If the tensile stress exceeds the tensile strength of the material, thermal cracks develop as shown in Figure ٦. Thermal cracks typically occur in the transverse direction perpendicular to the direction of traffic. This type of cracking is usually equally spaced. This is a non-load associated type of cracking and it starts during the winter season. The width of the thermal cracks usually changes from summer to winter. In some cases, small cracks heal during the summer season.

In other cases, the width of the crack increases from one year to another.

Shoving

Shoving is a form of plastic movement resulting in a localized bulging of the pavement surface. Shoving can take a number of different forms such as upheaval (Figure ٧), "wash-boarding" or ripples across the pavement surface, or crescent shaped bulging. Shoving occurs in the asphalt layers that lack stability because of too much asphalt binder in the HMA mix, too soft asphalt binder, rounded aggregate particles, smooth aggregate texture, or too many fines in the mix.

Bleeding or Flushing

Bleeding or flushing is the upward movement of the asphalt binder resulting in the formation of a film of asphalt on the surface as shown in Figure ٨. Bleeding occurs when the HMA mix is too rich with asphalt binder that is forced to the surface when traffic load is applied especially in hot weather. Bleeding could be hazardous because it makes the pavement slippery when wet.

. Raveling

Raveling is the progressive separation of aggregate particles in a pavement from the surface downward or from the edge inward as shown in Figure ٩. Usually fine aggregate particles are separated first followed by coarse aggregates. Raveled surfaces are aged and typically look dry and weathered. Raveling is caused by one or more of several reasons such as lack of compaction, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the mix.

Polished Aggregate

Aggregate particles in the HMA may get polished smooth and create a slippery pavement surface. when wet (Figure ١٠). Some aggregates, particularly some types of limestone, become polished rather quickly under traffic.

Reflection Cracking

Cracks in the underneath layer might reflect in the overlay as shown in Figure ١١. Reflection cracking occurs frequently in asphalt overlays on concrete pavement and cement treated basis. They also occur when cracks in the old asphalt layer are not properly repaired before overlay. Reflect cracks may take several forms depending on the pattern of the crack in the underneath layer.

Pavement Performance

Figure ١٢ shows how the pavement condition varies with time or traffic applications. When the road is first built it typically has a good condition. With time and with the continuous applications of traffic loads the pavement gradually deteriorates and the condition gets worse.

The change of pavement condition with time or traffic is definedas performance. Performance is affected by several factors as discussed in the next section and cannot easily be predicted. When pavement condition reaches a certain unacceptable level the pavement reaches the end of its serviceable life. Performance prediction is important in order to ensure that the pavement reaches the unacceptable condition at the end of its designed life. Currently, there is no completely mechanistic (or theoretical) method to predict pavement performance. Empirical or mechanistic-empirical methods are currently being used to predict performance.

## Factors Affecting Performance of Flexible Pavements

Pavement performance is affected by several factors, which are traffic, soil and pavemet materials, environment, and construction and maintenance practice

### Traffic

Traffic has a major effect on pavement performance. Traffic characteristics that affect performance are traffic load, traffic volume, tyre pressure, and vehicle speed. Traffic load produces stresses and strains within the pavement structure and the subgrade, which gradually contribute to the development of pavement distresses. For example, heavier loads result in higher potential for fatigue cracking and rutting (Figures ٣ and ٤). Traffic volume affects pavement performance since larger number of load repetitions increases the chance for fatigue cracking. Also, higher tyre pressure produces higher stress concentrations at the pavement surface that could result in rutting and shoving in the HMS layer (Figure ٥a). Finally, vehicle speed affects the rate of applying the load. Since asphalt concrete is a visco-elastic plastic material, its response is affected by the rate of load application. Slow or stationary vehicles have more chances of developing rutting and shoving than high-speed vehicles. On the other hand, high travel speeds cause more severe bouncing of vehicles, and result in larger dynamic loading and increased roughness.

### Soil and Pavement Materials

Soil and pavement materials significantly affect pavement performance. Of course, high quality materials are needed to provide good support to traffic loads under various environmental conditions. Important material properties include mechanical properties such as elasticity, visco-elasticity, plasticity, temperature susceptibility, durability and aging characteristics. These properties affect how the material responds to traffic loads and environmental conditions such as temperature, freeze thaw effect, and rain.

