# Guidelines for Routine Maintenance of Concrete Pavements

**Product:** 0-5821-P1
**Project:** 0-5821
**Project Title:** Develop Guidelines for Routine Maintenance of Concrete Pavement

Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration
April 2008

**TEXAS TRANSPORTATION INSTITUTE**
The Texas A&M University System
College Station, Texas 77843-3135

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These guidelines were prepared from research conducted for the Texas Department of Transportation (TxDOT) on two projects. The current project, which determined the distresses and categories, was project 0-5821 "Develop Guidelines for Routine Maintenance of Concrete Pavements" (Jung, Freeman, and Zollinger 2008) and the CD ROM prepared by Scullion, Coppock, and C. Von Holdt, "Development of a Concrete Pavement Rehabilitation Training CD ROM," Texas Department of Transportation, August 2006.

The pictures of distresses come from the TxDOT distress manual (2007), the CD ROM, the Strategic Highway Research Program Distress Manual (1993), and pictures taken during this research.

## DISCLAIMER

**Layout of Guidelines**

The format of these guidelines will be to present the name and descriptions of the distresses, along with a variety of pictures, then provide guidance on the repair techniques and other considerations.

The distresses are listed alphabetically in the following repair groups of:

| Preservative | Functional CPR* | Structural CPR* | Remove and Replace |
|---|---|---|---|
| Edge Drop-off | Bump | Patch Deterioration | Corner Break |
| Joint Failure | Crack Spalling | Pumping | Punchout |
| Joint Seal | Faulting | | Shattered Slab |
| Joint Separation | Joint Spalling | | |
| Longitudinal Cracking | Settlement | | |
| Transverse Cracks | | | |

* CPR - Concrete Pavement Repair

## Preservative Distresses

In addition to these distresses, it is important to check that the drainage is performing properly and that no water remains on the pavement or in the ditches.  This may require reprofiling the shoulder or regrading and reprofiling the ditches.

Edge Drop-off

Joint Failure

Joint Seal

Continued.

## Preservative Distresses (Continued)

Joint Separation

Longitudinal Cracking

Transverse Cracking

Description: Edge/shoulder drop-offs are normally associated with the use of a flexible shoulder on pavements where the main lanes are concrete. Large differences in elevation of the main lanes versus the shoulder can be safety problems and should be addressed by maintenance forces. Frequently, the edge/shoulder joint has deteriorated and is now open. Water will enter this joint and cause erosion of the layers supporting the concrete. This can lead to rapid failure of the concrete slab. This problem has been largely eliminated in Texas in new pavements because of the use of tied concrete shoulders. The edge/shoulder problem is particularly severe with old, narrow jointed concrete pavements, which may have been only18 or 20 feet wide.


Possible Causes: In the case of flexible shoulders on concrete main lanes, this is a gradual deterioration process where it is often impossible to maintain the seal between the concrete and the shoulders. Moisture ingress leads to deterioration of the base layers.

Field Investigation: The field investigation will require identification of the location and severity of the problem. If the shoulders are to be replaced, boring should be made to determine what is in the existing shoulder. If a structural design is to be made to replace the existing shoulder then a DCP test can provide useful information on the condition of the subgrade support layer and provide an indication of the amount of undercutting required.

Repair Strategies: The best repair option will depend on the severity and extent of the problem.

- If the edge shoulder drop-off is small < 0.5 in., inactive, and not a safety or riding quality problem, it can be treated with maintenance forces. The existing joint should be sealed, and the shoulder can be leveled with a fine graded maintenance mix.
- If the edge shoulder drop-off is severe, but inactive, it can be milled and/or leveled up with hot-mix asphalt to restore ride quality.
- If the edge shoulder drop-off is severe and getting worse, it must be excavated and fully repaired. A full structural evaluation should be conducted.

Routine Maintenance: Typical routine maintenance, restoration and structural rehabilitation options for concrete pavements are provided below. Repair alternatives can consist of any combination of these options and other repair methods that are not listed.

**Crack/Joint Sealing** - Crack sealing prevents water intrusion into the longitudinal joints and the development of secondary deterioration, so all longitudinal joints should be sealed on a routine basis.

**Patching with Asphalt Concrete** - Patching with asphalt concrete can be used to level the edge shoulder drop-off if it is inactive. If the edge shoulder drop-off is active and if traffic is driving over this joint then this will be a temporary measure only.

**Do Nothing** - If the edge shoulder drop-off is shallow, does not present a safety or riding quality problem, and no cracks are present, doing nothing may be feasible.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the shoulder. This repair is feasible for active edge shoulder drop-offs and for repairing localized structural problems.

**Shoulder Retrofitting** - In severe cases the existing shoulder will need to be completely removed. If traffic will drive over the shoulder joint then a full structural design will need to be conducted.

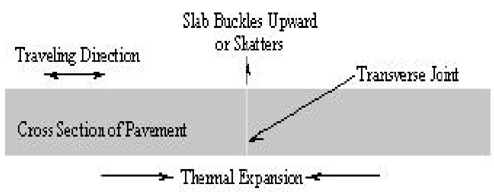
**Edge Drain Retrofitting** - This option should be considered if the only concern is moisture ingress at the longitudinal joint, and traffic will not be driving over the installed drainage system.

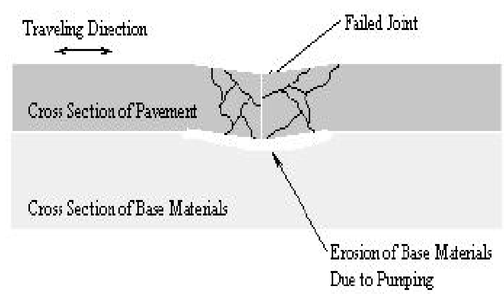
Structural Rehabilitation Options: Localized edge shoulder drop-offs are normally treated by the maintenance options described above. However, in the very rare occurrence that the edge shoulder drop-offs are widespread, then a full forensic investigation should be undertaken to identify the causes and optimum repair strategy.

Prevention: Use tied concrete shoulders in all new concrete pavement designs.

<u>Description</u>: Complete joint failure is often a progression from earlier distresses such as corner breaks, which are not adequately addressed, where moisture enters the lower layers and the joint deteriorates. However, joint failure can also be caused by buckling (or blowup), which is the upward displacement of the slab edge at a transverse joint. Each type of joint failure results in serious structural problems and a decrease in the riding quality. Localized failures are often an indicator of a construction defect relating to the dowel bar placement.

Joint failures must be repaired immediately. The safety of riders is greatly compromised if the joint failure is not repaired. Most, if not all, of the pavement's ride quality is lost from a joint failure.




<u>Possible Causes</u>: The most common causes of joint failure are:

**Insufficient Joint Width** - Insufficient joint width at expansion joints may lead to high compressive stresses during slab thermal expansion, which leads to joint failure.

**Incompressible Material in the Joint** - If incompressible materials enter the joint, this may constrain thermal expansion of the slabs, increase compressive stresses, and result in joint failure.

**Seized Dowel Bars** - If dowel bars do not operate effectively and restrict joint thermal expansion, this may also lead to an increase in stresses at the joint and result in joint failure. The dowels may not have been lubricated or they were misaligned during the placement of the concrete.

**Lack of Subgrade Support** - Lack of subgrade support at the joint due to pumping may cause large slab deflections. These deflections may cause progressive cracking and settlement until joint failure occurs.

**Non-Standard Joint Designs** - In the 1960s researchers tried a range of non-standard joint designs to replace the labor-intensive dowel bars. The most widely used were the wrinkle-tin joints. Over time these joints deteriorated which often resulted in locked joints and subsequent joint failure.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

- Visually inspect the joints for incompressible materials.

- If it is suspected that the dowel bars may have seized, take cores at the joint. Also conduct a load transfer test with a falling weight deflectometer (FWD). Seized joints often have a load transfer efficiency (LTE) greater than 100%.
- Conduct a ground coupled ground penetrating radar (GPR) survey to check for the location of the dowel bars.

Repair Strategies: The only maintenance technique that is effective for the repair of joint failure is full depth repair. If joint failures are widespread, rehabilitation of the pavement should be considered.

Routine Maintenance:

**Crack/Joint Sealing** - Crack sealing helps keep the cracks clear of debris, which may reduce joint failures.

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, such patching may not last very long under traffic loading.

**Do Nothing** - Joint failures normally present a safety problem and should be repaired as soon as possible. This is not a feasible option.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for joint failures.

