Concrete Distress – Assessments and Solutions

2017 Municipal Streets Seminar
November 15, 2017
Ames, Iowa

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Representing the CP Tech Center
Distress Guide 2017

- Surface Defects
- Surface Delamination
- Material Related Cracks
- Transverse & Diagonal Cracking
- Longitudinal Cracking
- Corner Cracking
- Spalling
- Faulting
- Joint Warping and Curling
- Blowups
- Settlement and Heaves
- Subgrades & Base Support Conditions
- CRCP
- Concrete Overlays, BCOA, BCOC, UBCOA, UBCOC
- Laboratory & Field Testing

Focus:
- Identification
- Causes
- Prevention
- Rehabilitation
Surface Defects

- Map Crazing
- Plastic Shrinkage Cracking
- Scaling
- Popouts
## Summary of Causes & Prevention of Surface Defects

<table>
<thead>
<tr>
<th>Distress</th>
<th>Causes</th>
<th>Prevention or Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Map Cracking (Crazing)</td>
<td>• Overworking/over-finishing of concrete surface</td>
<td>• Design concrete with low permeability</td>
</tr>
<tr>
<td></td>
<td>• Finishing while bleed water is present on surface</td>
<td>• Use blended cements or SCMs to control AAR</td>
</tr>
<tr>
<td></td>
<td>• Late or inadequate curing</td>
<td>• Use durable, nonreactive aggregates.</td>
</tr>
<tr>
<td></td>
<td>• Batching absorptive aggregates that are on the dry side of SSD</td>
<td>• Do not:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Overwork surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Spray water on surface during finishing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Finish while bleed water is present.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Sprinkle dry cement on surface to dry bleed water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Begin curing as soon as possible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Keep stockpiles wet when absorptive aggregates used</td>
</tr>
<tr>
<td>2. Plastic Shrinkage Cracking</td>
<td>• Rapid evaporation of moisture from the concrete surface</td>
<td>• Use durable mixtures with low w/cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimize cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce aggregate absorption of mix water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Employ proper hot-weather and cold-weather paving practices, as appropriate</td>
</tr>
</tbody>
</table>
## Summary of Causes & Prevention of Surface Defects

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<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Scaling</td>
<td>• Excessive use of deicing salts and freeze-thaw cycles&lt;br&gt;• Use of poor finishing and curing practices&lt;br&gt;• Failure to protect surface of newly placed fresh concrete from rain</td>
<td>• Ensure proper air-void system parameters (adequate air content and spacing factor) in concrete&lt;br&gt;• Use appropriate amounts of SCMs</td>
<td></td>
<td>• Ensure effective curing&lt;br&gt;• Do not:&lt;br&gt;  – Overwork surface&lt;br&gt;  – Spray water on surface during finishing&lt;br&gt;  – Finish while bleed water is present&lt;br&gt;  – Sprinkle dry cement on surface to dry bleed water&lt;br&gt;  – Protect slab from rain</td>
</tr>
<tr>
<td>4. Surface Polishing or Surface Wear</td>
<td>• Use of soft aggregates with poor abrasion resistance&lt;br&gt;• Use of poor surface finishing and curing practices.</td>
<td>• Use concrete mixtures with adequate strength</td>
<td>• Use hard wear-resistant aggregate</td>
<td>• Use proper finishing practices.&lt;br&gt;• Employ effective curing practices</td>
</tr>
</tbody>
</table>
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</tr>
</thead>
</table>
| 5. Popouts or Mortar Flaking | • Use of unsound or reactive aggregates  
• Aggregate expansion upon freezing (popout)  
• Excessive Vibration of concrete | • Use durable mixtures with low w/cm | • Use only sound, nonreactive aggregates that have been tested for undesirable fine particles | • Begin curing as soon as possible.  
• Use evaporation retarders to minimize moisture loss  
• Use effective stockpile management practices to minimize contaminants (see ACPA 2004) |
Treatment & Repairs

• Penetrating Sealers
  – for surface defects caused by deicing salts

• High Molecular Weight Methacrylate (HMWM)
  – achieves excellent penetration into cracks and can serve to strengthen the concrete by filling the crack and bonding it together

• Void Filling
  – cementitious, epoxy, and proprietary materials have all been used successfully to fill and repair clay ball voids

• Slab Replacement

• Overlay
Material Related Cracks

• Durability cracking, commonly referred to as D-cracking, is a distress associated with the freezing and thawing of critically saturated, susceptible coarse aggregate particles in the concrete.