### Environment

Environmental conditions that affect pavement performance include moisture, temperature, and their interaction. For example, moisture may reduce subgrade support and weakens various pavement layers. High temperatures soften asphalt concrete and could create rutting within the surface layer. Temperatures below freezing have a bad effect on pavement performance, especially cycles of freeze and thaw. As demonstrated in Figure ١٣, if the subgrade is wet and the temperature drops below freezing, ice lenses form. Since these ice lenses have larger volume than water, frost heave will develop and may create bulges in the pavement surface. If the temperature fluctuates above and below freezing points in the same season combined with poor drainage, subgrade support will be significantly reduced and could result in excessive deterioration of the pavement structure within a short period of time as shown in Figure ١٤.

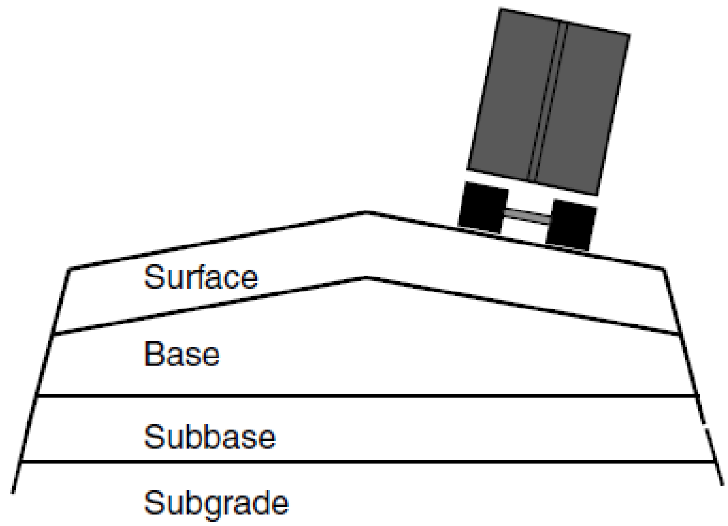


FIGURE ١ Typical layers of flexible pavement

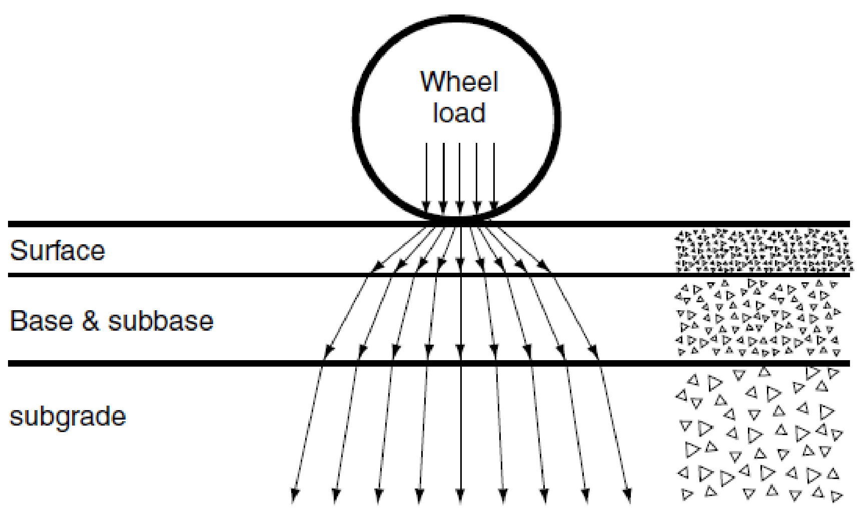


FIGURE ٢ Load distribution in flexible pavement.

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FIGURE ٣  Advanced stage of fatigue cracking.

FIGURE ٤ Rutting.

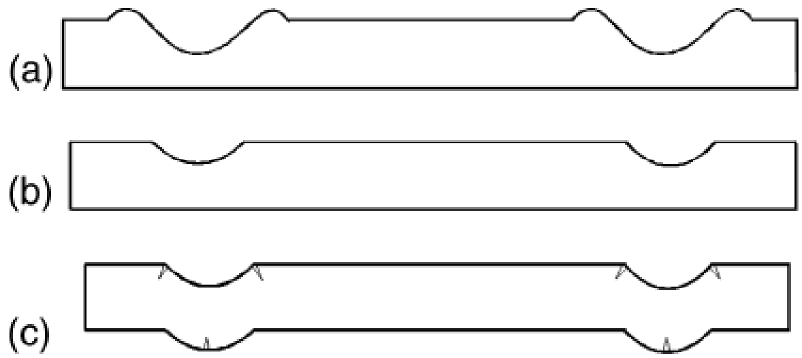


FIGURE ٥ Rutting due to: (a) Unstable asphalt concrete, (b) Densification of asphalt concrete, and (c) Deep settlement

FIGURE ٦ Thermal cracking.

