Appendix A

Pavement Distress Types and Causes

This Appendix provides descriptions of the types and causes of the distresses that occur in asphalt, concrete, and asphalt-overlaid concrete pavements, and asphalt and concrete shoulders. Many of the photos used in this Appendix are from the LTPP Distress Identification Manual.¹

Asphalt Pavement Distresses

Fatigue (Alligator) Cracking

Fatigue (also called alligator) cracking, which is caused by fatigue damage, is the principal structural distress which occurs in asphalt pavements with granular and weakly stabilized bases. Alligator cracking first appears as parallel longitudinal cracks in the wheelpaths, and progresses into a network of interconnecting cracks resembling chicken wire or the skin of an alligator. Alligator cracking may progress further, particularly in areas where the support is weakest, to localized failures and potholes.

Figure A-1. Fatigue (alligator) cracking in asphalt pavement.¹

Factors which influence the development of alligator cracking are the number and magnitude of applied loads, the structural design of the pavement (layer materials and thicknesses), the quality and uniformity of foundation support, the consistency of the asphalt cement, the asphalt content, the air voids and aggregate characteristics of the asphalt concrete mix, and the climate of the site (i.e., the seasonal range and distribution of temperatures).²³
Considerable laboratory research into the fatigue life of asphalt concrete mixes has been conducted. However, attempting to infer from such laboratory tests how asphalt concrete mix properties influence asphalt pavement fatigue life requires consideration of the mode of laboratory testing (constant stress or constant strain) and the failure criterion used. Constant-stress testing suggests that any asphalt cement property (e.g., lower penetration, higher viscosity) or mix property which increases mix stiffness will increase fatigue life. Constant-strain testing suggests the opposite: that less brittle mixes (e.g., higher penetrations, lower viscosities) exhibit longer fatigue lives. The prevailing recommendations are that low-stiffness (low viscosity) asphalt cements should be used for thin asphalt concrete layers (i.e., less than 5 inches), and that the fatigue life of such mixes should be evaluated using constant-strain testing, while high-stiffness (high viscosity) asphalt cements should be used for asphalt concrete layers 5 inches and thicker, and the fatigue life of such mixes should be evaluated using constant-stress testing.\(^3\) In practice, however, it is not common to modify the mixture stiffness for different asphalt concrete layer thicknesses.

**Bleeding**

Bleeding is the accumulation of asphalt cement material at the pavement surface, beginning as individual drops which eventually coalesce into a shiny, sticky film. Bleeding is the consequence of a mix deficiency: an asphalt cement content in excess of that which the air voids in the mix can accommodate at higher temperatures (when the asphalt cement expands). Bleeding occurs in hot weather but is not reversed in cold weather, so it results in an accumulation of excess asphalt cement on the pavement surface. Bleeding reduces surface friction and is therefore a potential safety hazard.

![Figure A-2. Tire marks evident in high-severity bleeding.](image)
**Block Cracking and Thermal Cracking**

**Block cracking** is the cracking of an asphalt pavement into rectangular pieces ranging from about 1 ft to 10 ft on a side. Block cracking occurs over large paved areas such as parking lots, as well as roadways, primarily in areas not subjected to traffic loads, but sometimes also in loaded areas. **Thermal cracks** typically develop transversely across the traffic lanes of a roadway, sometimes at such regularly spaced intervals that they may be mistaken for reflection cracks from an underlying concrete pavement or stabilized base.

![Figure A-3. Medium-severity block cracking.](image)

Block cracking and thermal cracking are both related to the use of an asphalt cement which is or has become too stiff for the climate. Both types of cracking are caused by shrinkage of the asphalt concrete in response to low temperatures, and progress from the surface of the pavement downward. The key to minimizing block and thermal cracking is using an asphalt cement of sufficiently low stiffness (high penetration), which is nonetheless not overly temperature-susceptible (i.e., likely to become extremely stiff at low temperatures regardless of its penetration index at higher temperatures).

**Bumps, Settlements and Heaves**

Bumps, settlements, and heaves in asphalt pavements may be due to frost heave, swelling or collapsing soil, or localized consolidation (such as that which occurs in poorly compacted backfill material at culverts and bridge approaches). Frost heave, soil swelling, and soil collapsing produce longer-wavelength surface distortions than localized consolidation.
**Frost heave** occurs in frost-susceptible soils, when sufficient water is available, in freezing climates such as the northern half of the United States. Water collects in a pavement’s subgrade by upward capillary movement from the water table and also by condensation. When the temperature in the soil drops below freezing, this water freezes and forms ice lenses, which may be up to 18 inches thick. It is the continued and progressive growth of these ice lenses as additional water is drawn to the freezing front that produces the dramatic raising of the road surface known as frost heave. Very fine sands and silts are most susceptible to frost heave because of their ability to draw water to considerable heights (e.g., 20 ft) above the water table. Clays also have considerable suction potential and are also susceptible to frost heave if their plasticity index is less than about 10 to 12. Lower permeabilities inhibit the formation of ice lenses. Clean sands and gravels and mixed-grain soils with less than 3 percent material smaller than 0.02 mm are not susceptible to frost action.

