Concrete Pavement Preservation Fundamentals

National Concrete Pavement Technology Center
Iowa's Lunch–Hour Workshop
In cooperation with the Iowa DOT
and the Iowa Concrete Paving Association

Investment

Protect the Investment

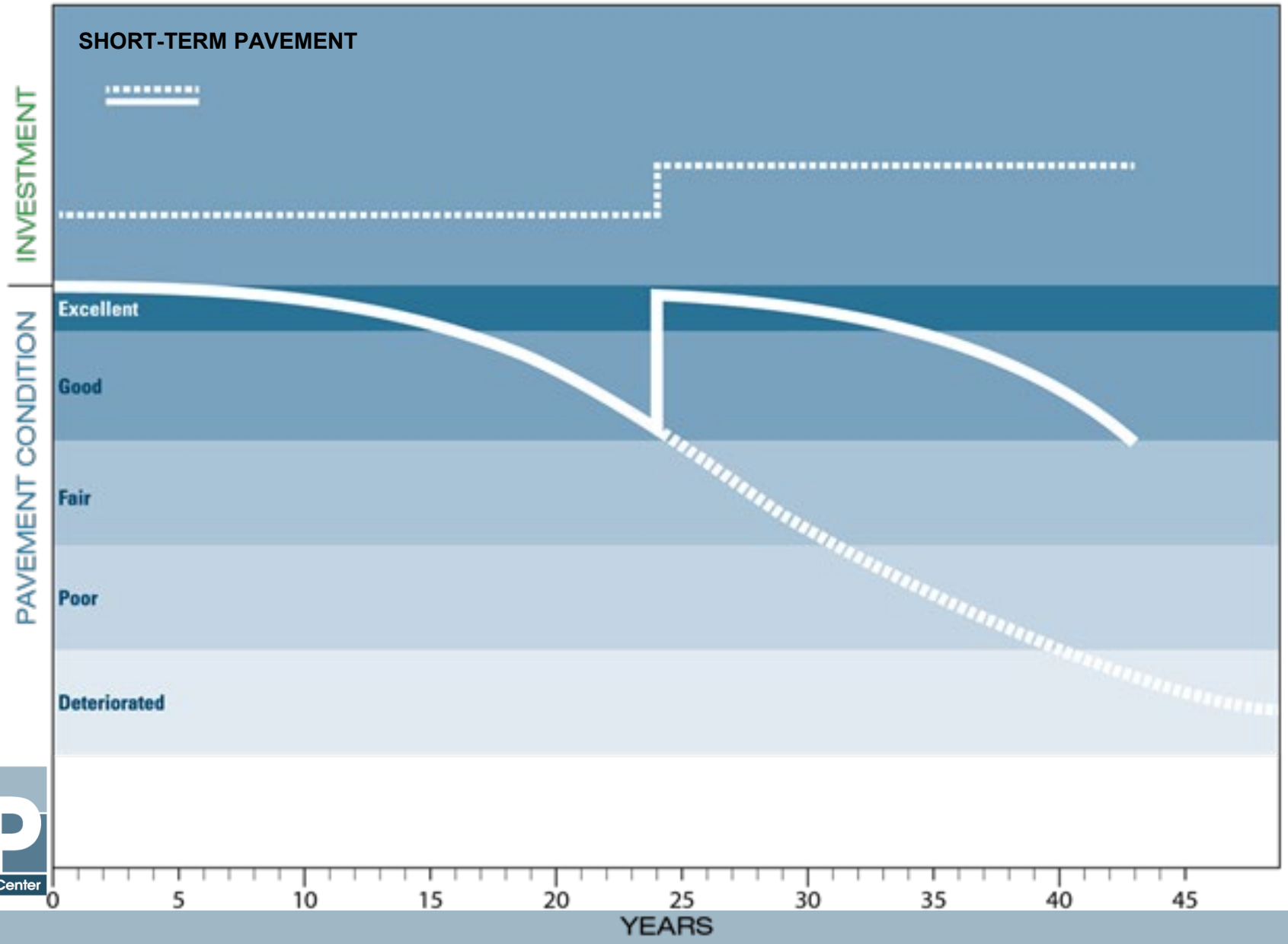
Review your Pavements

Plan for Preservation

Do it Correctly

Image Source: Omaha World Herald

Service Life



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Maintenance vs. Preservation

Preventative Maintenance

- Maintain (or improve) the condition of the transportation system to a functional state of operation[1]
- Part of asset management (routine & preventive maintenance)[1]
- Applied to structurally sound pavements with significant remaining life

Preservation

- Work planned & performed to improve or sustain the condition of the transportation facility to a good condition[1] (keep good roads good)
- Generally do not add capacity or structural value, but restore the overall condition[1]
- Extending life and restoring functional condition
- Collection of maintenance and minor rehabilitation

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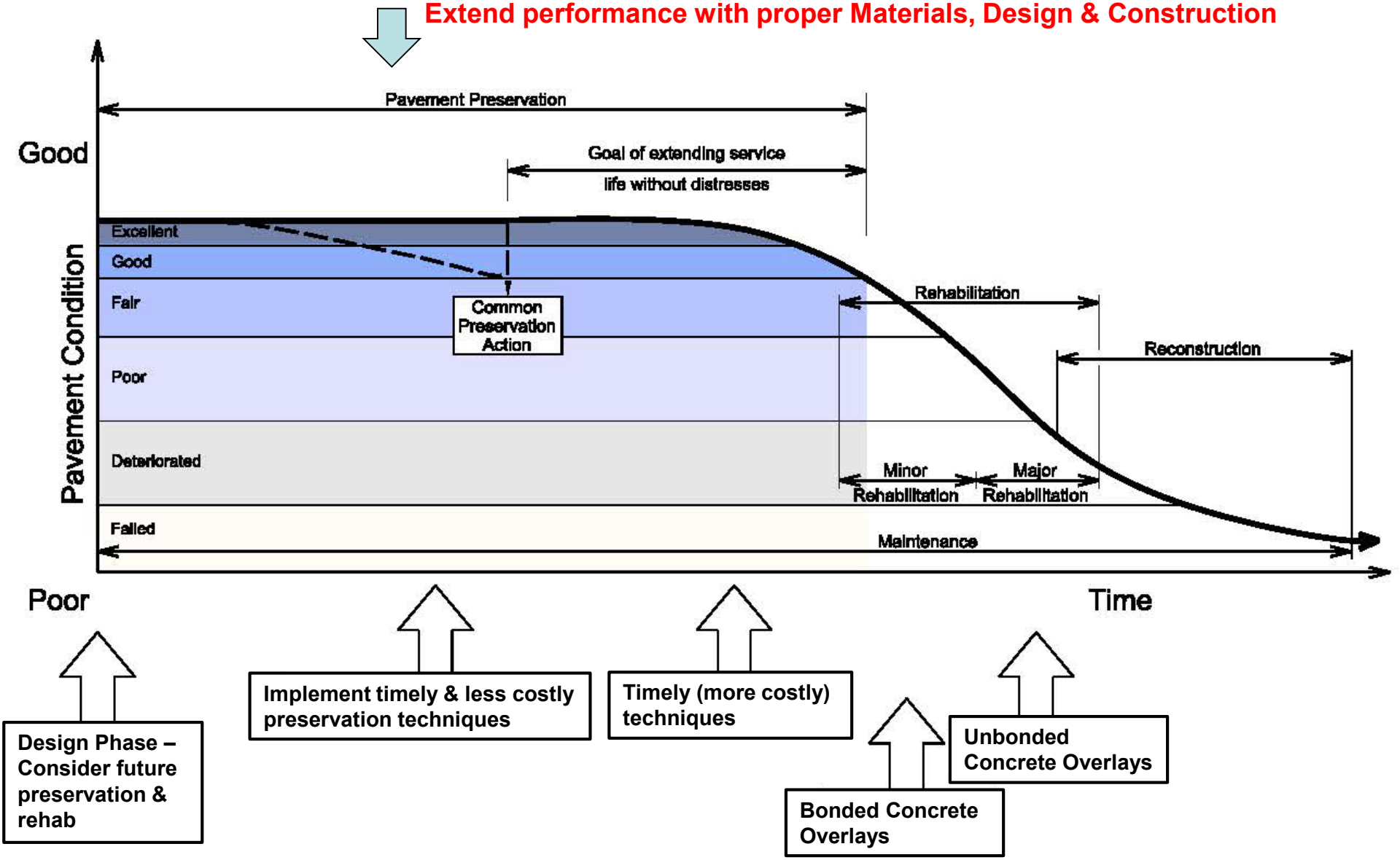
[1]Source: FHWA Guidance on Highway Preservation and Maintenance

Maintenance vs. Preservation



Trigger/Limit Values for Preservation (JPCP)

Start Programming

Performance Indicator	Trigger Value	Limit Value	Repair
Trans. Cracking	1.5-2.5% of slabs cracked	5-15% of slabs cracked	Partial, Full, Dowel Bar Repairs
Joint Deterioration	2.0-4.0% of joints	15-20% of joints	Partial-Depth Repair
Joint Faulting	1/8 inch	3/8 – 1/2 inches*	Dowel Bar Retrofit
Roughness	90 in/mi	170 in/mi*	Diamond Grinding

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* CP Tech Center

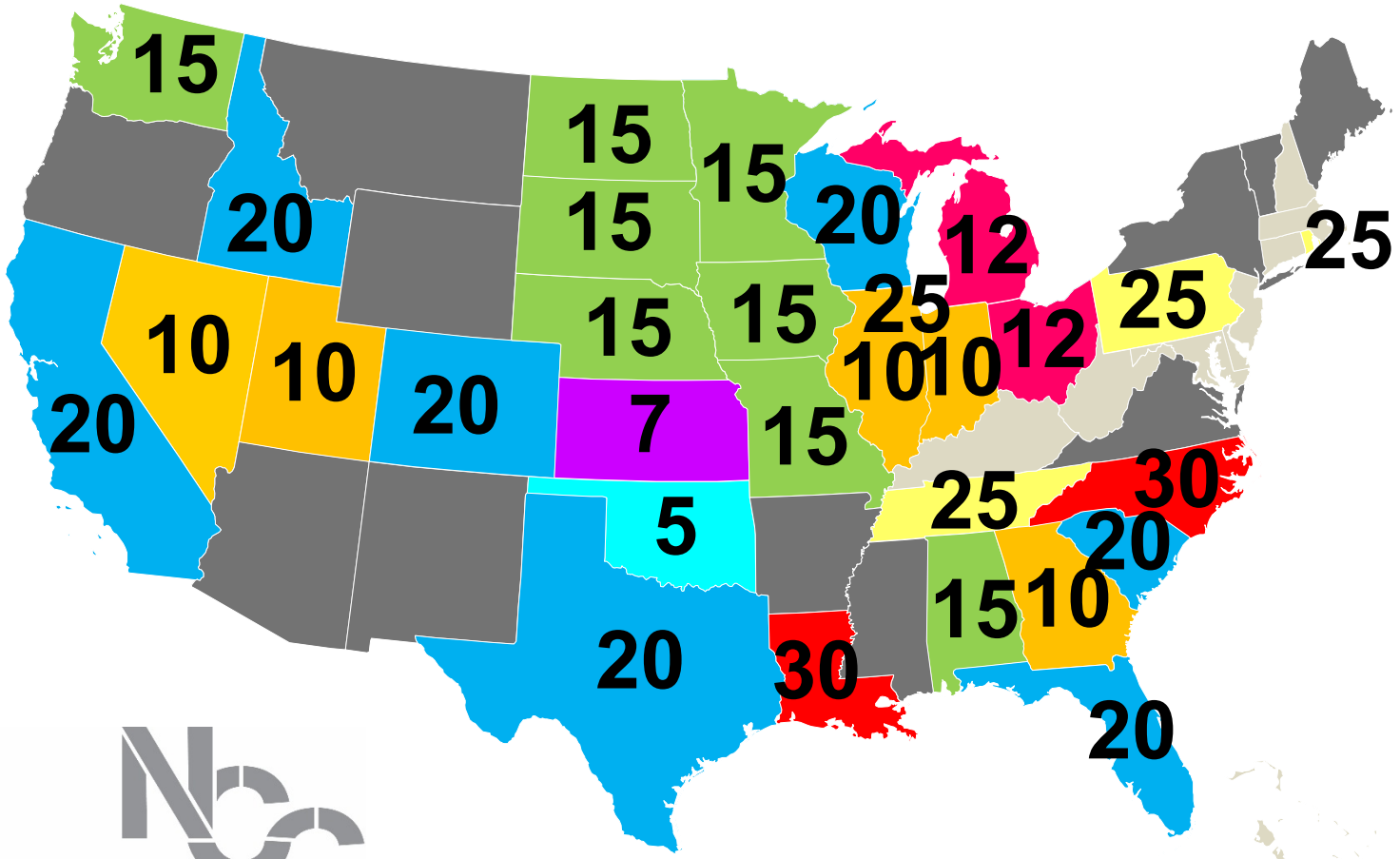
Values Adapted from Table 3.2 Preservation Guide

Treatment Performance Life

	Treatment	Expected Performance (Treatment Life), Years
*	Concrete joint resealing	8 - 15
*	Concrete crack sealing	8 - 15
	Diamond grinding	8 to 15
	Diamond grooving	10 to 15
*	Partial-depth concrete patching	12 - 20
*	Full-depth concrete patching	15 - 25
*	Dowel bar retrofit	15 - 20

* CP Tech Center (adapted from Preservation Guide)

Q3: Full Depth Repairs: What is your Agency's expected life of full depth repair?