• Alkali-aggregate reaction (AAR) describes a family of chemical reactions between certain susceptible aggregates and the alkali hydroxides in the concrete, which can lead to cracking of the concrete matrix and cracking.
D-Cracking

• Causes:
  Three factors are needed for D-cracking to develop:
  
  – 1) Concrete contains aggregates susceptible to D-cracking in sufficient quantity and size
  – 2) Concrete is exposed to sufficient moisture, and
  – 3) Concrete is exposed to repeated cycles of freezing and thawing

• Prevention
  – Effective way of preventing D-cracking is to avoid the use of susceptible aggregates
Alkali-Silica Reactivity (ASR)

- ASR is a deleterious reaction between alkalis in the pore solution and reactive silica in aggregate
- Common susceptible aggregates include chert, quartzite, gneiss, and shale, among others

Sequence of ASR Development

Reaction between the alkali hydroxides (Na, K & OH) from the cement and unstable silica, SiO₂, in some types of aggregate.

The reaction produces an alkali-silica gel.

The gel absorbs water from the surrounding paste ...

... and expands.

The internal expansion eventually leads to cracking of the surrounding concrete.
Material Related Cracks - Prevention

ASR Prevention
• Use SCMs
• Avoid susceptible aggregates

D-Cracking Prevention
• Use durable aggregates
• Provide adequate drainage

Required Levels of SCMs to Control ASR (Thomas, Fournier, and Folliard 2013) – Distress Guide

<table>
<thead>
<tr>
<th>Type of SCM</th>
<th>Total Cementitious Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-calcium fly ash (&lt;8% CaO; typically Class F fly ash)</td>
<td>20 to 30</td>
</tr>
<tr>
<td>Moderate-calcium fly ash (8 - 20% CaO; can be Class F or Class C fly ash)</td>
<td>25 to 35</td>
</tr>
<tr>
<td>High-calcium fly ash (&gt;20% CaO; typically Class C fly ash)</td>
<td>40 to 60</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>8 to 15</td>
</tr>
<tr>
<td>Slag Cement</td>
<td>35 to 65</td>
</tr>
</tbody>
</table>
Material Related Cracks - Treatment and Repairs

Repairs
- Partial-Depth Repair
- Full-Depth Repair/Slab Replacement
- Retrofitted Edge Drains
- Unbonded Concrete Overlay

Maintenance
- Joint Filling/Sealing
- Edge Drain Maintenance
- Topical Treatments
Longitudinal and Transverse Cracking

Types
- Volumetric changes (concrete) – dry shrinkage/thermal contraction
- Volumetric changes (subgrade) – poor soils/drainage
- Settlement and poor support
- Slab length
- Sawing practices
- Traffic loading (design)
- Sympathy cracks
Volumetric Changes in Concrete

1. Dry Shrinkage - Increased risk for drying shrinkage cracking are:
   - High $w/cm$ ratio.
   - High cement contents.
   - High-early strength cements.
   - High CTE values of the coarse aggregate.

2. Thermal Contraction Cracking
   - Temperatures can play a critical role, such that elevated ambient temperatures can induce an early set to the concrete that leads to significant contraction (and potentially cracking) later when it cools.
   - Sudden change in ambient temperatures.
   - Paving reaches a higher peak temperature than concrete that is placed later in the day; this is because the peak heat of hydration of the concrete (which typically occurs about 4 to 8 hours after paving) coincides with the hottest part of the summer day.
Volumetric Changes in Subgrade

Surface Water

Subsurface Water

Zone exposed to constant high moisture levels.

