Distresses and Treatment/Repair Methods in Flexible and Rigid Pavements

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Section 1 — Background

Overview

A highway pavement is a structure consisting of layers of natural and processed materials above the natural ground (often called subgrade or roadbed). A pavement's primary function is to distribute the vehicle loads from the top of the pavement to a larger area of the subgrade without causing any damage to the subgrade.

The pavement structure should be able to provide an acceptable riding quality, satisfactory skid resistance, favorable light-reflecting characteristics, and low noise. The aim is to ensure that the transmitted wheel loads are sufficiently reduced, so that they do not exceed the capacity of all the layers of pavement including the subgrade.

A pavement is expected to meet the following requirements:

- Sufficient thickness to distribute the wheel-induced stresses to a reduced value on the subgrade soil.
- Structurally adequate to keep the cracking and deformation within tolerable limits.
- Structurally strong to withstand all types of stresses imposed upon it.
- Adequate coefficient of friction to prevent skidding of vehicles.
- Smooth surface to provide comfort to road users even at the expected speed.
- Produces least noise from moving vehicles.
- Dust and waterproof surface for avoiding reduced visibility.
- Drains water laterally or vertically without washing layer particles.
- Long service life with a desirable level of comfort considering the economy.

Two types of pavements are generally recognized: Flexible Pavements and Rigid Pavements, as shown in Figure 1.

A combination of these two pavements is also possible, and is termed Composite Pavement as shown in Figure 2.

Figure 1 Flexible and Rigid Pavements

Figure 2 Composite Pavement Black Topping (top) and White Topping (bottom)

Section 2 — Pavement Types

Flexible Pavements

- Flexible pavements are usually surfaced with Asphalt Materials. These pavements are called flexible because the pavement structures can flex or bend under a traffic loading.

- A flexible pavement structure requires several layers of materials because these layers are not stiff enough to distribute the wheel load to a large area (Figure 3).

- Beneath the asphalt layer, a crushed aggregate base layer is commonly seen. Below the base layer, a subbase layer is also used based on the subgrade strength.

- The natural subgrade soil can be improved by compaction or mixing of some improved soil, asphalt millings, low-quality aggregate based on the availability of these materials, and degree of improvement required.

Rigid Pavements

- Rigid pavements are composed of reinforced or non-reinforced Portland cement concrete (PCC) surface course.

- Such pavements are stiffer than flexible pavements due to the high modulus of elasticity [typically 3000–4000 Ksi (21–28 GPa) for PCC and 500–1000 Ksi (3.4–6.9 GPa) for asphalt layer] of the PCC material.

- These pavements can have reinforcing steel to reduce thermal cracking or eliminate joints. Each of these pavement types distributes load over the subgrade in a different fashion.

- Rigid pavements, because of PCC's high elastic modulus, tend to distribute the load over a relatively wide area of a subgrade (Figure 3).

- The concrete slab itself supplies most of a rigid pavement's structural capacity. On the other hand, a flexible pavement having a low modulus distributes loads over a smaller area. It requires a thicker pavement, which is achieved through a combination of thin layers due to field compaction difficulty of constructing a thicker layer.

- Compared to flexible pavements, rigid pavements are placed either directly over the prepared subgrade or over a single layer of granular or stabilized material called base course.

- In rigid pavements, the load is distributed by the slab action, in which the pavement behaves like an elastic plate resting on an elastic medium.

- Rigid pavements should be analyzed by the "plate theory" instead of the "layer theory", assuming an elastic plate resting on an elastic foundation.

- The "plate theory" assumes the concrete slab as a medium thick plate that is plane before loading and remains plane after loading.

- Bending of the slab due to wheel load and temperature variation causes tensile and flexural stresses within the pavement layers.

- Layered elastic models assume that each pavement structural layer is homogeneous, isotropic, and linearly elastic. In other words, it is the same everywhere and will rebound to its original form once the load is removed.

- The plate theory is a simplified version of layer theory that assumes the concrete slab as a medium thick plate which is plane before loading and to remain plane after loading. Bending of the slab due to wheel load and temperature variation and the resulting tensile and flexural stress.

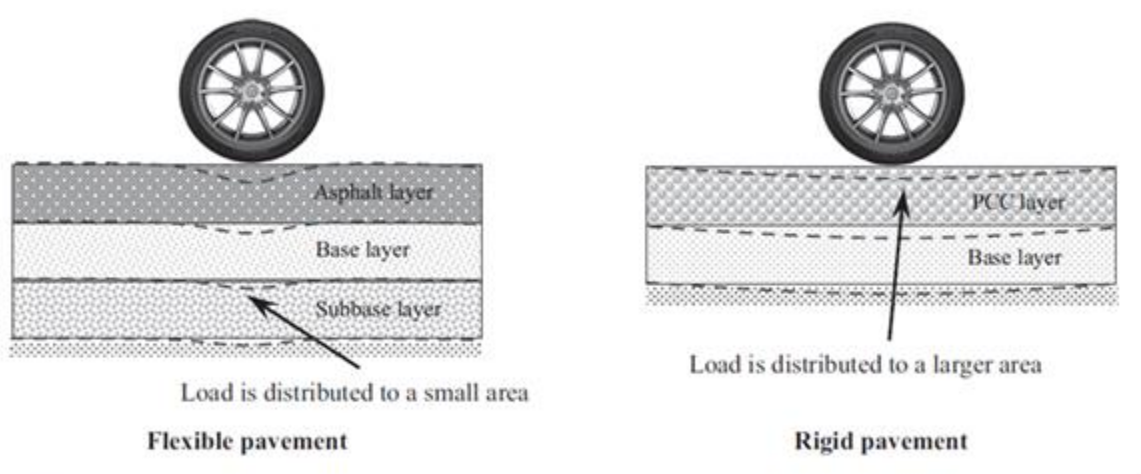

Figure 3 Deformation Behaviour of Flexible and Rigid Pavements

Components of Pavements

The road pavement structure layers are: surface course, base course, subbase course, and subgrade course.

Flexible Pavements

Surface Course

The surface course consists of multiple layers of pavement structure where the top layer is directly exposed to traffic as shown in Figure 4. The surface course is also called the wearing course. For flexible pavements, the bituminous surface is the wearing course, whereas in rigid pavements the concrete surface act as the base course cum wearing course. The wearing course reduces the percolation of water and provides an anti-skid and abrasion-resistant riding surface. The functions of surface or wearing course are as follows:

- To provide a smooth and uniform rigid surface.
- To resist the abrasive forces of traffic.
- To prevent dust nuisance.
- To act as a structural part of the pavement.

Base Course

The base course is a layer or layers of specified or select material of designed thickness placed on a subbase or subgrade (if a subbase is not used) to provide a uniform and stable support for binder and surface courses.

The base course is the most important layer of a road structure which transfers the stresses developed due to traffic impacts through the wearing course. The base course layer provides the required foundation stiffness and structural strength.

Good quality crushed aggregates in line with technical specifications have to be used as shown in Figure 5. If the crushed aggregates do not meet the required criteria, it can be stabilized with Portland cement, lime, or asphalt. In the case of high-quality pavements, the crushed aggregates are treated with asphalt or Portland cement. The functions of the base course are as follows:

- To act as the foundation of the road pavement and to transfer the traffic load safely to the subbase and subgrade.
- To withstand high shearing stresses due to the impact of traffic.
- To prevent the undesirable entry of subgrade soil in the pavement when the base course is constructed directly over the subgrade.

Figure 4 Surface Course/ Wearing Course

Figure 5 Base Course

Subbase Course

The subbase course comes between the base course and subgrade course as shown in Figure 6. The material used for this layer shall satisfy the specifications in terms of gradation, strength, and plastic characteristics.

This layer is necessary if the subgrade is of poor quality. In that case, an additional layer of burnt clinkers, gravel, slag, etc., is provided to strengthen the sub grade. The functions of the subbase course are as follows:

- The subbase layer enhances the bearing capacity of the subgrade and improves the load distribution capacity of the base course and wearing course.
- The subbase course prevents the entry of finely graded subgrade soil to the base course layer.
- The subbase course prevents the capillary rise of water and enables free drainage of water entering the pavement.
- The subbase material must be free draining for this application with suitable systems must be included in the pavement design for collecting and removing any accumulated water from the subbase.
- The subbase layer provides insulation to the subgrade layer against frost.
- The subbase course is used for raising the heights of pavements to be in line with the natural water table.
- The subbase course provides a perfect hard stratum for remaining construction activities.

Figure 6 Subbase Course

Subgrade Course

The subgrade is the compacted natural soil below the pavement layers and it is the finished or compacted surface on which the pavement rests. The subgrade course is also known as the formation and serves as the foundation of the pavement layers as shown in Figure 7.

Depending on the nature of the terrain, the subgrade can be an embankment or a cutting or it will be in line with natural ground level. The load-bearing strength of the subgrade structure is determined by the California bearing ratio test (CBR).

The material used for subgrade shall be locally available, strong, and cheap. The subgrade serves as the foundation and acts as a uniform support to the pavements.

Figure 7 Subgrade Course

Flexible pavements can be classified into two types as shown in Figure 8:

- Conventional (the base layer consists of crushed aggregates).
- Full-Depth (the base layer, also known as black base, consists of hot mix asphalt instead of crushed aggregates).