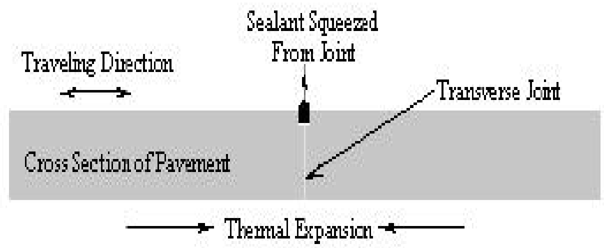
Structural Rehabilitation Options: The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

| | |
|---|---|
| HMA Overlay | Thin-bonded Concrete Overlay |
| Unbonded Concrete Overlay | Flexible Base Overlay and HMA Overlay |
| Rubblization and HMA Overlay | Crack and Seat with Flexible Base Overlay and HMA Overlay |
| Reconstruction (TxDOT Pavement Design Guide) | |

Prevention: The following practices can minimize the occurrence of joint failure:

- Frequently inspect and maintain joints to identify and react to joint sealant and incompressible material problems.
- Properly install load transfer devices at joints.
- Clean joints properly before overlaying the pavement.

Description: Joint seal extrusion occurs when the joint sealant is squeezed from the joint. Extrusion may occur at longitudinal joints, but is most common at transverse joints.




Possible Causes: The causes of joint sealant extrusion are:

**Excessive compressive forces at the joint** - Excessive compressive forces at the joint resulting from high thermal expansion or slab creep may squeeze the sealant out of the joint.

**Sealant deterioration** - Deteriorated sealant as a result of adhesive failure, cohesive failure, or abnormal ageing may extrude from the joint.

**Improper joint construction** - Improper joint construction, such as inadequate groove shape, too much sealant, and failure to clean joint properly prior to sealing may lead to sealant extrusion.

**Traffic action** - Once the joint seal has initiated, traffic action may pull the sealant from the joint.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

- Insufficient joint widths should be identified visually. Inspect the slab size to determine if due to high thermal expansion or slab creep.
- Deteriorated sealant can be inspected by inserting a knife blade on the joint face and then twisting. Effortless penetration indicates a lack of adhesion.
- Joints can be visually inspected to determine if improper joint construction is the cause of the joint failure.

Repair Strategies: Joint sealant extrusion will not cause a structural or safety threat initially. If the joint sealant extrusion is left untreated, water and incompressible materials may infiltrate into the joint, and joint spalling or joint failure may result.

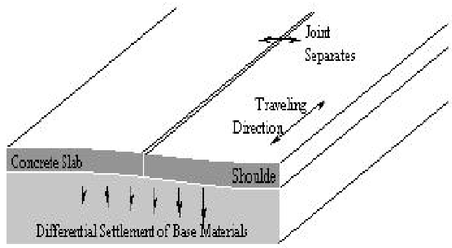
Maintenance Options: Joint sealant extrusion should only be repaired by cleaning the joint and resealing. If the joint is left untreated, water and incompressible materials may enter the joint and create secondary problems.

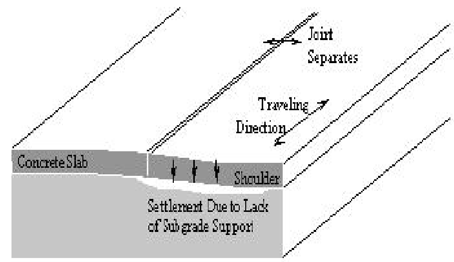
Prevention: The following practices can minimize the occurrence of joint failure:

- Frequently inspect and maintain joints to identify and react to joint sealant extrusion problems early.
- Properly install joint sealant.
- Use high quality joint sealant.

Description: Joint separation is the lateral slippage of slabs resulting in the widening of a longitudinal joint. Joint separation usually occurs between the traffic lane and the shoulder. Lane separation is not considered serious unless water can easily infiltrate into the joint. The infiltration of water may cause additional damage or movement.

Once the joint separates, the infiltration of water may cause damage to the underlying layers, additional movement, or structural problems. If a leveling course is not used to compensate for the movement, then, at a minimum, the joint should be filled with a sealant or an asphalt mix to reduce water infiltration.




Possible Causes: The causes of joint separation are:

**Fractured or Corroded Transverse Tiebars at the Longitudinal Joint** - Fractured tiebars may occur due to the tiebars being bent forward and then bent back during construction, resulting in tiebar damage. Corroded tiebars may also be a cause.

**Not Enough Tiebars Used at the Longitudinal Joint** - Generally, the maximum tiebar spacing should be 36 inches and should at least be a one-half inch in diameter. If the spacing is greater than 36 inches, or if the tiebars are less than one-half inch in diameter, the chances of failure of the tiebars increase, resulting in the joint separation.

**No Transverse Tiebars Used at the Longitudinal Joint** - If no transverse tiebars are used, the joint can easily separate.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

Check for tiebar condition, placement, spacing, and diameter. This can be accomplished by locating the tiebars using Ground Coupled GPR, slab removal, or coring.

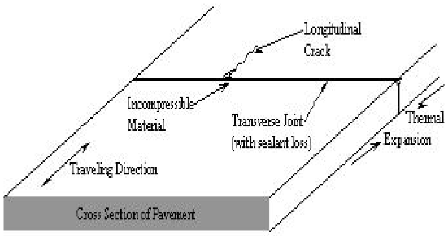
Routine Maintenance: As a short-term repair, grouting of the longitudinal joint could be conducted to reduced safety problems related to joint separation.

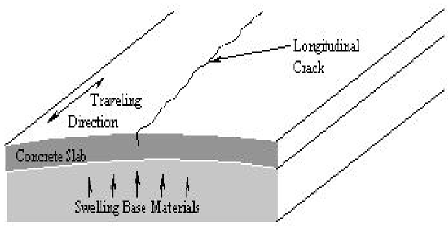
Maintenance Options: If the joint has not separated more than one-half inch, then cross stitching and stapling may be options.

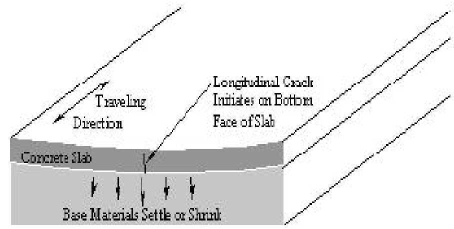
Prevention: The following practices can minimize the occurrence of the joint separation. Use multiple piece tiebars with the spacing specified in the relevant TxDOT concrete pavement standard.

Preservative Distress Type - Longitudinal Cracks — Pavement Type Affected - JCP, CRCP

Description: Longitudinal cracks are cracks that are approximately parallel to the centerline of the roadway. Such cracks are generally straight, but in some instances they may be curved. In severe cases, the pavements may also be faulted on one side of the crack.



Possible Causes: The most common causes of longitudinal cracking are:

**Improper Joint Construction** - Improper joint construction is the most common cause of longitudinal cracking. The primary cause is not sawing the joints soon enough (animation) after placement (the recommended timing is no later than 24 hours). Problems have also been found when cracks are not sawn deep enough (animation) (the recommended saw depths are one third of the concrete pavement depth for concrete containing gravel coarse aggregate; and one fourth of the concrete pavement depth for concrete containing limestone coarse aggregate). These cracks occur early in the pavement life and run fairly straight and parallel to the centerline.

**Loss of Foundation Support** - Improper compaction, inadequate stabilization, and/or water ingress may result in a loss of foundation support (animation) and differential settlement. This may cause the pavement to fault due to bending stresses, causing a longitudinal crack to form at the surface of the pavement. Cracks from this cause may occur at any stage of the pavement life and normally run in a curved shape along the road.

**Reflection Cracking from Stabilized Base** - A cracked stabilized base layer may cause reflection cracking (animation) to propagate upward through the concrete layer. Cracks from this cause normally occur in the early stages of the pavement life on pavements where stabilized bases are used.

Less common causes could be:

**<u>Heaving up of High Plasticity Index (PI) Swelling Soils</u>** - Swelling soils may result in an upward movement of the pavement. This upward movement will create bending stresses throughout the thickness of the slab. Since the tensile bending stresses are occurring on the top surface of the slab, the longitudinal crack may initiate on the top surface. Cracks from this cause may occur at any time during the pavement life.

**<u>Edge Drying of High PI Swelling Soils</u>** - Edge drying of highly plastic soils may cause shrinkage and longitudinal cracking of the subgrade. This crack may propagate upward through the base layers and the concrete layer to form a longitudinal crack. These cracks may occur at any time during the pavement life. They are typically related with subgrade soils having a Plasticity Index of more than 35. Contributing factors include summer drought, steep side slopes, and roadside trees, all of which contribute to the drying out of the subgrade.

**<u>Warping and Curling Stresses</u>** - Warping and curling stresses in jointed pavements may initiate a longitudinal crack. Temperature differentials may cause the edges of the slab to curl upward. The weight of the slab will restrain the slab from curling, thereby creating tensile stresses at the top of the slab which may cause a longitudinal crack to form from the top downward. This longitudinal crack will usually form at the center of the slab. Cracks from this cause may occur at any time of the pavement life, but normally occur during periods of large temperature differentials. Shoulders that are not tied, poor bond between the slab and the subbase, and large slab dimensions may be contributing factors.