Water Table – 100% Saturation

Capillary Fringe

Different Soils; Uniform Support; Drainage Characteristics
## Subgrade Treatment Based on Subgrade Conditions

<table>
<thead>
<tr>
<th>No</th>
<th>Subgrade Conditions</th>
<th>Treatment</th>
</tr>
</thead>
</table>
| 1  | Varying types of soil  
• Meets M & D tests  
• Passes proof roll test | Disc and mechanically blend soils (8 in. lifts to 2 ft. depth) for subgrade  
Compact to 95% standard proctor |
| 2  | Uniformly wet soils  
• Does not pass proof rolling or density test | Dry subgrade by disking  
If drying weather is not available or soils are too wet, utilize quick lime, cement or fly ash |
| 3  | Expansive or unsuitable soils | Chemically stabilize soil with cement (changes the PL and LL to acceptable levels.  
Remove unsuitable soils and replace with select material |
### Longitudinal and Transverse Cracking – Causes and Prevention

<table>
<thead>
<tr>
<th>Causes</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive slab length</td>
<td>Follow guidelines, saw to adequate depth</td>
</tr>
<tr>
<td>Late sawing</td>
<td>Maximize sawing window, increase labor/equip forces</td>
</tr>
<tr>
<td>Inadequate saw depth</td>
<td>Check blades, saw to T/3 on transverse joints</td>
</tr>
<tr>
<td>Traffic loading</td>
<td>Use proper thickness, keep construction traffic away from edges</td>
</tr>
</tbody>
</table>
Cracking Treatment and Repairs

Repairs
• Full-depth repair
• Cross-stitching/Slot stitching (longitudinal cracking)
• Crack sealing/Filling (if not working crack)
• Diamond grinding

Maintenance
• Crack sealing

Appendix 9-6 Iowa DOT Construction Manual
• Concrete slabs undergo non-uniform volumetric changes due to temperature and moisture gradients.

• A gradient is the variation that occurs in temperature and/or moisture from the bottom of the concrete slab to the top.

• The slab is normally colder on the top than the bottom from late at night through mid-morning, resulting in a negative temperature gradient.
Curling and Warping

- Jointed concrete pavements can experience upward and downward curvature on a daily basis due to changing temperature gradients (curling) and over time develop upward curvature due to moisture gradients (warping).

- Long-term moisture gradients are almost always negative, with the top of the slab being drier than the bottom; this results in upward warping from the shrinkage that develops in the slab surface as it dries.
Causes – Curling

• Greatest impact on the development of temperature curling is the concrete’s coefficient of thermal expansion (CTE).

• As the volume of concrete is predominately aggregate, the aggregate (particularly the coarse aggregate) has a large influence on CTE.

• Limestone aggregates produce concrete with the lowest CTE values.

• Rapid Temperature Changes
Causes – Warping

• Capillary pores have a large influence on concrete strength and permeability. They have a large influence on the volumetric change that concrete undergoes with changes in moisture. As concrete dries, the pores begin to empty, starting with the largest pores first. In such small pores, as they transition from being full to partially-filled with water.

• In smaller gel pores, the surface tension of the water increases as does the stress pulling the pore walls inward. The result is concrete shrinks as it dries, thus the need for joints to accommodate the shrinkage.

• As dry concrete is re-wetted, the opposite occurs. Empty or partially empty capillary pores take up water, the smallest pores first, until full.

• Concrete slabs that undergo cycles of wetting and drying at the surface but remain largely saturated on the bottom will develop upward curvature that will continue to increase for years to come.
Sizes of Concrete Components

- Water
- Silica fume
- Cement, slag, fly ash
- Rock
- Sand
- CH crystals
- Spacing between C-S-H
- Capillary voids
- C-S-H agglomerations
- Interfacial zone
- Minimum Air Space
- Entrained air
- Entrained air

Scale:
- 0.1 nm
- 1 nm
- 10 nm
- 100 nm
- 1 μm
- 10 μm
- 100 μm
- 1 mm
- 10 mm
- 100 mm
Filling of Smallest Pores - Gel and Capillary Pores -
(10 to 18 hours)

