APPENDIX C
DISTRESS IDENTIFICATION MANUAL

JOINTED REINFORCED CONCRETE PAVEMENTS

INTRODUCTION

The distress definitions were developed initially on the airfield distress identification manual by Shahin, Darter and Kohn\(^1\) and the "Standard Nomenclature and Definitions for Pavement Components and Deficiencies" (Special Report 113, Highway Research Board); and considerably further developed through extensive field surveys and discussions with state highway engineers. This manual Distress Identification Manual for Jointed Reinforced Concrete Pavements was developed under NCHRP Project 1-19, Development of a Nationwide Concrete Pavement Evaluation System.

Name of Distress: Blow-up

Description: Most blow-ups occur during the spring and hot summer at a transverse joint or wide crack. Infiltration of incompressible materials into the joint or crack during cold periods results in high compressive stresses in hot periods. When this compressive pressure becomes too great, a localized upward movement of the slab or shattering occurs at the joint or crack. Blow-ups are accelerated due to a spalling away of the slab at the bottom creating reduced joint contact area. The presence of "D" cracking or freeze-thaw damage also weakens the concrete near the joint resulting in increased spalling and blow-up potential.

Severity Levels:

*L - Blow-up has occurred, but only causes some bounce of the vehicle which creates no discomfort.

*M - Blow-up causes a significant bounce of the vehicle which creates some discomfort. Temporary patching may have been placed because of the blow-up.

*H - Blow-up causes excessive bounce of the vehicle which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage, requiring a reduction in speed for safety.

How to Measure: Blow-ups are measured by counting the number existing in each uniform section. Severity level is determined by riding in a mid- to full-sized sedan weighing approximately 3000-3800 lbs. (13.3-16.9 kN) over the uniform section at the posted speed limit. The number is not as important as the fact that initial blow-ups signal a problem with "lengthening" or gradual down hill movement -- and others should be expected to occur until the maximum distance is down to 1000 ft between blowups. The distance required to develop full restraint of an interior section.

*L = Low severity level
*M = Medium severity level
*H = High severity level
Acceleration of Blow-ups Due to Moisture:

A significant amount of moisture infiltrating into a joint may carry incompressibles into the joint. Over a long time period this action would accelerate the buildup of incompressibles and thus increase the potential for blow-ups.
Figure C.1. High Severity Buckling type Blow-up

Figure C.2. High Severity Shattering Type Blow-up
Name of Distress: Corner Break

Description: A corner break is a crack that intersects the joints at a distance less than 6 ft (1.8 m) on each side measured from the corner of the slab. A corner break extends vertically through the entire slab thickness. It should not be confused with a corner spall which intersects the joint at an angle through the slab and is typically within 1 ft (0.3 m) from the slab corner. Heavy repeated loads combined with pumping, poor load transfer across the joint, and thermal curling and moisture warping stresses result in corner breaks.

Severity Levels:

L - Crack is tight (hairline). Well sealed cracks are considered tight. No faulting or break-up of broken corner exists. Crack is not spalled.

M - Crack is working and spalled at medium severity, but break-up of broken corner has not occurred. Faulting of crack or joint is less than 1/2 inch (13 mm). Temporary patching may have been placed because of corner break.

H - Crack is spalled at high severity, the corner piece has broken into two or more pieces, or faulting of crack or joint is more than 1/2 inch (13 mm).

How to Measure: Corner breaks are measured by counting the number that exists in the uniform section. Different levels of severity should be counted and recorded separately. Corner breaks adjacent to a patch will be counted as "patch adjacent slab deterioration."
Acceleration of Moisture will usually infiltrate into the subsurface
Corner Breaks of a pavement through a transverse and longitudinal
Due to Moisture: joint. If excess moisture accumulates beneath the
slab and heavy repeated loads are applied, pumping of the subbase will occur creating a void under the
slab corner. A loss of support under the corner of the slab greatly increases load stresses and corner
cracking may occur.
Figure C.4. High Severity Corner Break
Name of Distress: Depression

Description: Depressions in concrete pavements are localized settled areas. There is generally significant slab cracking in these areas due to uneven settlement. The depressions can be located by stains caused by oil droppings from vehicles, and by riding over the pavement. Depressions can be caused by settlement or consolidation of the foundation soil or can be "built in" during construction. They are frequently found near culverts. This is usually caused by poor compaction of soil around the culvert during construction. Depressions cause slab cracking, roughness, and hydroplaning when filled with water of sufficient depth.