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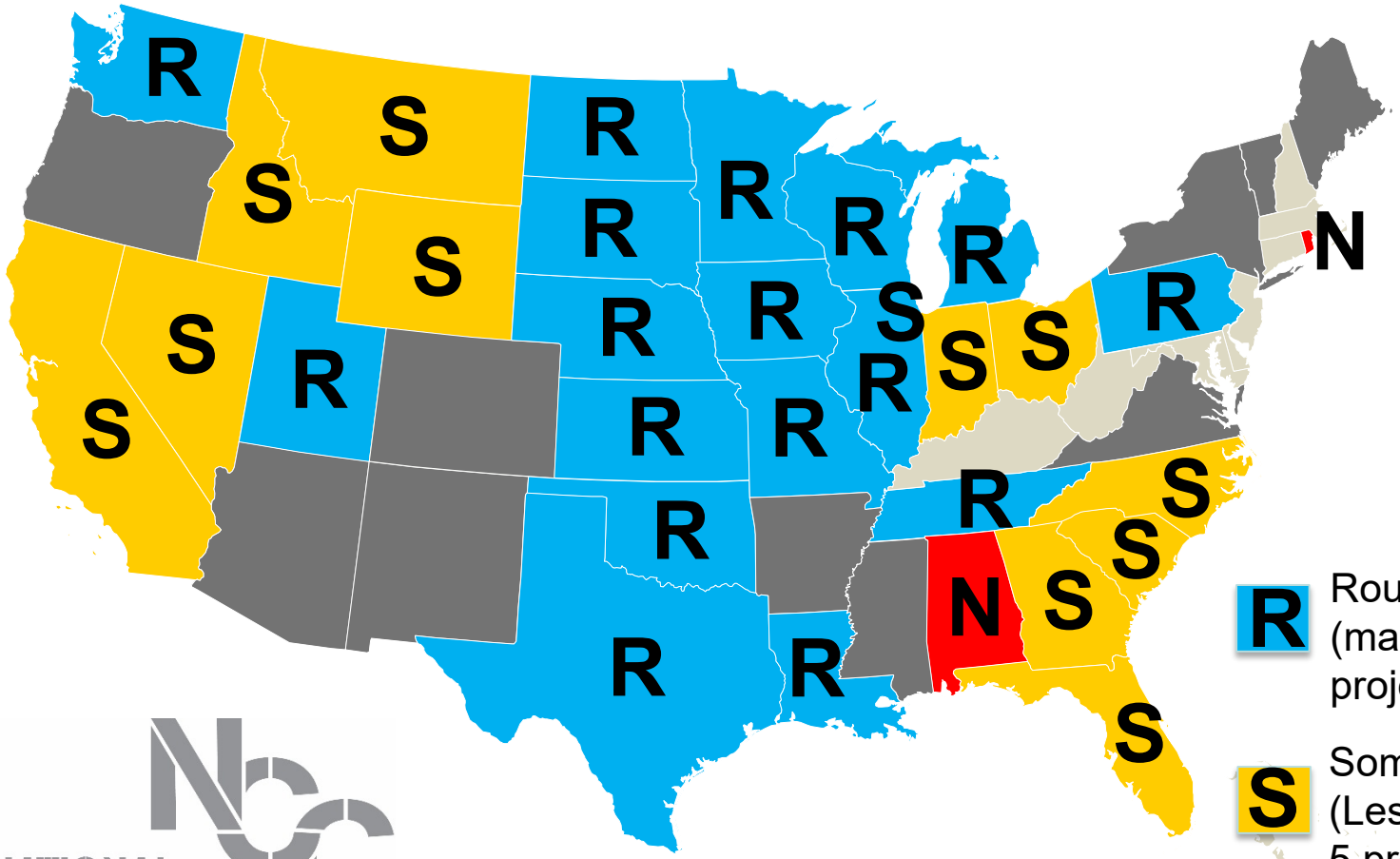
Q5: Partial Depth Repairs: What is your Agency's experience doing partial depth repairs?



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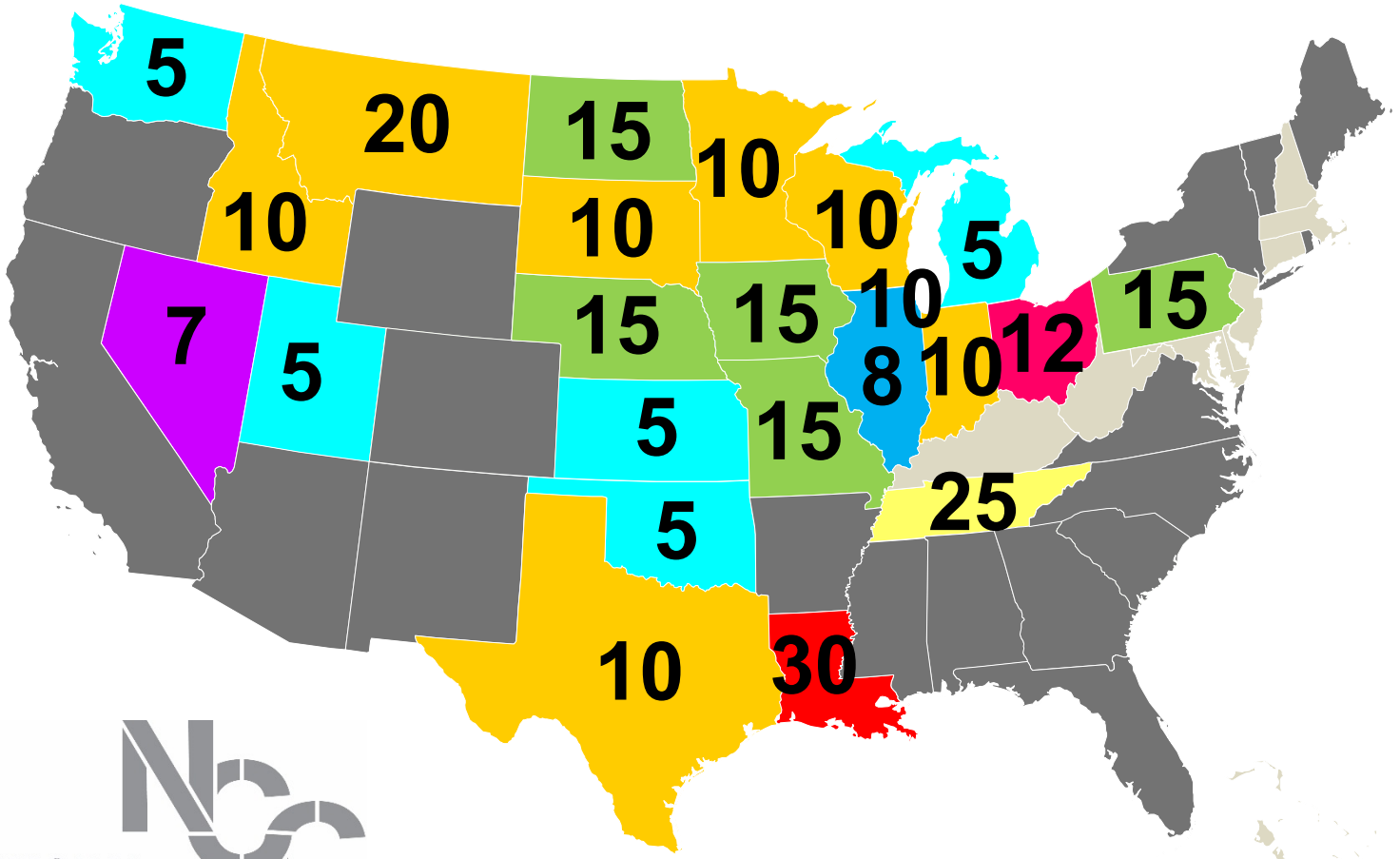
2017 Survey

Q7: Partial Depth Repairs: What is your Agency's expected life of partial depth repair?



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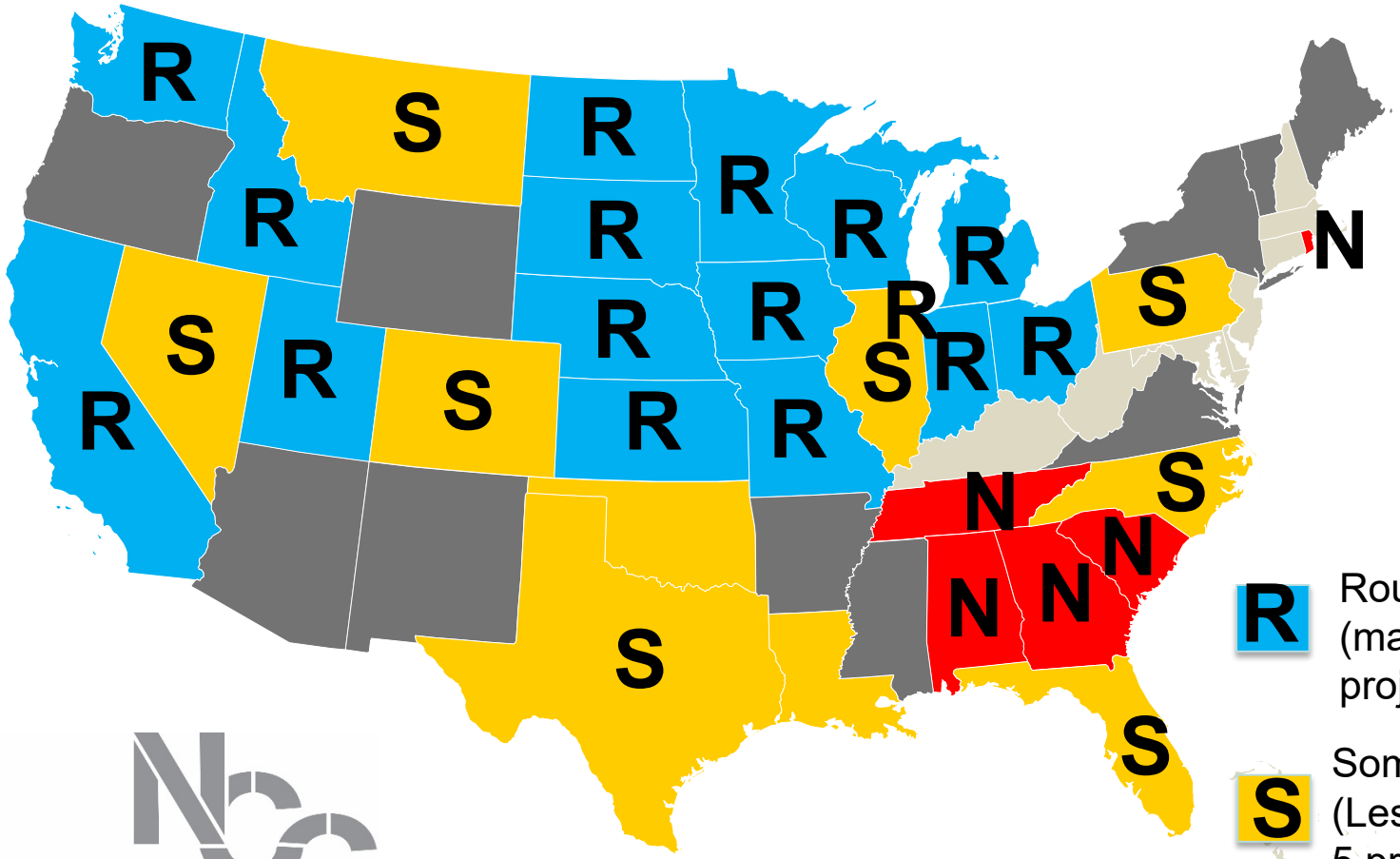
Q9: Dowel Bar Retrofits: Does your Agency have any experience doing dowel bar retrofit repairs?