**Swelling soils** are those clays and shales which are susceptible to experiencing significant volume increases when sufficient moisture is available to increase the ratio of voids (air and water) to solids, especially in the absence of an overburden pressure. Overburden pressure may be reduced when underlying material is excavated, and replaced by a pavement. If the moisture content of these soils is normally low (i.e., in a dry climate), and evaporation of moisture from the soil is hindered by the presence of the pavement, considerable swelling may result. Swelling soils are responsible for pavement heaving, poor ride quality, and cracking in many areas of the southern and western United States.

**Collapsing soils** are those soils which are susceptible to experiencing significant volume decreases when their moisture content increases significantly, even without an increase in surface load. Soils which are susceptible to collapsing include loessial soils, weakly cemented sands and silts, and certain residual soils. Such materials typically have a loose, open structure in which the larger bulky grains are held together by capillary films, montmorillonite (or other clay materials), or soluble salts. Many collapsible soils are associated with dry or semi-arid climates, while others are commonly found on flood plains and in alluvial fans as the remains of slope wash and mud flows.

**Longitudinal Cracking**

Nonwheelpath longitudinal cracking in an asphalt pavement may reflect up from the edges of an underlying old pavement or from edges and cracks in a stabilized base, or may be due to poor compaction at the edges of longitudinal paving lanes. Longitudinal cracking may also be produced in the wheelpaths by the application of heavy loads or high tire pressures. It is important to distinguish between nonwheelpath and wheelpath longitudinal cracking when
conducting condition surveys; only wheelpath longitudinal cracking should be considered along with alligator cracking in assessing the extent of load-related damage which has been done to the pavement.

Figure A-4. Medium-severity longitudinal cracking. ¹

Pothole

A pothole is a bowl-shaped hole through one or more layers of the asphalt pavement structure, between about 6 inches and 3 feet in diameter. Potholes begin to form when fragments of asphalt concrete are displaced by traffic wheels, e.g., in alligator-cracked areas. Potholes grow in size and depth as water accumulates in the hole and penetrates into the base and subgrade, weakening support in the vicinity of the pothole.⁷

Figure A-5. High-severity pothole. ¹
**Pumping**

Pumping is the ejection of water and erodible fines from under a pavement under heavy wheel loads. On asphalt pavements, pumping is typically evidenced by light-colored stains on the pavement shoulder near joints and cracks.

![Figure A-6. Water bleeding and pumping.](image)

The major factors which contribute to pumping are the presence of excess water in the pavement structure, erodible base or subgrade materials, and high volumes of high-speed, heavy wheel loads.

**Ravelling and Weathering**

Ravelling and weathering are progressive deterioration of an asphalt concrete surface as a result of loss of aggregate particles (ravelling) and asphalt binder (weathering) from the surface downward. Ravelling and weathering occur as a result of loss of bond between aggregates and the asphalt binder. This may occur due to hardening of the asphalt cement, dust on the aggregate which interferes with asphalt adhesion, localized areas of segregation in the asphalt concrete mix where fine aggregate particles are lacking, or low in-place density of the mix due to inadequate compaction. High air void contents are associated with more rapid aging and increased likelihood of ravelling. Increased asphalt film thickness can significantly reduce the rate of aging and offset the effects of high air voids. Surface softening and aggregate dislodging due to oil spillage are also classified as ravelling.
Ravelling and weathering may pose a safety hazard if deteriorated areas of the surface collect enough water to cause hydroplaning or wheel spray. Loose debris on the pavement surface which may also be picked up by vehicle tires is also a potential safety hazard.