Severity Levels:

L - Depression causes a distinct bounce of vehicle which creates no discomfort.

M - Depression causes significant bounce of the vehicle which creates some discomfort.

H - Depression causes excessive bounce of the vehicle which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage, requiring a reduction in speed for safety.

How to Measure: Depressions are measured by counting the number that exists in each uniform section. Each depression is rated according to its level of severity. Severity level is determined by riding in a mid- to full-sized sedan weighing approximately 3000-3800 lb. (13.3-16.9 kN) over the uniform section at the posted speed limit.
Depressions will hinder the runoff of water after a rainstorm. The water will be collected in the depressions, thus increasing the exposure time of the water to cracks and joints. This allows more water to infiltrate through the pavement surface into the base, subbase, and subgrade. Higher moisture contents in the subgrade will propagate other distress such as pumping and corner cracking.
Name of Distress:  Durability ("D") Cracking

Description:
"D" cracking is a series of closely spaced crescent-shaped hairline cracks that appear at a PCC pavement slab surface adjacent and roughly parallel to transverse and longitudinal joints, transverse and longitudinal cracks, and the free edges of pavement slab. The fine surface cracks often curve around the intersection of longitudinal joints/cracks and transverse joints/cracks. These surface cracks often contain calcium hydroxide residue which causes a dark coloring of the crack and immediate surrounding area. This may eventually lead to disintegration of the concrete within 1-2 ft. (0.30-0.6 m) or more of the joint or crack, particularly in the wheelpaths. "D" cracking is caused by freeze-thaw expansive pressures of certain types of coarse aggregates and typically begins at the bottom of the slab which disintegrates first. Concrete durability problems caused by reactive aggregates are rated under "Reactive Aggregate Distress."

Severity Levels:

L - The characteristic pattern of closely spaced fine cracks has developed near joints, cracks, and/or free edges; however, the width of the affected area is generally <12 in. (30 cm) wide at the center of the lane in transverse cracks and joints. The crack pattern may fan out at the intersection of transverse cracks/joints with longitudinal cracks/joints. No joint/crack spalling has occurred, and no patches have been placed for "D" cracking.

M - The characteristic pattern of closely spaced cracks has developed near the crack, joint or free edge and: (1) is generally wider than 12 in. (30 cm) at the center of the lane in transverse cracks and/or joints; or (2) low or medium severity joint/crack or corner spalling has developed in the affected area; or (3) temporary patches have been placed due to "D" cracking induced spalling.

H - The pattern of fine cracks has developed near joints or cracks and (1) a high severity level of spalling at joints/cracks exists and considerable material is loose in the affected area; or (2) the crack pattern has developed generally over the entire slab area between cracks and/or joints.

How to Measure:
"D" cracking is measured by counting the number of joints or cracks (including longitudinal) affected. Different severity levels are counted and recorded separately. "D" cracking adjacent to a patch is rated as patch-adjacent slab deterioration. "D" cracking should not be counted if the fine crack pattern has not developed near cracks, joints and free edges. Pop-outs and discoloration of joints, cracks and free edges may occur without "D" cracking.
Acceleration of "D" cracking is believed to be directly related to moisture which infiltrates into the concrete and saturates certain aggregates (such as limestone) which are highly absorptive. These aggregates, which are relatively weak, become saturated and expand upon freezing. The expanded aggregate, confined by the concrete matrix, will either break apart or stress the concrete around it. The concrete gradually breaks down after many cycles of freeze-thaw forming the characteristic crack pattern. Areas such as joints and cracks subjected to constant free moisture exhibits much more "D" cracking than concrete in dryer areas such as the slab interior.
Figure C.5. Low Severity “D” Cracking

Figure C.6. Medium Severity “D” Cracking
Figure C.7. Medium Severity “D” Cracking

Figure C.8. High Severity “D” Cracking
Figure C.9. High Severity "D" Cracking
Name of Distress: Faulting of Transverse Joints and Cracks

Description: Faulting is the difference of elevation across a joint or crack. Faulting is caused in part by a buildup of loose materials under the approach slab near the joint or crack as well as depression of the leave slab. The buildup of eroded or infiltrated materials is caused by pumping from under the leave slab and shoulder (free moisture under pressure) due to heavy loadings. The warp and/or curl upward of the slab near the joint or crack due to moisture and/or temperature gradient contributes to the pumping condition. Lack of load transfer contributes greatly to faulting.