Air Entrainment

Capillary Pores

Entrapped Air

Weiss 2014
# Curling & Warping

<table>
<thead>
<tr>
<th>Distress</th>
<th>Causes</th>
<th>Design</th>
<th>Material Selection</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab Curling</td>
<td>• Temperature gradient in slab induces slab curvature and stress</td>
<td>• Accommodate curling in design through proper joint spacing, load transfer, and base restraint</td>
<td>• When possible, use coarse aggregate with a low CTE</td>
<td>• White pigmented curing compound can help surface cool.</td>
</tr>
<tr>
<td></td>
<td>• High CTE aggreg. • contribute to higher levels of curvature and stress</td>
<td></td>
<td></td>
<td>• Risk of early-age cracking from curling can be reduced by not paving prior to a major temperature fluctuation (i.e. cold front)</td>
</tr>
<tr>
<td>Slab Warping</td>
<td>• Moisture gradient in slab induces slab curvature and stress</td>
<td>• Accommodate warping in design through proper joints spacing, load transfer, and base restraint</td>
<td>• Use concrete mixtures with lower potential for drying shrinkage (e.g. lower paste content)</td>
<td>• Minimize evaporation from the concrete surface at an early age; white pigmented curing compounds can help</td>
</tr>
<tr>
<td></td>
<td>• Arid climates, poor drainage, and concrete mixtures susceptible to shrinkage will contribute to higher levels of curvature and stress</td>
<td></td>
<td></td>
<td>• Paving during high temperatures can be a contributing factor; employ hot-weather concreting techniques</td>
</tr>
</tbody>
</table>

CTE: Coefficient of Thermal Expansion
Blowups

• Blowups often occur in the heat of the day as expansion results in a buildup of pressure that can be dramatically released as the pavement thrusts upwards and/or shatters.
Blowups- Concrete Material Factors

• Under most circumstance, the volume of the concrete is never greater than the day it is placed. There are exceptions, however, that sometimes lead to blowups.

• Material factors that can lead to expansion beyond the original concrete volume include moisture and/or temperature effects and expansive reactions.

• As dry concrete is re-wetted empty or partially empty capillary pores take up water, the smallest pores first, until full and the menisci disappear. The pore walls rebound, but not to the same degree as where they started.
Volumetric Expansion Due to Moisture and/or Temperature Effects

• The coefficient of thermal expansion (CTE) defines how a material changes in length with a change in temperature.

• It has been observed that thermal length change is often complicit in the occurrence of blowups, with increasing frequency as temperatures increases.

• Blowups is further increased if the heatwave is accompanied by a significant precipitation which results in saturation and further expansion of the concrete.
Blowups Treatment & Repairs

Blowups are caused by multiple factors that often combine to create excessive compressive stress in the slab

- **Treatment of Incompressible Materials**
  - Incompressible material in joints can only be treated by cleaning the joints and resealing them. Procedures for joint resealing can be found in Smith and Harrington (2014).

- **Repair**
  - The most common repair strategy is to construct a full-depth repair.
Spalling

Freeze thaw damage

Saturated joint backer rod damage

Saturated joint with unsound aggregate

Incompressible joint damage

Deflection spalling from heavy vertical loads

Early saw joint raveling

Chloride penetration

Dowel bar misalignment
# Spalling - Causes

<table>
<thead>
<tr>
<th>Distress</th>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| Spalling         | (Material or Chemical)          | **Magnesium & Calcium Chlorides**  
Deicing chemicals react with Calcium Hydroxide (CH) causing flaking of hardened paste                              |
|                   | Freeze Thaw Damage              | Damage to the paste of the concrete from:  
• Poor air entrainment system  
• Saturated concrete joints/cracks  
• Chemical breakdown of the concrete from deicing salts such as calcium and magnesium chloride (Calcium Oxychlorides) |
|                   | Thermal Expansion               | High coefficient of thermal expansion (CTE) of the aggregate results in higher compressive stresses at the joint or crack.                      |
| Spalling         | (Physical)                      | Infiltration  
Infiltration of incompressibles into poorly sealed or unsealed joints.                                                                              |

**Longitudinal Freeze Damage From Backer Rod**
Spalling – Deicers

- The formation of Calcium Silicate Hydrate (C-S-H) and Calcium Hydroxide (CH) are the two principal ingredients that mesh into a solid mass forming concrete pavement.