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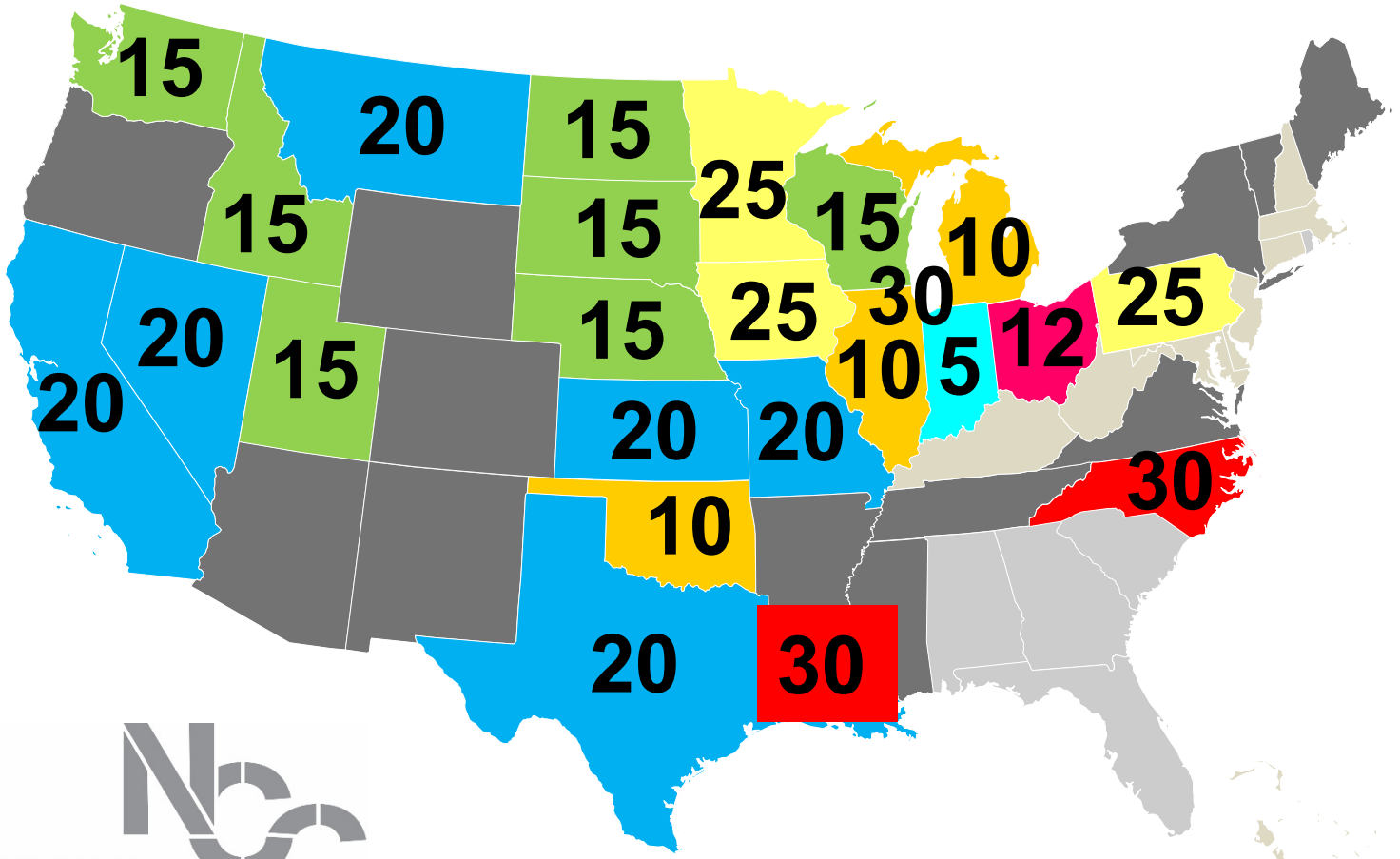
2017 Survey

Q10: Dowel Bar Retrofits: What is your Agency's expected life of dowel bar retrofit repair?



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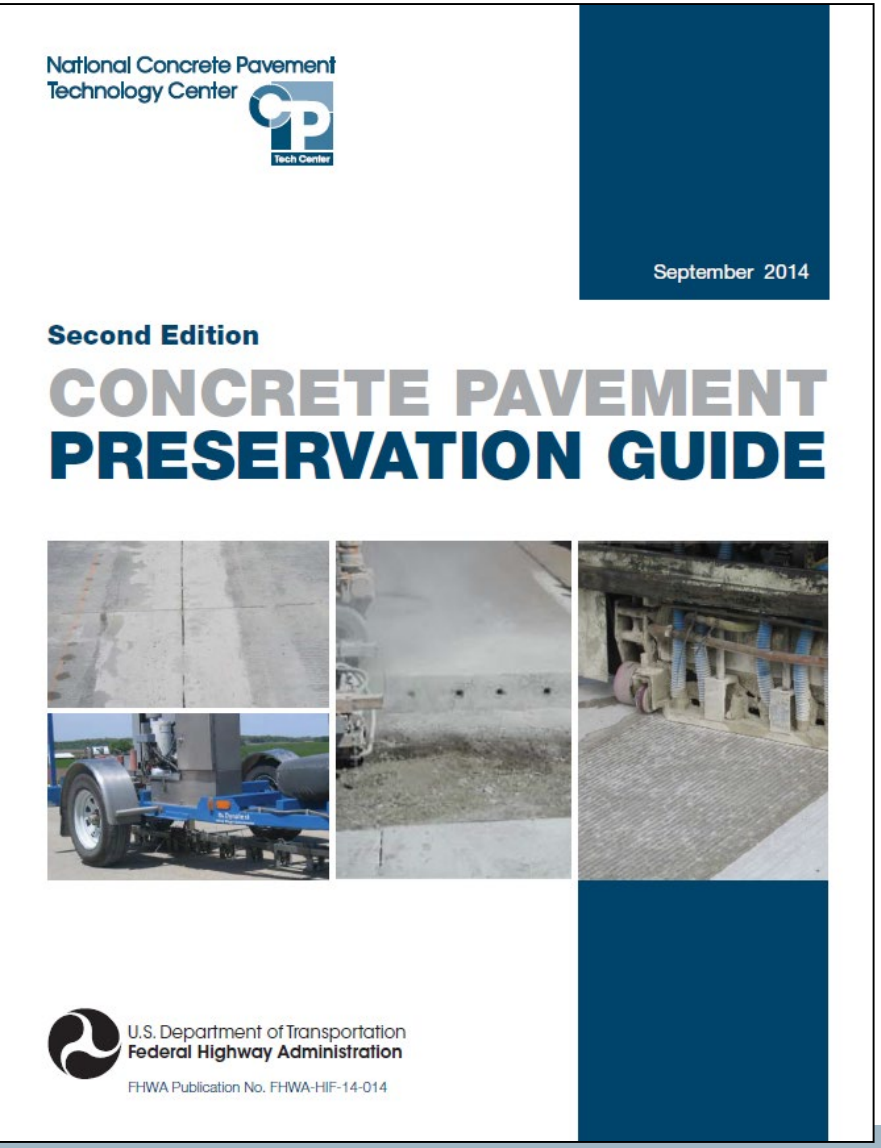
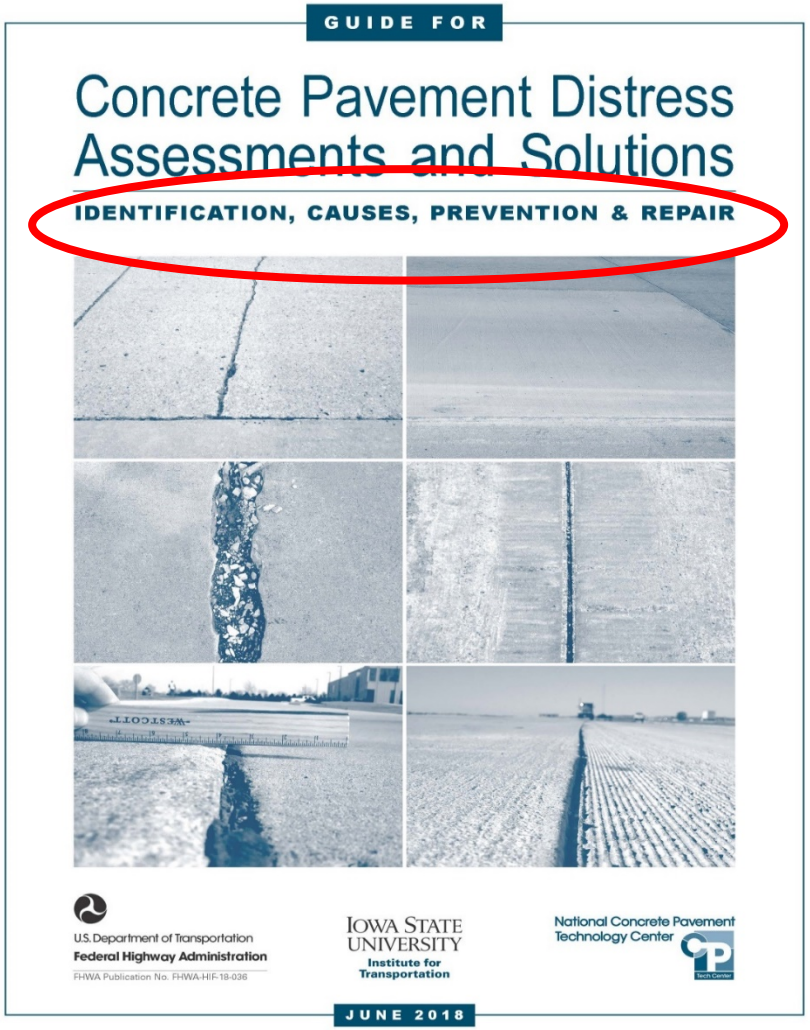
Concrete Pavement Preservation Guide 2014



- Contains 12 Chapters on Preservation Techniques
- Focus on Repair Techniques

  (How to do it)

Distress Assessments & Solutions



DIVISION 1 – FULL DEPTH CONCRETE PAVEMENTS

- 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

Google:
CP Tech Center
Distress Manual
(pdf & ePub)

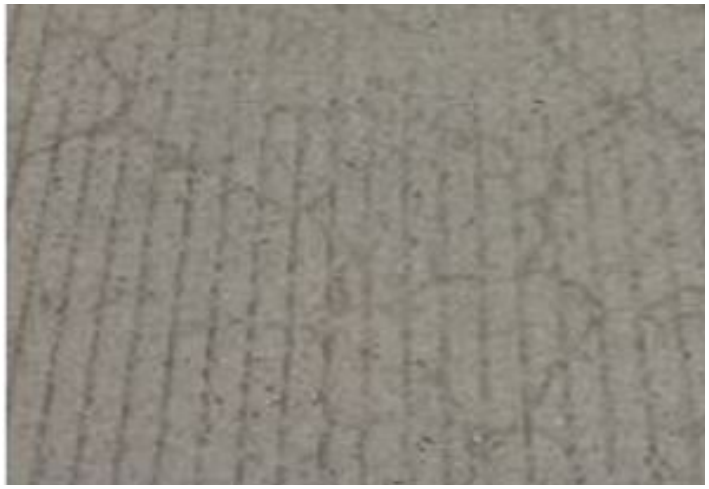
DIVISION 2 – CONCRETE OVERLAYS

- Concrete Overlays, BCOA, BCOC, UBCOA, UBCOC
- Laboratory & Field Testing

https://cptechcenter.org/news/new-concrete-pavement-distress-manual-available/

Full Depth Pavements

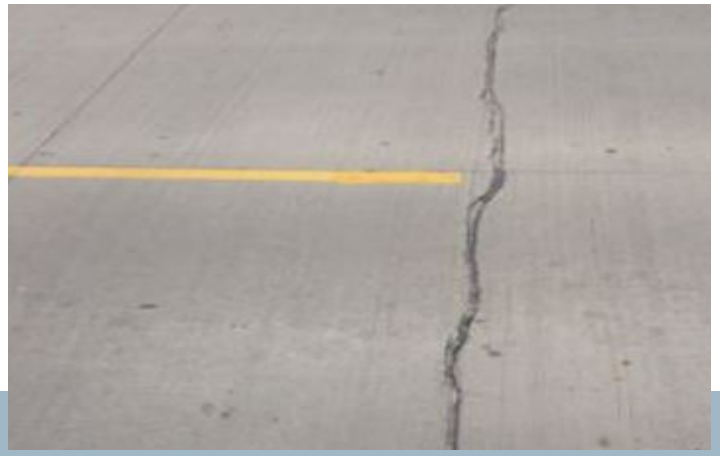
Ch 2. Surface Defects



Ch 3. Surface Delamination

Ch 4. Material-Related Cracks

Ch 5. Transverse/Diagonal Cracking



Full Depth Pavements

Ch 6. Longitudinal Cracking

Ch 7. Corner Cracking

Ch 8. Spalling

Chapter 9. Faulting

Full Depth Pavements

Ch 10. Joint Curling and Warping

Ch 11. Blowups

Ch 12. Subgrades and Base Support

Ch 13. CRCP

CHAPTER 14. INTRODUCTION TO DIVISION 2: CONCRETE OVERLAYS

This chapter will help quickly identify where in Division 2 of this manual you can find more detailed guidance on distresses in concrete overlays (causes and solutions). A brief overview of each chapter is provided along with a description of the overlay type being addressed