FIGURE ٧ Shoving

FIGURE ٨ Bleeding or flushing

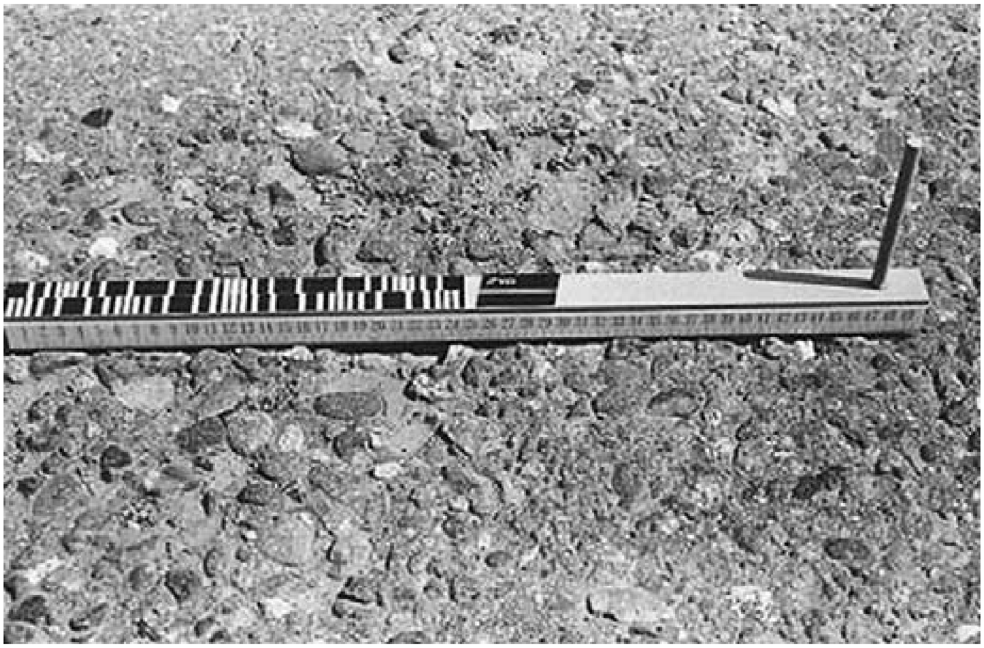

FIGURE ٩ Raveling.