**Poor Construction Practices** - In a recent forensic study longitudinal cracking of the slab was attributed to a soft layer which was found on top of the asphalt base layer. The cracking was attributed to heavy rainfall that occurred after the placement of the steel. This rain washed a soft soil layer into the section that was not removed prior to placing the concrete.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

- If the cracks run straight and parallel to the centerline, and no faulting has occurred, then problems with improper joint construction are suspected. Take cores at the longitudinal joint to see if full depth cracks have formed at the joint or not.
- If the cracks are curved and the pavement has either faulted or there is a substantial change in cross-slope due to differential settlement (as measured by a straight edge), then the loss of foundation support is suspected. Conduct a DCP investigation and take a soil sample of the subgrade soil in the settled area. Check the amount and type of stabilizer used. Research has shown that with clay soils, lime stabilizer contents in excess of 6% are required to provide permanent stabilization.
- If the pavement has a stabilized base layer and reflection cracking is suspected, take cores at the longitudinal crack to see if cracks propagate through all layers.

<u>Laboratory Investigation</u>: Laboratory testing is generally not required to validate the cause of longitudinal cracking. However, if problems are suspected in the subgrade then Shelby tube samples should be extracted and the samples used to map soil strata and test if material properties meet design specifications. If inadequate stabilization is suspected, see the TxDOT stabilization guidelines to determine the stabilization requirements.

<u>Repair Strategies</u>: The best repair option will depend on the cause of the cracks, the presence of other distresses, and possibly numerous other factors. The first decision is whether to perform routine maintenance, maintenance, or structural rehabilitation of the pavement. The basis of this decision is an understanding of the causes of the distress, which should give an indication of how the pavement will perform in the future. The following guidelines are given:

- If the cause of the cracks indicates that the cracks should remain fairly inactive over time, routine maintenance should be adequate.
- If the cause of the cracks indicates that the cracks will be active over time, but is not the result of widespread structural deficiencies, maintenance should be appropriate.
- If the cause of the cracks indicates widespread structural deficiencies over the length of the pavement, rehabilitation should be considered.

An understanding of the future deterioration of the pavement and all other pertinent factors should form the basis of developing several feasible repair alternatives. The preferred repair option should then be selected from this list of feasible alternatives. Typical routine maintenance, maintenance, and structural rehabilitation options for concrete pavements are provided below. Repair alternatives can consist of any combination of these options, and other repair methods that are not listed.

Routine Maintenance:

**Crack/Joint Sealing** - Crack sealing prevents water intrusion into the cracks and the development of secondary deterioration, so all cracks should be sealed on a routine basis. If the cracks are narrow and inactive, sealing may be all that is required.

**Do Nothing** - The do nothing alternative is a poor choice with cracking, as cracks allow water to enter the pavement and cause secondary distresses. This option should not be selected without adequate justification.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for active longitudinal cracks and for repairing localized structural problems.

**Cross-stitching** - Cross-Stitching maintains load transfer across the crack and prevents further widening of the crack. Stitching is feasible for narrow longitudinal cracks that are relatively inactive. If the cause of the cracks is related to poor foundation support, stitching may not be effective.

**Slab Stabilization** - Slab stabilization can be used in conjunction with stitching to fill voids beneath the pavement, but this repair is not usually used with this distress.

Structural Rehabilitation Options: The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

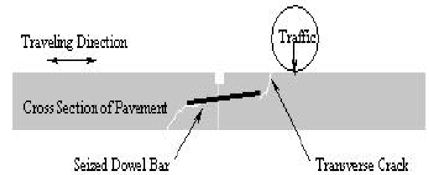
HMA Overlay
Thin-bonded Concrete Overlay
Unbonded Concrete Overlay
Flexible Base Overlay and HMA Overlay
Rubblization and HMA Overlay
Crack and Seat with Flexible Base Overlay and HMA Overlay
Reconstruction (TxDOT Pavement Design Guide)

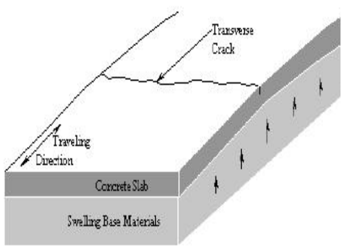
Prevention: The following practices can minimize the occurrence of longitudinal cracking:

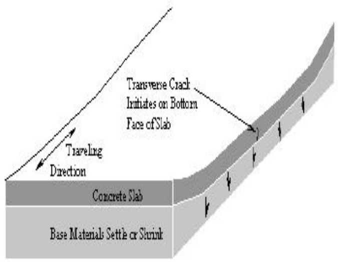
- Limit the slab width (maximum width = 15 ft).
- Saw the joint deep enough (t/3 for gravel aggregates, t/4 for limestone aggregates, where t is the slab thickness).

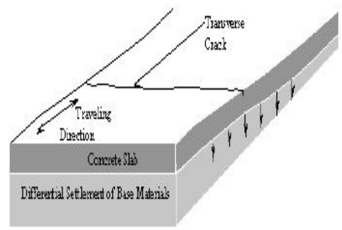
- Saw joints as quickly as possible (as soon as the concrete can support the sawing equipment, and no later than 24 hours after placement).
- Provide a permanent foundation layer consisting of a designed base and stabilized layer.
- Provide adequate drainage to reduce moisture content changes to the base materials.
- Reseal joints as soon as joint sealant deterioration is noticed.

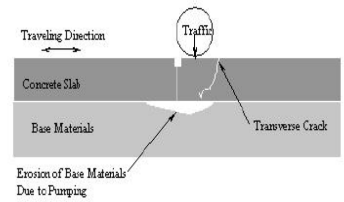
Description: Transverse cracks are generally straight cracks that follow a course approximately at right angles to the centerline of the pavement.



Possible Causes:

**Improper Joint Design** - Excessive slab length is a joint design error that may result in excessive tensile stresses in the slab and lead to transverse cracking.

**Improper Joint Construction** - Improper joint construction by failing to saw joints soon enough or deep enough may cause transverse cracks to form away from the joint.

**Dowel Bar Seizure** - Seized dowel bars restrict contraction and expansion of the slab and may lead to transverse cracks near the end of the dowel bars.

**Improper Slab Design or Construction** - Improper slab design or construction resulting in inadequate slab thickness or inadequate material strength may lead to transverse cracks.

**Swelling Soils** - Swelling soils may result in upward movement of the pavement and cause excessive tensile stresses at the top of the slab, which may initiate transverse cracks from the top down.

**Loss of Foundation Support** - Loss of foundation support may result in excessive bending stresses and the development of transverse cracks. This may be from the erosion of base material at the joint or elsewhere in the slab.

**Frost Heave** - Frost heave of the underlying soils may result in upward movement of the pavement and cause excessive tensile stresses at the top of the slab, which may initiate transverse cracks from the top down.

The development of transverse cracks may be accelerated by warping and curling stresses in the slab, but these stresses are not expected to be the primary cause of transverse cracks.

Field Investigation: Inspect slab dimensions to determine if of excessive length.

- Take a core through the joint to inspect if the joints are cracked through.
- Take a core through the dowels to inspect if they are seized.
- Take a core to evaluate the slab thickness and material strength.
- If swelling soils are suspected, take soil samples for laboratory testing.
- Take cores or use GPR to inspect for voids and loss of foundation support.
- Take cores to determine is frost heave has produced upward expansion of the slab.

Laboratory Investigation: The following laboratory testing may be required:

- Material strength test – splitting tensile strength test (Tex-421-A)
- Sulfate tests.

- Atterberg limits.

Maintenance Options: The following repair strategies are recommended:

1) If the transverse cracks are inactive and no secondary distresses have occurred, the cracks can be left unrepaired or sealed if wide enough.

2) If the transverse crack is active due to either swelling soils or loss of foundation support, the base materials must be treated with full depth repair.

Prevention: The following practices can minimize the occurrence of Transverse Cracking:

- adequate design by limiting slab length,
- appropriate sawing of the joints,
- adequate dowel bar placement to prevent seizure,
- adequate slab thickness design and concrete strength,
- provide proper drainage,
- use stabilized base materials, and
- adequate compaction.

## **Functional CPR**

Functional distresses are more serious than preservative distresses and cause roughness problems with the pavement. The deterioration rate on these distresses is usually quite slow and provides many opportunities for repair.

Bump

Crack Spalling

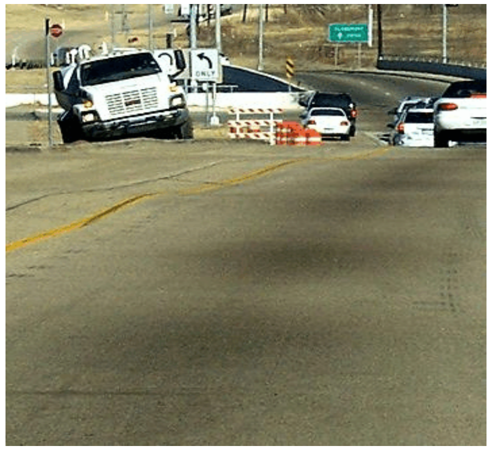
Faulting

Continued.