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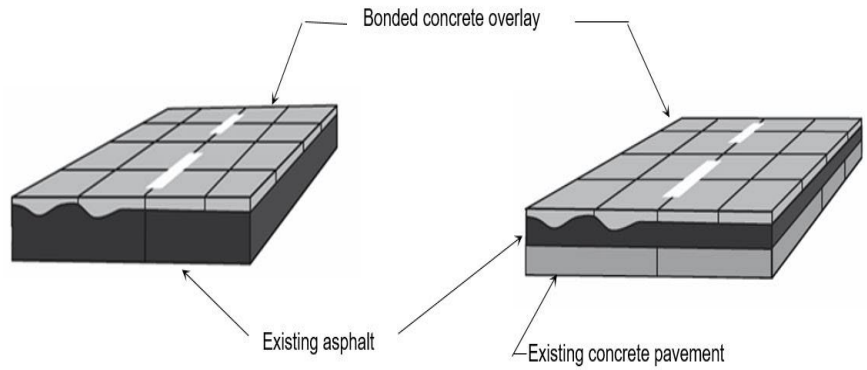
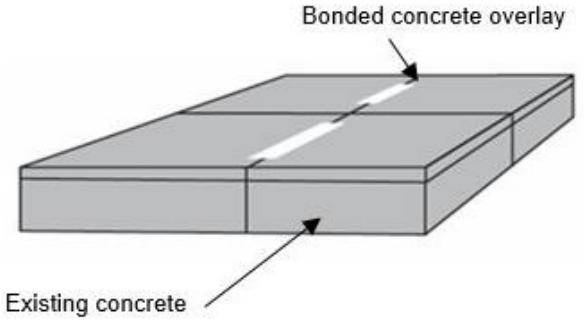
Concrete Overlay Distress Manual Chapters

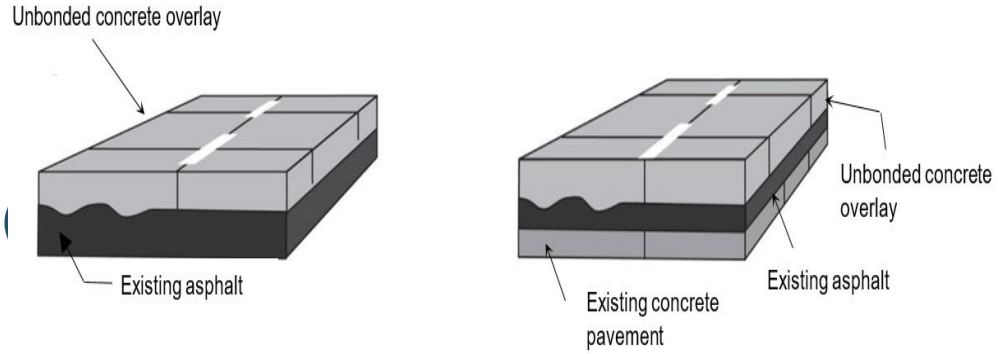
Ch 15. Bonded Concrete Overlay on Asphalt (BCOA)



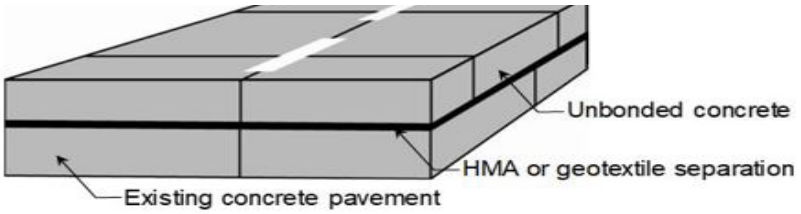
Ch 16 Bonded Concrete Overlay on Concrete (BCOC)



Ch 17. Unbonded Concrete Overlay on Asphalt (UBCOA)



Ch 18. Unbonded Concrete Overlay on Concrete (UBCOC)



Ch. 15 Concrete Overlay on Asphalt (BCOA)

Interior Structure/ Unbonded Cracks

Longitudinal lane-shoulder joint spall due to shoulder heave

Compression-transverse joint due to slab expansion & adjacent joints not opening

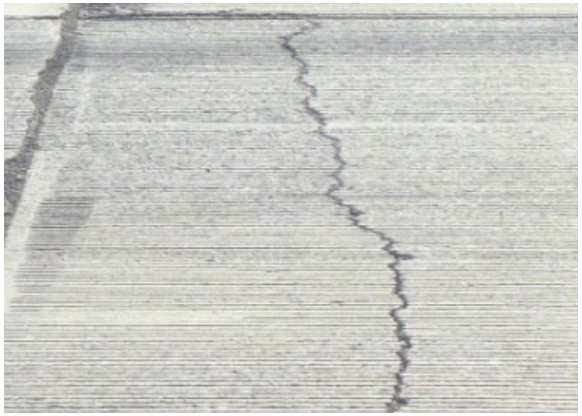
Transverse joint faulting

Panel migration/slippage

Mult. Longitudinal cracking in wheel path

Ch 16. BONDED CONCRETE OVERLAY ON CONCRETE (BCOC)

Reflective crack over transverse crack

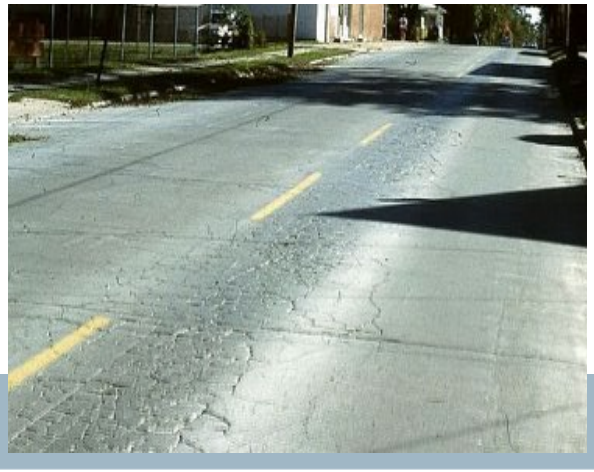


Multiple panel cracks near panel end due to debonding

Longitudinal crack-overlay fatigue after debonding

Late sawing/or saw cut not directly over existing joint/crack

Wheel path cracking-debond & fatigue cracking of overlay

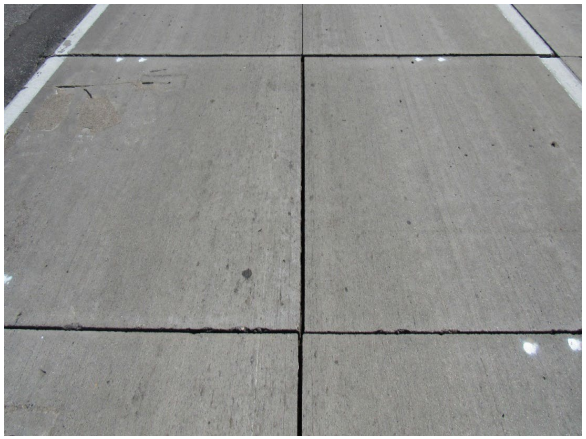


Reflective crack-not cutting a joint over existing crack

Ch. 17 UNBONDED CONCRETE OVERLAY ON ASPHALT (UBCOA)

Longitudinal cracking in wheel path with tied & widened shoulders

Faulting & panel movement of UBCOA due to deformation of the underlying HMA



Diagonal longitudinal crack over widened section

Cracking- misaligned dowels; paint marks dowel basket

Mid-panel cracking

Blowups

Ch 18 UNBONDED CONCRETE OVERLAY ON CONCRETE (UBCOC)

Longitudinal cracking in wheel path with tied & widened shoulders (UBCOC)

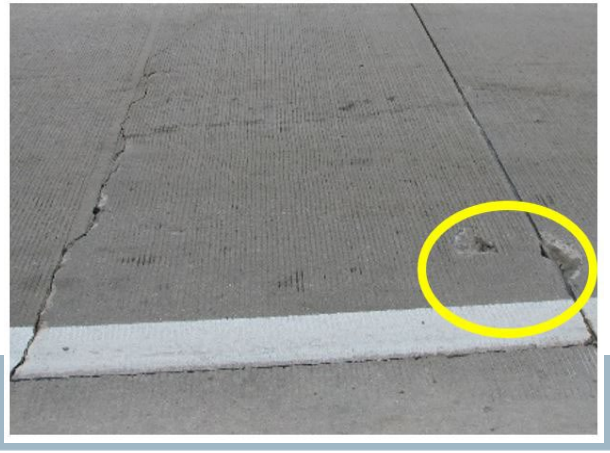
Transverse joint faulting of UBCOC

Longitudinal cracking in wheel path in UBCOC

Transverse reflective cracking of UBCOC

UBOC Mid-panel cracking

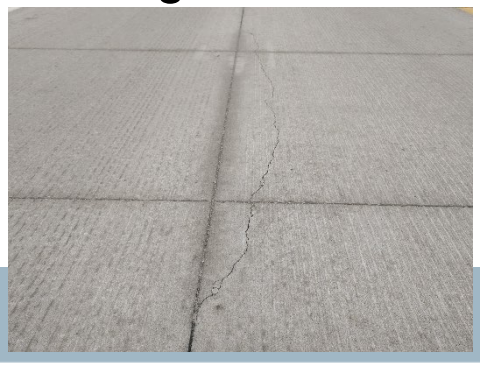
Cracking due to misaligned dowels, (yellow oval shows the exposed end of dowel



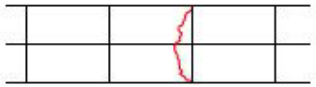
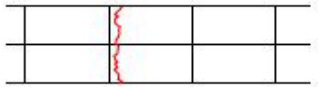
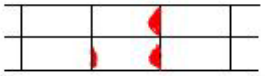
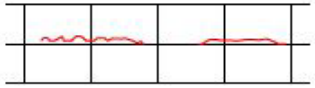
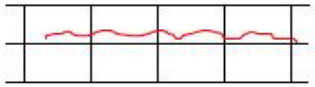
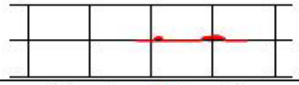
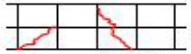
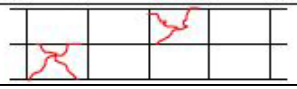
COMMON DISTRESS TYPES

Longitudinal and Transverse Cracking – Causes and Prevention

Causes	Prevention
Excessive slab length	Follow guidelines, saw to adequate depth
Late sawing	Maximize sawing window, increase labor/equip forces
Inadequate saw depth	Check blades, saw to T/4 on transverse joints (T/3 on longitudinal and CD joints)
Non-Uniform support volume changes	Uniform drainage, compact & subgrade soils, chemically stabilize subgrade if needed
Traffic loading	Use proper thickness, keep construction traffic a from edges