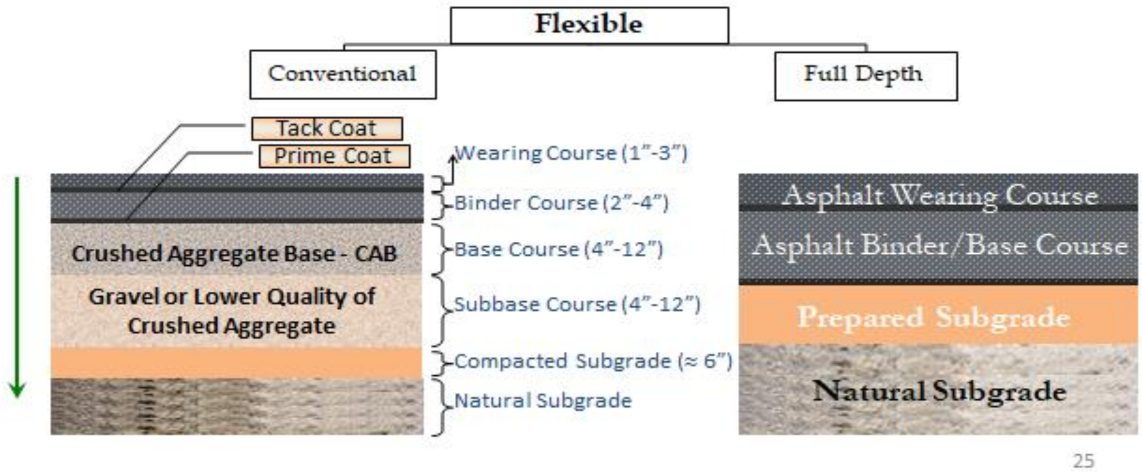

Figure 8 Cross-Sectional View of Flexible Pavements

Additional Information on the Surface Course (Asphalt Concrete Layer)

Asphalt Binder

The asphalt binder, sometimes referred to as the asphalt cement binder or the asphalt cement, is an essential component of asphalt concrete; it is, as the name implies, the cement that holds the aggregate together. The asphalt binder is a co-product of the petroleum-refining system that produces gasoline, diesel fuel, lubricating oil, as well as several other petroleum products. The asphalt binder is produced from the thick, heavy residue (residuum) that remains after distillation of petroleum to remove fuels and lubricants. The residuum is processed further by methods such as steam treatment (steam distillation) to remove any vestiges of gas oil or lubricating oil constituents and/or by oxidation until the treated residuum meets the desired specifications required of an asphalt binder. Once the binder has been produced, for demanding, high-performance applications, small amounts of additives may be blended into the binder to produce a modified binder; for example, polymer additives produce a polymer-modified binder. The asphalt binder is viscoelastic: viscous and soft at high temperature/slow loading time (e.g. standing load). Elastic and stiff at low temperature/fast loading time.

Wearing Course

- Top course of asphalt pavement - usually dense graded HMA.
- The surface layer of a pavement that takes the wear of traffic.

- Resists distortion under traffic.
- Provides smooth & skid-resistant riding surface.
- Waterproof to protect pavement and subgrade (SG).

  (Refer to Figure 8).

Binder Course

- HMA too thick to be compacted in one layer.
- Larger size aggregates, (compact 2-3" at a time).
- The term binder course refers to a European standard description of the second layer of asphalt pavement, described in the UK as a base course.

  (Refer to Figure 8).

Tack Coat

- Asphalt emulsion diluted with water.
- Bond between surface being paved & overlying course.
- Very thin & uniformly cover entire surface.

  (Refer to Figure 8).

  The application of the tack coat is clearly shown in Figure 9.

Figure 9 Tack Coat Application

Prime Coat

Low-viscosity cutback asphalt applied to an absorbent surface. (Refer to Figure 8).

The application of the prime coat is clearly shown in Figure 10.

Figure 10 Prime Coat Application

Rigid Pavements

Figure 11 clearly displays a typical cross-sectional view of a rigid pavement.

Figure 11 Cross-Sectional View of Typical Rigid Pavements

When concrete is poured, it is very important to cut expansion joints in the concrete slab. By cutting control joints in the concrete, the random cracking that inevitably occurs in concrete slabs soon after the concrete is poured and set can be better controlled. These cuts are called Construction Cuts (also called Construction joints, Expansion Cuts, or Expansion joints) and must be correctly positioned and done within 24 hours of the concrete being poured, otherwise there is a significant risk of concrete cracking (unless other jointing methods are used). Saw cuts are a used to create control joints in concrete, which help control where cracking occurs due to shrinkage. The cuts should be made at a pre-determined spacing and only after the concrete has obtained sufficient strength but before internal cracking begins. Therefore, the timing of saw cuts is critical.

Rigid pavements can be classified into four types:

- Jointed Plain Concrete Pavement (JPCP) as shown in Figure 12.

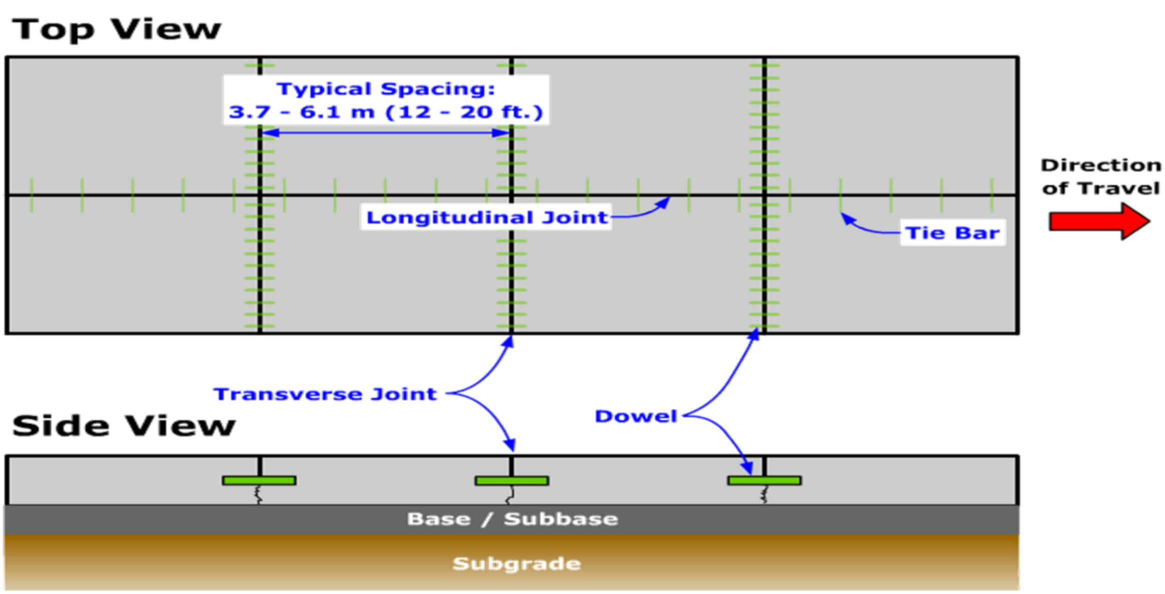

Figure 12 Top View and Side View of Jointed Plain Concrete Pavement

- Jointed Reinforced Concrete Pavement (JRCP) as shown in Figure 13.

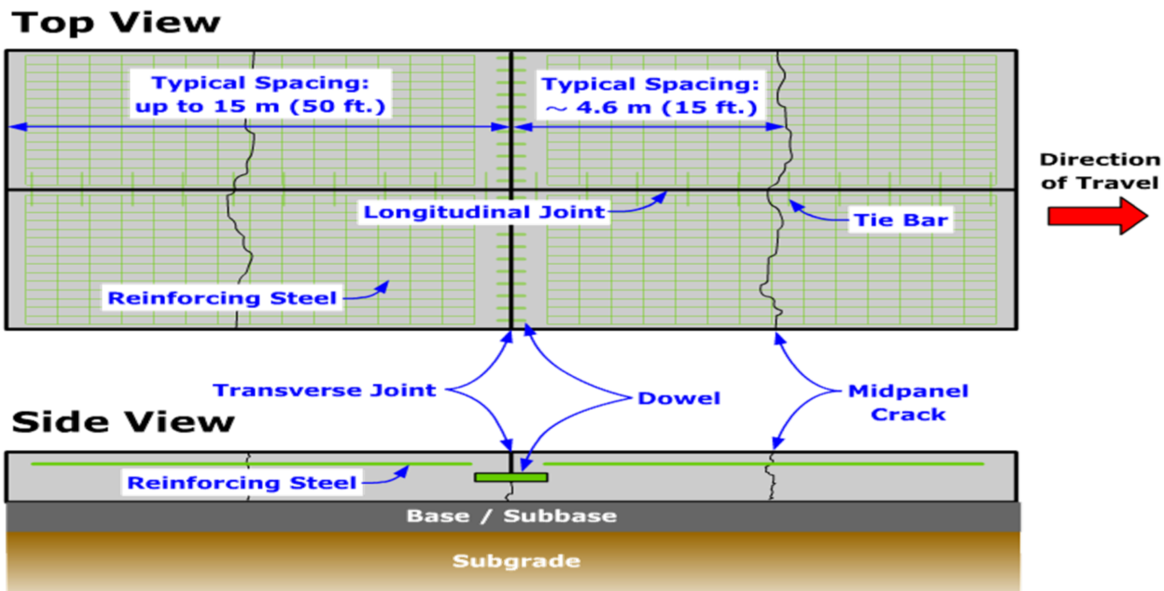

Figure 13 Top View and Side View of Jointed Reinforced Concrete Pavement

- Continuously Reinforced Concrete Pavement (CRCP) as shown in Figure 14.