**Rutting**

Rutting is the formation of longitudinal depression of the wheelpaths, most often due to consolidation or movement of material in either the base and subgrade or in the asphalt concrete layer. Another, unrelated, cause of rutting is abrasion due to studded tires and tire chains. Deformation which occurs in the base and underlying layers is related to the thickness of the asphalt concrete surface, the thickness and stability of the base and subbase layers, and the quality and uniformity of subgrade support, as well as the number and magnitude of applied loads.
Deformation which occurs only in the asphalt concrete later may be the result of either consolidation or plastic flow. Consolidation is the continued compaction of asphalt concrete by traffic loads applied after construction. Consolidation may produce significant rutting in asphalt layers which are very thick and which are compacted during construction to initial air void contents considerably higher than the long-term air void contents for which the mixes were designed. Plastic flow is the lateral movement of the mix away from the wheelpaths, most often as a result of excessive asphalt content, exacerbated by the use of small, rounded aggregates and/or inadequate compaction during construction.

Asphalt cement stiffness is believed to play a relatively minor role in rutting resistance of asphalt mixes which contain well-graded, angular, rough-textured aggregates. Stiffer asphalt cements can increase rutting resistance somewhat, but the tradeoff is that mixes containing stiffer cements are more prone to cracking in cold weather.

Wheelpath ruts greater than a third to a half an inch in depth are considered by many highway agencies to pose a safety hazard, due to the potential for hydroplaning, wheel spray, and vehicle handling difficulties.

**Shoving and Corrugation**

Shoving and corrugation are terms which refer to longitudinal displacement of asphalt concrete in a localized area. Shoving and corrugation are produced by traffic loading, but are indicative of an unstable liquid asphalt mix (e.g., cutback or emulsion).
**Slippage Cracking**

Slippage cracking occurs as a result of a low-strength asphalt mix in the surface layer and/or poor bond between the surface layer and underlying layer, in areas where vehicles brake and turn. Slippage cracking is thus uncommon in highway pavements, but is common in local roads and streets, particularly at intersections.

![Figure A-10. Slippage cracking.](image)

**Stripping**

Stripping is a loss of bond between aggregates and asphalt binder which typically progresses upward from the bottom of an asphalt concrete layer. Stripping may be manifested by several different types of distress, including premature rutting, shoving, ravelling, and cracking. It is often necessary to examine a sample from the asphalt concrete to determine if stripping is occurring in the layer. Stripping may not be evident from visual examination of the exterior of an asphalt concrete core, since the circumference of the core may be damaged by the coring drill. It may be necessary to split the core apart to examine its interior. If stripping has occurred, partially coated or uncoated aggregates will be visible. Severe stripping represents a loss of structural integrity of the asphalt concrete layer, since its effective thickness is reduced as the stripping progresses.

Factors related to the likelihood of stripping include the mineral and chemical composition of the aggregate, the exposure history of the aggregate (freshly crushed versus weathered stone), the physical and chemical properties of the asphalt cement, the presence of moisture, and the construction methods used. The likelihood of stripping may be reduced by using compatible
aggregates and asphalt cements, drying the aggregate to a minimal water content prior to mixing with asphalt cement, achieving adequate compaction, providing adequate surface and subsurface drainage, and using an effective antistripping additive. Several antistripping agents are available; hydrated lime has been shown effective in research studies.\textsuperscript{9,10}

Concrete Pavement Distresses

Alkali-Aggregate Reaction

Reactive aggregates contain silicates or carbonates which react chemically with alkalies (i.e., sodium and potassium) in portland cement paste. The product of the reaction is a gel-like material which absorbs water and swells, causing progressive expansion and cracking of the concrete. Both coarse and fine aggregate particles can react with cement paste. The reaction continues until all of the alkali in the cement is consumed, but deterioration of the concrete can continue even after that time, as the gel product continues to absorb water and expand into cracks in the concrete.

![Figure A-11. Map cracking attributable to alkali-silica reactivity (ASR).](image)

The most significant factors influencing the occurrence of reactive aggregate distress are the relative reactivity of the aggregate, the fraction of reactive aggregate in the mix, the particle size of the aggregate, the alkali content of the cement, and the availability of free water. Reactive aggregate distress may develop rapidly, but more often develops gradually over a period of many years.
In the United States, aggregates containing reactive silica or siliceous minerals are found predominantly in the West and Southwest, although some have been found in the Southeast. Aggregates containing reactive carbonates have been found in the Midwest and Northeast regions of the United States and Canada.

Visible signs of reactive aggregate distress are fine, closely spaced longitudinal or map cracks emanating from transverse joints and cracks, small joint widths, compressed joint sealant, and joint spalling, all of which indicate compressive stress buildup in the pavement. Blowups may also occur in pavements with reactive aggregates. Expansion of a concrete pavement with reactive aggregates may cause shoving of bridge decks and cracking of bridge structures. Close inspection of concrete affected by alkali-aggregate reaction will reveal the presence of the gel product around aggregate particles and a network of fine cracks throughout the cement matrix.