Recommended Repairs for PCC Cracking

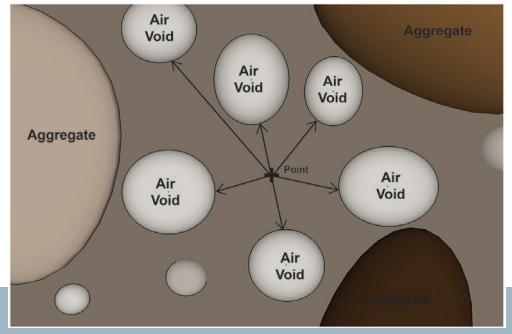
Defect	Orientation	Location	Description	Dowelled/Undowelled Transverse Joints	Recommended Repair	
Plastic Shrinkage	Any	Anywhere	Partial-depth and more than 0.007 in. wide	Either	Do nothing	
Uncontrolled Crack	Transverse	Mid-Panel	Full-Depth	Undowelled	Saw/route and seal crack	
				Dowelled	Full-Depth Repair or LTR[a]	
Uncontrolled Crack	Transverse	Crosses or ends at transverse joint	Full-Depth	Undowelled	Saw & seal crack; Epoxy sawed joint if uncracked	
				Dowelled	Full-Depth Repair or If crack jumps from sawcut to edge of slab within 3 feet of edge of slab, stop sawcut, saw & seal crack	
Uncontrolled Crack	Transverse	Parallel to & within 5 ft. of joint	Full-Depth	Undowelled	Saw and seal crack Seal joint	
				Dowelled	Full-Depth repair to replace crack and joint	
Spalled sawcut or uncontrolled crack	Transverse	Anywhere	Spalling; more than 3.0 in.wide	Either	Partial-Depth Repair	
Uncontrolled Crack	Longitudinal	Relatively parallel to & within 1 ft. of joint; May cross or end at longitudinal joint	Full-Depth	Either	Saw/route & seal the crack or cross-stitch the crack Epoxy sawed joint if uncracked	
Uncontrolled Crack	Longitudinal	Relatively parallel to & within wheel path; 1 - 5 ft. from joint	Full-Depth, hairline, or spalled	Either	Remove and replace panel or cross-stitch crack	
Uncontrolled Crack	Longitudinal	Relatively parallel to & further than 5 ft. from a longitudinal joint or edge	Full-Depth	Either	Cross-stitch crack	
Spalled sawcut or uncontrolled crack	Longitudinal	Anywhere	Spalled	Either	Partial-Depth Repair	
Uncontrolled Crack	Diagonal	Anywhere	Full-Depth	Either	Full-Depth Repair	
Uncontrolled Crack	Multiple per panel	Anywhere	Two or more full depth cracks dividing panel into 3 or more pieces	Either	Remove and replace panel	

Iowa DOT Construction Manual Appendix 9-6

Spalling - Causes

Distress	Category	Description
Spalling (Material or Chemical)	Heavy application of 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 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.
	Compression Shear	Compression shear from deflection of the slab, lack of load transfer, or lack of subgrade support
	Chipping/Fraying	Early sawing of the joint which chips or frays the edges of the joint.
	Moving Dowels	Dowel bar movement from misaligned dowels.

Joint Deterioration/Spalling



Air Distribution

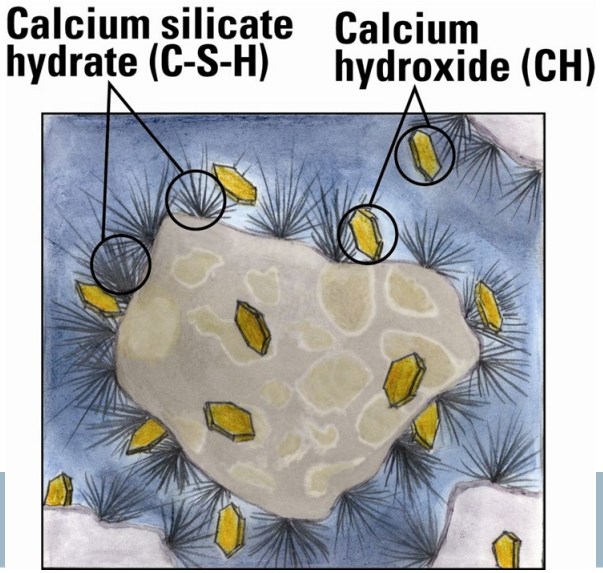
Super Air Meter

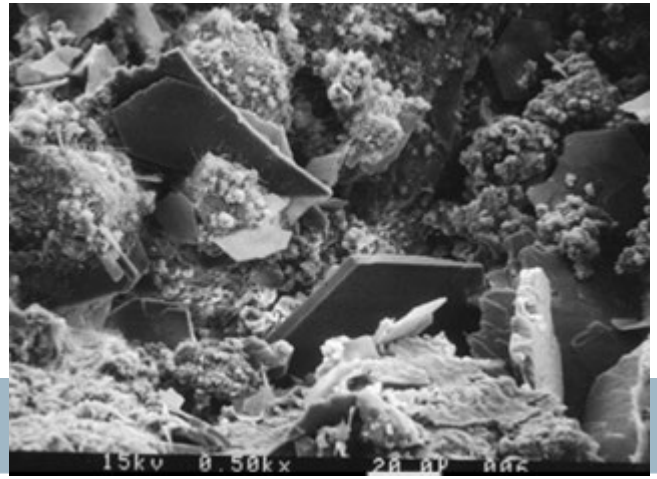
How do we get low permeability?

Use SCMs to tie up CH

Cement
+
Water **=** **C-S-H**
+

SCM + Water + CH = more C-S-H





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COMMON REPAIR METHODS

Partial-Depth Repair

Key Factors for Success

- Proper selection of candidate projects
- Proper material selection
- Identification of repair boundaries
- Use of joint/crack reformers
- Achieving good bond
- Proper placement and curing

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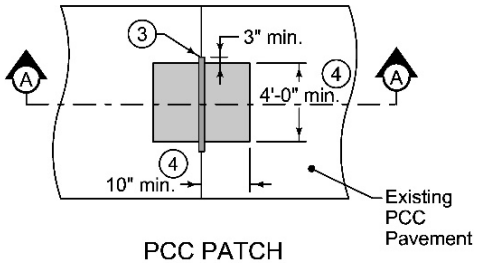
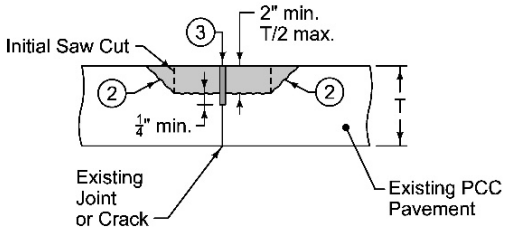
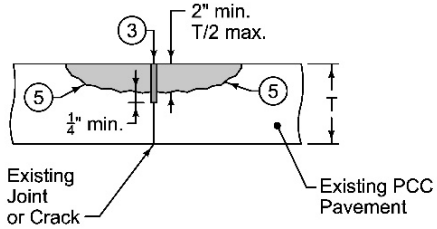
Partial-Depth Repair



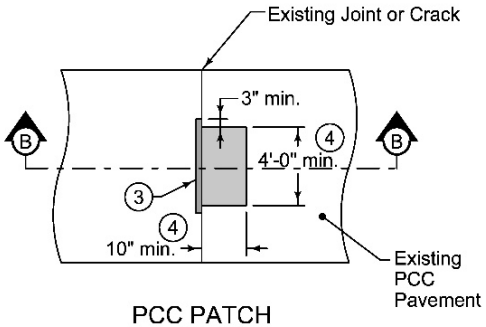
PCC PATCH
ACROSS JOINT



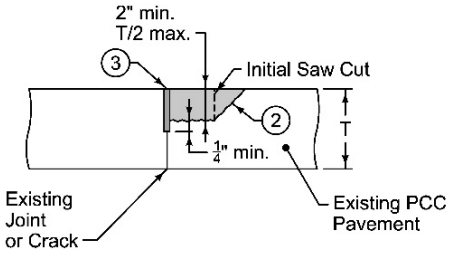
SECTION A-A
(Option 1: Sawed Edges)



SECTION A-A
(Option 2: Milled Edges)

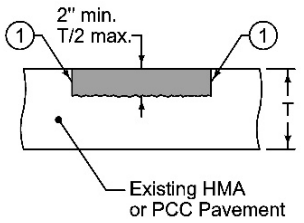


PCC PATCH
ABUTTING JOINT



SECTION B-B

1. Vertical saw cut (typical). Apply tack coat to sides and bottom.
2. Taper the sides of the removal area 30 to 60 degrees from vertical. Apply cement grout to sides and bottom.
3. Saw and seal existing joint.
4. Extend patch limits at least 3 inches beyond distressed area.
5. When milled removal is allowed, sawed vertical edges are not required. Apply cement grout to milled area.



HMA PATCH

FIGURE 7040.104

SHEET 1 OF 1

SUDAS

REVISION	
1	10-17-17

7040.104

SHEET 1 of 1

SUDAS Standard Specifications

PARTIAL DEPTH PATCHES

Partial Depth Repairs
SUDAS & Iowa DOT

- SUDAS (7040) requires compression relief material
- Iowa DOT (2530) allows compression relief boards or sawcutting for patches greater than 6’

- Iowa DOT (2530)
  - Partial Depth Finish Patches < 6’ long
  - Partial Depth PCC Joint and Crack Repair Patches **≥** 6’

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Partial-Depth Repair Steps

1. Sounding
2. Marking Removal
3. Removal
4. Sand & Air Blast

1 

2 

3 

4 

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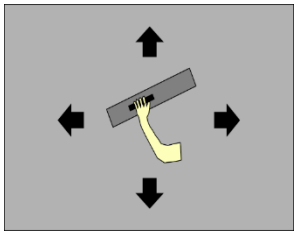
Partial-Depth Repair Steps

5. Compression relief
6. Grout/Epoxy
7. Patch (Grout edge)
8. Curing
9. Joint seal

5 

6 

7 

7 

7 

8 

9 

Partial-Depth Repair Removal Sawing / Jackhammers

- Small to medium walk-behind saw for perimeter cuts
  - Maneuverability
  - Positioning on paint marks

- Select light-weight hammer
  - 15 to 30 pound
  - More control
  - Less fatigue
- Use chisel or narrow spade bit for removal

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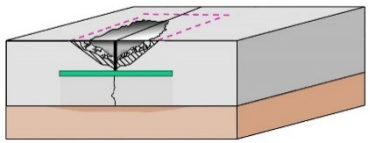
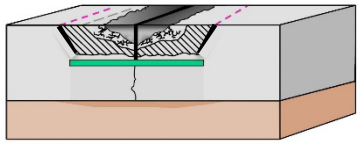
Partial-Depth Repair Removal Milling



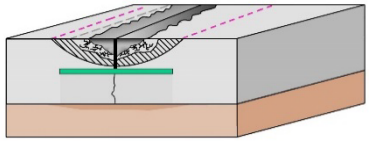
V Head

High Flow Skid Steer



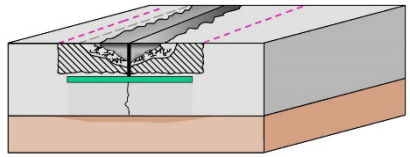
Tapered Head

18K-lb Milling Machine



Rounded Head

18K-lb Milling Machine



Vertical Head

18K-lb Milling Machine

Partial Depth Repair (Over-depth Repairs)

- SUDAS: pay 2 x cost of partial depth repair for full depth repair

- Iowa DOT: pay for over-depth patches area calculated at mid depth of patch in addition to partial depth quantity

Full-Depth Repair

Key Factors for Success

- Removal (4’ min.)
- Dowel bar holes (grout or epoxy)
- Cleaning holes
- Proper material selection
- Proper placement and curing