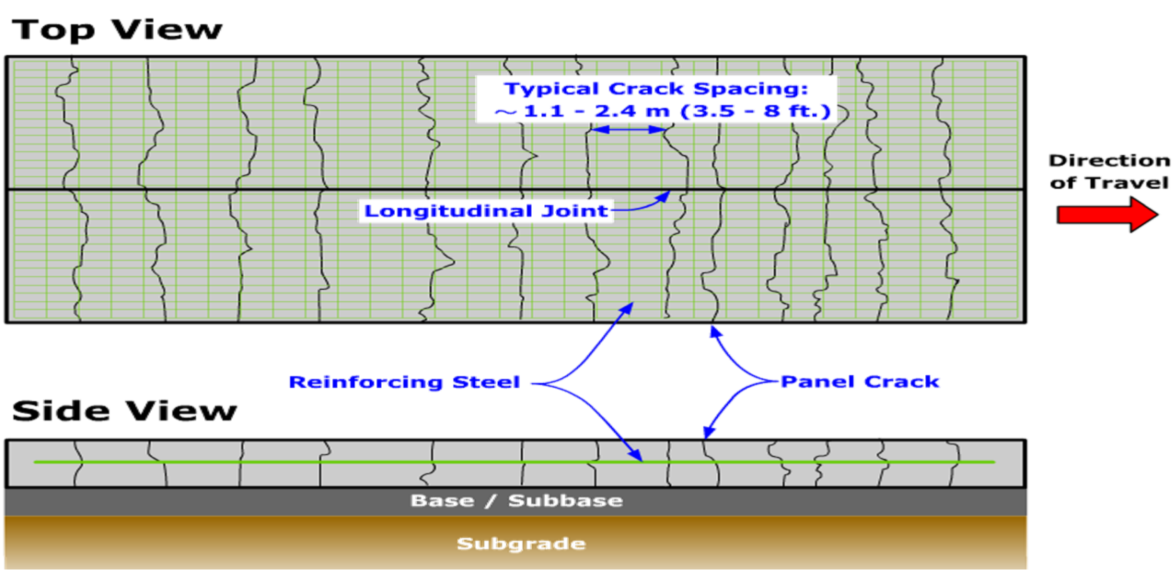

Figure 14 Top View and Side View of Continuously Reinforced Concrete Pavement

- Prestressed Concrete Pavement (PCP) as shown in Figure 15.

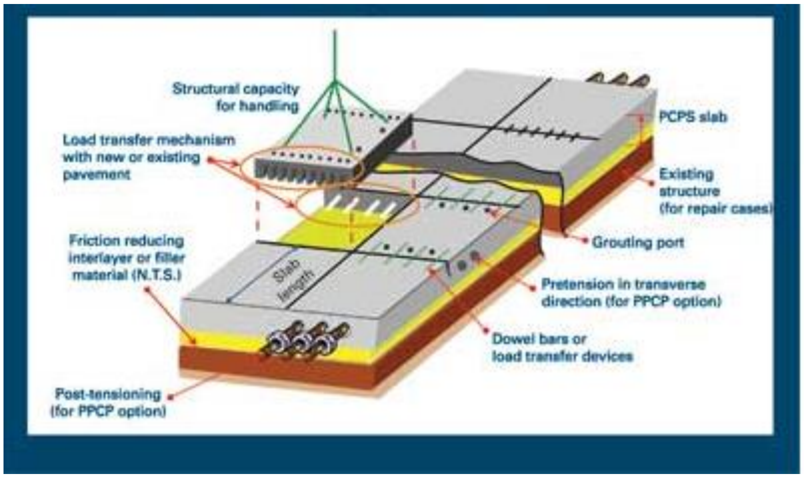

Figure 15 Precast Concrete Pavement Components

Tie Bars

Tie bars, also known as Deformed Steel Bars or Connectors, are placed along the longitudinal joint used to hold the faces of abutting slabs in contact (AASHTO, 1993) as shown in Figure 16. Although they may provide some minimal amount of load transfer, they are not designed to act as load transfer devices and should not be used as such (AASHTO, 1993).

Figure 16 Tie Bars in Rigid Pavements

Dowel Bars

Dowel bars are placed across transverse joints in concrete pavements to allow movement as shown in Figure 17. They are inserted at the mid-depth of the slab and coated with a bond-breaking material to restrict bonding to the PCC. Thus dowels help to transfer loads allowing expansion and contraction of adjacent slabs independently. Dowel bars are short steel bars that are installed in concrete slabs to provide a mechanical connection that does not restrict horizontal joint movement. They are designed to reduce joint deflection and stress in the approach and leave slab by increasing load transfer efficiency.

Figure 17 Dowel Bars in Rigid Pavements

Figure 18 illustrates the placement of tie bars and dowel bars in rigid pavements.

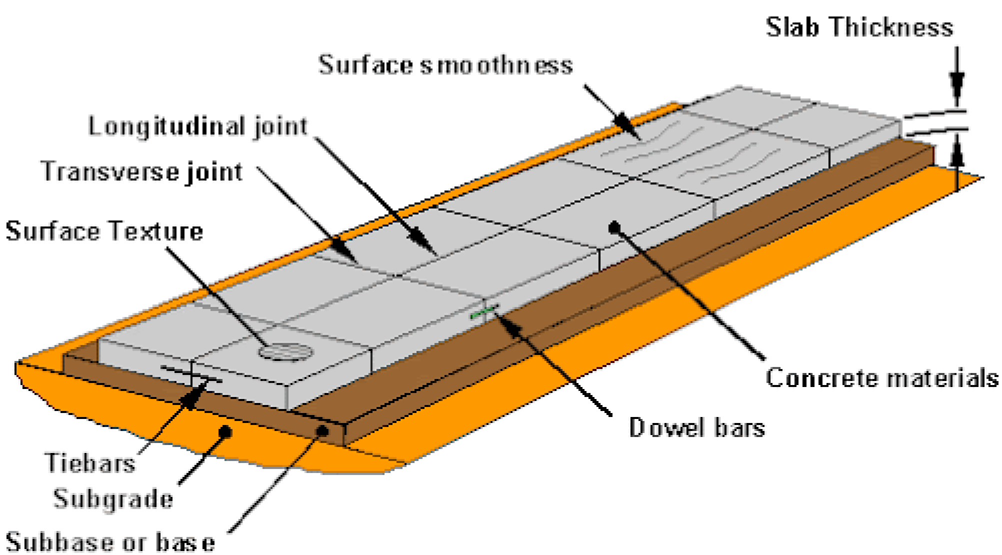

Figure 18 Tie Bars and Dowel Bars in Rigid Pavements

A dowel bar retrofit (DBR) is a method of reinforcing cracks in highway pavement by inserting steel dowel bars in slots cut across the cracks. It is a technique which several U.S. states' departments of transportation have successfully used in repairs to address faulting in older jointed plain concrete pavements.

Plate dowels allow contraction of the slab in two lateral directions. Traditional dowel bars have to be inserted through timber formwork making the removal of the formwork difficult. Plate dowels use a plastic sleeve that is nailed to the timber formwork making the formwork removal very simple. Steel plate dowels carry loads across a construction joint, maintain vertical alignment between adjacent slabs, and allow concrete shrinkage both perpendicular and parallel to the joint. Construction joints are formed or placed into slabs to define stopping places or the extent of an individual concrete placement.

Section 3 — Flexible Pavements Distress

Flexible pavement failure is caused by a number of variables including water intrusion, stress from heavy vehicles, expansion and contraction from seasonal temperature changes, and sun exposure. It is important to keep track with proper maintenance like crack and asphalt sealing to prevent cracks from forming and spreading.

The cracks form due to the forces applied by turning or braking motion of vehicles. Distortions in an asphalt pavement are caused by instability of an asphalt mix or weakness of the base or subgrade layers. The following section is a summary of the major flexible pavement distresses. Each distress discussion includes (1) pictures, (2) a description of the distress, (3) why the distress is a problem, and (4) typical causes of the distress.

Index of Flexible Pavements Distresses

Lane/Shoulder Drop-Off

Longitudinal Cracking

Patching/Patching Deterioration

Polished Aggregates

Potholes

Rutting

Slippage Cracking

Stripping

Transverse (Thermal) Cracking

Water Bleeding and Pumping

Weathering/Raveling

Alligator/Fatigue Cracking

Description: Fatigue or alligator cracking is defined as a series of interconnected cracks caused by fatigue failure of the HMA surface (or stabilized base) under repeated traffic loading. In thin pavements, cracking initiates at the bottom of the HMA layer where the tensile stress is the highest then propagates to the surface as one or more longitudinal cracks. This is commonly referred to as "bottom-up" or "classical" fatigue cracking. In thick pavements, the cracks most likely initiate from the top in areas of high localized tensile stresses resulting from tire-pavement interaction and asphalt binder aging (top-down cracking). After repeated loading, the longitudinal cracks connect forming many-sided sharp-angled pieces that develop into a pattern resembling the back of an alligator or crocodile. Figures 19, 20, and 21 illustrate various forms of alligator/fatigue cracking.