**Blowup**

A blowup is a shattering or upward buckling of concrete pavement slabs at a joint or working crack, often occurring in both traffic lanes simultaneously. Blowups occur when horizontal compressive forces in the slab increase greatly due to expansion of the slabs, and the joints either become completely closed, or closing of the joints and cracks is impaired by infiltrated incompressibles.
Blowups usually occur in the spring (after incompressibles have infiltrated during winter months), in the midmorning to midday (as pavement temperatures rise). A shattering blowup will crumble the concrete for a few feet on each side of the joint or crack. A buckling blowup will raise the pavement by several inches on one or both sides of the joint or crack. Both kinds of blowups are safety hazards which require emergency repair.

Spacing of joints and cracks is a primary factor in blowup potential. JRCP and CRCP are susceptible to blowups, since their joints and cracks are space far enough apart, and thus open wide enough in cool periods, to permit substantial infiltration of incompressibles. Blowups rarely occur in JPCP.

Blowups may also occur in one lane of a concrete pavement when full-depth repairs are being placed in an adjacent lane in hot weather, and the repair area is left open during the day or is filled with asphalt concrete rather than portland cement concrete. Therefore, full-depth repairs are often constructed across all lanes under such conditions, even if only one lane is really in need of repair. For the same reason, pressure relief joints, when needed, should always be placed across all traffic lanes rather than individual lanes.

Concrete pavements which experience expansion due to reactive aggregates are also very susceptible to blowups. It has also been suggested that “D” cracking increases blowup potential, by reducing the cross-sectional area of sound concrete at joints and crack faces to bear the compressive stress which builds up in the pavement. Poor joint sealant conditions and erodible base materials are also believed to contribute to blowup potential.

**Bumps, Settlements and Heaves**

Bumps, settlements, and heaves in concrete pavements may be due to frost heave, swelling or collapsing soils, or localized consolidation. **Frost heave, swelling soils, and collapsing soils** were described earlier, in the section of this Appendix on asphalt pavement distresses.

**Bumps** sometimes develop at bridge approaches not because of localized consolidation, mentioned earlier, but because of terminal treatments used for CRCP or JRCP. Terminal treatments fall into two categories: anchorage systems, which are intended to prevent slab movement, and expansion joints, which are intended to accommodate slab movement. Lug anchor systems are somewhat effective in restraining movement at slab ends. Sometimes, however, the slabs can push on the lug anchors enough to bend them out of position. This causes one or more bumps at the pavement surface which produce roughness and can also be a safety hazard. Expansion joints may be interlocking finger-type systems, a section of asphalt
no more than a few feet long, constructed on a sleeper slab, or a wide-flange steel beam with expansion joint filler material on either side, constructed on a sleeper slab. Good performance has been reported for the wide-flange beam design. The asphalt concrete expansion joint design, on the other hand, tends to perform poorly. Movement of the slab ends toward the bridge compress the asphalt concrete and creates a rough and sometimes unsafe bump.

**Corner Break**

Corner breaking is a major structural distress in jointed concrete pavements. A corner break is a diagonal crack that intersects a transverse joint or crack and a longitudinal joint less than 6 ft from the corner of the slab. A corner break is a vertical crack through the full thickness of the slab, unlike a corner spall, which runs diagonally downward through only part of the slab thickness.

![Figure A-13. Corner breaks.](image)

Corner breaks are the result of fatigue damage: heavy wheel load repetitions at slab corners cause corner deflections and stresses in the top surface of the slab, resulting in fatigue damage and eventual cracking. Factors which influence the development of corner breaks include the number and magnitude of applied loads, the thickness and stiffness of the concrete slab, the stiffness and uniformity of the base, the degree of load transfer at transverse and longitudinal joints and cracks, the quality of drainage, and climatic influences (daily and seasonal temperature and moisture cycles which influence slab curling, joint and crack opening, and foundation support).
Two different situations may lead to corner cracking. In the first situation, a combination of poor load transfer, poor drainage, and weak base support permit excessive downward deflection of the slab. As fines are pumped out from under the leave corner and collect under the approach corner, the leave corner becomes progressively less supported and experiences progressively higher deflections and stresses under loads. In this situation, corner breaks tend to occur on the leave side of the transverse joint before they occur on the approach side, and usually occur along the outer edge of the slab, where load transfer and moisture conditions are worse.