Severity Levels: Severity is determined by the average faulting over the joints within the sample unit.

How to Measure: Faulting is determined by measuring the difference in elevation of slabs at transverse joints for the slabs in the sample unit. Faulting of cracks are measured as a guide to determine the distress level of the crack. Faulting is measured one foot in from the outside (right) slab edge on all lanes except the inner-most passing lane. Faulting is measured one foot in from the inside (left) slab edge on the inner passing lane. If temporary patching prevents measurement, proceed on to the next joint. Sign convention: + when approach slab is higher than departure slab, - when the opposite occurs. Faulting never occurs in the opposite direction.

Figure C.10. Crack Faulting
Acceleration of Faulting Due to Moisture: Studies have shown that faulting is definitely accelerated by free moisture beneath the slab near the joints and cracks. When a heavy load is applied near the joint or crack, this free moisture is subjected to high pressure and consequently moves at high velocity, which erodes the subbase. The fine particles are either pumped out onto the pavement surface, creating a void into which the slab settles, or migrates from the front slab to the back slab, causing the back slab to rise. Free moisture contents may also soften the subgrade so much that the slab settles. Dowels or other mechanical load transfer devices (LTD) used at joints help minimize faulting. However, many times they are not sufficient to prevent faulting because of excess pumping, deteriorated PCC, and high bearing stress of dowel on PCC under load.
Figure C.11. Joint Faulting
<table>
<thead>
<tr>
<th>Name of Distress:</th>
<th>Joint Load Transfer System Associated Deterioration (Second Stage Cracking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>This distress develops as a transverse crack a short distance (e.g., 9 in. (23 cm)) from a transverse joint at the end of joint dowels. This usually occurs when the dowel system fails to function properly due to extensive corrosion or misalignment. It may also be caused by a combination of small diameter dowels and heavy traffic loadings.</td>
</tr>
<tr>
<td>Severity Levels:</td>
<td>L - Hairline (tight) crack with no spalling or faulting or well-sealed crack with no visible faulting or spalling.</td>
</tr>
<tr>
<td></td>
<td>M - Any of the following conditions exist: the crack has opened to a width less than 1 inch (25 mm); the crack has faulted less than 1/2 inch (13 mm); the crack may have spalled to a low or medium severity level; the area between the crack and joint has started to break up but pieces have not been dislodged to the point that a tire damage or safety hazard is present; or temporary patches have been placed due to this joint deterioration.</td>
</tr>
<tr>
<td></td>
<td>H - Any of the following conditions exist: a crack with width of opening greater than 1 inch (25 mm); a crack with a high severity level of spalling; a crack faulted 1/2 inch (13 mm) or more; or the area between the crack and joint has broken up and pieces have been dislodged to the point that a tire damage or safety hazard is present.</td>
</tr>
<tr>
<td>How to Measure:</td>
<td>The number of joints with each severity level are counted in the uniform section.</td>
</tr>
</tbody>
</table>

Figure C.12. Low Severity Joint Load Transfer System Associated Deterioration in Traffic Lane at Top of Photo
Acceleration of Joint Load Transfer System Associated Deterioration Due to Moisture: If water containing chlorides infiltrates the joint, it may cause corrosion several inches along the dowels. This corrosion may result in a "frozen" joint, which leads to joint deterioration and openness of intermediate cracks. Some corrosion will likely occur even without salt. However, use of deicing salt speeds the corrosive action.
Figure C.13. Medium Severity Joint Load Transfer System Associated Deterioration

Figure C.14. High Severity Joint Load Transfer System Associated Deterioration
Figure C.15. High Severity Joint Load Transfer System Associated Deterioration
Name of Distress: Joint Seal Damage of Transverse Joints

Description: Joint seal damage exists when incompressible materials and/or water can infiltrate into the joints. This infiltration can result in pumping, spalling, and blow-ups. A joint sealant bonded to the edges of the slabs protects the joints from accumulation of incompressible materials, and also reduces the amount of water seeping into the pavement structure. Typical types of joint seal damage are: (1) stripping of joint sealant, (2) extrusion of joint sealant, (3) weed growth, (4) hardening of the filler (oxidation), (5) loss of bond to the slab edges, and (6) lack or absence of sealant in the joint.