Figure 19 Bad Fatigue Cracking

Figure 20 Fatigue Cracking from Frost Action

Figure 21 Fatigue Cracking from Edge Failure

Problem: Indicator of structural failure, cracks allow moisture infiltration, roughness, may further deteriorate to a pothole.

Possible Causes: Inadequate structural support, which can be caused by a myriad of

things. A few of the more common ones are listed here:

- Decrease in pavement load supporting characteristics.
- Loss of base, subbase or subgrade support (e.g., poor drainage or spring thaw resulting in a less stiff base).
- Stripping on the bottom of the HMA layer (the stripped portion contributes little to pavement strength so the effective HMA thickness decreases).
- Increase in loading (e.g., more or heavier loads than anticipated in design).
- Inadequate structural design.
- Poor construction (e.g., inadequate compaction).

Repair: A fatigue cracked pavement should be investigated to determine the root cause of failure. Any investigation should involve digging a pit or coring the pavement to determine the pavement's structural makeup as well as determining whether or not subsurface moisture is a contributing factor. Once the characteristic alligator pattern is apparent, repair by crack sealing is generally ineffective. Fatigue crack repair generally falls into one of two categories:

- Small, localized fatigue cracking indicative of a loss of subgrade support. Remove the cracked pavement area then dig out and replace the area of poor subgrade and improve the drainage of that area if necessary. Patch over the repaired subgrade.
- Large fatigue cracked areas indicative of general structural failure. Place a Hot Mix Asphalt (HMA) overlay over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contributes little or no strength.

Bleeding

Description: Bleeding is defined as a film of asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface (as in the third photo) that can become quite sticky. Figures 22 and 23 illustrate various forms of bleeding.

Figure 22 Bituminous Surface Treatment Bleeding in Wheel Paths

Figure 23 HMA Bleeding from Overasphalting

Problem: Loss of skid resistance when wet.

Possible Causes: Bleeding occurs when asphalt binder fills the aggregate voids during hot weather and then expands onto the pavement surface. Since bleeding is not reversible during cold weather, asphalt binder will accumulate on the pavement surface over time. This can be caused by one or a combination of the following:

- Excessive asphalt binder in the HMA (either due to mix design or manufacturing).
- Excessive application of asphalt binder during Bituminous Surface Treatment (BST) application (as shown in figures 22 and 23).
- Low HMA air void content (e.g., not enough room for the asphalt to expand into during hot weather).

Repair: The following repair measures may eliminate or reduce the asphalt binder film on the pavement's surface but may not correct the underlying problem that caused the bleeding:

- Minor bleeding can often be corrected by applying coarse sand to blot up the excess asphalt binder.

- Major bleeding can be corrected by cutting off excess asphalt with a motor grader or removing it with a heater planer. If the resulting surface is excessively rough, resurfacing may be necessary.

Block Cracking

Description: Block cracking is defined as interconnected cracks that divide the pavement up into rectangular pieces as shown in Figure 24. Blocks range in size from approximately 0.1 m^2 (1 ft^2) to 9 m^2 (100 ft^2). Larger blocks are generally classified as longitudinal and transverse cracking. Block cracking normally occurs over a large portion of pavement area but sometimes will occur only in non-traffic areas.

Figure 24 Block Cracking

Problem: Allows moisture infiltration, roughness.

Possible Causes: HMA shrinkage and daily temperature cycling. Typically, caused by an inability of asphalt binder to expand and contract with temperature cycles because of the following:

- Asphalt binder aging.

- Poor choice of asphalt binder in the mix design.

Repair: Strategies depend upon the severity and extent of the block cracking:

- Low severity cracks (< 1/2 inch wide). Crack seal to prevent (1) entry of moisture into the subgrade through the cracks and (2) further raveling of the crack edges. HMA can provide years of satisfactory service after developing small cracks if they are kept sealed.

- High severity cracks (> 1/2-inch-wide and cracks with raveled edges). Remove and replace the cracked pavement layer with an overlay.

Corrugation and Shoving

Description: Corrugating and shoving is a form of plastic movement typified by ripples (corrugation) or an abrupt wave (shoving) across the pavement surface as illustrated in Figure 25. The distortion is perpendicular to the traffic direction. Usually occurs at points where traffic starts and stops (corrugation) or areas where HMA abuts a rigid object (shoving).

Figure 25 Corrugation and Shoving

Problem: Roughness.

Possible Causes: Usually caused by traffic action (starting and stopping) combined with an unstable (i.e. low stiffness) HMA layer (caused by mix contamination, poor mix design, poor HMA manufacturing, and excessive moisture in the subgrade).

Repair: A heavily corrugated or shoved pavement should be investigated to determine the root cause of failure. Repair strategies generally fall into one of two categories:

- Small, localized areas of corrugation or shoving. Remove the distorted pavement and patch.
- Large corrugated or shoved areas indicative of general HMA failure. Remove the damaged pavement and overlay.

Depression

Description: Depression is defined as localized pavement surface areas with slightly lower elevations than the surrounding pavement as illustrated in Figure 26. Depressions are very noticeable after a rain when they fill with water.

Figure 26 Depression in Left Lane and Shoulder

Problem: Roughness, depressions filled with substantial water can cause vehicle hydroplaning.

Possible Causes: Frost heave or subgrade settlement resulting from inadequate compaction during construction.

Repair: By definition, depressions are small localized areas. A pavement depression should be investigated to determine the root cause of failure (i.e., subgrade settlement or frost heave). Depressions should be repaired by removing the affected pavement then digging out and replacing the area of poor subgrade. Patch over the repaired subgrade.

Joint Reflection Cracking

Description: Joint reflection cracking are cracks in a flexible overlay of a rigid pavement. The cracks occur directly over the underlying rigid pavement joints as illustrated in Figures 27 and 28. Joint reflection cracking does not include reflection cracks that occur away from an underlying joint or from any other type of base (e.g., cement or lime stabilized).

Problem: Allows moisture infiltration, roughness.

Figure 27 Joint Reflection Cracking on an Arterial

Figure 28 Joint Reflection Cracking Close-Up

Possible Causes: Movement of the Portland Cement Concrete (PCC) slab beneath the HMA surface because of thermal and moisture changes. Generally, not load initiated, however loading can hasten deterioration.

Repair: Strategies depend upon the severity and extent of the cracking:

- Low severity cracks (< 1/2-inch-wide and infrequent cracks). Crack seal to prevent (1) entry of moisture into the subgrade through the cracks, and (2) further raveling of the crack edges. In general, rigid pavement joints will eventually reflect through an HMA overlay without proper surface preparation.

- High severity cracks (> 1/2-inch-wide and numerous cracks). Remove and replace the cracked pavement layer with an overlay.

Longitudinal Cracking

Description: Longitudinal cracking are cracks parallel to the pavement's centerline or laydown direction as illustrated in Figures 29 and 30. These cracks are usually a type of fatigue cracking.

Figure 29 Longitudinal Cracking as the Onset of Fatigue Cracking

Figure 30 Longitudinal Cracking from Poor Joint Construction

Problem: Allows moisture infiltration, roughness, indicates possible onset of alligator cracking and structural failure.

Possible Causes:

- Poor joint construction or location. Joints are generally the least dense areas of a pavement. Therefore, they should be constructed outside of the wheel path so that they are only infrequently loaded. Joints in the wheel path like those shown in Figure 30, will general fail prematurely.

- A reflective crack from an underlying layer (not including joint reflection cracking).

- HMA fatigue (indicates the onset of future alligator cracking).

- Top-down cracking.

Repair: Strategies depend upon the severity and extent of the cracking:

- Low severity cracks (< 1/2-inch-wide and infrequent cracks). Crack seal to prevent (1) entry of moisture into the subgrade through the cracks, and (2) further raveling of the crack edges. HMA can provide years of satisfactory service after developing small cracks if they are kept sealed.

- High severity cracks (> 1/2-inch-wide and numerous cracks). Remove and replace the cracked pavement layer with an overlay.

Patching/Patching Deterioration

Description: Patching is defined as an area of pavement that has been replaced with new material to repair the existing pavement as illustrated in Figures 31, 32, and 33. A patch is considered a defect no matter how well it performs.

Figure 31 Failing Patch

Figure 32 Patch over Localized Distress

Figure 33 Utility Cut Patch

Problem: Roughness.

Possible Causes:

- Previous localized pavement deterioration that has been removed and patched.
- Utility cuts.

Repair: Patches are themselves a repair action. The only way they can be removed from a pavement's surface is by either a structural or non-structural overlay.

Polished Aggregates

Description: Polished aggregates are areas of HMA pavement where the portion of aggregate extending above the asphalt binder is either very small or there are no rough or angular aggregate particles as illustrated in Figures 34 and 35.

Figure 34 Stone Matrix Asphalt at a Test Track

Figure 35 Five Years of Wear

Problem: Decreased skid resistance.

Possible Causes: Repeated traffic applications. Generally, as a pavement ages the protruding rough, angular particles become polished. This can occur quicker if the aggregate is susceptible to abrasion or subject to excessive studded tire wear.