## Functional CPR (Continued)

Joint Spalling

Settlement



Description: A bump is a localized upward bulge of the pavement from its original constructed longitudinal profile. The bump or swell is usually a result of soil or base movements, often initiated by climatic factors. Cracking on the surface of the slab may result from bumps. Bumps can severely impact riding quality and are most easily seen as dark areas on the pavement where the oil from vehicles has dropped from the impact of going over the bump. Often when inspecting problems in the field, it is difficult to determine if the localized roughness is caused by a bump (upward movement) or settlement (downward movement). A rod and level survey or profilometer survey may be required to differentiate the two.

Possible Causes: Three causes of bumps are:

1. **Swelling of the Subgrade** - Many high PI clay subgrade materials have a high propensity to swell when they come into contact with water. Large areas in Texas are known to have highly expansive soils. The swelling of the subgrade will cause a localized bump on the pavement surface.
2. **Sulfate Heave** - Sulfate heave may be another cause of the bump. The heave occurs when subgrade materials that contain high levels of sulfates are treated with calcium based stabilizers.
3. **Frost Heave** - Frost heave of the underlying layers caused by the freezing of trapped moisture may also result in a bump. This rarely occurs in Texas. It could possibly occur in the Amarillo and Lubbock Districts.

Field Investigation: The field investigation always requires a visual inspection. If the cause is not obvious, soil boring can be performed with further analysis in the laboratory. Testing is conducted in both problem and non-problem areas.

Laboratory Investigation: If cause 1 or 2 is suspected, the designer should consider one or more of the following validation tests:

**Atterburg Limits**. (Soils with a Plasticity Index > 35 are often highly expansive).

**Potential Vertical Rise** (TxDOT Test Method Tex-124-E).

**Sulfate Content** (TxDOT Test Method Tex-145-E) test conducted on raw soil from site.

**Water Content**.

**Soil Strata Mapping**.

Further discussion of the sulfate issue can be found at ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/tech/sulfates.pdf. If sulfate heave is suspected, advanced tests involving Scanning Electron-microscopes and X-Ray Diffraction can be conducted by the Soils and Aggregates section of the Construction Division in Austin. One concern is whether the sulfate heave will continue or if the reaction is complete. A first step in this determination will be to measure the amount of un-reacted sulfates in the existing stabilized layer.

If the cause is not obvious from this testing, review the causes of settlements.

Routine Maintenance:

**Crack/Joint Sealing** - Crack sealing prevents water intrusion into the cracks and the development of secondary deterioration, so all cracks should be sealed on a routine basis. If the cracks are narrow and inactive, sealing may be all that is required.

**Patching with Asphalt Concrete** - Patching with asphalt concrete can be used to level the bump if it is inactive. If the bump is active, this will be a temporary measure only.

**Do Nothing** - If the bump is inactive, does not present a safety or riding quality problem, and no cracks are present, doing nothing may be feasible.

Maintenance:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for active bumps and for repairing localized structural problems. Undercutting will be required if swelling is the cause. Hot mix must be placed directly under the new concrete.

**Grinding and Grooving** - Used for low severity bumps.

**Edge Drain Retrofitting** - This option should be considered if excavation and reconstruction is needed and if water is entering the pavement structure.

Structural Rehabilitation Options: Localized bumps are normally treated by the maintenance options described above. However, in the very rare occurrence that the bumps are widespread, a full forensic investigation should be undertaken to identify the causes and optimum repair strategy. The use of vertical moisture barriers to stabilize the soil moisture content was tried in several projects in Texas in the 1970s; research reports are available on this topic. Mixed results have been obtained with this process recently (Bryan District 2002). The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Both of the major causes (swelling soils or sulfate heave) are attributed to moisture entering the problem layer. Any rehabilitation action short of full reconstruction should evaluate techniques of minimizing water ingress. The most economic rehabilitation option for bumps is often an HMA overlay.

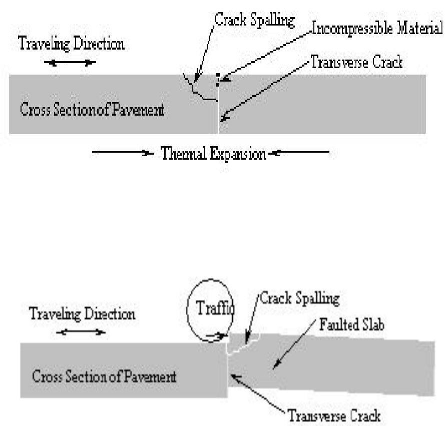
Prevention: The following practices can minimize the occurrence of bumps:

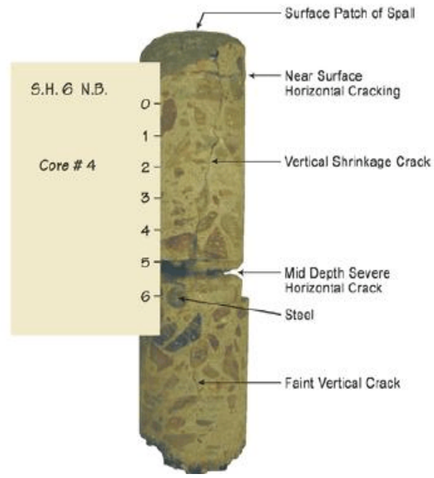
- Conduct a thorough soils investigation for any new project, including PI and sulfate determination.
- If swelling soils (high PI) are a concern, measure the potential vertical rise of the site with Tex Method 124E. Follow the recommendations in the online design guide for selecting undercutting and select fill requirements. Follow the recommendations of the study.
- If sulfates are a concern, follow the recommendations of TxDOT's Stabilization Guidelines Manual.

Guidelines on these options are given in TxDOT's online design manual.

Functional Distress Type - Crack Spalling Pavement Type Affected - JCP, CRCP

Description: Crack spalling is the loss of concrete around an existing transverse crack. The depth of the spall is frequently around 1 inch and typically extends 6 to 12 inches from the existing crack. Spalling may occur along the whole length, or only a portion of the length of the crack and may occur on either side of a crack. Spalling is a problem in several areas of Texas causing substantially reduction in the ride quality of the pavement, and can cause accelerated structural failure of the slab.



The progression of crack spalling may result in additional cracking in the slab or even present a safety issue. The repair of crack spalling is also necessary to prevent more debris from entering the joint. Crack spalling is progressive and when both sides of a crack have spalled, a pothole is likely to follow.

Possible Causes: The mechanism of spalling is not fully understood, but near-surface horizontal delaminations that result from the ineffective curing of the placed concrete are the root cause. Once near-surface delaminations have occurred, various mechanisms, such as traffic loading and thermal cycling, can deteriorate the delamination into spalling. A study of spalling in Houston revealed that spalling was not a direct result of chemical processes, such as alkali silica reaction (ASR) and delayed etteringite formation (DEF). In the Houston District, severe spalling is often associated with the use of gravel aggregates in continuously reinforced concrete pavement. Severe spalling is rarely a problem with pavements constructed with limestone aggregates. It is suspected that the loss of bond between the concrete and gravel aggregates expedite spalling if horizontal delaminations are already present.

The most common cause of crack spalling is the ineffective curing of concrete that leads to near-surface horizontal delaminations.

Hot weather and high wind that cause high evaporation are known to negatively affect the curing process and cause near-surface delaminations.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

Use a sounding hammer or the ground coupled GPR to identify the extent and severity of spalling.

If possible, determine weather conditions during paving operations (i.e., high wind speed, high temperatures). Refer to the nomograph from the Portland Cement Association manual titled, "Design and Control of Concrete Mixtures," (Skokie, IL, 1988) to determine the evaporation rate of the concrete. If the evaporation rate exceeds 0.2 lb/sq. ft/hr, the possibility of horizontal delaminations increases.

Laboratory Investigation: The following laboratory investigations are recommended:

Identify the type and source of the aggregates used in the concrete. Contact TxDOTs Rigid Pavement and Concrete Materials Branch, Materials and Pavements Section, Construction Division (512-506-5858) to determine if the thermal coefficient of expansion of this aggregate is high.

Obtain construction date and review weather records during construction to check if weather may have affected curing. Refer to the PCA nomograph described earlier.

Review curing methods and curing compounds used during construction. Contact TxDOTs Rigid Pavement and Concrete Materials Branch, Materials and Pavements Section, Construction Division (512-506-5858) to determine if the curing compound has been effective in the past.

If delaminations are found at lower depths in spalled sections of concrete, additional testing may be required. Advanced testing of the crack interfaces of the mid-depth cracks can be undertaken using Scanning Electron Microscope and X-Ray Diffraction techniques (available at Rigid Pavement and Concrete Materials

Branch) to determine if ASR or DEF reactions are initiating in these cracks. Their occurrence will mandate the use of an effective crack seal to minimize further water intrusion, which will accelerate this process.

Repair Strategies: Little can be done to retard the development of spalling once it initiates. It is, therefore, feasible to leave the distress until it starts affecting ride quality and then repair it.