Severity Levels:

L - Joint sealant is in good condition throughout the section with only a minor amount of any of the above types of damage present. Little water and no incompressibles can infiltrate through the joint.

M - Joint sealant is in fair condition over the entire surveyed section, with one or more of the above types of damage occurring to a moderate degree. Water can infiltrate the joint fairly easily; some incompressibles can infiltrate the joint. Sealant needs replacement within 1-3 years.

H - Joint sealant is in poor condition over most of the sample unit, with one or more of the above types of damage occurring to a severe degree. Water and incompressibles can freely infiltrate the joint. Sealant needs immediate replacement.

How to Measure: Joint sealant damage of transverse joints is rated based on the overall condition of the sealant over the entire sample unit.
| Acceleration of Joint Seal Damage Due to Moisture: | Water will reduce the bond between sealant and PCC to a point that the sealant is easily removed by moisture, vehicle tires and other means. The removal of sealant can lead to many other problems such as pumping, softening of subgrade, "D" cracking and spalling. |
Figure C.16. Low Severity Joint Seal Damage

Figure C.17. Medium Severity Joint Seal Damage
Figure C.18. High Severity Joint Seal Damage
<table>
<thead>
<tr>
<th>Name of Distress:</th>
<th>Lane/Shoulder Dropoff or Heave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Lane/shoulder dropoff or heave occurs when there is a difference in elevation between the traffic lane and shoulder. Typically the outside shoulder settles due to consolidation or a settlement of the underlying granular or subgrade material, or pumping of the underlying material. Heave of the shoulder may occur due to frost action or swelling soils. Dropoff of granular or soil shoulder is generally caused from blowing away of shoulder material from passing trucks.</td>
</tr>
<tr>
<td>Severity Level:</td>
<td>Severity level is determined by computing the mean difference in elevation between the traffic lane and shoulder.</td>
</tr>
<tr>
<td>How to Measure:</td>
<td>Lane/shoulder dropoff or heave is measured in the sample unit at all joints when joint spacing is &gt;50 ft. (15 m), at every third joint when spacing is &lt;50 ft. (15 m). It is also measured at mid-slab in each slab measured at the joint. The mean difference in elevation is computed from the data and used to determine severity level. Measurements at joints are made 1 ft. (0.3 m) from the transverse joint on the departure slab only on the outer lane/shoulder.</td>
</tr>
</tbody>
</table>

Figure C.19. Lane/Shoulder Drop-off
Acceleration of Dropoff Due to Moisture:

Moisture entering through the longitudinal joint between the shoulder and lane results in excess free moisture in the underlying material. This material then becomes soft and settles under loads, and/or pumping will occur disintegrating the material and creating a void. In both cases the shoulders will then settle downward producing the dropoff. Heave is caused by (1) frost heave from ice lenses, or (2) swelling subgrade soils. Both settlement or heave usually results in shoulder edge cracking and breakup in conjunction with traffic load encroachment.
Figure C.20. Lane/Shoulder Heave
Name of Distress: Lane/Shoulder Joint Separation

Description: Lane/shoulder joint separation is the widening of the joint between the traffic lane and the shoulder generally due to movement in the shoulder. If the joint is tightly closed or well sealed so that water cannot easily infiltrate, then lane/shoulder joint separation is not considered a distress.

Severity Level: No severity level is recorded if the joint is tightly sealed.

L - Some opening but less than or equal to 0.12 inch (3 mm).

M - More than 0.12 inch (3 mm) but equal to or less than 0.4 inch (10 mm) opening.

H - More than 0.4 (10 mm) opening. Gravel or sod shoulders are rated as high.

How to Measure: Lane/shoulder joint separation is measured and recorded in inches (or mm) near transverse joints and at mid-slab. The mean separation is used to determine the severity level.

