

**DEFECTS
IN
FLEXIBLE AND RIGID PAVEMENTS**

Defects in Flexible Pavements

- **Fatigue (alligator) cracking**
- **Bleeding**
- **Block cracking**
- **Depression**
- **Joint reflection cracking**
- **Longitudinal cracking**
- **Patching**
- **Potholes**
- **Rutting**
- **Slippage cracking**
- **Stripping**
- **Transverse (thermal) cracking**
- **Water bleeding and pumping**

Defects in Rigid Pavements

- Blowup (Buckling)
- Corner Break
- Durability Cracking (D Cracking)
- Faulting
- Joint Load Transfer System Deterioration
- Linear (Panel) Cracking
- Patching
- Shrinkage Cracking
- Spalling

Fatigue (Alligator) Cracking

- **Description:** 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.

Bad fatigue cracking



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



Fatigue cracking from edge failure



Fatigue cracking from frost action

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, sub-base 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:

Repair

- *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 an 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: A film of asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface that can become quite sticky.



Bleeding in wheelpaths

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:

1. Excessive asphalt binder in the HMA (either due to mix design or manufacturing)
2. Excessive application of asphalt binder during BST application (as in the above figures)
3. Low HMA air void content (e.g., not enough room for the asphalt to expand into during hot weather)



HMA bleeding from over-asphalting

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: Interconnected cracks that divide the pavement up into rectangular pieces. Blocks range in size from approximately 0.1 m² (1 ft²) to 9 m² (100 ft²). 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.

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:

- 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.

Depression

Description: Localized pavement surface areas with slightly lower elevations than the surrounding pavement. Depressions are very noticeable after a rain when they fill with water.

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.



Depression in left lane and shoulder

Joint Reflection Cracking

Description: Cracks in a flexible overlay of a rigid pavement.

The cracks occur directly over the underlying rigid pavement joints. 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
- **Possible Causes:** Movement of the PCC slab beneath the HMA surface because of thermal and moisture changes. Generally not load initiated, however loading can hasten deterioration.



Joint reflection cracking on an arterial

Repair:

Strategies depend upon the severity and extent of the cracking:

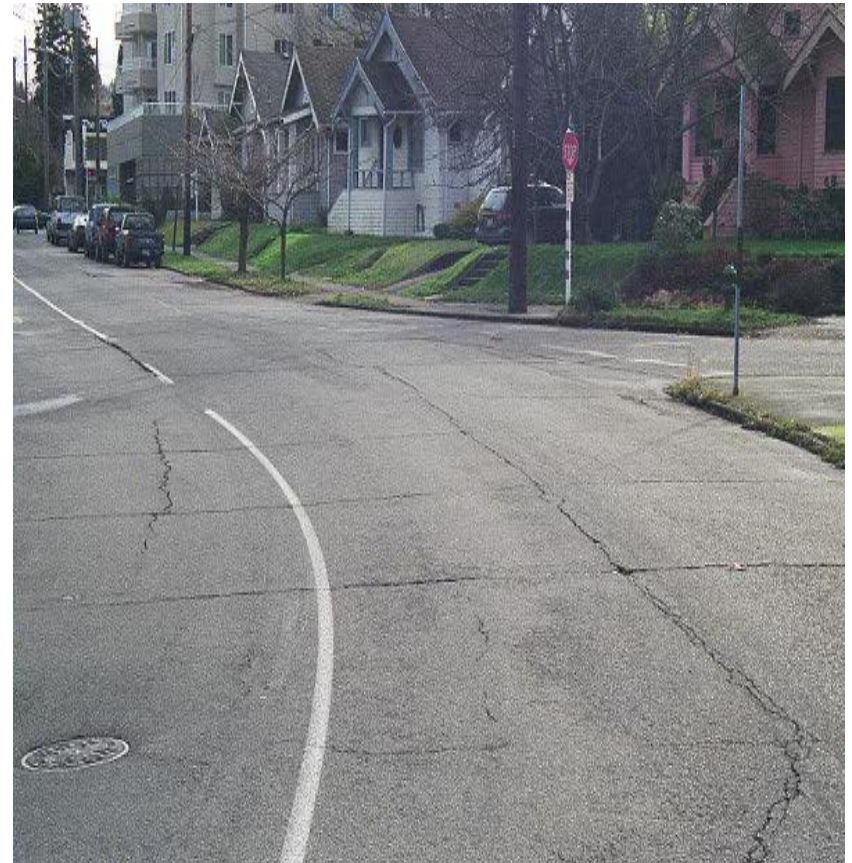
- *Low severity cracks (< 1/2 inch wide and infrequent cracks).*

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.