Repair: Apply a skid-resistant slurry seal or BST or overlay.

Potholes

Description: Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course as illustrated in Figures 36 and 37. They generally have sharp edges and vertical sides near the top of the hole. Potholes are most likely to occur on roads with thin HMA surfaces (25 to 50 mm (1 to 2 inches)) and seldom occur on roads with 100 mm (4 inch) or deeper HMA surfaces.

Figure 36 Pothole from Fatigue Cracking

Figure 37 Developing Pothole

Problem: Roughness (serious vehicular damage can result from driving across potholes at higher speeds), moisture infiltration.

Possible Causes: Generally, potholes are the end result of alligator cracking. As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is dislodged is called a pothole.

Repair: In accordance with patching techniques.

Rutting

Description: Rutting is defined as surface depression in the wheel path as illustrated in Figures 40 and 41. Pavement uplift (shearing) may occur along the sides of the rut. Ruts are particularly evident after a rain when they are filled with water. There are two basic types of rutting: mix rutting and subgrade rutting. Mix rutting occurs when the subgrade does not rut yet the pavement surface exhibits wheel path depressions as a result of compaction/mix design problems. Subgrade rutting occurs when the subgrade exhibits wheel path depressions due to loading. In this case, the pavement settles into the subgrade ruts causing surface depressions in the wheel path.

Figure 38 Mix Rutting

Figure 39 Rutting from Mix Instability

Problem: Ruts filled with water can cause vehicle hydroplaning, can be hazardous because ruts tend to pull a vehicle towards the rut path as it is steered across the rut.

Possible Causes: Permanent deformation in any of a pavement's layers or subgrade usually caused by consolidation or lateral movement of the materials due to traffic loading. Specific causes of rutting can be:

- Insufficient compaction of HMA layers during construction. If it is not compacted enough initially, HMA pavement may continue to densify under traffic loads.
- Subgrade rutting (e.g., as a result of inadequate pavement structure).
- Improper mix design or manufacture (e.g., excessively high asphalt content, excessive mineral filler, insufficient amount of angular aggregate particles). Ruts caused by studded tire wear present the same problem as the ruts described here, but they are actually a result of mechanical dislodging due to wear and not pavement deformation.

Repair: A heavily rutted pavement should be investigated to determine the root cause of failure (e.g. insufficient compaction, subgrade rutting, poor mix design or studded tire wear). Slight ruts (< 1/3 inch deep) can generally be left untreated. Pavement with deeper ruts should be leveled and overlaid.

Slippage Cracking

Description: Slippage cracking are crescent or half-moon shaped cracks generally having two ends pointed into the direction of traffic as illustrated in Figure 42.

Figure 40 Slippage Cracking

Problem: Allows moisture infiltration, roughness.

Possible Causes: Braking or turning wheels cause the pavement surface to slide and deform. The resulting sliding and deformation is caused by a low-strength surface mix or poor bonding between the surface HMA layer and the next underlying layer in the pavement structure.

Repair: Removal and replacement of affected area.

Stripping

Description: Stripping is defined as the loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward as illustrated in Figures 43, 44, and 45. When stripping begins at the surface and progresses downward it is usually called raveling. Figure 45 shows the surface effects of underlying stripping.

Figure 41 Core Hole showing Stripping at the Bottom

Figure 42 Stripping at the Bottom of the Hole

Figure 43 Fatigue Failure from Stripping

Problem: Decreased structural support, rutting, shoving/corrugations, raveling, or cracking (alligator and longitudinal).

Possible Causes: Bottom-up stripping is very difficult to recognize because it manifests itself on the pavement surface as other forms of distress including rutting, shoving/corrugations, raveling, or cracking. Typically, a core must be taken to positively identify stripping as a pavement distress.

- Poor aggregate surface chemistry.
- Water in the HMA causing moisture damage.
- Overlays over an existing open-graded surface course. Based on Washington State Department of Transportation (WSDOT) experience, these overlays will tend to strip.

Repair: A stripped pavement should be investigated to determine the root cause of failure (i.e., how did the moisture get in?). Generally, the stripped pavement needs to be removed and replaced after correction of any subsurface drainage issues.

Transverse (Thermal) Cracking

Description: Transverse or thermal cracking are cracks perpendicular to the pavement's centerline or lay down direction as illustrated in Figures 46, 47, and 48. Usually a type of thermal cracking.

Figure 44 Large Patched Thermal Crack

Figure 45 Smaller Patched Thermal Crack

Figure 46 Small Thermal Crack

Problem: Allows moisture infiltration, roughness.

Possible Causes: Several including:

- Shrinkage of the HMA surface due to low temperatures or asphalt binder hardening.
- Reflective crack caused by cracks beneath the surface HMA layer.
- Top-down cracking

Repair: Strategies depend upon the severity and extent of the cracking:

- Low severity cracks (< 1/2-inch-wide and infrequent cracks). Crack seal to prevent (1) entry of moisture into the subgrade through the cracks, and (2) further raveling of the crack edges. HMA can provide years of satisfactory service after developing small cracks if they are kept sealed.
- High severity cracks (> 1/2-inch-wide and numerous cracks). Remove and replace the cracked pavement layer with an overlay.

Water Bleeding and Pumping

Description: Water bleeding occurs when water seeps out of joints or cracks or through an excessively porous HMA layer as illustrated in Figure 49. Pumping occurs when water and fine material is ejected from underlying layers through cracks in the HMA layer under moving loads as illustrated in Figure 50.

Figure 47 Water Bleeding Up Close

Problem: Decreased skid resistance, an indication of high pavement porosity (water bleeding), decreased structural support (pumping).

Possible Causes: Several including:

- Porous pavement as a result of inadequate compaction during construction or poor mix design.
- High water table.
- Poor drainage.

Figure 48 Cement Treated Base Pumping through HMA Cracks

Repair: Water bleeding or pumping should be investigated to determine the root cause. If the problem is a high water table or poor drainage, subgrade drainage should be improved. If the problem is a porous mix (in the case of water bleeding) a fog seal or slurry seal may be applied to limit water infiltration.

Weathering/Raveling

Description: As pavement ages and hardens, the asphalt binder and fine aggregate may begin to wear away. This process is called weathering. As weathering progresses, the coarse aggregate becomes exposed, dislodged, and missing, resulting in a distress called raveling; so ravelling can be defined as the progressive disintegration of an HMA layer from the surface downward as a result of the dislodgement of aggregate particles as illustrated in Figures 38 and 39.

Figure 49 Raveling Due to Low Density

Figure 50 Raveling from Snow Plot

Problem: Loose debris on the pavement, roughness, water collecting in the raveled locations resulting in vehicle hydroplaning, loss of skid resistance.

Possible Causes: Several including:

- Loss of bond between aggregate particles and the asphalt binder as a result of:

- A dust coating on the aggregate particles that forces the asphalt binder to bond with the dust rather than the aggregate.

- Aggregate segregation. If fine particles are missing from the aggregate matrix, then the asphalt binder is only able to bind the remaining coarse particles at their relatively few contact points.

- Inadequate compaction during construction. High density is required to develop sufficient cohesion within the HMA. Figure 39 shows a road suffering from raveling due to inadequate compaction caused by cold weather paving.

• Mechanical dislodging by certain types of traffic (studded tires, snowplow blades or tracked vehicles).

Repair: A raveled pavement should be investigated to determine the root cause of failure. Repair strategies generally fall into one of two categories:

- Small, localized areas of raveling. Remove the raveled pavement and patch.

- Large raveled areas indicative of general HMA failure. Remove the damaged pavement and overlay.

Types of Asphalt Surface (Flexible Pavements) Treatment

Definition: Asphalt Surface Treatments refer to the reconditioning of the wearing (surface) course of older existing asphalt pavements. The term may also be applied to the final phases of new asphalt pavement construction. Surface treatments are installed by placing a layer of new asphalt binder on the existing pavement as illustrated in Figure 51.

Figure 51 New Asphalt Binder over an Existing Pavement

Index of Asphalt Surface Treatment

Fog Seal

Slurry seal

Chip Seal

Microsurfacing

Scrub Seal

Cape Seal

Coats

Fog Seal

Fog Seal is a spray application of a special asphalt emulsion (a thin liquid oil) to an existing asphalt pavement surface (Figures 52 and 53). It seals narrow cracks and narrow pores, restores surface color of the pavement, and preserves the underlying pavement structure.

Fog Seal contains globules of paving asphalt, water, an emulsifying agent or surfactant, and sometimes a rejuvenator. Soap is a common form of a surfactant. A rejuvenator is an asphalt additive that when applied to the existing pavement will slightly soften the pavement it is applied to creating a better bond.

Figure 52 Fog Seal

Figure 53 Fog Seal Application

Slurry Seal

Slurry Seal is the mixture of water, asphalt emulsion, well-graded fine aggregate, and some additives as shown in Figures 54 and 55.

It is applied in a thin layer of 3- to 6-mm layers to seal the pavement. and prevent some minor distresses such as raveling, minor/narrow cracks, crack joints, mat tearing, etc. However, it provides no structural strength. A Slurry Seal is similar to a Fog Seal except the slurry seal has aggregates as part of the mixture.