Routine Maintenance:

**Patching with Asphalt Concrete** - Patching with asphalt concrete can be used as a temporary measure to improve ride quality and safety problems.

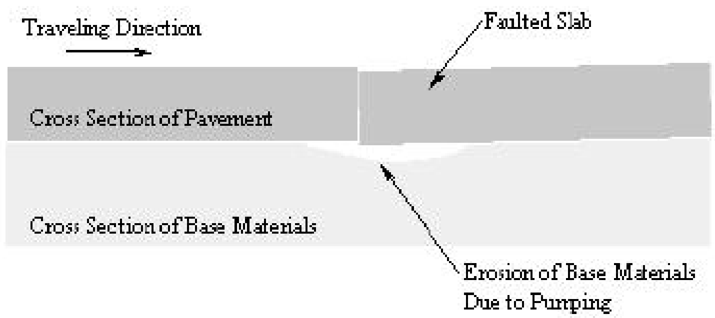
Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for deep spalling, which is greater than 1/3 the thickness of the slab.

**Partial Depth Repair** - This repair is feasible if the spalling is less than 1/3 the thickness of the slab. Studies are underway to determine the most effective spall repair material.

Prevention: Following proper curing guidelines and techniques and careful selection of the aggregate can minimize the occurrence of spalling.

Description: Joint faulting is the differential vertical displacement of the slab edge across a transverse joint. The difference in elevation results in a step deformation. The approach slab edge is usually higher than the departure slab edge due to impact effects as the load moves across the joint and the effect of pumping.




Possible Causes: The most common causes of faulting are:

**Erosion of Support by Pumping** - Water enters a joint subjected to traffic action and the vertical slab movement under load propels the water back and forth under the slab in a pumping action, which erodes the underlying slab support, creates a void under the departure slab and a build up of fines under the approach slab. Faulting will then be the result.
Erosion used to be a major problem for slabs built on untreated select fill bases or with some cement treated base materials. It is not too common with new pavements built on non erodible bases but it is common on jointed concrete pavement built before 1980.

**Lack of Adequate Load Transfer** - Faulting frequently occurs on jointed pavements where an inadequate load transfer system is used to transfer load from one slab to another. An inadequate load transfer system may be the use of no load transfer steel, or the use of inadequate steel. The high load stress, which is not distributed to the adjacent slab, leads to high deflections of the slab under loading. The high deflections result in more rapid settlement and degradation of the support layers. Traffic action and free moisture under the slab accelerate the development of faulting in this manner. Support layers that are susceptible to moisture can accelerate the development of faulting if free moisture is available beneath the pavement.

Field Investigation: Guidelines for the identification of the most common cause of distress are as follows:

- Conduct load transfer deflection testing across the faulted joints. This can be done using the Falling Weight Deflectometer (FWD) or the Rolling Deflectometer (RDD).
- Conduct a non-contact GPR survey to detect voids and moisture beneath the joints.
- Conduct a ground-coupled GPR survey to determine if the joints contain any load transfer devices. This is often necessary with older pavements where as-built information is not available. The presence of joint steel can easily be detected with a 1.5 GHz ground-coupled survey.
- Conduct a DCP survey to identify the quality of the underlying material near the faulted joint.
- Use a dry drill to gain access to the base. Check in the drilled hole for the presence of voids or moisture directly beneath the slab.

Repair Strategies: Most localized faulting problems can be repaired by using maintenance techniques, such as slab stabilization, grinding, and dowel bar retrofitting. Maintenance techniques may be ineffective on pavements that have widespread faulting problems that originate from the use of moisture susceptible support layers and/or inappropriate load transfer design. In these cases, structural rehabilitation may be the only solution.

An understanding of the future deterioration of the pavement and all other pertinent factors should form the basis of developing several feasible repair alternatives. The preferred repair option should then be selected from this list of feasible alternatives. Typical routine maintenance, maintenance, and structural rehabilitation options for concrete pavements are provided below. Repair alternatives can consist of any combination of these options and other repair methods that are not listed.

Routine Maintenance:

**Crack/Joint Sealing** - Joint sealing prevents water intrusion into the underlying layers at the joint. Since free moisture accelerates the development of faulting, joints should be maintained on a regular basis, particularly in high rainfall areas and on pavements with moisture susceptible support layers.

**Do Nothing** - Faulting creates a ride quality problem to the traveling public. In cases where the faulting is of low severity (< 0.25 inches) and the pavement has aged, little benefit can be derived from repairing the faulting. In these cases, the do nothing alternative may be a viable option until the faulting progresses to a higher level of severity where it has a greater effect on the ride quality.

Maintenance Options:

**Full Depth Repair** - Full depth repair of the pavement joint can reinstate the support layers at the joint and replace the joint load transfer system. This treatment may be feasible if the support layers have degraded as a result of pumping, and the joint load transfer system is inadequate.

**Dowel Bar Retrofit** - Dowel Bar Retrofit may be used to retrofit a load transfer system when an inadequate system exists. Many old pavements were built without steel load transfer systems, where the only load transfer is by means of aggregate interlock. With the action of traffic over time, the aggregate interlock wears out so the load transfer diminishes and faulting occurs. Dowel Bar Retrofit is most feasible on pavements with poor load transfer systems, but with little degradation of the underlying layers or voids beneath the joint. After retrofitting, the slab is usually ground to give a good ride.

**Slab Stabilization** - Slab stabilization can be used in conjunction with Dowel Bar Retrofit to fill voids beneath the pavement.

**Slab Jacking** - Slab jacking with grouts of various types has been tried in several places around Texas. Slabs can be raised but this technique was in some cases found to be only a temporary solution. In some cases lifting the corner of slabs has resulted in future problems at mid-slab. This method is not recommended.

**Grinding and Grooving** - Grinding can be used to improve ride quality by eliminating the fault. However, this action does not treat the cause of the distress and is best used in conjunction with other treatments, such as dowel bar retrofitting (DBR). Experience has shown that without additional treatments such as DBR, the faulted section will reappear in less than 2 years if only grinding is used.

Structural Rehabilitation Options: The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

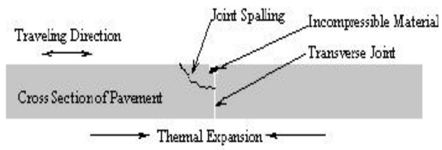
HMA Overlay
Thin-bonded Concrete Overlay
Unbonded Concrete Overlay
Flexible Base Overlay and HMA Overlay
Rubblization and HMA Overlay
Crack and Seat with Flexible Base Overlay and HMA Overlay
Reconstruction (TxDOT Pavement Design Guide)

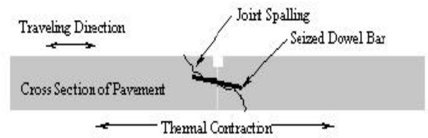
Prevention: The following practices can minimize the occurrence of faulting.

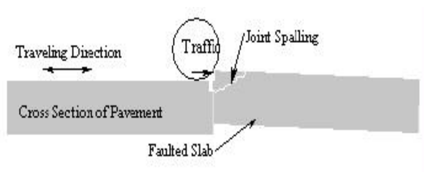
- Use subbases that are not moisture susceptible.
- Provide adequate drainage to prevent water infiltration.
- Provide sufficient load transfer devices.
- Maintain joint seals to prevent water infiltration at the joint.

Description: Joint spalling is the chipping of the concrete slab at the edges of longitudinal or transverse joints. The spalling may occur along the whole length, or only a portion of the length of the joint and may occur on either side of the joint. Joint spalling is due to excessive local pressure at the joint. This pressure may be due to a combination of traffic action, thermal expansion, and/or steel corrosion. After both sides of a joint have spalled, the spalling may progress into a pothole.

Joint spalling will reduce the riding quality of the pavement. The progression of joint spalling may result in additional cracking in the slab or even present a safety issue. The repair of joint spalling is also necessary to prevent more debris from entering the joint.



Possible Causes: The most common causes of spalling are:

**Improperly Designed or Constructed Joints** - Certain joint designs have exhibited spalling. In particular, the "wrinkled tin" transverse joint design has resulted in spalling.

**Misaligned Dowel Bars** - A misaligned dowel bars doesn't allow the joint to expand and contract, which results in concrete stresses to build up at the joint. This can result in spalling at the joint.

**Incompressible Materials in the Joints** - Wide joints allow incompressible material to enter. In warmer weather, the increasing temperatures will cause the slab to expand. The material in the joint creates restraint and will prevent the slab from expanding. The restraint results in excessive compressive stresses at the joint causing spalling.

**Traffic Action** - If the slab is faulted at the joint, the spalling may be a result of traffic striking the raised edge of the slab.

**Freeze-Thaw Damage** - Water entering the joint may saturate the concrete around the joint. Freezing temperatures may result in freezing and thawing damage, such as spalling, around the joint.