Figure 6.12. Example of gang drill used for dowel bar installation

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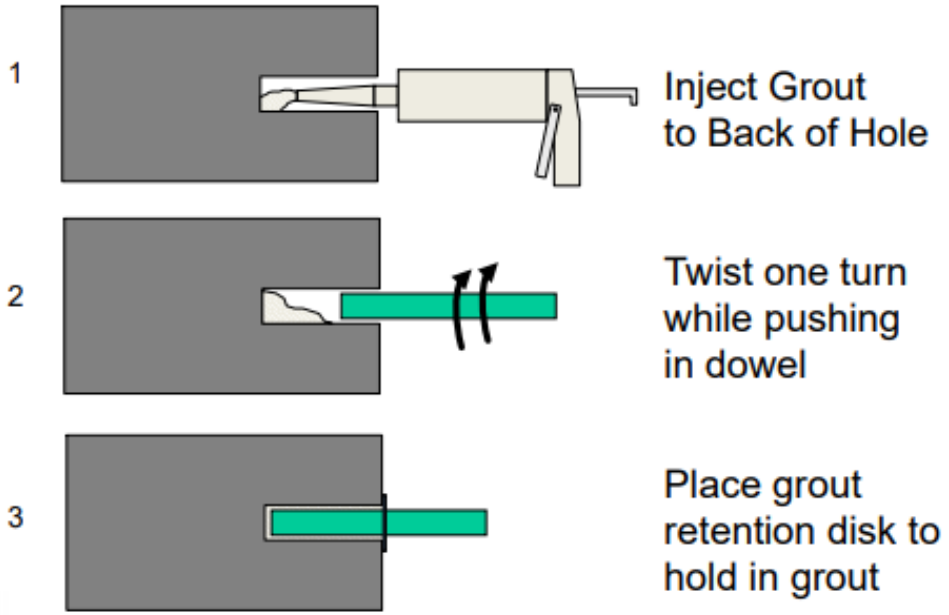
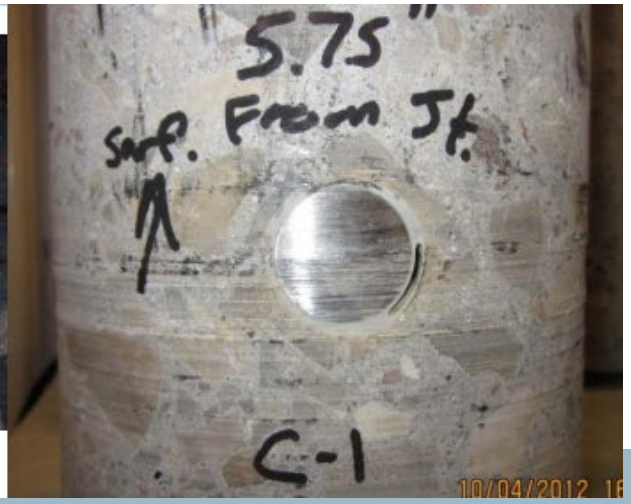
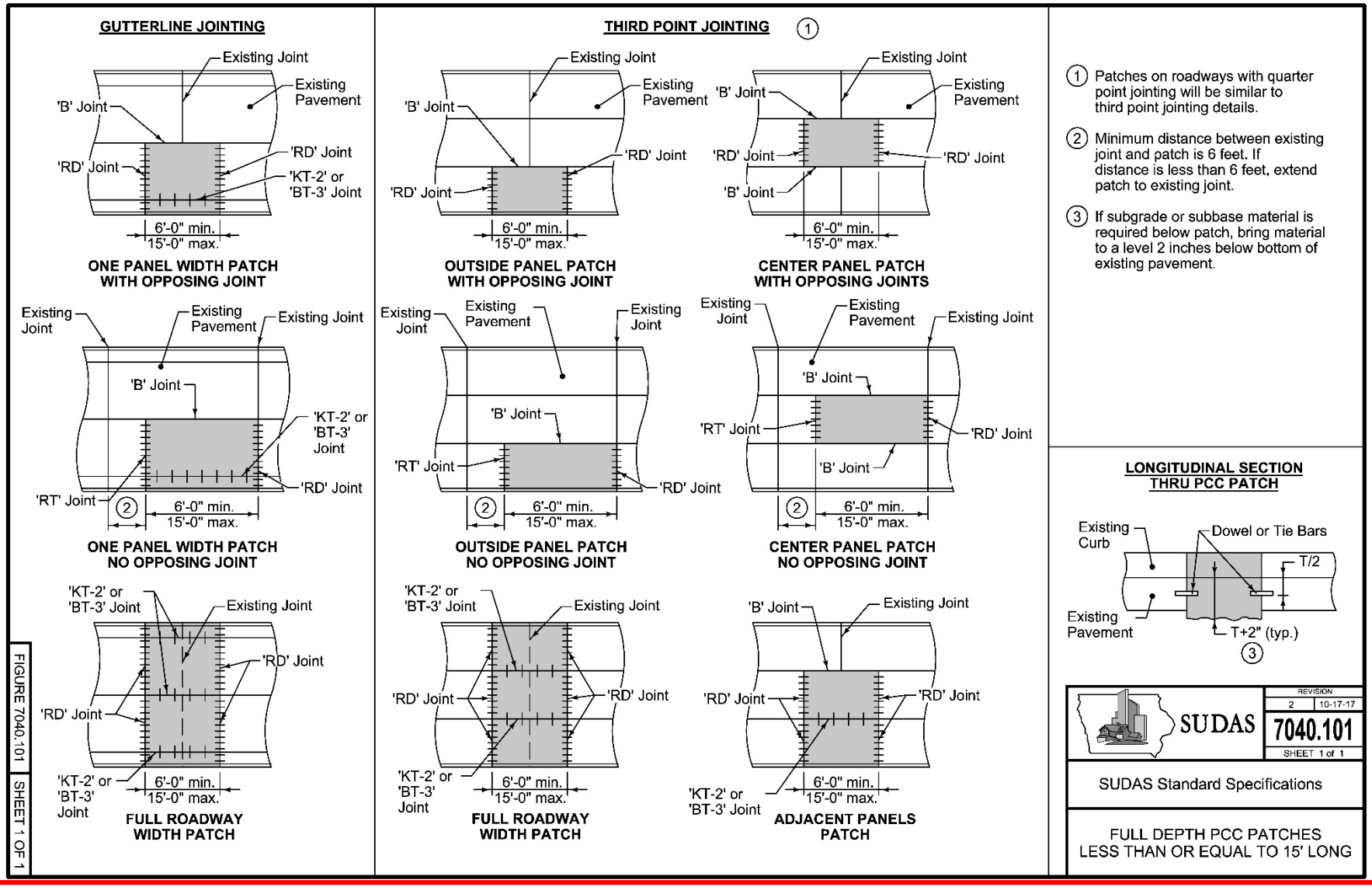
Full Depth Repairs - Construction



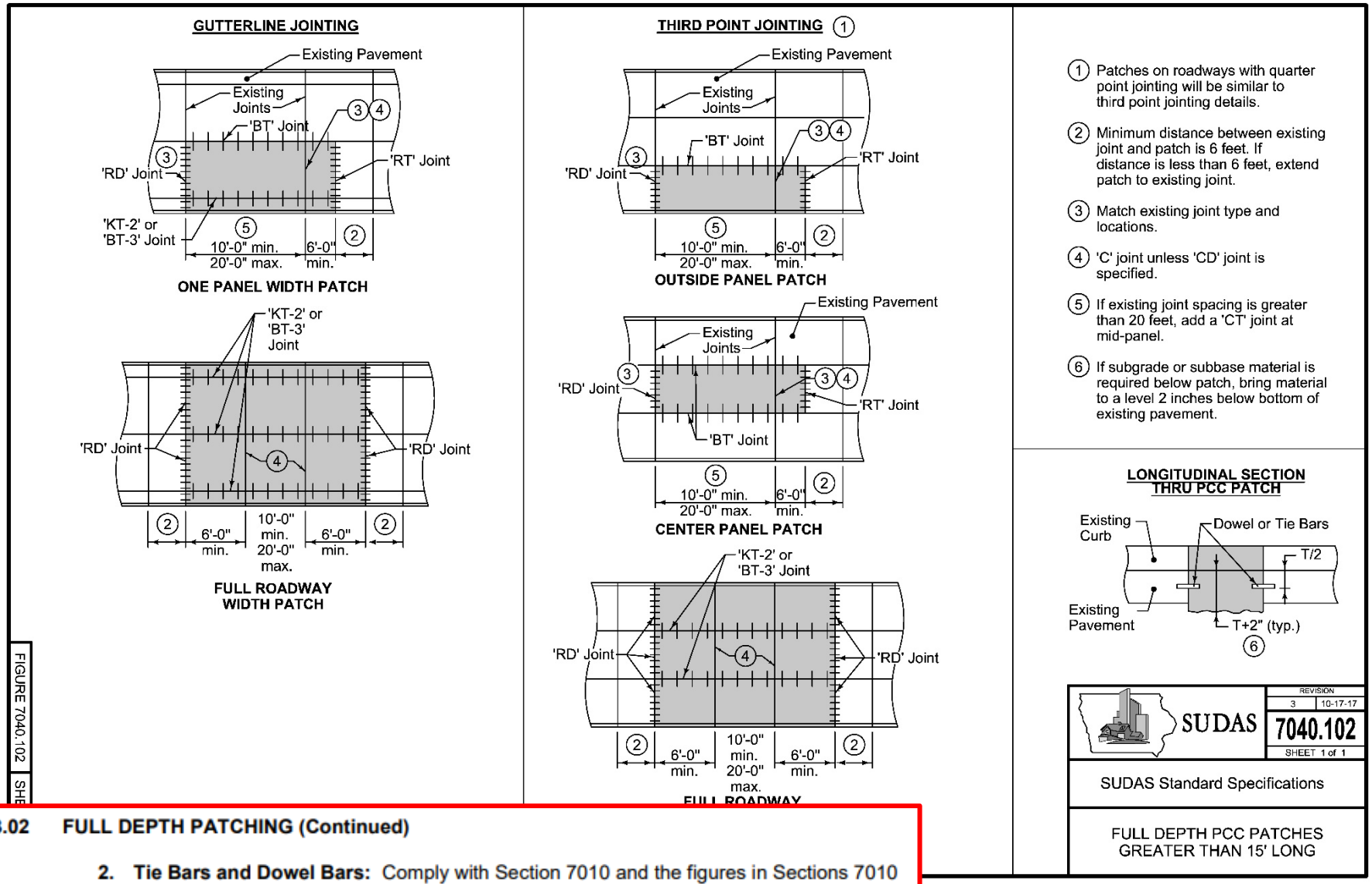


Full-Depth Repair



Iowa DOT: Full Depth Finish Patches By Area & By Area 50'+(SY) and By Count (Each)
SUDAS: By Area (SY)

Full-Depth Repair



3.02 FULL DEPTH PATCHING (Continued)

2. **Tie Bars and Dowel Bars:** Comply with Section 7010 and the figures in Sections 7010 and 7040.
   a. When there is a common line between two adjacent patches, a bent bar may be placed in a keyway and later straightened.
   b. Coat dowel bars extending into the patch area with a bond breaker. Do not coat tie bars.

Full-Depth Repair - Opening

Table 6.6. Minimum Opening Strengths for FDRs (ACPA 2006)

Slab Thickness, mm (in.)	Strength for Opening to Traffic, MPa (lbf/in.²)			
	Repair Length <3 m (10 ft)		Slab Replacements	
	Compressive	3rd-Point Flexural	Compressive	3rd-Point Flexural
150 (6.0)	20.7 (3000)	3.4 (490)	24.8 (3600)	3.7 (540)
175 (7.0)	16.5 (2400)	2.6 (370)	18.6 (2700)	2.8 (410)
200 (8.0)	14.8 (2150)	2.3 (340)	14.8 (2150)	2.3 (340)
225 (9.0)	13.8 (2000)	1.9 (275)	13.8 (2000)	2.1 (300)
250+ (10.0+)	13.8 (2000)	1.7 (250)	13.8 (2000)	2.1 (300)

Concrete Pavement Preservation Guide, Second Edition

Table 7010.01: Minimum Age and Tested Strength of Pavement Before Opening

Class of Mix	Type of Cement	Minimum Age For Opening[1]	Minimum Compressive Strength (psi)	Minimum Flexural Strength Center Point (psi)
C	Type I	7 Days[2]	3,000	500
M	Type I	48 Hours	3,000	500

[1] Opening without testing only allowed upon approval of Engineer
[2] Five calendar days for concrete 9 inches thick or more.