Figure C.21. Lane/Shoulder Separation (Asphalt Shoulder)
Acceleration of Lane/Shoulder Joint Separation Due to Moisture: Excess moisture beneath the shoulder may result in frost heave and/or settlement of the shoulder causing lane/shoulder joint opening. Once the joint is open additional moisture can enter which accelerates many distresses as described under Lane/Shoulder Dropoff or Heave.
Figure C.22. Lane/Shoulder Separation (PCC Shoulder)

Figure C.23. Lane/Shoulder Separation (high severity due to gravel shoulder)
Name of Distress: Longitudinal Cracks

Description: Longitudinal cracks occur generally parallel to the centerline of the pavement. They are often caused by improper construction of longitudinal joints, or by a combination of heavy load repetition, loss of foundation support, and thermal and moisture gradient stresses.

Severity Levels: 

L - Hairline (tight) crack with no spalling or faulting, or a well sealed crack with no visible faulting or spalling.

M - Working crack with a moderate or less severity spalling and/or faulting less than 1/2 inch (12 mm).

H - A crack with width greater than 1 inch (25 mm); a crack with a high severity level of spalling, or, a crack faulted 1/2 inch (13 mm) or more.

How to Measure: Cracks are measured in linear feet (or meters) for each level of distress. The length and average severity of each crack should be identified and recorded.

Figure C.24. Low Severity Longitudinal Crack
Acceleration of Longitudinal Cracking Due to Moisture:

Longitudinal cracking is generally not initially caused by excess moisture. If, however, excessive moisture accumulates in the slab foundation causing significant loss of support or frost heaving, and this could lead to increased slab cracking.
Figure C.25. High Severity Longitudinal Crack in Center Lane
<table>
<thead>
<tr>
<th>Name of Distress:</th>
<th>Longitudinal Joint Faulting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Longitudinal joint faulting is a difference in elevation of two traffic lanes measured at the longitudinal joint. It is caused primarily by heavy truck traffic and settlement of the foundation.</td>
</tr>
<tr>
<td>Severity Levels:</td>
<td>Severity level is determined by measuring the maximum fault.</td>
</tr>
<tr>
<td>How to Measure:</td>
<td>Where the longitudinal joint has faulted, the length of the affected area and the maximum joint faulting is recorded.</td>
</tr>
</tbody>
</table>

Figure C.26. Longitudinal Joint Faulting
Acceleration of Excess free moisture beneath the slab in a given
Longitudinal area may cause the layers to settle or pump under
Joint Faulting heavy repeated loads resulting in faulting along the
Due to Moisture: lane joint.
Name of Distress: Patch Deterioration (including replaced slabs)

Description: A patch is an area where a portion or all of the original slab has been removed and replaced with a permanent type of material (e.g., concrete or hot-mixed asphalt). Only permanent patches should be considered.

Severity Levels:

L - Patch has little or no deterioration. Some low severity spalling of the patch edges may exist. Faulting across the slab-patch joint must be less than 1/4 inch (6 mm). Patch is rated low severity even if it is in excellent condition.

M - Patch has cracked (low severity level) and/or some spalling of medium severity level exists around the edges. Minor rutting may be present. Faulting of 1/4 to 3/4 inch (6-19 mm) exists. Temporary patches may have been placed because of permanent patch deterioration.

H - Patch has deteriorated by spalling, rutting, or cracking within the patch, to a condition which requires replacement.

How to Measure: The number of patches within each uniform section is recorded. Patches at different severity levels are counted and recorded separately. Additionally, the approximate square footage (or meters) of each patch and type (i.e., PCC or asphalt) is recorded. All patches are rated either L, M, or H.

Figure C.27. Low Severity Asphalt Patch Deterioration
Acceleration of Excess moisture accumulated beneath the patch or
Patching De-
in the patch/pavement joint can cause high deflections
terioration resulting in pumping, spalling along the joints and
Due to Moisture: eventually breakup of the patch.
Figure C.28. High Severity Asphalt Patch Deterioration

Figure C.29. Low Severity Concrete Patch Deterioration
Figure C.30. Medium Severity Concrete Patch Deterioration

Figure C.31. High Severity Concrete Patch Deterioration
Name of Distress: Patch Adjacent Slab Deterioration

Description: Deterioration of the original concrete slab adjacent to a permanent patch is given the above name. This may be in the form of spalling of the slab at the slab/patch joint, "D" cracking of the slab adjacent to the patch, a corner break in the adjacent slab, or a second permanent patch placed adjacent to the original patch.

