Full- and Partial-Depth Repair of Continuously Reinforced Concrete Pavement

TxDOT Implementation Project 5-9045-5-P1

Moon Won
Texas Tech University
Outline

• CRCP Behavior and Performance
• Full-Depth Repair (FDR)
• Partial-Depth Repair (PDR)
CRCP Behavior and Performance

• **Deflections** and, to a lesser degree, load transfer efficiency (LTE) at transverse cracks are the key to CRCP performance.
CRCP Behavior and Performance

• Deflections and, to a lesser degree, load transfer efficiency (LTE) at transverse cracks are the key to CRCP performance.

• Control of deflections by steel reinforcement, adequate slab support and slab thickness
Overall Performance of CRCP in Texas

- Punchout: 1 per 8.8 lane miles
- Concrete Patch: 1 per 4.6 lane miles
- Asphalt Patch: 1 per 88 lane miles
Large Surface Defects: 46.6%
True Punchouts: 14.2%
Construction Joints: 20.7%
Repair Joints: 18.5%
FULL-DEPTH REPAIR OF CRCP
Full-Depth Repair of CRCP

• Conduct only when needed. (i.e., when CRCP distress extends through the slab depth)
• If distresses are limited to the top half of the slab, use partial-depth repair.
Key to Successful Full-Depth CRCP Repairs

- **Lower deflections** at transverse repair joints
- **Sound base support** along the perimeter of repair areas
Evaluation of the Performance of FDRs

Deflection Testing using FWD

FDR section

10 ft 10 ft 10 ft 10 ft
Inside Lane

Outside Lane

Point #

Deflection [mils]
Welded

Epoxy

Inside Lane

Outside Lane

P1  P2  P3  P4  P5  P6  P7  P8  P9  P10  P11  P12

Point #

Deflection [mils]

P1  P2  P3  P4  P5  P6  P7  P8  P9  P10  P11  P12

Deflection [mils]
Outside Lane

Half moon crack

Point #

Deflection [mil]
Outside Lane

Point #

Deflection [mil]
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Important Findings

• Deflections at **transverse repair joints** are **higher** than those at other areas, which explains poor performance of FDRs.

• Efforts should be made to strengthen transverse repair joints.
Amarillo IH 40

- 9-in CRCP + 600 #/SY ASB
- Completed in 1979
PLANS OF PROPOSED
STATE HIGHWAY IMPROVEMENT
CARSON AND GRAY COUNTIES
INTERSTATE HIGHWAY 40
FROM: 2.0 MI. WEST OF GROOM
TO: 2.0 MI. EAST OF GROOM
FEDERAL AID PROJECT 140-1(99)110
GRADING, STRUCTURES, FLEXIBLE BASE, ASPHALT
STABILIZED BASE, ASPH. CONC. PAV. & CONCRETE PAVEMENT
(UNIT II CONSTRUCTION)

TOTAL NET LENGTH OF PROJECT = 29.33133FT. = 5,655.56MI.
NET LENGTH OF CONTROL 275-6-45 = 22.62756FT. = 4,497MI.
NET LENGTH OF CONTROL 275-5-19 = 6,643.37FT. = 1,256MI.

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

Jack O. Light
DISTRICT ENG'T.

[Signatures and dates]
TYPICAL SECTION NO. 2 - EAST BOUND LANES

To be used between the following Stations: 1438 + 00 to 1452 + 00
1705 + 00 to 1729 + 9065
Slab Thickness vs Deflections

Deflection @ 9,000 lbs [mils]

Slab Thickness (in)
L5

Geophone Location (inch)

Deflection (mils)

Shoulder 1
Shoulder 2
Shoulder 3
Shoulder 4
Large Crack Spacing

Geophone Location (in)

Deflection (mils)

- L1_1
- L1_2
- L1_3
- L1_4
- L1_5
- L2_1
- L2_2
- L2_3
- L2_4
- L2_5
Medium Crack Spacing

Geophone Location (in)

Deflection (mils)
Small Crack Spacing

Geophone Location (in)

Deflection (mils)

S1_1
S1_2
S1_4
S1_5
S2_1
S2_2
S2_4
S2_5
Review of Specifications Item 361
361.3. Construction.