Note: Maturity Testing is not required for FDR

SUDAS Standard Specifications

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Dowel Bar Retrofit

- Restores load transfer
- Reduces probability of pumping, faulting, and corner breaks
- Improves long-term rideability
- Increases service life

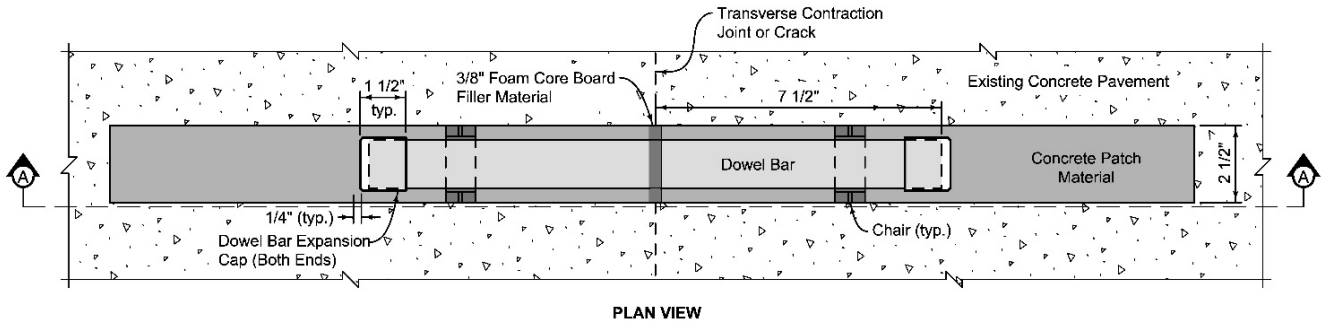
Tech Center

Dowel Bar Retrofit

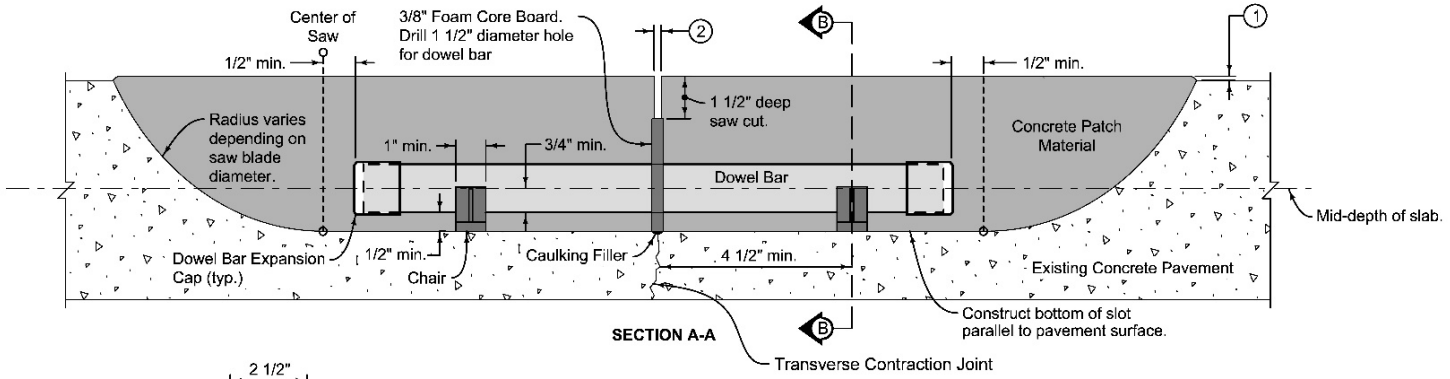
- Need compressible insert
- 3 bars per wheel path, 6 bars per lane, 12” spacing
- 14” min. length

Pavement Thickness (in.)	Dowel Diameter (in.)
8	1.0
8 to 9.5	1.25
≥ 10”	1.5

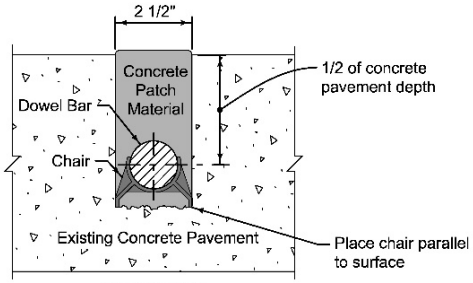
Dowel Bar Retrofit



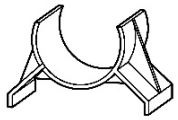
PLAN VIEW



SECTION A-A



SECTION B-B



CHAIR DETAIL

1. Extend concrete patch material 1/8" above existing concrete surface for projects to be diamond ground; construct flush if diamond grinding is not required.
2. Sawcut joint width 3/16" min to 5/16" max. Saw after concrete patch material has set.

FIGURE 7040.106

SHEET 1 OF 1

SUDAS

REVISION	
New	10-17-17

7040.106

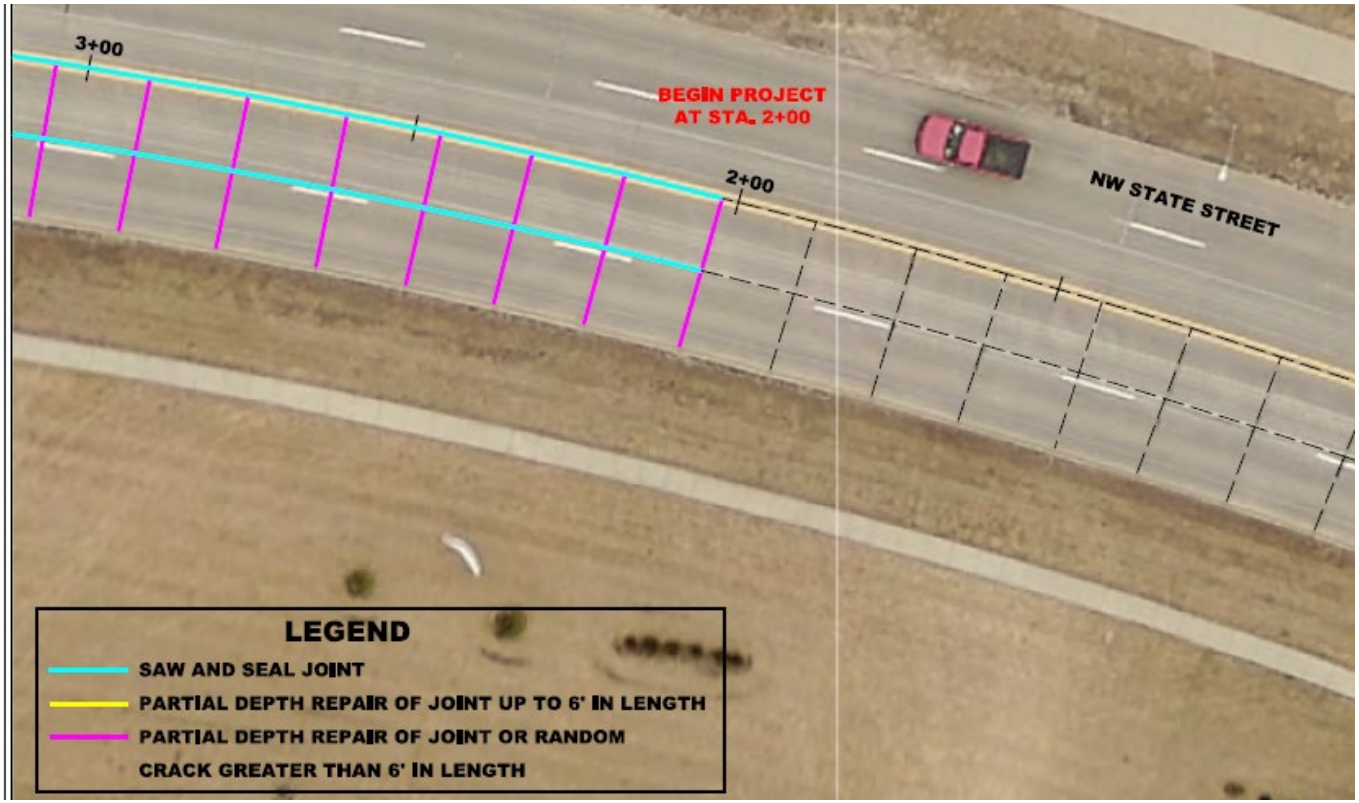
SHEET 1 of 1

SUDAS Standard Specifications

DOWEL BAR RETROFIT

Case Study – NW State St, Ankeny

ITEM NO.	SUDAS NO.	ITEM	UNIT	TOTAL QTY	AS-BUILT QTY
DIVISION 7		STREETS AND RELATED WORK			
7.01	7040-1.08-C	Partial Depth Patches, PCC	SF	1,355	
7.02	7040-1.08-D	Crack and Joint Cleaning and Filling, Hot Pour	LF	1,545	
DIVISION 8		TRAFFIC CONTROL			
8.01	8030-108-A-O	Temporary Traffic Control	LS	1	
8.02	Special	Portable Dynamic Message Signs (PDMS)	CDAY	5	
DIVISION 11		MISCELLANEOUS			
11.01	11,020-1.08-A	Mobilization	LS	1	



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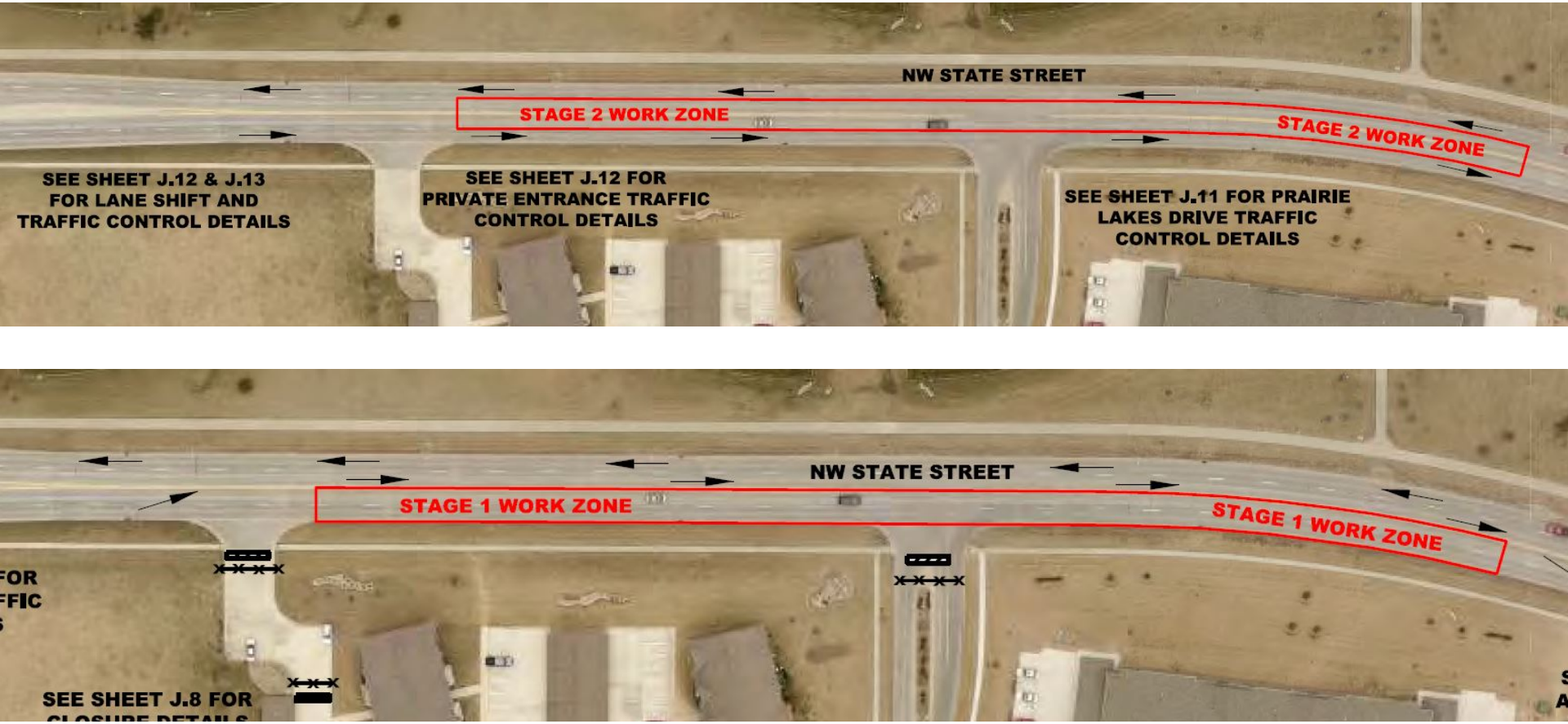
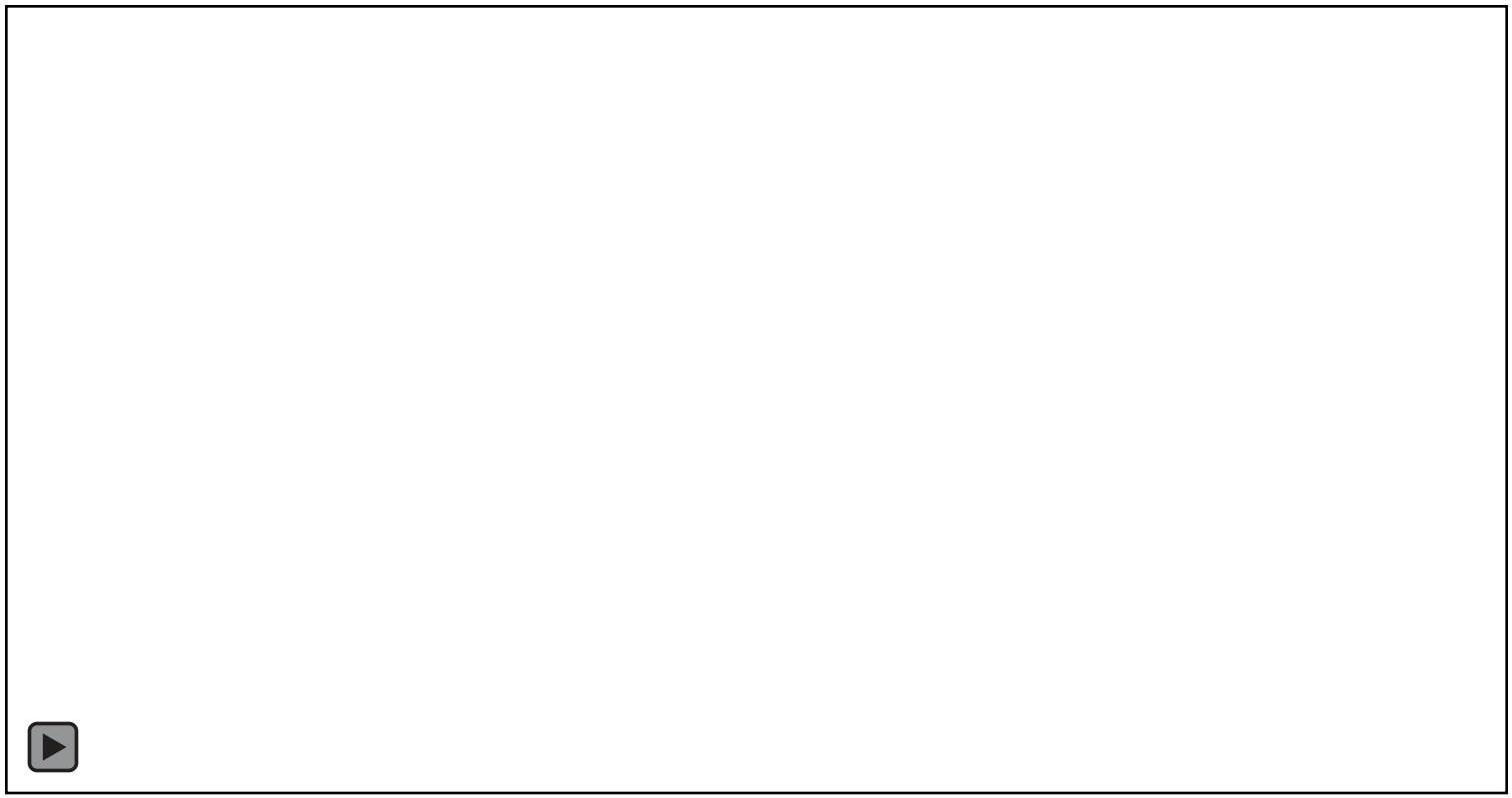
Credit: Adam Lust, City of Ankeny