In the second situation, a combination of poor load transfer, a stiff base layer, and temperature and/or moisture gradients that make the top of the slab cooler and/or drier than the bottom of the slab cause the slab corners to curl or warp up out of contact with the base. When heavy wheel loads are applied to the unsupported corners, they produce high stresses in the slab and contribute to the fatigue damage which eventually results in corner breaks. In this situation, corner breaks may occur on either the leave side or the approach side of the transverse joint. In jointed concrete pavements with perpendicular joints, corner breaks related to curling will more often occur along the outer edge of the slab, but in pavements with skewed joints, corner breaks may occur at the acute-angled corners along both the inner and outer edges of the slab.

**Curling/Warping Roughness**

Upward deformation of slab corners in jointed concrete pavements can contribute to roughness. Three different temperature and moisture mechanisms, alone or in combination, may cause upward deformation of slab corners. One is cyclic curling which occurs due to a negative (nighttime) temperature gradient, i.e., the top of the slab being cooler and contracting more than the bottom of the slab. The second is permanent curling, also called construction curling, which occurs when a high positive (daytime) temperature gradient exists in the slab as it hardens. The third is warping due to moisture gradient in the slab, i.e., the top being drier and contracting more than the bottom of the slab. Moisture warping may be permanent to some degree and also seasonally cyclic.  

**“D” Cracking**

“D” cracking is progressive deterioration of concrete which occurs as a result of freeze-thaw damage in large aggregates. “D” cracking occurs frequently in concrete pavements in the northeastern, north central, and south central regions of the United States. While “D” cracking is not caused by traffic loads, it does diminish the structural integrity of the concrete, particularly at the outer slab edges, along the centerline, and in the wheelpaths near joints and cracks.
The major factors which influence the development of “D” cracking are the availability of moisture (including the quality of base drainage), the occurrence of freeze-thaw cycles, the coarse aggregate composition (sedimentary rocks such as limestone and dolomite are generally the most susceptible), the pore size distribution of the coarse aggregate, and the maximum aggregate size. The fine aggregate does not influence the likelihood of “D” cracking. The level of air entrainment, likewise, does not influence the likelihood of “D” cracking (although air entrainment does improve resistance to scaling caused by freeze-thaw damage in the cement mortar). The composition or brand of cement has little or no influence on “D” cracking.

Figure A-14. High-severity “D” cracking.
Faulting

Faulting is a difference in elevation across a joint or crack. Faulting is the result of pumping under many heavy wheel repetitions, which erodes support beneath the leave sides of joints or cracks, and builds up fines beneath the approach sides. Faulting is a major contributor to roughness in JPCP and JRCP, but is not a significant problem for CRCP. Faulting is also not usually a significant problem for low-volume roads and streets.

Figure A-15. Transverse joint faulting. 23

Joint Seal Damage

Joint seal damage may take several different forms. Extrusion refers to the joint sealant being pushed or pulled out of the joint by slab movement or traffic wheels. Infiltration is the presence of incompressibles and/or vegetation either within the joint sealant material or between the joint sealant and the joint reservoir walls. Oxidation is hardening of the sealant due to exposure to the elements and ultraviolet radiation. Adhesive failure is loss of bond between the sealant and the walls of the joint sealant reservoir. Cohesive failure is splitting within the sealant material due to excessive tensile strain. Joint seal damage may be caused by the use of an inappropriate sealant type, improper joint sealant installation, or simply aging of the sealant.
Joint Spalling

Joint spalling and joint deterioration are terms which refer to cracking, chipping, or fraying of concrete slab edges within about 2 ft of transverse joints. Joint spalling may develop predominantly in the top few inches of the slab, or may develop at a greater depth below the surface, depending on the environmental conditions at the time of construction.

Joint spalling has several possible causes, including excessively early wet sawing of transverse joints, infiltration of incompressibles (especially where delamination has occurred due to inadequate curing), high reinforcing steel, alkali-aggregate reaction, “D” cracking, misaligned or corroded load transfer devices, weak concrete in the vicinity of the joint (e.g., honeycombing caused by poor consolidation) or damage caused by cold milling, grinding, or joint cleaning.

Figure A-16. Spalling of transverse joint.
Linear Cracking

Concrete pavements exhibit several types of linear cracking. **Transverse cracking** is the predominant structural distress in jointed plain concrete highway pavements. Repeated heavy wheel loads cause fatigue damage in the concrete slab, which eventually results in slab cracking. Since the greatest stresses are generally produced by wheel loads at the outer slab edge, midway between the transverse joints, transverse cracking most commonly results at midslab. Factors which influence the development of transverse fatigue cracking include the number and magnitude of applied loads, the thickness and stiffness of the concrete slab, the stiffness and uniformity provided by the base and foundation, the degree of friction between the slab and base, the degree of load transfer at transverse and longitudinal joints and cracks, the quality of drainage, and climatic influences (daily and seasonal temperature and moisture cycles which influence slab curling, joint and crack opening, and foundation support).