Field Investigation: Guidelines for the identification of the most common causes of distress are as follows:

- Visually inspect the joints for incompressible materials, misaligned dowels, and faulting.

- If freeze-thaw damage is suspected, validate by taking cores through the joint and near the joint to see if freeze-thaw damage or D-cracking is present.

<u>Repair Strategies</u>: An asphalt patch or partial depth patch concrete patch may be effective for a short time frame. However, the only long-term repair strategy is full depth repair if the pavement will not be overlaid.

<u>Routine Maintenance</u>:

**<u>Patching with Asphalt Concrete</u>** - Patching with asphalt concrete can be used as a temporary measure to improve ride quality and safety problems.

Little can be done to retard the development of spalling once it initiates. It is, therefore, feasible to leave the distress until it starts affecting ride quality and then repair it.

<u>Maintenance Options</u>:

**<u>Full Depth Repair</u>** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for deep spalling, which is greater than 1/3 the thickness of the slab.

**<u>Partial Depth Repair</u>** - This repair is feasible if the spalling is less than 1/3 the thickness of the slab. Studies are underway to determine the most effective spall repair material.

Prevention: The following practices can minimize the occurrence of joing spalling:

- Frequent observation of pavement sections can provide early identification of debris in the joints. Clean and re-seal joints if incompressible material have entered the joints.
- Be sure that the dowels are aligned properly during construction.
- Use proper joint designs as indicated in the current TxDOT standards.

Description: Settlement is the downward vertical movement of the pavement from its original constructed longitudinal profile. The settled pavement will introduce roughness into the pavement section and in extreme cases can be a safety concern. Secondary issues may be slab cracking and the ponding of water. It is often difficult to discriminate between settlements (downward) and bumps (upward). Bumps are discussed elsewhere in this section.

The main problem with settlement is the increase in the pavement roughness. Once a pavement settles, severe pitch and roll may occur, causing the driver some discomfort. Ponding may also be a result of settlement. Ponding creates a safety concern since hydroplaning may become a problem. Settlement may also cause slab cracking due to the increased bending of the slab.

Possible Causes: The possible causes of settlement are:

**Lack of Support** - The pavement may settle due to lack of support. This is frequently associated with a loss of stabilization in a subbase or treated subgrade layer. This is mostly attributed to inadequate design of the stabilizer content to be used to provide a permanent stabilized layer. Often stabilizer contents are selected based on district experience and no lab tests are run. However, Texas soils are so variable that lab tests should be run. The recommended procedure should include a retained strength of a moisture conditioned sample. The TxDOT Stabilization Design Guide should be used to select stabilizer contents.

If the stabilizer disappears then causes could include a) the presence of high levels of organic content in the natural soil or b) leaching caused my moisture ingress.

**Poor Localized Compaction Procedures** - A single bump often occurs directly over structures such as culverts, where the poor quality of the backfill material or inadequate compaction procedures may be the cause. Settlements are also common on bridge approaches.

**Large Voids** - Broken water pipes have caused large voids under several pavements in Texas. Sink hole activity is rare.

Field Investigation: The field investigation always requires a visual inspection. If the cause is not obvious then DCP testing and soil boring can be performed with further analysis in the laboratory.

**DCP Testing to Check the Penetration Rate Through Base and Subbase Layers**. Testing is conducted in both a problem and non problem area. Penetration rates through a stabilized layer should be less than 0.5 inches per blow and through normal fill material less than 1 inch per blow.

**Ground Coupled GPR Testing to Detect Voids**. This equipment is available at TTI.

**Soil Boring and Sampling of the Underlying Layers**.

Routine Maintenance: None.

Maintenance Options:

- If the settlement appears stable in that it is not deteriorating with time, an asphalt overlay can be placed as a leveling course as a short-term strategy.
- If the settlement is localized and due to poor support, a full depth repair is the only permanent solution. The moisture sensitive base should be removed and replaced. An asphalt overlay can be placed.
- If the settlement is due to small voids beneath the pavement, slab undersealing could be used, but such stabilization techniques may only be a short-term solution. Undersealing has not been effective in wet areas where the underlying support is poor. The voids and associated pavement roughness reappear in a short time. The only effective long-term solution is full depth repair.

Structural Rehabilitation Options: None.

Prevention: The following practices can minimize the occurrence of settlements:

- Conduct a thorough soils investigation for any new project, including PI, organic, and sulfate determination.
- To select the optimal stabilizer content, follow the recommendations of the TxDOT Stabilization Guidelines Manual.
- Guidelines on these options are given in the TxDOT online design manual.

## Structural CPR

Structural CPR distresses continue to deteriorate at a moderate rate and represent pavement problems that can become quite serious if left unrepaired.

Patch Deterioration

Pumping

Description: A concrete patch (a "longer lasting" repair) is a localized area of newer concrete which has been placed to the full depth of the existing slab as a method of correcting surface or structural defects.

Possible Causes: Patches are intended to repair bad areas in an existing pavement, however many times the patch itself deteriorates quickly or causes nearby disintegration. The causes for disintegration of the patch include:

- Poor compaction of the base/subgrade under the patch, usually caused by wet areas not being dried out properly, difficulties in compacting in the small space, construction activities in the patched area, and many others.
- In some cases, the concrete patching material itself may be substandard due to the relatively small amounts of materials being used, the length of time between the time the material is batched and the time it is finally placed, low air and pavement temperatures at the time of placement, segregation of the material, opening the pavement to traffic before adequate strength has been reached, at many others.

The causes for disintegration of the surround area include:

- Construction practices when installing load transfer devices,
- De-compaction of the area under the adjacent slab during repair operations,
- Spalling (causes will be the same as discussed under spalling), and
- Others.

Field Investigation: Typically a GPR investigation of the patched and nearby areas to confirm water under the slab and in the base, along with FWD data collection for the slabs and adjacent areas to confirm load transfer are conducted.

Repair Strategies: An asphalt patch or partial depth concrete patch may be effective for a short time frame. However, the only long-term repair strategy is full depth repair if the pavement will not be overlaid. In some cases, the patches are a substantial source of roughness, which must be corrected to improve the pavement.

Routine Maintenance:

**Patching with Asphalt Concrete** - Patching with asphalt concrete can be used as a temporary measure to improve ride quality and safety problems.

Little can be done to retard the development of spalling once it initiates. It is, therefore, feasible to leave the distress until it starts affecting ride quality and then repair it.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for deep spalling, which is greater than 1/3 the thickness of the slab.

**Partial Depth Repair** - This repair is feasible if the spalling is less than 1/3 the thickness of the slab. Studies are underway to determine the most effective spall repair material.

**Diamond Grinding** - Diamond grinding removes a thin layer at the surface of hardened PCC pavement using closely spaced diamond blades. This repair is feasible if the aggregates are not hard. Hard aggregates will reduce production rates, increase cost, and may contribute to excessive spalling.

**HMA Overlay** - An overlay will cover up all of the patches, provide a smoother surface, and increase the pavement score. For a pavement with a substantial number of patches (>10/mi) an overlay is often the only technique that will improve the PMIS score.

Prevention: Use of proper construction and patching techniques will minimize the deterioration of the patch and surrounding areas.

Description: Pumping is the expulsion of water and silts, sands, or clays from joints or cracks when load is applied to the pavement. If water enters the joint or crack it may erode the underlying layers of the pavement. When load is applied to the approach slab, the water will propel underneath the departure slab. When the load moves to the departure slab, the water will propel back underneath the approach slab. The constant movement of water back and forth will erode the base layers and create cavities underneath the pavement. The cavities may also create slab rocking where the edge of the slab moves vertically when load is applied to an undowelled pavement. Pumping of the pavement can be considered a major distress. After pumping is observed, failure of the pavement is not far behind.

Possible Causes: The cause of pumping is:

**Water Entering Cracks and Joints** - Pumping results when water is allowed to enter the joint or crack. The movement of the water under the slab when a load is applied erodes the base materials.

**Erodable Materials** - Erosion was a major problem with slabs built with untreated select fill bases or with some cement treated base materials. This is not too common with new pavements built on non-erodible bases, but it is common on jointed concrete pavements built before 1980.

Field Investigation: The field inspection for water being ejected from joints of fine materials near the surface of the crack or joint usually involves a visual survey during or after a rain. A subsurface investigation by conducting some soil borings of the underlying layers to inspect base material is also possible

Repair Strategies: Most localized pumping problems can be repaired by using maintenance techniques, such as slab stabilization, full depth repair or retrofitting edge drains. Maintenance techniques may be ineffective on pavements that have widespread pumping problems that originate from the use of erodable materials. In these cases, structural rehabilitation may be the only solution.

An understanding of the future deterioration of the pavement and all other pertinent factors should form the basis of developing several feasible repair alternatives. The preferred repair option should then be selected from this list of feasible alternatives. Typical routine maintenance, maintenance, and structural rehabilitation options for concrete pavements are provided below. Repair alternatives can consist of any combination of these options and other repair methods that are not listed.