- Magnesium and calcium chloride will react with CH with water at between 32°F and 122°F, depending on the salt concentration.
Spalling – Deicers (Calcium Oxychloride)

• This reaction results in the formation of calcium oxychloride which results in flaking (expansion) of the hardened paste causing significant damage particularly in joints.
• Oxychloride expansion can be 3 times greater than freeze-thaw expansion.
• The use of SCM’s (fly ash, slag, and silica fume) will reduce formation of calcium oxychlorides by tying up CH
• Use of sealers has also shown the potential to limit interaction between salts and CH
Spalling – Saturation & Poor Air

- Saturation
- Marginal aggregate soundness
- Poor air void system
  - Spacing $\leq 0.008$ in.

Shadowing
Second- Filling of Larger Pores -Entrained and Entrapped Air- (months to years)

- Entrained and Entrapped Air

Weiss 2014

Air Entrainment

Capillary Pores

Gel Pores

Entrapped Air

\[ S_{\text{Nick}} = S_{\text{Mat}} \]

\[ S_{\text{Int}} \]

\[ \sqrt{\text{Time}} \]

Weiss 2014
Critical Saturation Rates

Weiss 2014
Spalling – Summary of Prevention

• Prevent saturation
• Reduce concrete permeability
  (Use fly ash to tie up CH)
• Ensure adequate air entrainment

Image of a Super Air Meter (SAM)
(Photo credit Tyler Ley)
Spalling - Treatment and Repairs

Repairs

• Partial-Depth Repair
• Full-Depth Repair/Slab Replacement
• Retrofitted Edge Drains
• Unbonded Concrete Overlay

Maintenance

• Winter maintenance
• Maintaining sealed joints
• Maintaining sub-drain systems
Settlement and Heaves

Causes
• Inadequate base compaction
• Consolidation of support layers under traffic
• Subgrade soil movement
• Loss of support (contamination of base layers)
• Frost heave
• Expansive soils
## Settlement and Heaves Prevention

<table>
<thead>
<tr>
<th>Causes</th>
<th>Design</th>
<th>Material Selection</th>
<th>Construction</th>
<th>Preventive Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor consolidation</td>
<td>Characterize soil based on engineering properties</td>
<td>Limit % fines to 10% (passing #200 sieve)</td>
<td>Proper compaction</td>
<td>Routine joint sealing</td>
</tr>
<tr>
<td>Volume changes in soil</td>
<td>Compaction specification based on optimum M &amp; D</td>
<td>Uniform soil, blend, granular subbase or chemical treatment</td>
<td>Uniform soil, blend, granular subbase or chemical treatment</td>
<td>Periodic maintenance of drainage system including cleanout of outlets</td>
</tr>
<tr>
<td>Excessive moisture</td>
<td>Provide drainage</td>
<td>Use drainable subbase</td>
<td>Dry soils</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consider chemical stabilization</td>
<td></td>
<td>Compact at optimum M &amp; D</td>
<td></td>
</tr>
</tbody>
</table>
Faulting
## Faulting - Causes

<table>
<thead>
<tr>
<th>Distress</th>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faulting (Physical)</td>
<td>Load Transfer Loss</td>
<td>Failure of aggregate interlock or mechanical devices that transfer load across pavement joints and cracks</td>
</tr>
<tr>
<td></td>
<td>Pumping</td>
<td>Longitudinal and transverse cracks and unsealed joints which allow water intrusion and lead to future faulting including loss of load transfer</td>
</tr>
<tr>
<td></td>
<td>Loss of Seal Integrity</td>
<td>Portal for intrusion of water into the grade</td>
</tr>
<tr>
<td>Faulting (Material or Chemical)</td>
<td>Poor Aggregate Soundness</td>
<td>Poor quality coarse aggregate leads to early loss of load transfer due to low shear capacity Aggregate particles deteriorate resulting in loss of support</td>
</tr>
</tbody>
</table>
Faulting - Treatment and Repairs