![Transverse Crack](image1)

Figure A-17. Transverse crack in jointed plain concrete pavement.

In jointed reinforced and continuously reinforced concrete pavements, midslab transverse cracking develops early as a result of drying shrinkage. Under repeated heavy wheel load applications, the reinforcing steel across the shrinkage crack may rupture and the crack will subsequently fault and spall. Thus, transverse crack deterioration in JRCP and CRCP is also a major structural distress, although its cause differs from that of transverse cracking in JPCP.
Another type of transverse cracking sometimes occurs parallel to and within about 2 ft of dowelled transverse joints. This type of cracking is caused by either dowel misalignment or dowel lockup.

**Longitudinal cracking** occurs in concrete highway and street pavements, but is not usually due to fatigue damage. The most frequent causes of longitudinal cracking in highway and street pavements are improper longitudinal joint construction (inadequate sawcut depth, inadequate joint insert placement depth, or late sawing), foundation movement (settlements or heaves), or shrinkage (excessive slab width). Longitudinal cracks may also form to connect existing transverse or diagonal cracks.
Diagonal cracking is similar to transverse cracking except that it crosses slabs at an angle other than perpendicular to the slab edge. Diagonal cracking differs from corner breaking in that, if it does intersect a transverse joint or crack, it does so at a considerable distance (more than 6 ft) from the slab corner. A shattered slab is one which is broken into four or more pieces by transverse, diagonal, and/or longitudinal cracks.

**Map Cracking, Crazing, and Scaling**

Crazing, also called map cracking, is a network of fine cracks in the top surface of a concrete slab, usually extending no deeper than a half inch into the concrete. Crazing or map cracking is usually caused by overfinishing, but may also be indicative of alkali-aggregate reaction. The latter affects the full thickness of the slab rather than the surface only, so although the two causes may be difficult to distinguish by visual observation alone, alkali-aggregate reaction may also be indicated by related distresses (closure, spalling, longitudinal cracking, and/or blowups at joints and cracks), and by examination of concrete cores or fragments.

Crazing or map cracking is not itself a serious distress, since it detracts only from a pavement’s appearance and not from its ride quality, durability, or structural capacity. However, if crazing progresses to scaling, in which pieces of the concrete surface become loose, the pavement’s ride quality and durability may be reduced. Scaling may also occur as a result of reinforcing steel being too close to the surface. This type of scaling occurs without crazing and is usually evidenced by exposed reinforcing steel or reddish brown staining.

![Figure A-20. Scaling.](image)
Polishing

Polishing is the loss of friction of the concrete pavement surface in the wheelpaths, due to abrasion by tires. Polished wheelpaths look very smooth, even shiny, and feel smooth to the touch. When the wheelpaths become polished, surface friction is considerably reduced and the risk of skidding accidents increases.

Popouts

Popouts occur when water freezes in coarse aggregate particles near the top surface of a concrete slab, causing the aggregate to expand and pop out a small piece of concrete above the aggregate. Popouts are typically about 1 to 4 inches in diameter and about a half inch to 2 inches deep. Popouts detract from a pavement's appearance but are not considered worth repair because they generally do not affect a concrete pavement's ride quality, durability, or structural capacity. However, extensive popouts may increase tire noise, and may possibly aggravate “D” cracking by creating surface cracks through which water may enter into the slab.

Pumping

Pumping is the ejection of water and erodible fines from under a pavement under heavy wheel loads. As a concrete slab corner is deflected under an approaching heavy wheel load, water and erodible fines are pumped forward under the adjacent slab corner and also pumped upward through longitudinal and transverse joints and cracks. When the wheel crosses the joint or crack and deflects the leave slab corner, water and fines are forced backward under the approach corner, and up through joints and cracks. Pumped fines are typically visible as light-colored stains on the pavement shoulder near joints and cracks.