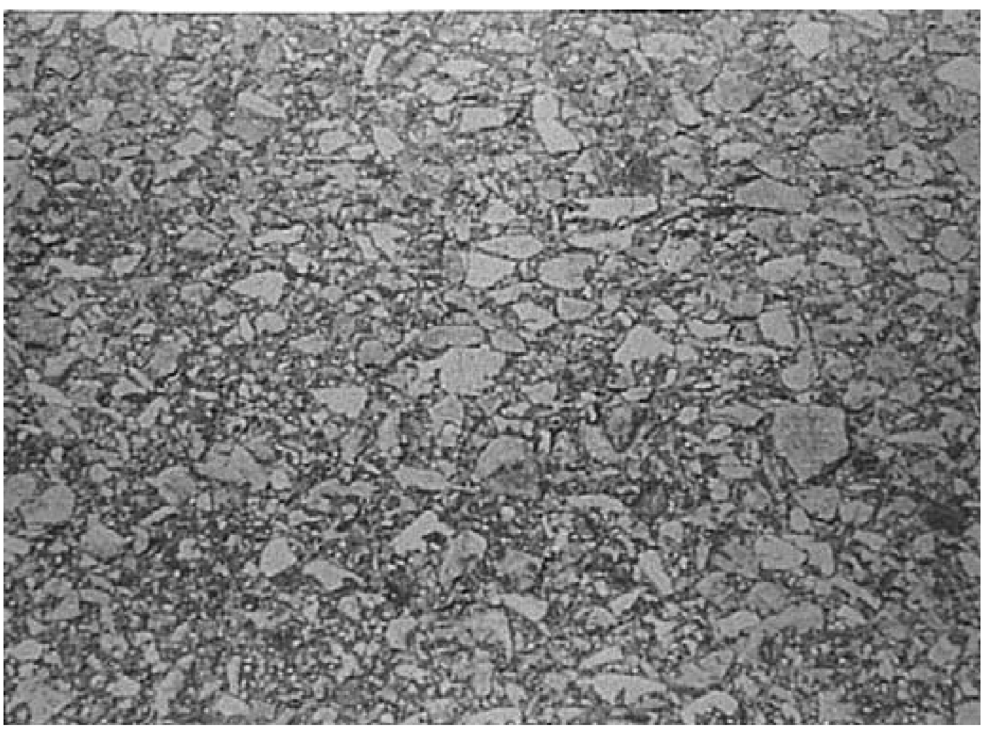

FIGURE ١٠ Polished aggregate.

FIGURE ۱۱ Reflection cracking.

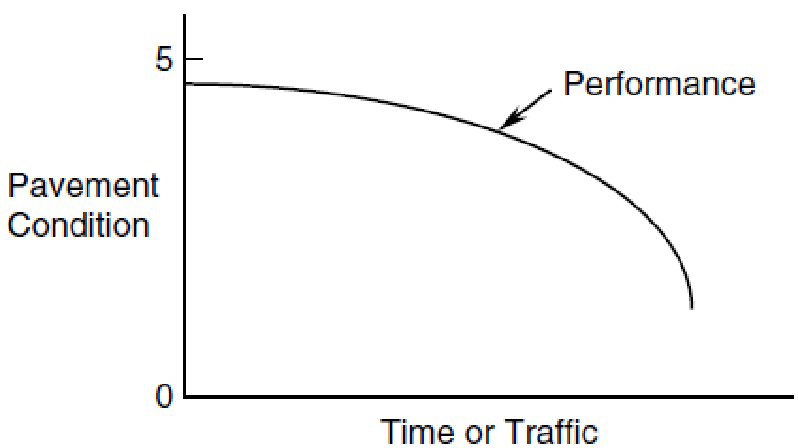


FIGURE ۱۲ Change of pavement condition versus time.

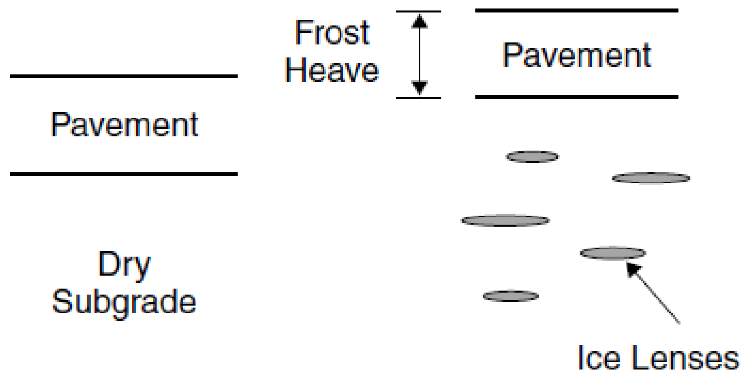


FIGURE ١٣ Effect of freeze and thaw on pavement response.

FIGURE١٤ Reflection cracking.

Construction and Maintenance Practice

In many cases, defects in pavement start during construction and propagate during service. In fact, poor construction procedure will almost always ensure poor pavement performance. For example, poor compaction of subgrade or any pavement layer allows excessive further compaction by traffic, which appears in the form of rutting and surface cracking. Poor placement of HMA during construction may result in weak transverse or longitudinal construction joints that are susceptible to early cracking and deterioration. Excessive air voids in the HMA layer due to poor compaction will result in fast aging followed by cracking. In contrast, too much compaction of HMA will result in too small amount of air voids that could create rutting or bleeding. Lack of smoothness of the pavement duringconstruction increases the dynamic impact of traffic, and consequently, speeds up theratedevelopingroughness during service.

**Maintenance**

t he combined effects of traffic loading and the environment will cause every pavement, no matter how well-designed/constructed to deteriorate over time. Maintenance and rehabilitation are what we use to slow down or reset this deterioration process. Maintenance actions, such as crack sealing, joint sealing, fog seals and patching help slow the rate of deterioration by identifying and addressing specific pavement deficiencies that contribute to overall deterioration. Rehabilitation is the act of repairing portions of an existing pavement to reset the deterioration process. For instance, removing and replacing the wearing course in a pavement provides new wearing course material on which the deterioration process begins anew.