Repairs
• Dowel Bar Retrofit
• Bonded Concrete Overlay (if faulting is less than 3/8” faulting or Unbonded Concrete Overlay for 3/8” to 5/8”)

Maintenance
• Diamond Grinding
Bonded Concrete Over Asphalt
BCOA

Over Full Depth Asphalt

Over Composites

Corner Cracks

Longitudinal Cracks

Blowup Crack
Bonded Concrete Over Concrete
BCOC

Multiple Cracks
Longitudinal Cracks
Reflective Cracks
Unbonded Concrete Over Asphalt
UBCOA

Over Full Depth Asphalt

Over Composites

Longitudinal Cracks

Transverse Crack

Faulting
Unbonded Concrete Over Concrete UBCOC

Longitudinal Cracks

Reflective Crack

Faulting
# Summary of Overlay Distresses

<table>
<thead>
<tr>
<th>Distress</th>
<th>Causes</th>
<th>Prevention or Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Longitudinal cracking in tied shoulders</td>
<td>• Differential movement (heaving) of materials underlying shoulders and/or widened sections</td>
<td>• Tie-bar placed at neutral axis if possible</td>
</tr>
<tr>
<td>and widened sections</td>
<td>• Tie-bar placed at the bottom of the concrete slab</td>
<td>• Utilize structural fibers in lieu of tie-bars</td>
</tr>
<tr>
<td></td>
<td>• Poor subbase drainage of widening or shoulder</td>
<td>• Provide for drainable subbase under shoulder</td>
</tr>
<tr>
<td></td>
<td>• Maximum tie-bar size of #4</td>
<td>• Chair or insert bars to specified tolerances</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• QC checks to confirm tie-bar location behind the paver</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Saw all contraction joints to a depth of T/3 except for BCOC which is full depth</td>
</tr>
<tr>
<td>2. Longitudinal cracking in wheelpath</td>
<td>• Inadequate slab thickness</td>
<td>• Structural fibers may increase load transfer in thin overlays</td>
</tr>
<tr>
<td></td>
<td>• Debonding for BCOA &amp; BCOC due to curl/warp or deteriorated existing pavement</td>
<td>• Existing HMA Asphalt should be resistant</td>
</tr>
<tr>
<td></td>
<td>• Improper slab dimensions</td>
<td>• Control the temperature and moisture of the HMA at time of paving</td>
</tr>
<tr>
<td></td>
<td>• Inadequate load transfer</td>
<td>• Adequate curing</td>
</tr>
<tr>
<td></td>
<td>• Avoid placing longitudinal joints in the wheelpath</td>
<td>• Sawcut longitudinal joints to T/3</td>
</tr>
<tr>
<td></td>
<td>• Existing HMA should be resistant</td>
<td>• Limit construction traffic on remaining HMA to prevent damage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provide clean existing pavement</td>
</tr>
<tr>
<td>Distress</td>
<td>Causes</td>
<td>Design</td>
</tr>
<tr>
<td>----------</td>
<td>------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 3. Transverse cracking | • Reflective cracking of underlying thermal cracks | • Set profile grade to assure adequate thickness of existing HMA asphalt remains after milling | • Securely anchor baskets  
• Adjust anchoring for non-uniform conditions  
• Do not cut shipping wires on the baskets  
• Sawcut transverse joints to T/3 except for BCOC which are full depth |
| 4. Blowups | • Undeployed joints non-uniform subbase friction  
• Incompressibles in the joints  
• Expansion due to heavy rain, excessive heat or both | • Appropriate slab dimensions for the design thickness  
• Specify sealing joints to prevent incompressibles from filing the joints  
• A full-depth transvers sawcut for BCOC  
• Ensure that the underlying pavement is well drained | • Saw cut joints to T/3 except for BCOC which are full depth  
• Seal all joints |
THANK YOU!

National Concrete Pavement Technology Center