Routine Maintenance:

**Crack/Joint Sealing** - Joint sealing prevents water intrusion into the underlying layers at the joint. Since free moisture is needed for pumping to take place, joints should be maintained on a regular basis, particularly in high rainfall areas and on pavements with erodable bases.

**Do Nothing** - Pumping creates cavities underneath the joints and may result in pavement faulting or slab rocking. After pumping is observed, failure of the pavement is not far behind. As a minimum, the joint should be sealed to prevent more water from entering the joint. ***Doing nothing is not a good alternative.***

Maintenance Options:

**Full Depth Repair** - Full depth repair of the pavement joint can reinstate the base materials and replace the joint load transfer system. This treatment may be feasible if the support layers are erodable and/or the joint load transfer system is inadequate.

**Edge Drain Retrofitting** - Edge drain retrofitting can allow trapped water to drain from the pavement, which reduces the water available for pumping.

Structural Rehabilitation Options: The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

HMA Overlay
Thin-bonded Concrete Overlay
Unbonded Concrete Overlay
Flexible Base Overlay and HMA Overlay
Rubblization and HMA Overlay
Crack and Seat with Flexible Base Overlay and HMA Overlay
Reconstruction (TxDOT Pavement Design Guide)

Prevention: The following practices can minimize the occurrence of pumping:

- Provide adequate drainage to prevent water from coming in contact with base materials.
- Frequently inspect the joint sealant to prevent water infiltration.
- Use stabilized base or base that is less susceptible to erosion.

## Remove and Replace Distresses

Remove and replace distresses have progressed to the point that they need to be replaced immediately. If repaired quickly, the damaged area can be contained. If left unrepaired, more areas will rapidly become severely distressed.

Corner Breaks

Punchouts

Shattered Slabs

Description: A corner break is a crack that extends from a transverse joint or crack to a longitudinal joint or the pavement edge. Each end of the crack should be less than 6 feet from the corner of the slab. If one end of the crack is further than 6 feet from the corner of the slab, the crack should be categorized as a diagonal crack and not a corner break. A corner break extends through the thickness of the slab. Settlement of the corner after breaking creates a ride quality and safety problem.

Possible Causes: A corner break is a result of repeated loading on the slab corner combined with a lack of subgrade support. In older jointed concrete pavements water enters the lower layers through the transverse joint or the poorly maintained shoulder joint. If water reaches the base materials, heavy repeated loads across a joint can cause pumping and erosion of the subgrade. The lack of support creates a cantilever effect across the corner. Excessive tensile stresses on the top of the slab cause cracking, which results in the corner break. Poor load transfer across the joint, thermal curling stresses, and moisture warping stresses may also contribute to the stresses that form a corner break.

If corner breaks occur early in the life of the pavement (i.e., within the first month), then construction practices may have contributed to the occurrence of this distress. For example, if the dowel bars are misaligned or are not properly lubricated, then the dowels can cause the joint to lock up, resulting in corner break cracking at the end of the dowel bars. Also, inadequate concrete form work could contribute to the formation of the corner breaks.

Field Investigation: Poor support is the primary cause of corner breaks, so the quality of the base material should be validated by taking cores of the base material for laboratory testing.

In order to investigate the amount of sub-slab material that will need to be replaced, it is recommended that a DCP test be conducted to identify if substantial undercutting will be needed to provide a stable support layer.

Laboratory Investigation: This investigation is not normally required. However, if the cause of the problem is a loss of stabilization from the base layer then TxDOT Stabilization Guidelines should be consulted. Tests could be undertaken to measure the moisture susceptibility of any proposed base layer.

Repair Strategies: The only maintenance technique that is effective for the repair of corner breaks is full depth repair. If corner breaks are widespread, rehabilitation of the pavement should be considered.

Routine Maintenance:

**Crack/Joint Sealing** - Joint sealing may prevent moisture penetrating the subgrade materials and reduce the effects of pumping and erosion, which lead to corner breaks. Crack sealing of the corner crack does little to maintain the corner break. Resealing the longitudinal joint will be critical to slow the development of this distress.

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, such patching may not last very long under traffic loading.

**Do Nothing** - Once a corner break has occurred, little can be done to retard the further development of the distress. Low severity corner breaks have little effect on safety and ride quality, but the crack allows moisture to penetrate the support layers and accelerates deterioration. Due to the increased rate of deterioration, corner breaks normally need to be maintained fairly soon after occurrence.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for corner breaks.

Structural Rehabilitation Options: If 10 percent or more of the joints have corner breaks, the following structural rehabilitation options should be considered. Also, if the corner breaks have deteriorated, they need to be repaired before using the HMA overlay option. The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

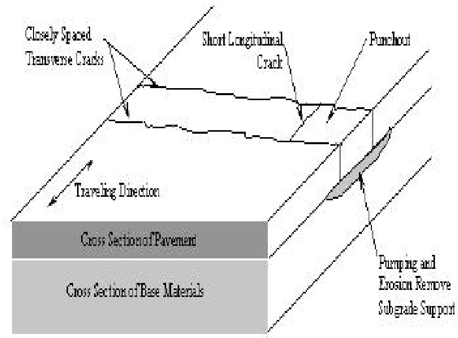
HMA Overlay
Thin-bonded Concrete Overlay
Unbonded Concrete Overlay
Flexible Base Overlay and HMA Overlay
Rubblization and HMA Overlay
Crack and Seat with Flexible Base Overlay and HMA Overlay
Reconstruction (TxDOT Pavement Design Guide)

Prevention: The following practices can minimize the occurrence of the corner breaks:

- Ensure proper drainage to reduce the amount of moisture coming into contact with the base materials.
- Frequently inspect and repair transverse cracks and joints to prevent water from entering though the cracks.
- Use a stabilized base that is less susceptible to weathering, erosion and settlement.
- Be sure the dowel bars are aligned properly and proper concrete formwork is used.

Description: A punchout is a full-depth block of pavement, formed at the edge, when a longitudinal crack forms between two existing transverse cracks. The existing cracks are closely spaced, usually less than 4 feet apart. The punchout is often rectangular, but some may appear in other shapes. Punchouts are most common in continuously reinforced concrete pavements.

The interconnecting cracks will not create any riding or safety problems. The cracks will allow additional moisture to come into contact with the base materials, resulting in accelerated erosion and pumping.



The punchout will develop spalled edges, settlement, and rupturing reinforcement under heavy loads. Once spalling and settlement have occurred, safety and riding quality problems will follow. Also, the punchout will expand to nearby cracks if it is not immediately repaired.

Possible Causes: The primary cause of punchouts in older CRCP, placed from the 1950s through the 1960s, is poor base support due to erodible bases and poor edge support due to the use of flexible pavement shoulders. A punchout initiates with two closely spaced transverse cracks. Moisture enters the pavement base typically via the shoulder joint or through the surface cracks. This water weakens and erodes the base material, often pumping initiates and a subslab void is formed. With some of the base support removed, a cantilever is created between the transverse cracks. Heavy load applications will connect the transverse cracks with a longitudinal crack. The punchout progresses with spalling of the cracks, rupturing of the reinforcing steel, and eventually settlement of the punchout below the original surface of the pavement.

The traditional punchout described above was common in many of the older CRCP designs in Texas. However, with the current use of non-erodible base materials and tied concrete shoulders, punchouts are now a rare occurrence.

Recently a second cause of punchouts has been identified to be the presence of mid slab horizontal cracking in the CRCP. The horizontal cracks are typically at the level of the reinforcing steel. In this case, the reinforcing steel may not rupture, but the concrete will deteriorate. Research is currently ongoing to determine the causes of mid slab horizontal cracking.

<u>Field Investigation</u>: In many cases the cause of the classical punchouts is clear and the repair strategy is a full-depth repair. However, if a field investigation is needed it could include a GPR survey to look for subslab moisture. Samples of the base material can also be removed. In order to investigate the amount of subslab material that will need to be replaced it is recommended that a DCP test be conducted. This will identify if substantial undercutting will be needed to provide a stable support layer. In the case of horizontal cracks, a ground coupled GPR survey can also be helpful in identifying problems within the slab.

<u>Repair Strategies</u>: The only maintenance technique that is effective for the repair of punchouts is full depth repair. If punchouts are widespread, rehabilitation of the pavement should be considered.

<u>Routine Maintenance</u>:

**<u>Crack/Joint Sealing</u>** - Crack sealing on reinforced concrete pavements, where cracks are numerous, is not feasible if the concrete has deteriorated. However, crack sealing may be possible if the concrete has not deteriorated (i.e., the cracks are still tightly closed and have not spalled).

With CRCP with asphalt shoulders it is very important to have a good seal between the shoulders and the concrete main-lanes. Preventing water from entering the lower layers will retard the onset of punchouts.

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, asphalt patches may not last very long under traffic loading.

**Do Nothing** - The nature of punchouts is such that little can be done to retard the development of the distress once it initiates. It is therefore feasible to leave the distress until it starts affecting ride quality and then repair it.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for punchouts.