Severity Levels: Severity levels are the same as that described for the particular distress found. A second permanent patch placed adjacent to a previously placed permanent patch will be rated here as medium severity. Temporary patches placed because of this deterioration will also be rated here as medium severity. Temporary patches placed because of this deterioration will also be rated as medium severity.

How to Measure: The number of permanent patches with distress in the original slab adjacent to the patch at each severity level will be counted and recorded separately. Additionally, the type of patch (AC or PCC) and distress will be recorded separately.
Acceleration of 
Patch Adjacent to the patch can cause high deflections resulting in 
Slab Deterioration pumping, loss of support, and settlement or breakup 
Due to Moisture: of the slab near the patch.
Figure C.33. Patch Adjacent Slab Deterioration ("D" Cracking & temporary patching)

Figure C.34. Patch Adjacent Slab Deterioration (second Patch, spalling, "D" cracking and temporary patching)
<table>
<thead>
<tr>
<th>Name of Distress:</th>
<th>Popouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>A popout is a small piece of concrete that breaks loose from the surface due to freeze-thaw action, expansive aggregates, and/or nondurable materials such as mudballs, chert, and chalcedony. The occurrence of extensive popouts may be indicative of unsound aggregates and &quot;D&quot; cracking. Popouts typically range from approximately 1 inch (25 mm) to 4 inches (10 cm) in diameter and from 1/2 inch to 2 inches (13-51 mm) deep.</td>
</tr>
<tr>
<td>Severity Levels:</td>
<td>No degrees of severity are defined for popouts. The average popout density must exceed approximately one popout per square yard (square meter) over the entire slab area before they are counted as a distress.</td>
</tr>
<tr>
<td>How to Measure:</td>
<td>The density of popouts can be determined by counting the number of popouts per square yard (square meter) of surface in areas having typical amounts.</td>
</tr>
</tbody>
</table>
Acceleration of Popouts Due to Moisture: Moisture saturation of unsound aggregates results in popouts.
Name of Distress: Pumping and Water Bleeding

Description: Pumping is the movement of material by water pressure beneath the slab when it is deflected under a heavy moving wheel load. Sometimes the pumped material moves around beneath the slab, but often it is ejected through joints and/or cracks (particularly along the longitudinal lane/shoulder joint with an asphalt shoulder). Beneath the slab there is typically particle movement counter to the direction of traffic across a joint or crack that results in a buildup of loose materials under the approach slab near the joint or crack. Many times some fine materials (silt, clay, sand) are pumped out leaving a thin layer of relatively loose clean sand and gravel beneath the slab, along with voids causing loss of support. Pumping occurs even in pavement sections containing stabilized subbases.

Water bleeding occurs when water seeps out of joints and/or cracks. It many times drains out over the shoulder in low areas.

Severity Levels:

L - Water is forced out of a joint or crack when trucks pass over the joints or cracks; water is forced out of the lane/shoulder longitudinal joint when trucks pass along the joint; or water bleeding exists. No fines can be seen on the surface of the traffic lanes or shoulder.

M - A small amount of pumped material can be observed near some of the joints or cracks on the surface of the traffic lane or shoulder. Blow holes may exist.

H - A significant amount of pumped materials exist on the pavement surface of the traffic lane or shoulder along the joints or cracks.

How to Measure: If pumping or water bleeding exists anywhere in the sample unit it is counted as occurring at highest severity level as defined above.
Acceleration of Pumping
Due to Moisture:

Pumping of materials cannot occur if excess water is not available. Significant pumping leads to increase of several distresses.
Figure C.36. Low Severity Pumping (Water Bleeding)

Figure C.37. Medium Severity Pumping (pumped material like this occurs only at a few of the joints and cracks)
Figure C.38. High Severity Pumping
Name of Distress: Reactive Aggregate Distress

Description: Reactive aggregates either expand in alkaline environments or develop prominent siliceous reaction rims in concrete. It may be an alkali-silica reaction or an alkali-carbonate reaction. As expansion occurs, the cement matrix is disrupted and cracks. It appears as a map cracked area; however, the cracks may go deeper into the concrete than in normal map cracking. It may affect most of the slab or it may first appear at joints and cracks.