Figure 54 Slurry Seal

Figure 55 Slurry Seal Application

Chip Seal

Chip Seal is a rapid setting emulsion sprayed onto the pavement followed by rolling in the high-quality, washed, crushed, and single-sized aggregate typically 9.5 or 6.7 mm as shown in Figures 56 and 57. A Chip Seal is named after the chips or the small crushed rock on the surface. A Chip Seal seals the narrow cracks, helps bind the cracked pavement together, provides a wearing surface, and prevents reflective cracking.

Asphalt emulsions used in Chip Seal applications contain globules of paving asphalt, water, an emulsifying agent or surfactant, polymer, and sometimes a rejuvenator.

Figure 56 Chip Seal

Figure 57 Chip Seal Application

Microsurfacing

Microsurfacing is similar to Slurry Seal. It consists of the application of a mixture of water, asphalt emulsion, aggregate (very small crushed rock), and chemical additives to an existing asphalt concrete pavement surface. Polymer is commonly added to the asphalt emulsion to provide better mixture properties.

Microsurfacing is a polymer-modified emulsion mix of aggregates, mineral fillers, water, and additives. It uses a 100% crushed, high-quality aggregate that passes through 9.5-mm sieve.

Polymer is commonly added to the asphalt emulsion to provide better mixture properties. The major difference between slurry seal and microsurfacing is in how they break or harden.

Slurry relies on evaporation of the water in the asphalt emulsion.

The asphalt emulsion used in microsurfacing contains chemical additives which allow it to break without relying on the sun or heat for evaporation to occur.

Microsurfacing is effective in treating rutting, moderate distress, and narrow crack width.

The major difference between Slurry Seal and Microsurfacing is in how they “break” or harden. Slurry relies on evaporation of the water in the asphalt emulsion. The asphalt emulsion used in Microsurfacing contains chemical additives that allow it to break without relying on the sun or heat for evaporation to occur. Refer to Figures 58 and 59.

Figure 58 Microsurfacing

Figure 59 Microsurfacing Application

Scrub Seal

Scrub Seal is an application that is very close to a Chip Seal treatment where Asphalt Emulsion and crushed rock are placed on an asphalt pavement surface. Refer to Figures 60 and 61.

The only difference is that the asphalt emulsion is applied to the surface of the road through a series of brooms placed at different angles.

A Scrub Seal provides an excellent treatment opportunity to treat a heavily distressed road cost-effectively.

Figure 60 Scrub Seal

Figure 61 Scrub Seal Application

Cape Seal

Cape Seal is an application of a Chip or Scrub Seal followed by the application of Slurry Seal or Microsurfacing at a later date as illustrated in Figure 62.

The Chip or Scrub Seal is used to seal and bind the cracks in the existing pavement.

The Slurry Seal or Microsurfacing serves to improve the chip retention and smoothness of the driving surface.

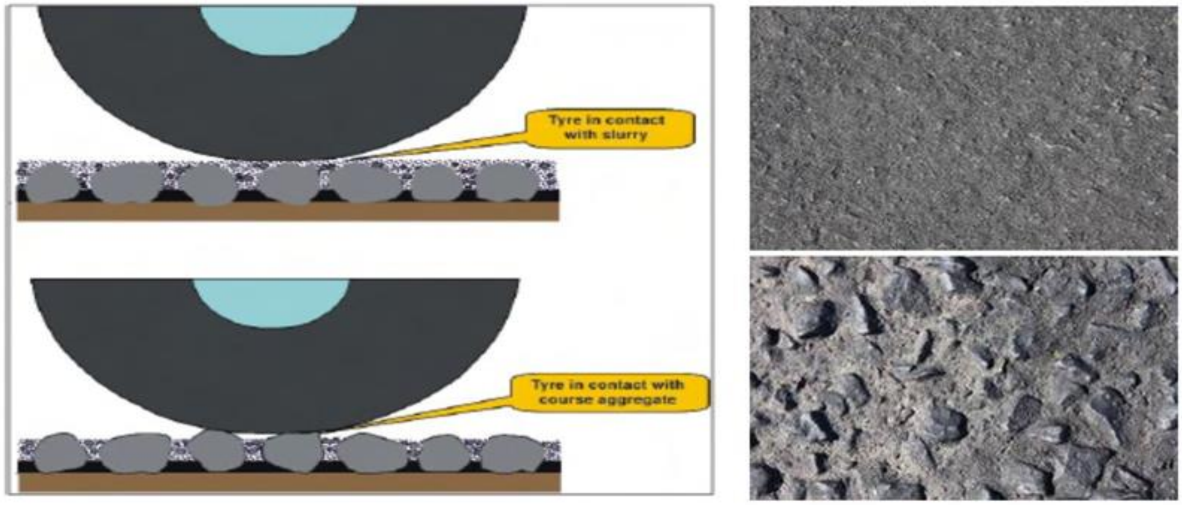

Figure 62 Cape Seal

Coats

Prime Coat is a low-viscosity liquid asphalt or emulsified asphalt used to seal a granular surface prior to the placement of surface treatment as illustrated in Figures 63 and 64.

Tack Coat is an emulsified asphalt-diluted slow setting that is applied to existing pavement surfaces when stated as illustrated in Figure 64. The placing of Tack Coats ensures good bonding between the layers.

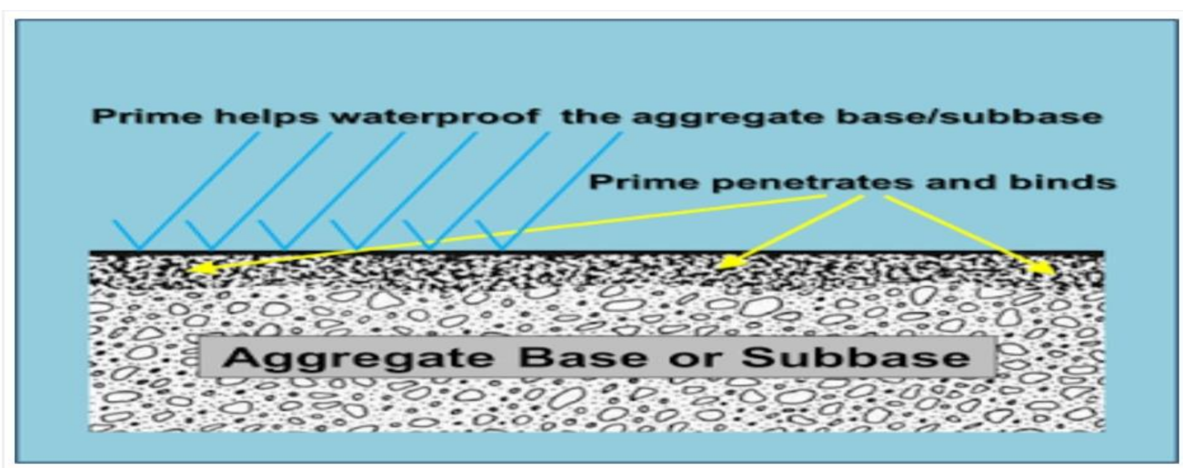

Figure 63 Coats

Figure 64 Typical Layers of a Flexible Pavement

Section 4 — Rigid Pavements Distress

The main causes of failure in rigid pavements due to faulting are: the pumping or the erosion of material under the pavement, resulting in voids under the pavement slab causing settlement. The temperature changes and moisture changes cause curling of the slab edges.

Poor soil support results to pavement failure. Soil stabilization thru hydraulic binders can help prevent the weakening of soil due to moisture. Leakage from underground water pipes deteriorates the soil that anchors the pavement due to erosion. It may result in a hole or a localized void on the pavement.

Index of Rigid Pavements Distresses

Blowup (Buckling)

Corner Break

Durability Cracking (D Cracking or Alkali Silica Reaction ASR)

Faulting

Joint Load Transfer System Deterioration

Linear (Panel) Cracking

Patching

Polished Aggregates

Popouts

Pumping/Water Bleeding

Punchout

Reactive Aggregates Distresses

Shrinkage Cracking

Spalling

Blowup (Buckling)

Description: Blowup or buckling is a localized upward slab movement and shattering at a joint or crack as illustrated in Figure 65. Usually occurs in spring or summer and is the result of insufficient room for slab expansion during hot weather.

Figure 65 Severe Blowup

Problem: Roughness, moisture infiltration, in extreme cases (as in Figure 65 right) can pose a safety hazard.

Possible Causes: During cold periods (e.g., winter) PCC slabs contract leaving wider joint openings. If these openings become filled with incompressible material (such as rocks or soil), subsequent PCC slab expansion during hot periods (e.g., spring, summer) may cause high compressive stresses. If these stresses are great enough, the slabs may buckle and shatter to relieve the stresses. Blowup can be accelerated by:

- Joint spalling (reduces slab contact area and provides incompressible material to fill the joint/crack).

- D cracking (weakens the slab near the joint/crack area).
- Freeze-thaw damage (weakens the slab near the joint/crack area).

Repair: Full-depth patch.

Corner Break

Description: Corner break is a crack that intersects the PCC slab joints near the corner as illustrated in Figures 66 and 67. "Near the corner" is typically defined as within about 2 m (6 ft) or so. A corner break extends through the entire slab and is caused by high corner stresses.

Figure 66 Corner Break on a Residential Street

Figure 67 Corner Break on a Highway

Problem: Roughness, moisture infiltration, severe corner breaks will fault, spall, and disintegrate.