Joint reflection cracking on an arterial

Longitudinal Cracking

- **Description:** Cracks parallel to the pavement's centerline or laydown direction. Usually a type of fatigue cracking.
- **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 wheelpath so that they are only infrequently loaded. Joints in the wheelpath like those shown in third through fifth figures, 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](#)

Longitudinal cracking from poor joint construction



Longitudinal cracking as the
onset of fatigue 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

Description: An area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs.

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.



Potholes

Description: Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course. These 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

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



Pothole from fatigue cracking

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.



Developing pothole

Repair: In accordance with patching techniques

Rutting

- **Description:** Surface depression in the wheelpath. 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 wheelpath depressions as a result of compaction/mix design problems. Subgrade rutting occurs when the subgrade exhibits wheelpath depressions due to loading. In this case, the pavement settles into the subgrade ruts causing surface depressions in the wheelpath.
- **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)



Mix rutting

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: Crescent or half-moon shaped cracks generally having two ends pointed into the direction of traffic.

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: The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward. When stripping begins at the surface and progresses downward it is usually called raveling. The photo shows the surface effects of underlying stripping.



Core hole showing stripping at the bottom

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 WSDOT experience, these overlays will tend to strip.*

Repair: A stripped pavement should be investigated to determine the root cause of failure. Generally, the stripped pavement needs to be removed and replaced after correction of any subsurface drainage issues



Fatigue failure from stripping

Transverse (Thermal) Cracking

Description: Cracks perpendicular to the pavement's centerline or laydown direction.

Usually a type of thermal cracking.

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

Large patched thermal crack



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

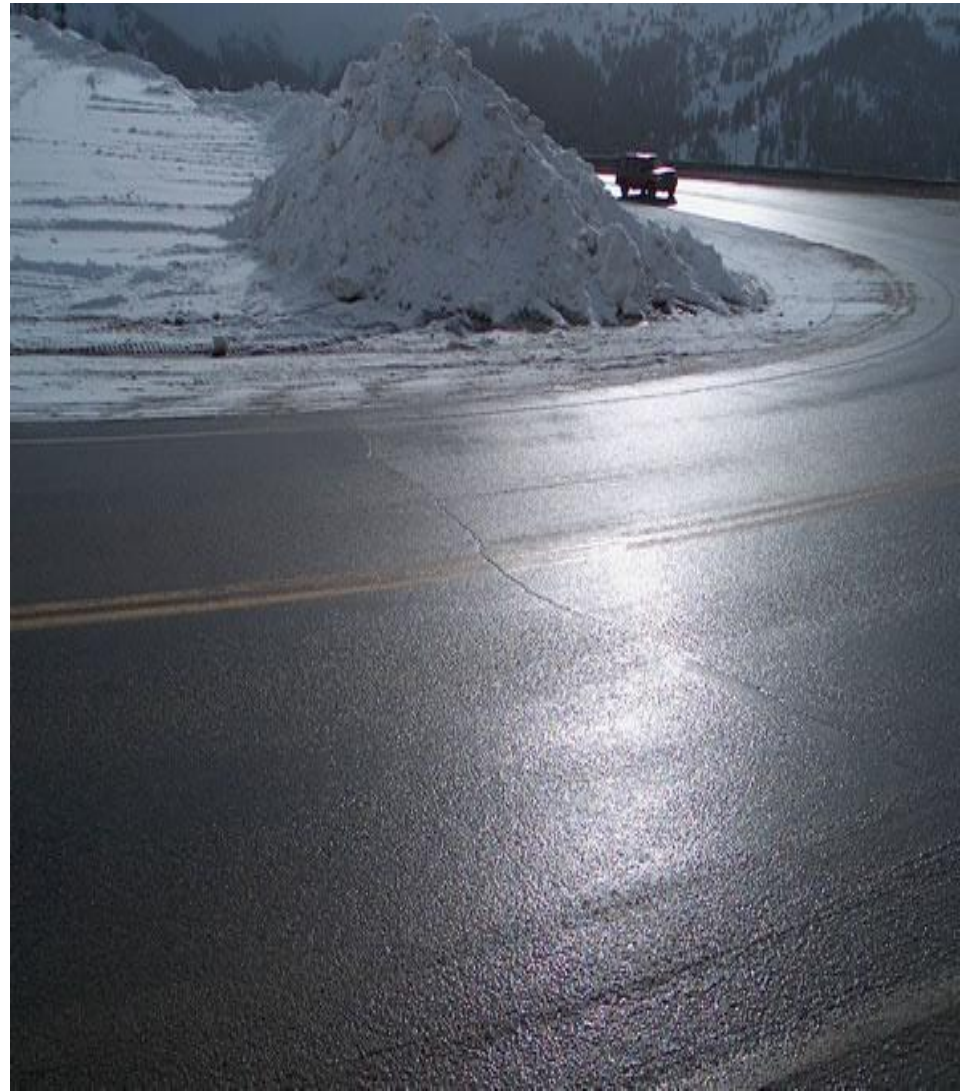
- *Low severity cracks (< 1/2 inch wide and infrequent cracks).*

Crack seal to prevent

- (1) entry of moisture into the subgrade through the cracks and
- (2) further raveling of the crack edges.