**Flexible Pavement Maintenance**

Bituminous Surface Treatments
Crack Seals
Fog Seals
HMA Patching
Non-Structural Overlays

A bituminous surface treatment (BST), also known as a seal coat or chip seal, is a thin protective wearing surface that is applied to a pavement or base course. BSTs can provide all of the following:

A waterproof layer to protect the underlying pavement. Increased skid resistance.
A filler for existing cracks or raveled surfaces.
An anti-glare surface during wet weather and an increased reflective surface for night driving.
Historically, BSTs have been in use since the ١٩٢٠s, primarily on low volume gravel roads. BSTs are increasingly in use as a preventative maintenance procedure on flexible pavements of good structure.

**Purpose**

A BST offers preventive maintenance from the effects of sun and water, both of which may deteriorate the pavement structure. BSTs create a new wearing course, as well as a waterproof covering for the existing pavement. A BST makes it more difficult for water to enter the base material, and preventing freeze thaw damage for those locations with below freezing temperatures.

BSTs also increase the surface friction of the pavement, due to the addition of the cover aggregate. This combats the effects of raveling, which can make the pavement slippery and stopping difficult. A BST gives good, gripping texture to the pavement surface.

BSTs should be applied to a distress-free to moderately distressed pavement surface. A two to four year service life is common, while five year service lives are achievable.

Materials

BSTs are created using two main materials: asphalt and a cover aggregate.

Asphalt

Asphalt (as asphalt binder, cutback asphalt or asphalt emulsion) and aggregate (uniformly graded).

The asphalt is typically an emulsion. Care must be taken with the weather on the day of construction – ideally, a warm day with low humidity is preferred. BSTs should never be constructed on rainy days or when rain is predicted. Rain can dilute the asphalt binder if it has not yet cured, bringing the binder to the top of the cover aggregate; after the water evaporates, tires can pick up the loose aggregate or track binder across the surface.

Cutback Asphalt

While cutback asphalt is historically an option for BSTs, the solvent used (usually gasoline or kerosene) is expensive and potentially dangerous. A cutback is asphalt dissolved in a solvent, allowing the asphalt to be pumped and sprayed without heating it to high temperatures. The solvent evaporates into the surrounding air, leaving the asphalt binder. Once the solvent has completely evaporated, the cutback has cured. Fast setting time cutbacks use gasoline, while kerosene is used for longer curing times.

Cutback asphalt usage has declined in recent years due to pollution and health concerns.

Asphalt Emulsion

Today, asphalt emulsions are more commonly used. An emulsion consists of an oil suspended in water. In this case, the asphalt cement is the oil component. A surfactant (also called an emulsifying agent) needs to be added in order to make the oil and water mix. Having the asphalt suspended in water allows the placing temperature for a BST to be significantly lower than for a hot mix asphalt.

A surfactant offers two benefits – one, it causes asphalt to form tiny droplets that will suspend in water by lowering the surface tension between the asphalt and the water. Two, a surfactant determines the electrical charge of the emulsion. Aggregate will have an electrical charge, usually negative. Since opposite charges will attract, it is important to choose an emulsion with the opposite charge, which will enhance the binding of the asphalt to the aggregate. Cationic (having a positive charge) emulsions are typically used.

Figure١٥. Close-up of asphalt emulsion being sprayed onto a prepared surface. The spray bar allows for consistent coverage of one lane-width at a time.

Figure١٦. The emulsion spray bar in action. Note the distinctive brown color before the emulsion "breaks."

Figure١٧. The emulsion color turns to black after it is said to have "broken."

Figure ١٨. The aggregate should be added to the emulsion before the emulsion breaks. Note that in this photo, the aggregate was added too late, which is poor procedure.

The next largest (by volume) ingredient in an asphalt emulsion is the water. Water forms approximately one-third of the volume of the emulsion. Asphalt particles will, with the help of the emulsifying agent, suspend in the water. It is important to note that if the emulsion breaks (when the asphalt and water separate from one another) the emulsion will change from brown to black. The aggregate must be applied and rolled before the emulsion breaks. When the emulsion breaks, the water evaporates, and the asphalt remains on the roadway.