The major factors which contribute to pumping are the presence of excess water in the pavement structure, erodible base or subgrade materials, poor deflection load transfer across joints and cracks, and high volumes of high-speed, heavy wheel loads. Warping and curling of slab corners due to moisture and temperature gradients may also contribute to high corner deflections and pumping.
**Punchout**

Punchouts are a form of cracking which is unique to continuously reinforced concrete pavement. A punchout occurs when two closely spaced shrinkage crack lose load transfer, resulting in high deflections and high stresses under wheel loads in the “cantilever beam” section of concrete between the cracks. Eventually a short longitudinal crack forms to connect the two transverse cracks, and the broken piece of concrete punches down into the base. Punchouts and working transverse cracks are the two major structural distresses in CRCP. Factors which influence the development of punchouts are the number and magnitude of applied wheel loads, slab thickness and stiffness, base stiffness, steel content, drainage conditions, and erosion of support along the slab edge.
Asphalt-Overlaid Concrete Pavement Distresses

Reflection Cracking

Reflection cracking occurs in asphalt overlays of concrete pavements as a result of stress concentration in the asphalt concrete layer, due to movement at joints, cracks, asphalt patches, and expansion joints in the underlying concrete slab. This movement may be either bending or shear induced by wheel loads, or may be horizontal contraction and expansion induced by temperature changes. The magnitudes of load-induced movements are influenced by the overlay thickness and the thickness and stiffness of the concrete pavement and supporting layers. The magnitudes of horizontal movements are influenced by daily and seasonal temperature cycles, the coefficient of thermal expansion of the concrete slab, and the spacing of joints and cracks.

In an asphalt overlay of a jointed concrete pavement, some reflection cracks typically develop within the first few years after placement of an overlay, and sometimes within the first year. The quantity of reflection cracking that is likely to occur is very difficult to predict without knowing how much of the crack and joint deterioration present prior to overlay was repaired, and what type of repairs were placed. Reflection cracks should not appear for several years in an asphalt overlay of a continuously reinforced concrete pavement, as long as the CRCP is adequately repaired with tied or welded reinforced concrete.
The rate at which reflection cracks deteriorate depends on the factors listed above as well as the number and magnitude of applied loads. The rate of initial occurrence of reflection cracks is easier to model and predict, but arguably less important, than the rate of deterioration of reflection cracks to medium and high severity levels.

Reflection cracking can have a considerable, often controlling, influence on the life of an asphalt-overlaid concrete pavement. Deteriorated reflection cracks reduce a pavement’s serviceability and also require frequent maintenance, such as sealing, milling, and patching. Reflection cracks also permit water to enter the pavement structure, which may accelerate loss of bond between the asphalt and concrete layers, stripping in the asphalt, “D” cracking or reactive alkali-aggregate reaction in concrete prone to these problems, and softening of the base and subgrade.

**Fatigue Cracking**

Fatigue cracking in an asphalt concrete layer occurs as a result of repeated tensile strain in the asphalt layer. Since an asphalt overlay of a concrete slab, even if unbonded, should never experience significant tension under flexural loading, true fatigue cracking should never occur in a stable asphalt overlay of a sound concrete slab. If longitudinal or alligator-type cracking does appear in an asphalt-overlaid concrete pavement, it indicates one of the following unusual conditions: (a) an unstable asphalt concrete mix coupled with loss of bond between the asphalt and concrete layers, or (b) complete degradation of the concrete, e.g., extensive and severe “D” cracking. In this latter case, the breakdown of the concrete is more likely to be concentrated in localized areas near joints and cracks, and produce potholes and localized failures where the wheelpaths cross these areas.

**Rutting**

Rutting in asphalt overlays of concrete pavements occurs as a result of plastic flow of the mix laterally away from the wheelpaths, due to shear stress produced by applied loads. This plastic deformation normally occurs relatively slowly and only develops into ruts of significant depths after several years. Mix deficiencies which increase an asphalt overlay’s tendency to rut include rounded aggregates, excessive fines, improper aggregate gradation, stripping-susceptible aggregates, low air void content, low asphalt cement viscosity, and high asphalt content.\(^8\)
The magnitude of shear stress experienced by the overlay under loading also depends on the asphalt/concrete interface bonding condition and the asphalt thickness. Shear stress in the asphalt is lowest when the asphalt and concrete are fully bonded, and increases as bond degrades. When the asphalt and concrete are fully bonded, shear stress increases with overlay thickness. This has been cited as a possible reason that very thin overlays do not fail primarily due to rutting. When the asphalt and concrete are not bonded, asphalt shear stress is highest for overlay thicknesses in the range of 4 to 6 inches.26

Premature rutting, which develops unusually rapidly and reaches a critical level within a year or two, occurs sometimes in an inadequately designed mix as a result of shear failure. Mix deficiencies which have been identified as related to premature rutting potential include gradation problems and low air voids.27

**Stripping**

Stripping in asphalt concrete, and the factors which influence its likelihood, were described earlier in this Appendix in the section on asphalt pavement distresses. Asphalt overlays of concrete pavements become particularly susceptible to stripping when the bond between the asphalt and concrete layers is lost and water is able to collect at this interface.