Possible Causes: Severe corner stresses caused by load repetitions combined with a loss of support, poor load transfer across the joint, curling stresses and warping stresses.

Repair: Full-depth patch.

Durability Cracking (D Cracking or Alkali Silica Reaction ASR)

Description: Durability cracking is a series of closely spaced, crescent-shaped cracks near a joint, corner or crack as illustrated in Figure 68. It is caused by freeze-thaw expansion of the large aggregate within the PCC slab. Durability cracking is a general PCC distress and is not unique to pavement PCC.

Figure 68 D Cracking at Panel Corners

Problem: Some roughness, leads to spalling and eventual slab disintegration.

Possible Causes: Freeze-thaw susceptible aggregate.

Repair: "D" cracking is indicative of a general aggregate freeze-thaw problem. Although a full-depth patch or partial-depth patch can repair the affected area, it does not address the root problem and will not, or course, prevent "D" cracking elsewhere.

Faulting

Description: Faulting is defined as the difference in elevation across a joint or crack usually associated with undoweled JPCP as illustrated in Figures 69, 70, and 71. Usually the approach slab is higher than the leave slab due to pumping, the most common faulting mechanism. Faulting is noticeable when the average faulting in the pavement section reaches about 2.5 mm (0.1 inch). When the average faulting reaches 4 mm (0.15 in), diamond grinding or other rehabilitation measures should be considered.

Figure 69 Faulting from Ground Level

Figure 70 Faulting in the Truck Lane

Figure 71 Faulting Up-Close a Bus Stop

Problem: Roughness.

Possible Causes: Most commonly, faulting is a result of slab pumping. Faulting can also be caused by slab settlement, curling and warping.

Repair: Faulting heights of less than 3 mm (0.125 inch) need not be repaired. Faulting in an undoweled JPCP between 3 mm (0.125 inch) and 12.5 mm (0.5 inch) is a candidate for a dowel bar retrofit. Faulting in excess of 12.5 mm (0.5 inches) generally, warrants total reconstruction.

Joint Load Transfer System Deterioration

Description: Joint load transfer system deterioration is a transverse crack or corner break developed as a result of joint dowels as illustrated in Figure 72.

Problem: Indicator of a failed load transfer system, roughness.

Possible Causes: Load transfer dowel bars can fail for two principal reasons:

- Corrosion. If inadequately protected, dowel bars can corrode over time. The corrosion products occupy volume, which creates tensile stresses around the dowel bars, and a severely corroded dowel bar is weaker and may fail after repeated loading.

- Misalignment. Dowel bars inserted crooked or too close to the slab edge may create localized stresses high enough to break the slab. Misalignment can occur during original construction or during dowel bar retrofits.

Repair: Removal and replacement of the affected joint load transfer system followed by a full-depth patch for affected area.

Figure 72 Patched Failure

Linear (Panel) Cracking

Description: Linear cracking are linear cracks not associated with corner breaks or blowups that extend across the entire slab as illustrated in Figures 73, 74, and 75. Typically, these cracks divide an individual slab into two to four pieces.

Figure 73 Large Panel Crack

Figure 74 Panel Crack on a Residential Street

Figure 75 Panel Cracking in the Truck Lane

Problem: Roughness, allows moisture infiltration leading to erosion of base/subbase support, cracks will eventually spall and disintegrate if not sealed.

Possible Causes: Usually a combination of traffic loading, thermal gradient curling, moisture stresses and loss of support.

Repair: Slabs with a single, narrow linear crack may be repaired by crack sealing. More than one linear crack generally warrants a full-depth patch.

Patching

Description: Patching is an area of pavement that has been replaced with new material to repair the existing pavement as illustrated in Figures 76 and 77. A patch is considered a defect no matter how well it performs.

Figure 76 Patching on a Residential Street

Figure 77 Patching with Poor Edges

Problem: Roughness.

Possible Causes:

- Previous localized pavement deterioration that has been removed and patched.
- Utility cuts.

Repair: Patches are themselves a repair action. The only way they can be removed is through an overlay or slab replacement.

Polished Aggregates

Description: Polished aggregates are areas of PCC pavement where the portion of aggregate on the surface contains aggregate particles as illustrated in Figure 78.

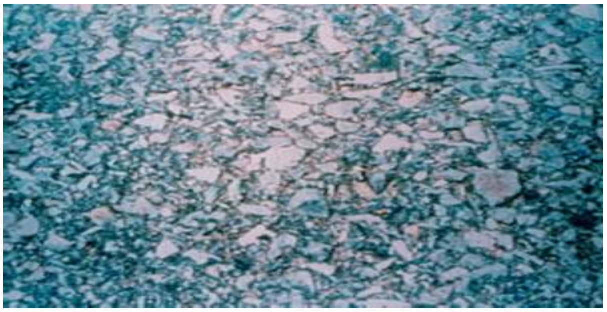

Figure 78 Polished Aggregates

Problem: Decreased skid resistance.

Possible Causes: Repeated traffic applications. Generally, as a pavement ages, the protruding rough, angular particles become polished. This can occur quicker if the aggregate is susceptible to abrasion or subject to excessive studded tire wear.

Repair: Diamond grinding or overlay.

Popouts

Description: Popouts are small pieces of PCC that break loose from the surface leaving small divots or pock marks as illustrated in Figures 79 and 80. Popouts range from 25 - 100 mm (1 - 4 inches) in diameter and from 25 - 50 mm (1 - 2 inches) deep.

Problem: Roughness, usually an indicator of poor material.

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

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

Repair: Isolated low severity popouts may not warrant repair. Larger popouts or a group of popouts can generally be repaired with a partial-depth patch.

Figure 79 Large Popouts

Figure 80 Popout Close-up

Pumping/Water Bleeding

Description: Pumping or water bleeding is defined as the movement of material underneath the slab or ejection of material from underneath the slab as a result of water pressure as illustrated in Figures 81, 82, 83, 84, and 85. Water accumulated underneath a PCC slab will pressurize when the slab deflects under load. This pressurized water can do one of the followings:

- Move about under the slab.

- Move from underneath one slab to underneath an adjacent slab. This type of movement leads to faulting.

- Move out from underneath the slab to the pavement surface. This results in a slow removal of base, subbase and/or subgrade material from underneath the slab resulting in decreased structural support.

Figure 81 Pumping in Action

Figure 82 Pumping Evidence during High Vehicle Simulator (HVS) Test

Figure 83 Pumping Damage

Figure 84 Broken Slabs with Pumping Evidence

Figure 85 Additional Pumping Evidence during High Vehicle Simulator (HVS) Test

Problem: Decreased structural support of the slab, which can lead to linear cracking, corner breaks and faulting.

Possible Causes: Water accumulation underneath the slab. This can be caused by such things as: a high water table, poor drainage, and panel cracks or poor joint seals that allow water to infiltrate the underlying material.

Repair: First, the pumping area should be repaired with a full depth patch to remove any deteriorated slab areas. Second, consideration should be given to using dowel bars to increase the load transfer across any significant transverse joints created by the repair. Third, consideration should be given to stabilizing any slabs adjacent to the pumping area as significant amounts of their underlying base, subbase or subgrade may have been removed by the pumping. Finally, the source of water or cause of poor drainage should be addressed.

Punchout

Description: Punchout is a localized slab portion broken into several pieces as illustrated in Figure 86. Typically, a concern only with CRCP.

Figure 86 Severe Punchout

Problem: Roughness, allows moisture infiltration leading to erosion of base/subbase support, cracks will spall and disintegrate.

Possible Causes: Can indicate a localized construction defect such as inadequate consolidation. In CRCP, it can be caused by steel corrosion, inadequate amount of steel, excessively wide shrinkage cracks or excessively close shrinkage cracks.

Repair: Full-depth patch.

Reactive Aggregates Distresses

Description: Reactive aggregates distresses is a pattern or map cracking (crazing) on the PCC slab surface caused by reactive aggregates as illustrated in Figure 87. Reactive aggregates are those that either expand or develop expansive by products when introduced to certain chemical compounds.

Figure 87 Severe Crazing

Problem: Roughness, an indication of poor aggregate - will eventually lead to PCC slab disintegration.

Possible Causes: This type of distress is indicative of poor aggregate qualities. Most commonly, it is a result of an alkali-aggregate reaction.

Repair: Partial-depth patch for small areas of scaling or slab replacement for large areas of scaling.

Shrinkage Cracking

Description: Shrinkage cracking is defined as hairline cracks formed during PCC setting and curing that are not located at joints as illustrated in Figures 88 and 89. Usually, they do not extend through the entire depth of the slab. Shrinkage cracks are considered a distress if they occur in an uncontrolled manner (e.g., at locations outside of contraction joints in JPCP or too close together in CRCP).

Figure 88 Shrinkage Cracks on Brand New Slabs

Figure 89 Severe Shrinkage Cracking

Problem: Aesthetics, indication of uncontrolled slab shrinkage. In JPCP they will eventually widen and allow moisture infiltration. In CRCP, if they are allowed to get much wider than about 0.5 mm (0.02 inches) they can allow moisture infiltration.