Severity Levels: Only one level of severity is defined. If alkali-aggregate cracking occurs anywhere in the slab, it is counted. If the reaction has caused spalling or map cracking, these are also counted.

How to Measure: Reactive-aggregate distress is measured in square feet or square meters.

Figure C.39. Reactive Aggregate Distress (Photo for Jointed Plain Concrete Pavement)
Acceleration of Reactive Aggregate

Distress Due to Moisture:

The spalling caused by reactive aggregates is not caused by excess moisture.
<table>
<thead>
<tr>
<th>Name of Distress:</th>
<th>Scaling and Map Cracking or Crazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description:</td>
<td>Scaling is the deterioration of the upper 1/8-1/2 inch (3-13 mm) of the concrete slab surface. Map cracking or crazing is a series of fine cracks that extend only into the upper surface of the slab surface. Map cracking or crazing is usually caused by over-finishing of the slab and may lead to scaling of the surface. Scaling can also be caused by reinforcing steel being too close to the surface.</td>
</tr>
<tr>
<td>Severity Levels:</td>
<td>L - Crazing or map cracking exists; the surface is in good condition with no scaling. M/H - Scaling exists.</td>
</tr>
<tr>
<td>How to Measure:</td>
<td>Scaling and map cracking or crazing are measured by area of slab in square feet or meters.</td>
</tr>
</tbody>
</table>

Figure C.40. Scaling
Figure C.41. Scaling

Acceleration of Scaling, Map Cracking and Aging Due to Moisture: This distress is not caused by excess free moisture.
Name of Distress: Spalling (Transverse and Longitudinal Joint/Crack)

Description: Spalling of cracks and joints is the cracking, breaking, or chipping (or fraying) of the slab edges within 2 ft. (0.6 m) of the joint/crack. A spall usually does not extend vertically through the whole slab thickness, but extends to intersect the joint at an angle. Spalling usually results from (1) excessive stresses at the joint or crack caused by infiltration of incompressible materials and subsequent expansion, (2) disintegration of the concrete from freeze-thaw action of "D" cracking, (3) weak concrete at the joint (caused by honeycombing), (4) poorly designed or constructed load transfer device (misalignment, corrosion), and/or (5) heavy repeated traffic loads.

Severity Levels:

L - The spall or fray does not extend more than 3 ins. (8 cm) on either side of the joint or crack. No temporary patching has been placed to repair the spall.

M - The spall or fray extends more than 3 ins. (8 cm) on either side of the joint or crack. Some pieces may be loose and/or missing but the spalled area does not present a tire damage or safety hazard. Temporary patching may have been placed because of spalling.

H - The joint is severely spalled or frayed to the extent that a tire damage or safety hazard exists.

How to Measure: Spalling is measured by counting and recording separately the number of joints with each severity level. If more than one level of severity exists along a joint, it will be recorded as containing the highest severity level present. Although the definition and severity levels are the same, spalling of cracks should not be recorded. The spalling of cracks is included in rating severity levels of cracks. Spalling of transverse and longitudinal joints will be recorded separately. Spalling of the slab edge adjacent to a permanent patch will be recorded as patch adjacent slab deterioration. If spalling is caused by "D" cracking, it is counted as both spalling and "D" cracking at appropriate severity levels.
Acceleration of Spalling (Joint) due to Moisture: Free moisture that is retained in the joint has sufficient time to saturate the concrete near the joint. Many years of freeze/thaw cycles may break down the concrete into a spalled condition in combination with traffic and incompressibles. Joint spalling caused by "D" cracking is directly accelerated by moisture.
Figure C.42. Low Severity Spalling (Fray)

Figure C.43. Low Severity Spalling
Figure C.44. Medium Severity Spalling

Figure C.45. High Severity Spalling
Figure C.46. High Severity Spalling

Figure C.47. High Severity Spalling
Name of Distress: Spalling (Corner)

Description: Corner spalling is the ravelling or breakdown of the slab within approximately 1 ft. (0.3 m) of the corner. However, corner spalls with both edges less than 3 ins. (8 cm) long will not be recorded. A corner spall differs from a corner break in that the spall usually angles downward at about 45° to intersect the joint, while a break extends vertically through the slab. Corner spalling can be caused by freeze-thaw deterioration, "D" cracking, and other factors.