Case Study – NW State St, Ankeny



Credit: Adam Lust, City of Ankeny

Case Study – NW State St, Ankeny



Credit: Adam Lust, City of Ankeny

Case Study – NW State St, Ankeny

Credit: Adam Lust, City of Ankeny

CASE STUDY – Asbury Rd, Dubuque

- CONSTRUCTED IN 1991, 0.50 MILE IN LENGTH
- ROADWAY WIDTH OF 41’ BOC , 8” PCC NO DOWELS
- ADT = 7,300 - 7,700
- DOWEL BAR RETROFIT, FULL DEPTH REPAIR, DIAMOND GRINDING AND CLEAN JOINTS / SEAL
- FIRST OF ITS KIND FOR THE CITY
- MARCH 5, 2015, ESTIMATE: $334,510
- 3 BIDS: $317,620 - $347,500
- 45 WORKING DAY CONTRACT
- ❖ FAVORABLE BID - UNIT PRICES ALLOWED CITY TO ADD ADDITIONAL REHAB TO CENTER TURN LANE, ADDITIONAL FULL DEPTH REPAIRS, AND JOINT SEALING

CP Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – Asbury Rd, Dubuque

Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – Asbury Rd, Dubuque

Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – Asbury Rd, Dubuque

Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – Asbury Rd, Dubuque

DIAMOND GRINDING

- SUDAS SPECIFICATION FOR RIDEABILITY - 22 INCHES/MILE
- WESTBOUND **BEFORE** = 42.96 (INCHES/MILE)
  - ✓ WESTBOUND **AFTER** = 12.36 (INCHES/MILE)
- EASTBOUND **BEFORE** = 53.33 (INCHES/MILE)
  - ✓ EASTBOUND **AFTER** = 10.61 (INCHES/MILE)
- CENTER TURN LANE **BEFORE** = 37.71 (INCHES/MILE)
  - ✓ CENTER TURN LANE **AFTER** GRINDING = 13.38 (INCHES/MILE)

CP Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – Asbury Rd, Dubuque

COMPLETED PROJECT - DETAILS

▪ PROJECT COMPLETION:	29 WORKING DAYS 45 DAY CONTRACT	
▪ FINAL CONSTRUCTION COST:	$354,822	$31 / SY
▪ TOTAL PROJECT COST: INCLUDES: DESIGN, CONSTRUCTION, INSPECTION	$400,791	$35 / SY
▪ DOWEL BARS INSTALLED:	3,300	
▪ FULL DEPTH PATCHES, PCC:	350 SY	
▪ DIAMOND GRINDING:	11,600 SY	
▪ TRAFFIC CONTROL:	$37,000	

CP Tech Center

Credit: Robert Schiesl, City of Dubuque

CASE STUDY – West Des Moines

Investigation

Design

- Plans
- Standard Specification
- Standard detail

Construction

Credit: Jeff Nash, City of West Des Moines

CASE STUDY – US 30, Denison

Pavement Condition

- Joint Spalling
- Corner cracks
- Low friction
- Previous patches

Patching & Dowel bar Retrofit

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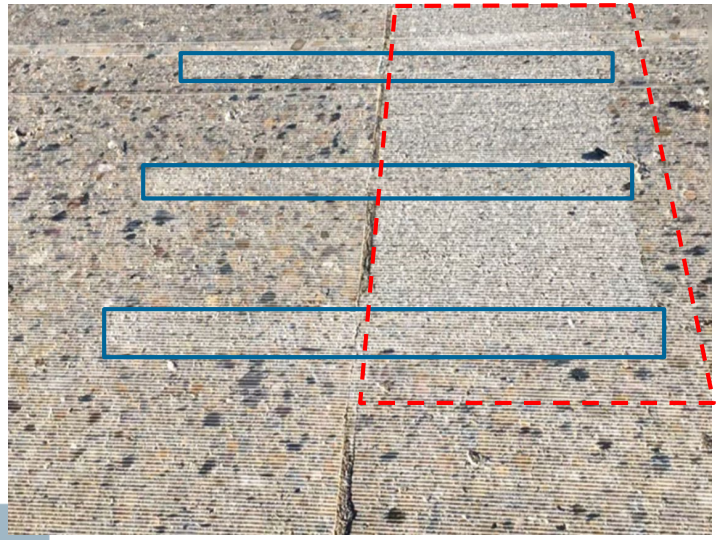
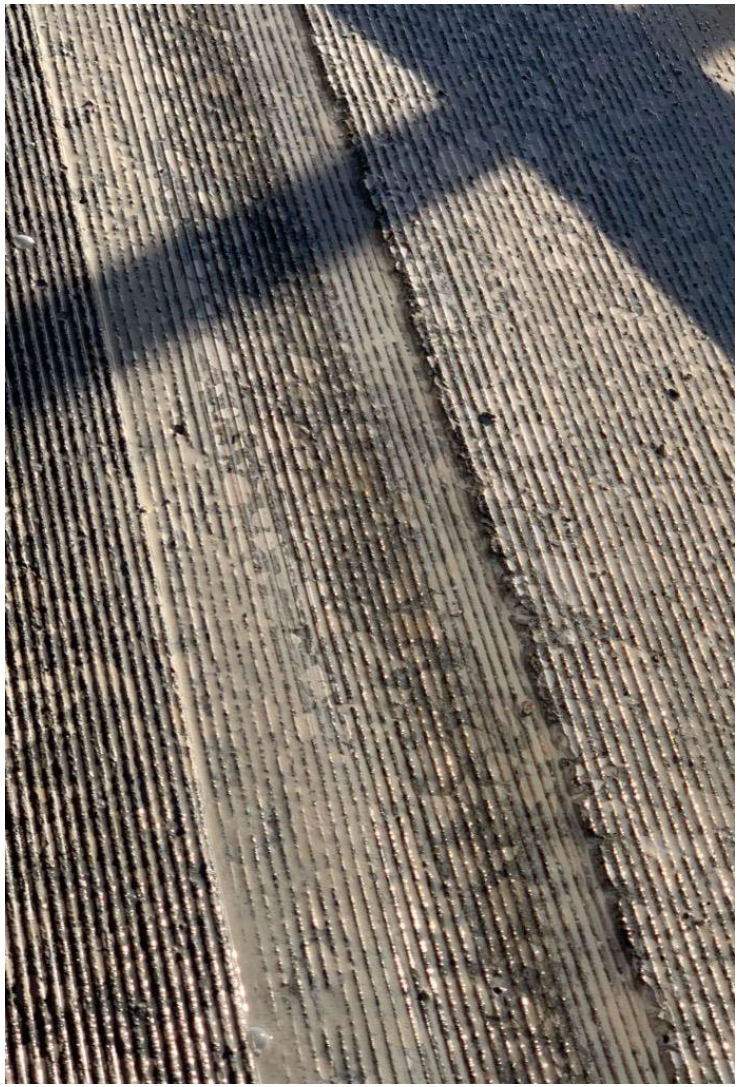
CASE STUDY – US 30, Denison





Dowel bar retrofit and diamond grinding

CASE STUDY – US 30, Denison

- Previous IRI – 277 inches/mile (2017)
- New IRI – 116.7 inches/mile
- Previous PCI – 18 (very poor)
- Estimated new PCI – 87 (good)

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Table 12.3. Concrete Pavement Preservation Treatments Based on Distress (adapted from Hall et al. [2001]).]

	Concrete Pavement Preservation Treatment											
Distress	Slab Stabilization	Slab Jacking	Partial-Depth Repair	FDR	Retrofitted Edgedrains	DBR	Cross Stitching/ Slot Stitching	Diamond Grinding	Diamond Grooving	Joint Resealing	Crack Sealing	Thin Concrete Overlay
Corner breaks			✓	✓							✓ [a]	
Linear cracking				✓			✓ [b]				✓ [a]	
Punchouts				✓								
D-cracking				✓ [c]								✓ [c]
Alkali-aggregate reaction				✓ [c]								✓ [c]
Map cracking, crazing, scaling			✓									✓
Joint seal damage										✓		
Joint spalling			✓	✓								✓
Blowup				✓								
Pumping	✓				✓	✓	✓					
Faulting						✓		✓				✓
Bumps, settlements, heaves		✓		✓				✓				✓
Polishing/ low friction								✓	✓			✓

Bid Prices

- Patch, Partial Depth Repair, PCC: $25-30/SF
- Patch, Full depth Repair: $100-130/ SY
- Dowel Bar Retrofit: $35-$40 EA
- Partial Depth PCC Joint and Crack Repair Patches- $35/ LF
- Pavement Surface Repair (Grind Limestone): $3-4/SY
- Pavement Surface Repair (Grind Gravel): $5-$6/SY
  (Slurry Management will add $)
- Crack & Joint Clean & Fill: $1.00 - $1.50 per foot
- Sealer Material: $1 per pound (6500-7000 lbs per mile)
- Mobilization: (5-8%) Varies by project

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Iowa DOT Bid Express (average prices)

THANK YOU!

Representing the National Concrete Pavement Technology Center