The asphalt cement is the primary ingredient in a BST. This asphalt is much like the asphalt used in hot mix paving. Sometimes, a latex or polymer modified asphalt may be used to improve early chip retention or BST durability.

Aggregate

Aggregates typically used include natural gravel or crushed stone. These must be clean and dust free, hard, and uniform. This is to provide a durable surface for traffic. It is common to limit the percent of material passing the No. ٢٠٠ sieve (٠.٠٧٥ mm) to about ١ percent or less since excessive dust can be a serious adhesion issue for BSTs.

Figure ١٩. The aggregate truck putting down ٢٠ to ٣٠ lb/SY application rate of ½” to No.٤ chips.

Figure٢٠. Receiving hopper of the chip spreader as the truck dumps.

Figure ٢١. Individual chip gates—this arrangement allows for variable chip application rates.

Figure ٢٢. Close-up of chip distribution gates.

Figure ٢٣. Application of "choke" stone.

Figure ٢٤. Rolling helps set the stone in the emulsion.

Aggregate used in construction of a BST should be placed only one layer thick. The exceptions to this is when adding choke stone or a second BST layer (a two layer BST is often referred to as a "double shot" treatment). Placing too much aggregate will cause aggregate pickup, whereby the well placed stones are dislodged, and may cause automobile windshield damage.

A small amount of excess aggregate, more than ٥% but less than ١٠%, may be placed in turning and stopping zones. This will reduce tire scuffing in the freshly laid BST.

<u>Aggregate Shape</u>

Aggregate shape can be described as either flat or cubical. It can also be either round or angular. These qualities will effect the seal coat in different ways.

If an aggregate is flat, the BST will lose chips excessively in the non-wheel path section of the road bed, or it may bleed in the wheel path. This is due to the pressure from automobile tires causing the flat chips to settle into the asphalt on their flattest side. The BST then becomes thinner where the tires pass over. Aggregate with a Flakiness Index of ٢٠% or lower should be used for high volume roadways.

Flakiness is not an issue in low volume applications, as many tire passes are needed in one area to cause this phenomenon. However, for most applications, cubical aggregate is preferred due to its stability.

Round aggregate is likely to roll and become displaced by traffic. Angular aggregates lock to one another. Areas with frequent snow plowing must take extra care in order to make sure a BST with a round aggregate will embed properly as the snow plow may shave off the taller pieces of stone.

On high volume roads, a double chip seal may be the better option. This is when a BST is placed atop another one. The aggregate on the bottom layer should be about twice as large as the one on the top. The smaller stones on top will be less likely to cause windshield damage and the surface is typically smoother than a single seal coat.

<u>Aggregate Size</u>

Aggregate gradation and size are important to the success of a BST. Gradation describes the distribution of large and small stones within the aggregate mix. For a BST, the two options are one-size aggregate or graded aggregate.

One-size aggregate is an aggregate mix that comprises roughly equal sized stones. If all the aggregate is approximately the same size, there are good void spaces for the asphalt to fill and adhere the stones to the pavement structure. Other benefits of one-size aggregate include good friction between the surface and vehicle tires due to maximizing tire-aggregate contact area, good drainage between stones, and simplicity in determining whether the amount of aggregate is sufficient.

Graded aggregate simply means that the aggregate has some distribution in size. There are many types of gradations, as in dense graded or gap graded. One difficulty that may arise from using graded aggregate is that the lower air voids in graded aggregate means that the binder may not fit between chips. Problems from bleeding to aggregate loss may occur.

Aggregate containing dust must ‘‘not’’ be used for a BST. Dust will prevent the aggregate from bonding to the asphalt binder and will create problems with excessive chip loss. One of two solutions to this problem may be used: either use a high float emulsion, which has wetting agents that assist with bonding in dusty aggregate, or wash the aggregate with clean potable water and then air dry.

Design

Design of BSTs must take into consideration all of the points mentioned in the Asphalt and Aggregate sections of this article. Material must be of good quality and the correct properties. The design must also take into consideration the amount of binder and cover aggregate to apply. In order to prevent excessive chip loss, about ٧٠ percent of the aggregate (and a minimum of ٥٠ percent) must be embedded in the residual asphalt – the asphalt left after the water or cutback has evaporated. With an asphalt emulsion, the binder must rise near to the top of the aggregate, otherwise the residual asphalt will be insufficient to properly embed the aggregate. The goal is to have the binder at about ٧٠% of the chip height after the binder has cured.