Possible Causes: All PCC will shrink as it sets and cures, therefore shrinkage cracks are expected in rigid pavement and provisions for their control are made. However, uncontrolled shrinkage cracking can indicate:

- Contraction joints sawed too late. In JPCP, if contraction joints are sawed too late the PCC may already have cracked in an undesirable location.

- Poor reinforcing steel design. In CRCP, proper reinforcing steel design should result in shrinkage cracks every 1.2 - 3 m (4 - 10 ft.).

- Improper curing technique. If the slab surface is allowed to dry too quickly, it will shrink too quickly and crack.

- High early strength PCC. In an effort to quickly open a newly constructed or rehabilitated section to traffic, high early-strength PCC may be used. This type of PCC can have a high heat of hydration and shrinks more quickly and to a greater extent than typical PCC made from unmodified Type 1 Portland cement.

Repair: In mild to moderate severity situations, the shrinkage cracks can be sealed and the slab should perform adequately. In severe situations, the entire slab may need replacement.

Spalling

Description: Spalling is defined as cracking, breaking or chipping of joint/crack edges as illustrated in Figures 90 and 91. Usually occurs within about 0.6 m (2 ft.) of joint/crack edge.

Figure 90 Spalling

Figure 91 Spalling from a Bad Construction Joint

Problem: Loose debris on the pavement, roughness, generally an indicator of advanced joint/crack deterioration.

Possible Causes: Possible causes are:

- Excessive stresses at the joint/crack caused by infiltration of incompressible materials and subsequent expansion (can also cause blowups).

- Disintegration of the PCC from freeze-thaw action or "D" cracking.

- Weak PCC at a joint caused by inadequate consolidation during construction. This can sometimes occur at a construction joint if (1) low quality PCC is used to fill in the last bit of slab volume or (2) dowels are improperly inserted.

- Misalignment or corroded dowel.

- Heavy traffic loading.

Repair: Spalling less than 75 mm (3 inches) from the crack face can generally be repaired with a partial-depth patch. Spalling greater than about 75 mm (3 inches) from the crack face may indicated possible spalling at the joint bottom and should be repaired with a full-depth patch.

Types of Concrete Pavements (Rigid Pavement) Treatment

Definition: There is a broad range of treatments that can be used in the preservation of concrete pavements. These treatments use different materials (or, in some cases, no materials), may be applied either globally across the pavement or locally where specific distresses or other issues exist, and may involve a small amount of removal of the existing pavement and/or the placement of new material.

Index of Concrete Surface Treatment

Slab Stabilization

Slab Jacking

Partial Depth Repair

Full Depth Repair

Retrofitted Edge Drains

Dowel Bars Retrofit

Cross Stitching

Diamond Grinding

Diamond Grooving

Joint Resealing

Crack Sealing

Concrete Overlay

Slab Stabilization

Filling of voids beneath concrete slabs by injecting cement grout, polyurethane, or other suitable materials through drilled holes in the concrete located over the void areas as illustrated in Figure 92.

Slab Jacking

Raising of settled concrete slabs to their original elevation by pressure injecting cement grout or polyurethane materials through drilled holes at carefully patterned locations as illustrated in Figure 93.

Figure 92 Slab Stabilization

Figure 93 Slab Jacking

Partial Depth Repair

Removal of small, shallow (top one-third of the slab) areas of deteriorated concrete and subsequent replacement with a cementitious or polymeric repair material as illustrated in Figure 94.

Full Depth Repair

Cast-in-place or precast concrete repairs that extend through the full thickness of the existing slab, requiring full-depth removal and replacement of full or partial lane-width areas as illustrated in Figure 95.

Retrofitted Edge Drains

Cutting of a trench along the pavement edge and placement of a longitudinal edge drain system (pipe or geo-composite drain, geotextile lining, bedding, and backfill material) in the trench, along with transverse outlets and headwalls as illustrated in Figure 96.

Figure 94 Partial Depth Repair

Figure 95 Full Depth Repair

Figure 96 Retrofitted Edge Drains

Dowel Bars Retrofit

Placement of dowel bars across joints or cracks in an existing concrete pavement to restore load transfer as illustrated in Figure 97.

Figure 97 Dowel Bars Retrofit

Cross Stitching

Placement of deformed tie bars into holes drilled at an angle through cracks (or, in some cases, joints) in an existing concrete pavement as illustrated in Figure 98.

Figure 98 Cross Stitching

Diamond Grinding

Removal of a thin layer of concrete (typically 0.12 to 0.25 inches) from the pavement surface, using special equipment fitted with a series of closely spaced, diamond saw blades as illustrated in Figure 99.

Figure 99 Diamond Grinding

Diamond Grooving

Cutting of narrow, discrete grooves into the pavement surface, either in the longitudinal direction (i.e., in the direction of traffic) or the transverse direction (i.e., perpendicular to the direction of traffic) as illustrated in Figure 100.

Figure 100 Diamond Grooving

Joint Resealing

Removal of existing deteriorated transverse and/or longitudinal joint sealant (if present), re-facing and pressure cleaning the joint sidewalls, and installing new material (liquid sealant and backer rod or preformed compression seal) as illustrated in Figure 101.

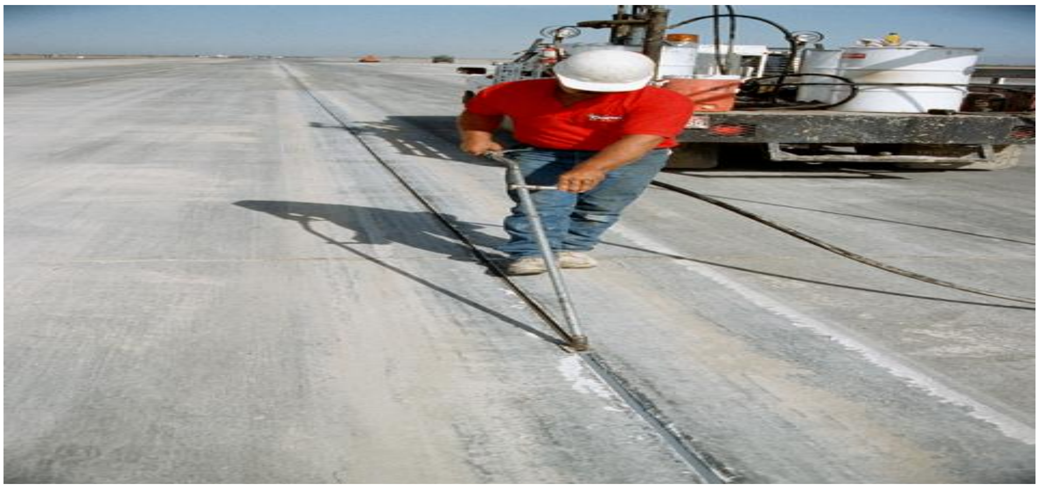

Figure 101 Joint Resealing

Crack Sealing

Sawing, power cleaning, and sealing cracks (typically transverse, longitudinal, and corner-break cracks wider than 0.125 inch) in concrete pavement using high-quality sealant materials as illustrated in Figure 102.

Figure 102 Crack Sealing

Concrete Overlay

Placement of a thin concrete layer (typically 3 to 4 inches thick) to a milled or prepared surface as illustrated in Figure 103.

Figure 103 Concrete Overlay

Tables 1 and 2 list the types of distresses, suggested preventive treatments, and suggested repair treatments for flexible pavements and rigid pavements, respectively.

Distress	Preventive treatments	Repair treatments
Alligator cracking	Surface/fog seal surface patch	Full-depth repair
Longitudinal cracking	Crack sealing	Partial-depth repair
Reflective cracking	Seal cracks Saw and seal cuts above joints	Full-depth repair
Block cracking	Seal cracks and chip seal	Chip seal
Depression	None	Leveling course Mill surface
Rutting	None	Leveling course Mill surface
Raveling	Rejuvenating seal	Chip seal/surface seal
Potholes	Crack sealing Surface patch	Full- or partial-depth repair
Polished aggregate	Seal coat	Slurry seal, chip seal, open-graded friction course
Slippage cracks	Better mix design and compaction	Slurry seal, chip seal, open-graded friction course
Joint cracks	Better construction practice	Seal
Corrugation	Better mix design and compaction	Thin overlay
Bleeding	Better mix design	Chip seal

Table 1 Candidate Repair and Preventive Treatments for Flexible Pavements

Distress	Preventive treatments	Repair treatments
JPCP pumping	Reseal joints Restore joint load transfer Subsurface drainage Edge support (tied PCC should edge beam)	Subseal or mud-jack PCC slabs (effectiveness depends on materials and procedures)
JPCP joint faulting	Subseal joints Reseal joints Restore load transfer Subsurface drainage Edge support (tied PCC should edge beam)	Grind surface Structural overlay
JPCP slab cracking	Subseal (loss of support) Restore load transfer Structural overlay	Full- or partial-depth repair
JPCP joint or crack spalling	Reseal joints	Full- or partial-depth repair
CRCP punchouts	Polymer or epoxy grouting Subseal (loss of support)	Full-depth repair
PCC disintegration	None	Full-depth repair Thick overlay

Table 2 Candidate Repair and Preventive Treatments for Rigid *Pavements*

Section 5 — References

- AASHTO 2015 Mechanistic-Empirical Pavement Design Guide: A Manual of Practice. Washington, DC: American Association of State and Highway Officials.