Severity Level:  
L - Spall is not broken into pieces and is in place and not loose.

M - One of the following conditions exists: Spall is broken into pieces; cracks are spalled; some or all pieces are loose or absent but do not present tire damage or safety hazard; or spall is patched.

H - Pieces of the spall are missing to the extent that the hole presents a tire damage or safety hazard.

How to Measure: Corner spalling is measured by counting and recording separately the number of corners spalled at each severity level within the sample unit.
Acceleration of Free moisture that is retained in the joint has
Spalling Corner sufficient time to saturate the concrete, particularly
Due to Moisture: near the corners. Many years of freeze/thaw cycles
may break down the concrete into a spalled condition in combination with traffic and in-
compressibles. Corner spalls caused by "D" cracking
are directly accelerated by moisture conditions.
Figure C.49. High Severity Corner

Figure C.50. High Severity Corner Spall
Name of Distress: Swell

Description: A swell is an upward movement or heave of the slab surface resulting in a sometimes sharp wave. The swell is usually accompanied by slab cracking. It is usually caused by frost heave in the subgrade or by an expansive soil. Swells can often be identified by oil droppings on the surface as well as riding over the pavement in a vehicle.

Severity Levels: L - Swell causes a distinct bounce of the vehicle which creates no discomfort.

M - Swell causes significant bounce of the vehicle which creates some discomfort.

H - Swell causes excessive bounce of the vehicle which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage, requiring a reduction in speed for safety.

How to Measure: The number of swells within the uniform section are counted and recorded by severity level. Severity levels are determined by riding in a mid- to full-sized sedan weighing approximately 3000-38000 lb. (13.3-16.9 kN) over the uniform section at the posted speed limit.

Figure C.51. Swell Due to Frost Heave
Acceleration of Swell Due to Moisture:

Swell can be accelerated by moisture in two ways: (1) frost heaves may occur in freeze climates, and (2) an expansive soil will swell when exposed to moisture. Frost heave is caused by the formation of ice crystals in a frost susceptible subgrade. The ice crystals grow until ice lenses form which produce frost heave. A swelling soil increases in volume when water content in the soil is increased, and decreases its volume when the water content is reduced. A swelling soil has a high plasticity index and can be determined by lab test or experience.
Figure C.52. Swell Due to Expansive Soil
Name of Distress: Transverse and Diagonal Cracks

Description: Linear cracks are caused by one or a combination of the following: heavy load repetition, thermal and moisture gradient stresses, and drying shrinkage stresses. Medium or high severity cracks are working cracks and are considered major structural distresses. They may sometimes be due to deep seated differential settlement problems. (Note: hairline cracks that are less than 6 feet (1.8 m) long are not rated).

Severity Levels:
L - Hairline (tight) crack with no spalling or faulting, a well sealed crack with no visible faulting or spalling.

M - Working crack with low to medium severity level of spalling, and/or faulting less than 1/2 inch (13 mm). Temporary patching may be present.

H - A crack with width of greater than 1 inch (25 mm); a crack with a high severity level of spalling; or, a crack faulted 1/2 inch (13 mm) or more.

How to Measure: The number and severity level of each crack should be identified and recorded. If the crack does not have the same severity level along the entire length, the crack is rated at the highest severity level present. Cracks in patches are recorded under patch deterioration.

Figure C.53. Low Severity Transverse Crack
<table>
<thead>
<tr>
<th>Acceleration of Transverse Cracking Due to Moisture:</th>
</tr>
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<tbody>
<tr>
<td>Transverse and diagonal cracking are generally not initially caused by excess moisture. If, however, excessive moisture accumulates in the slab foundation causing significant loss of support, this could lead to increased slab cracking. However, moisture can accelerate the severity of distress from low to high. Water that accumulates in the cracks could be absorbed into the PCC and possibly increase the potential for spalling along the crack through freeze-thaw action. Water also may infiltrate through a crack and saturate the subbase which increases deflection of the slab under load. Repeated loading of the slab causes the sides of the crack to wear down, spall and widen.</td>
</tr>
</tbody>
</table>
Figure C.54. Medium Severity Diagonal Crack (crack is tight even though it has some low spalling)

Figure C.55. Medium Severity Transverse Crack
Figure C.56. High Severity Transverse Crack

Figure C.57. High Severity Transverse Crack