One procedure which is commonly used is the McLeod Design Procedure. For more information on this, please refer to the Minnesota Seal Coat Handbook.

Figure٢٥. A basic goal is to achieve ٥٠% chip embedment into the binder. This shows an embedment of about ٥٠% which is good.

Figure ٢٦. Note that extra chips are swept to the roadside.

Distressed Pavement

Surface distress is “Any indication of poor or unfavorable pavement performance or signs of impending failure; any unsatisfactory performance of a pavement short of failure” (Highway Research Board, ١٩٧٠[١]). Surface distress modes can be broadly classified into the following three groups:

Fracture. This could be in the form of cracking (in flexible and rigid pavements) or spalling resulting from such things as excessive loading, fatigue, thermal changes, moisture damage, slippage or contraction.

Distortion. This is in the form of deformation (e.g., rutting, corrugation and shoving), which can result from such things as excessive loading, creep, densification, consolidation, swelling, or frost action.

Disintegration. This is in the form of stripping. raveling or spalling, which can result from such things as loss of bonding, chemical reactivity, traffic abrasion, aggregate degradation, poor consolidation/compaction or binder aging.

Thus, surface distress will be somewhat related to roughness (the more cracks, distortion and disintegration – the rougher the pavement will be) as well as structural integrity (surface distress can be a sign of impending or current structural problems).

Pavement must be repaired prior to the application of a BST.

Pavement can be tested in order to help determine what repairs should be made. Common tests include wheelpath rutting, roughness, and surface friction. If structural failure is suspected, a falling weight deflectometer test may be conducted.

Distress Correction

Once the pavement structural distress has been quantified, the distress must be corrected before constructing a BST.

An extensive pavement distress discussion (with photos) can be found at:

HMA Pavement Distress

PCC Pavement Distress

Base Repair

If the distress is so severe that the subgrade has been affected, the structure must be replaced through a full-depth dig-out, which may be done in a variety of ways. The designer must specify the area and depth of the repair for each section of the pavement.

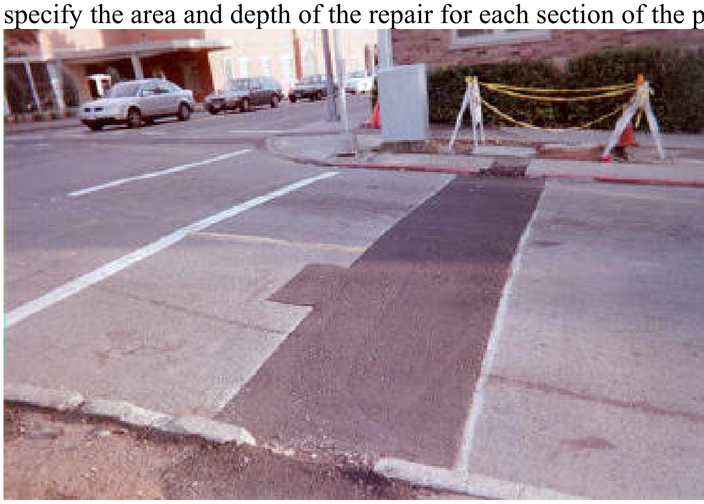

Figure ٢٧: Full-depth patch.

Patching

Patching may be done (in HMA, in PCC) to repair wheel ruts, edge raveling, and delaminated or pothole areas. Common construction practices in placing HMA for patching include use of a spreader box, grader/blade patching, or using a paver. Results from using any of these methods will be satisfactory if they are properly performed. To avoid chip loss, all paved repair areas must be fog sealed prior to applying BST. Fog sealing is the light application of an asphalt emulsion.