Structural Rehabilitation Options: If three or more punchouts per mile per year are occurring, the designer needs to consider the structural rehabilitation options listed below. The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

HMA Overlay
Thin-bonded Concrete Overlay
Unbonded Concrete Overlay
Flexible Base Overlay and HMA Overlay

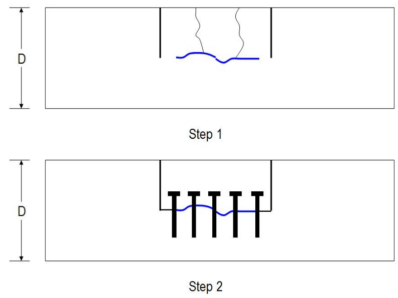
Rubblization and HMA Overlay
Crack and Seat with Flexible Base Overlay and HMA Overlay
Reconstruction (TxDOT Pavement Design Guide)

Prevention: The following practices can minimize the occurrence of punchouts.

- Provide proper drainage to reduce the amount of moisture coming into contact with the base materials.
- Use subbases that are not moisture susceptible. The use of a non-erodible asphalt layer has greatly reduced the occurrence of punchouts.
- Use tied concrete shoulders.

Partial Depth Punchout

Alternative Repair Strategy to Full Depth Repair



Description: Shattered slabs are formed when a series of cracks intersect to divide the slab into four or more pieces. Although the pieces still remain in their original position, they may settle below the original elevation of the pavement. Also, the intersecting cracks are usually accompanied by severe spalling.

Shattered slabs decrease the riding quality of the pavement as well as the structural capacity.

Possible Causes:

**Lack of Subgrade Support** - The slab may shatter due to lack of subgrade support. Erosion of the base materials may leave large voids beneath the rigid pavement and the pavement may settle into these voids. Improper compaction during construction may also leave voids or reduce subgrade stability.

**Swelling of Underlying Layers** - Sulfate induced swelling can cause upheavals in the slab, which results in bumps and eventually shattering of the slab.

**Overloading** - Overloading may cause excessive bending stresses in the slab and shatter the slab.

**Inadequate Joint Construction or Excessive Slab Dimensions** - Inadequate joint construction or excessive slab dimensions may lead to excessive tensile shrinkage stresses and mid-slab cracking in both the longitudinal and transverse directions of the slab. These cracks allow water to enter the slab and result in slab shattering.

Field Investigation: Visually inspect of shattered slab, check for other distresses such as pumping. If it is suspected that the cause is lack of support, both a GPR and DCP survey should be conducted. The GPR can attempt to detect wet areas under the slab. The DCP will confirm the quality of support under the slab. It will also provide information on the amount of undercutting required if slab replacement is necessary. If sulfate heave problems or loss of stabilization are suspected, then samples of the support layers should be removed for laboratory study.

Laboratory Investigation: Most shattered slabs are a direct result of loss of support so laboratory testing may not be required to validate the cause. However, if sulfate heave is suspected, sulfate levels in the natural soil should be measured with TxMethod 147-E. If loss of stabilization is suspected, a series should be conducted to determine the optimum stabilizer type and amount.

Repair Strategies: Routine maintenance can be used if the deterioration is not severe. This can slow the ingress of moisture to lower layers. If the distress is severe, then full depth replacement is the only option. If the distress is severe and widespread then full reconstruction or rubblization are the only options.

Routine Maintenance:

**Crack/Joint Sealing** - Crack sealing helps keep the reduce moisture ingress and possibly slow the rate of deterioration.

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, such patching may not last very long under traffic loading.

**Do Nothing** - Only an option if the cracks are hairline and no secondary distresses are observed.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement. This repair is feasible for all localized shattered slabs.

Structural Rehabilitation Options: The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

**Rubblization and HMA Overlay**. Rubblization is a good option provided that the support beneath the slab is adequate to permit adequate breakage of the concrete. The DCP can be used to determine if the support conditions are adequate for rubblization.

**Crack and Seat with Flexible Base Overlay and HMA Overlay.** Crack and seating of the concrete, followed a flexible base overlay and HMA overlay could be an option, primarily on low volume roadways.

**Reconstruction.** . If the support conditions beneath the slab are poor, reconstruction (TxDOT Pavement Design Guide) may be the only alternative. In this case a full structural design will be required.

Prevention: Ensuring that the slab is built on a non-erodible base layer. In Texas, the slab support consists of a stabilized base and a thin layer of hot mix asphalt concrete. Very few shattered slabs are found on pavements built on these bases. Concrete slabs should never be built directly on clay or treated subgrades.

Ensure that a full laboratory geotechnical investigation is conducted on the soils for any project. This includes sulfate determination as well as techniques for selecting optimal stabilizer types.

In the case of jointed concrete pavements, ensure that the slab length is 20 feet or less.

## **Asphalt Overlay of Concrete Pavement Distresses**

There are many asphalt distress types, but only two are typically found on asphalt overlays of concrete pavement. Rutting, alligator cracking, and the other distresses are typically caused by mix design problems.

Reflection Cracking

Reflection Failure

Description: Typically, within a few years, cracks will form above the joints and cracks in the existing concrete pavements. These cracks are typically very straight and regular, matching the joint pattern of the existing concrete pavements.

Possible Causes: Thermal stresses caused by the opening and closing of the underlying slab joint as the slab length changes due to temperature changes, combined with shear stresses associated with load transfer across the cracks or slabs, induce cracks in the asphalt surface layer.

Field Investigation: A routine distress survey will identify the regular nature of the cracking, however the use of a measuring wheel will ensure that the cracks are regular. An estimate of the crack width and the percentage of cracks that have deteriorated are also helpful.

Routine Maintenance:

**Crack Sealing** - If cracks are narrow and not badly spalled (less than 0.5 inch), crack sealing will maintain the pavement in good condition. Wider cracks may need a backer rod. Cracks that are spalling can not usually be sealed effectively.

Maintenance Options:

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, such patching may not last very long under traffic loading. Extensive patching may not be cost effective.

Structural Rehabilitation Options:

**Crack Relief Layer and Structural Overlay** - If the damaged area is extensive, but not badly spalled, an overlay using the newer crack attenuating mixes can repair the damage and reduce the rate of deterioration.

**Mill and replace** - If the damage is extensive and badly spalled, complete, or partial, removal and replacement is warranted.

Prevention: The best preventive measure is to ensure that the underlying concrete has good load transfer prior to placing the overlay.

Description: A reflection failure is an area of pavement that is badly deteriorated due to the condition of the underlying pavement. The area is usually very broken and pieces may be missing.

Possible Causes: The reflection failures are caused by a the reflection and surface deterioration due to the presence of a severely deteriorated patch, corner break, punchout, or shattered slab underneath the overlay.

Field Investigation: To the extent possible, the underlying distress should be determined and the field investigation should follow the procedure set for that distress.

Laboratory Investigation: To the extent possible, the underlying distress should be determined and the laboratory investigation should follow the procedure set for that distress.

Repair Strategies: In general, the repairs at this level will require removal and replacement of the asphalt overlay and underlying concrete pavement. Whether this will be contained to a localized area or cover the entire pavement will depend on the extent of the distress and the results of an estimate of the costs.

Routine Maintenance:

**Patching with Asphalt Concrete** - Patching with asphalt concrete could be used as a stopgap measure to temporarily improve the ride quality. However, such patching may not last very long under traffic loading.

Maintenance Options:

**Full Depth Repair** - Full depth repair reinstates the structural integrity of the pavement and will include removing and replacing both the underling concrete and surface asphalt pavement. This repair is feasible for all localized reflection failures. If the number of repairs becomes excessive, this option may not be cost effective.

Structural Rehabilitation Options: If three or more reflection failures per mile per year are occurring, the designer needs to consider the following structural rehabilitation options. The selection of an appropriate type of structural rehabilitation depends on numerous project factors other than the cause of distress. Any of the following structural rehabilitation options may be appropriate and should be evaluated on a case by case basis.

| | |
|---|---|
| HMA Overlay | Thin-bonded Concrete Overlay |
| Unbonded Concrete Overlay | Flexible Base Overlay and HMA Overlay |
| Rubblization and HMA Overlay | Crack and Seat with Flexible Base Overlay and HMA Overlay |
| Reconstruction (TxDOT Pavement Design Guide) | |

Prevention: The best preventive measure is to ensure that the underlying concrete has good load transfer prior to placing the overlay. In addition, distressed areas must be repaired prior to placing the overlay.

## References

SHRP, "Distress Identification Manual for the Long-Term Pavement Performance Project," Strategic Highway Research Program, National Research Council, Washington, D.C., SHRP-P-338, 1993.

"Pavement Management Information System Rater's Manual for Fiscal Year 2008," Texas Department of Transportation, June 2007.

Scullion, Tom, M. Coppock, and C. Von Holdt, "Development of a Concrete Pavement Rehabilitation Training CD ROM," Texas Department of Transportation, August 2006.