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

Small thermal crack



Water Bleeding and Pumping

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

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

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.



Water bleeding

Blowup (Buckling)

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

Problem: Roughness, moisture infiltration, in extreme cases can pose a safety hazard



Severe blowup

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: A crack that intersects the PCC slab joints near the corner. "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.

Problem: Roughness, moisture infiltration, severe corner breaks will fault, spalls and disintegrates



Corner break on a highway

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.



Corner break on a residential street

Durability Cracking ("D" Cracking)

Description: Series of closely spaced, crescent-shaped cracks near a joint or corner. 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.

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 but it does not address the root problem and will not prevent "D" cracking elsewhere.



"D" cracking at panel corners

Faulting

- **Description:** A difference in elevation across a joint or crack usually associated with undoweled JPCP. 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.
- **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.

Up close near a bus stop



Faulting from ground level



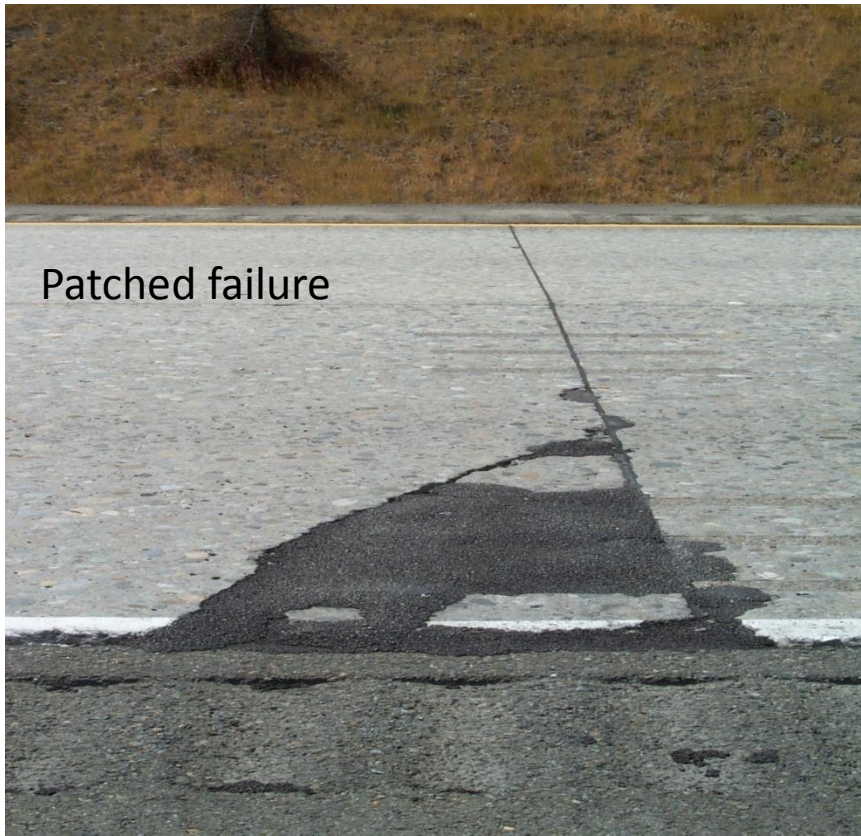
Joint Load Transfer System

Deterioration

Description: Transverse crack or corner break developed as a result of joint dowels.

Problem: Indicator of a failed load transfer system, roughness

Exposed failure with rusted dowel bars



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.

Linear (Panel) Cracking

Description: Linear cracks not associated with corner breaks or blowups that extend across the entire slab. Typically, these cracks divide an individual slab into two to four pieces.

Problem:

Roughness, allows moisture infiltration leading to erosion of base/sub-base support, cracks will eventually spall and disintegrate if not sealed