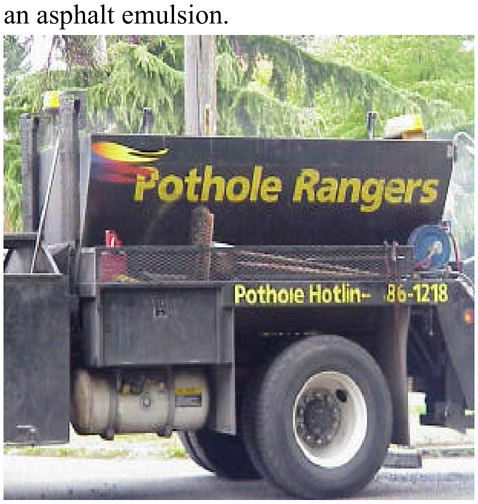


Figure ٢٨: Pothole patching truck with a hotbox

Figure ٢٩: Semi-permanent pothole repair

Fog seals can also be placed on a new chip seal after the final brooming to assist in aggregate retention and prevent the shedding and shelling of the new aggregate. The fog seal gives an additional layer of waterproofing to the new wearing course. In this type of use, the fog seal should be applied ٣ to ١٤ days after the chip seal was placed, with brooming to be completed immediately before the fog seal is placed.


Figure ٣٠: Parking lot showing no treatment on the left side and a fog seal on the right side.

Crack Sealing

Crack seals are used for repairing transverse and longitudinal cracks. This is typically the use of a rubberized tar material or mixture of sand and asphalt emulsion to fill the crack. Cracks and joints ١/٤″ or greater should be cleaned of any incompressible material including old sealant, and then sealed prior to applying a BST.

Figure ٣١: Crack sealing in western Oregon to repair transverse cracks.

Slurry Seal

A slurry seal ought to be applied at ٢٥% of the design life for maximum benefit in preserving the pavement structure. Maintenance with a slurry seal must be instituted before significant pavement deterioration occurs. Aggregate size, emulsion type, and any additives determine classification of the slurry seal. If distress is noted, crack sealing ought to be done before applying a slurry seal. When a slurry is placed over dry and raveling pavement, a tack coat should be done before the slurry seal.

Construction

A single layer BST is constructed in the following steps:

Surface preparation. Surface defects, such as potholes, are repaired and the existing surface is cleaned (e.g., by a street sweeper).

Asphalt material application. Typically, an asphalt emulsion is applied from a spray truck to the surface of the existing pavement (see Figure ١).

Aggregate application. A thin aggregate cover (only one stone thick) is spread over the asphalt material before it has set (see Figure ١٦ ). The aggregate usually has a uniform gradation.

Aggregate embedding. A roller (usually a pneumatic tire roller) is used to push the aggregate into the asphalt material and seat it firmly against the underlying pavement (see Figure ٣). Generally, about ٥٠ percent of each aggregate particle should be embedded in the asphalt material (see Figure ٤) after final rolling. About ٧٠ percent of each aggregate particle will be embedded after several weeks of traffic. It is common to place an aggregate "chokestone" on top of the uniformly graded larger aggregates after embedment. Chokestone is essentially a finer aggregate gradation (e.g., less than ١٢.٥ mm (١/٢ inch)) used to make a more dense aggregate matrix at the level of embedment (see Figure١٩ ). This more dense matrix helps prevent excessive aggregate loss due to traffic.

Multiple layer surface treatments are done by repeating the above process for each layer. Figure٢٣ shows a BST in Washington State.

Figure ٣٢. Spray truck applying CRS-٢P emulsion at a shot rate of ٠.٥٢ gallons/square yard (later increased to ٠.٥٨).

Figure ٣٣. ١/٢ inch minus chips being placed - note that the truck is driving backwards as is standard.

Figure ٣٤. Embedding the aggregate into the asphalt using a pneumatic tire roller.

Figure٣٥. Close up of BST before choke stone application. Not all BSTs use choke stone.

Figure ٣٦. Applying the choke stone.

Figure ٣٧. Close up of BST after choke stone application. Note tighter surface almost completely covering underlying asphalt.

Figure ٣٨. Finished BST before brooming.

Figure ٣٩. Pulling a rock out showing elasticity of CRS-٢P emulsion. Notice long "string".

Figure ٤٠. Final BST the next day after brooming. Note reduced speed.

Making Construction Joints

Construction joints are needed on any project that takes more than one day to complete. In order to make the joint sound and level with the previous day's construction, special practices must be used for the construction joint. These steps are laid out in the following images.

Figure ٤١. At the end of day, work is stopped and a construction joint is made for continuing the work the next day.

Figure ٤٢. When ready to restart construction, paper is needed.

Figure ٤٣. Place the paper at the joint.

Figure ٤٤. Position the emulsion sprayer to start the shot on the paper.

Figure٤٥. Start the shot on the paper.