**“D” Cracking**

“D” cracking in portland cement concrete, and the factors which influence its likelihood, were described earlier in this Appendix in the section on concrete pavement distresses. Field and laboratory studies have indicated that asphalt overlays do not halt the progression of “D” cracking, and in some cases accelerate it.28 Although the asphalt layer insulates the concrete to some extent, thereby raising the minimum pavement temperature and perhaps decreasing the number of freeze-thaw cycles which occur in the concrete, it also retards the rate of freezing, which is detrimental. Asphalt-overlaid concrete samples subjected to freeze-thaw testing in the laboratory have been shown to experience greater strength losses than nonoverlaid concrete samples.28

An asphalt overlay of a “D”-cracked concrete pavement might not exhibit significant visible distress until the “D” cracking reaches a very advanced state. The first signs of localized “D” cracking failures reflecting through an asphalt overlay are white fines pumping up through fine cracks in the overlay. These cracks eventually develop into pothole-like localized failures in the wheelpaths, along the centerline, along the outer edge of the pavement, and even cracking in the wheelpath resembling alligator cracking. By the time the visible distress progresses to this
point, the underlying degradation caused by “D” cracking is likely to be widespread and severe. Deflection testing and coring are very important supplements to visual surveying in assessing the full extent of “D” cracking deterioration beneath an asphalt overlay.24

**Asphalt and Concrete Shoulder Distresses**

**Lane/Shoulder Dropoff**

Lane/shoulder dropoff is a difference in elevation between the pavement edge and the shoulder. It is caused by erosion or settlement of the shoulder, or by resurfacing of the pavement without extending the resurfacing across the shoulder. A lane/shoulder dropoff of 2 inches or more is a potential safety hazard.

**Lane/Shoulder Separation**

Lane/shoulder separation is a widening of the joint between the edge of the pavement and the shoulder. It may result from differential movement of the pavement and the shoulder, or erosion of the shoulder material. Separation makes the lane/shoulder more difficult to maintain sealed, and permits the easier entry of water into the pavement structure, at the place where pavement deflections are already highest and foundation support to the pavement structure tends to be weakest. A wide separation along the lane/shoulder joint could also pose a safety hazard.

![Figure A-24. Lane-to-shoulder separation.](image)

**Lane/Shoulder Joint Seal Damage**

Lane/shoulder joint seal are vulnerable to the same types of damage that were previously described for transverse joint seals: extrusion from the joint, oxidation, adhesive failure, cohesive failure, etc. Lane/shoulder joints between concrete traffic lanes and asphalt shoulders
are notoriously difficult to keep well sealed, but poorly sealed or unsealed lane/shoulder joints are also common in concrete pavements with concrete shoulders and asphalt pavements with asphalt shoulders. The lane/shoulder joint has been cited as the principal point of entry of surface water into a pavement structure.

**Linear Cracking**

The types of linear cracking most often noted on asphalt shoulders are block cracking and transverse thermal cracking. Both of these are related to the asphalt cement having become too stiff for the climate, as described earlier in this Appendix in the section on asphalt pavement distresses. Asphalt shoulders are likely to develop block and/or transverse cracking more rapidly than adjacent asphalt traffic lanes because they receive very little traffic.

The types of linear cracking most often noted on concrete shoulders are shrinkage cracks caused by excessive shoulder joint spacing, and “sympathy” cracks produced by opening of joints or cracks in the adjacent concrete lanes. A shorter joint spacing in the concrete shoulder than in the adjacent traffic lanes may, on the other hand, produce sympathy cracks in the traffic lanes. This is particularly problematic in continuously reinforced concrete pavements with jointed concrete shoulders and/or jointed concrete ramps.

**Pumping**

In addition to the manifestations of pumping in asphalt and concrete pavements described earlier, pumping of water and fines out through lane/shoulder joints may result in staining of the shoulder surface (which is merely a cosmetic problem), and the formation of blowholes along the lane/shoulder joint in an asphalt shoulder. This type of distress is often accompanied by or progresses into degradation of a width of about 6 inches of shoulder material along the lane/shoulder joint.

Figure A-25. Staining on shoulder due to pumping of fines.
**Weathering**

Weathering in asphalt concrete, and the factors which influence its likelihood, were described earlier in this Appendix in the section on asphalt pavement distresses. Asphalt shoulders are more vulnerable to the effects of weathering than asphalt traffic lanes, because they receive fairly little traffic and therefore the asphalt mix is not kneaded by vehicle tires as it is in the traffic lanes.
References for Appendix A


19 Marks, V. J. and Dubberke, W., “Durability of Concrete and the Iowa Pore Index Test,” *Transportation Research Record* No. 853, 1982.