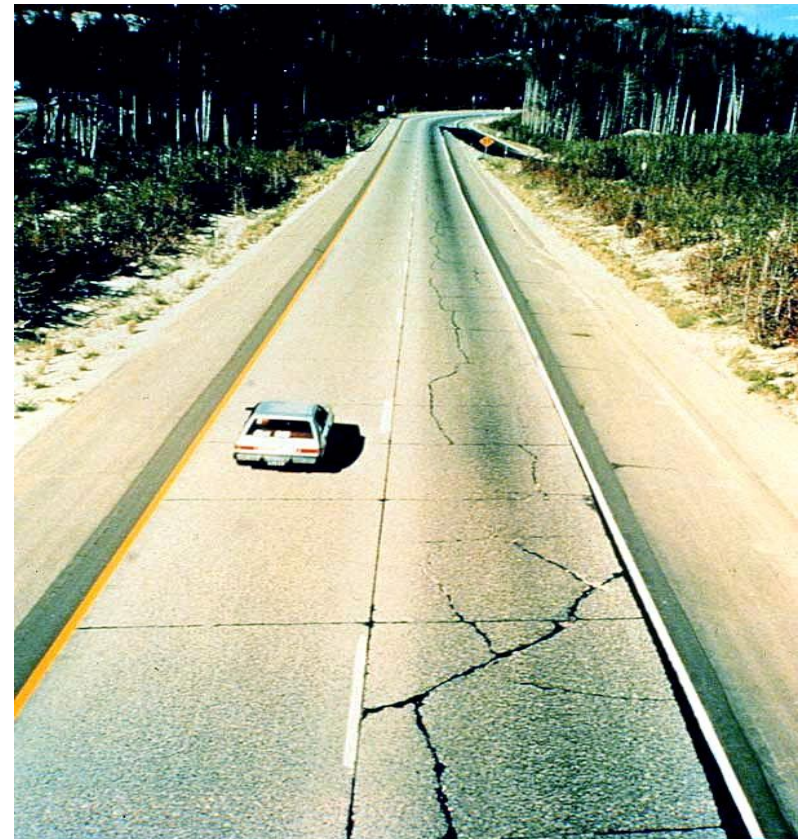


Large panel crack

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.



Panel cracking in the truck lane

Patching

Description: An area of pavement that has been replaced with new material to repair the existing pavement. A patch is considered a defect no matter how well it performs.

Problem: Roughness



Patch on a residential street



Patch with poor edges

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.



Large utility patch

Shrinkage Cracking

Description: Hairline cracks formed during PCC setting and curing that are not located at joints. Usually, these cracks do not extend through the entire depth of the slab. Shrinkage cracks are considered a distress if they occur in an uncontrolled manner.

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 they can allow moisture infiltration

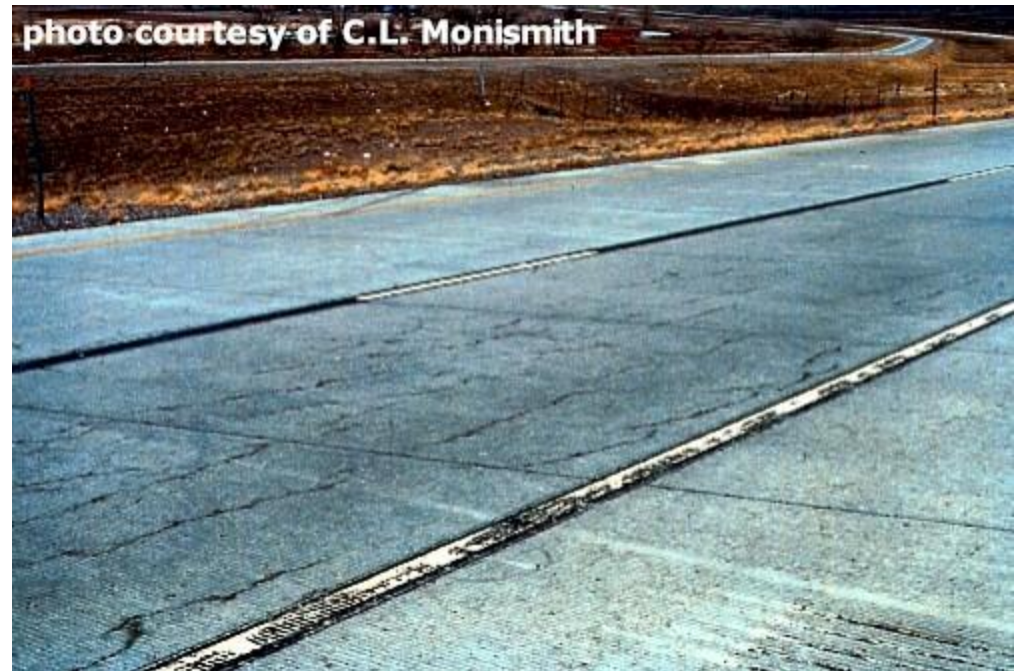


Shrinkage cracks on brand new slabs

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, poor 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 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.



Severe shrinkage cracking

Spalling

Description: Cracking, breaking or chipping of joint/crack edges. Usually occurs within about 0.6 m (2 ft.) of joint/crack edge.

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



Possible Causes

Possible causes are (AASHTO, 1993):

- 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 compaction 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 indicate possible spalling at the joint bottom and should be repaired with a full-depth patch.