Epoxy-grout all tiebars for at least a 12-in. embedment into existing concrete. **Completely fill the tiebar hole with Type III, Class A or Class C epoxy before inserting the tiebar into the hole.**
Existing Pavement

- Left
- Mid-left
- Mid-right

Full depth repair section

7.5" 11.0" 11.0" 13.0" 11.5" 12.5" 11.0" 14.5" 10.0" 11.0" 13.0" 12.0" 13.0" 10.0"

13' – 5'
THE STEEL SPACING FOR CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP) AND JOINTED REINFORCED CONCRETE PAVEMENT (JRCP) SHALL BE REINFORCED AS SHOWN IN TABLE NO. 1.

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<thead>
<tr>
<th>TYPE OF REINFORCEMENTS</th>
<th>TYPE PAVEMENT</th>
<th>PAVEMENT THICKNESS (INCHES)</th>
<th>TIEBARS</th>
<th>REGULAR REBARS</th>
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8-in CRCP
8-in CRCP

3-in AC Overlay

8-in CRCP

3-in AC Overlay

8-in CRCP
8-in CRCP

3-in AC Overlay

8-in CRCP

3-in AC Overlay

8-in CRCP
Coring

3-in AC Overlay

8-in CRCP
361.3. Construction.

Provide grout retention disks for all tiebar holes.
Remove or repair loose or damaged base material, and replace or repair it with approved base material to the original top of base grade. Place a polyethylene sheet at least 4 mils thick as a bond breaker at the interface of the base and new pavement. Allow concrete used as base material to attain sufficient strength to prevent displacement when placing pavement concrete.
Remove or repair loose or damaged base material, and replace or repair it with approved base material to the original top of base grade. Place a polyethylene sheet at least 4 mils thick as a bond breaker at the interface of the base and new pavement. Allow concrete used as base material to attain sufficient strength to prevent displacement when placing pavement concrete.
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361.3. Construction.

dowel bars in place. Demonstrate, through simulated job conditions, that the bond strength of the epoxy-grouted tiebars meets a pullout strength of at least 3/4 of the yield strength of the tiebar when tested in accordance with ASTM E 488 within 18 hr. after grouting. Increase embedment depth and retest when necessary to meet testing requirements. Perform tiebar testing before starting repair work.
Drill-Epoxy Evaluations

• Test procedures
• Preliminary test
• Main test
Drill a hole

Clean a hole

Clean a hole

Remove stain on a rebar
Exposed part

Embedded part

Fill the hole with epoxy
Insert a rebar in the hole

Grout a rebar with epoxy

Prevent the epoxy leak

Steel plate
Apply pressure

LVDT

The pulled out length
Preliminary test
Experimental factors

- Used #6 rebar for all tests
- Compressive strength of concrete at testing day: 8,485 and 8,274 psi

- Quantity of epoxy
- Curing time of epoxy
- Hole condition
Test 1
- 1 Hour curing
- Enough epoxy

Test 2
- 1 Hour curing
- Not enough epoxy
Hole condition
Hole condition

Displacement [in.]

Steel Stress [psi]

Clean

Dirty

Steel Stress [psi]

Displacement [in.]
Main test
Dirty and clean hole

![Graph showing steel stress vs. displacement for dirt and clean conditions.]

- **Steel stress [psi]**
  - Dirty line (red)
  - Clean line (blue)

- **Displacement [in.]**
Specification method
Non-compliance
Put more epoxy on rebar of Non-compliance

Non-compliance 1

Non-compliance 2
Epoxy injecting method

![Graph showing steel stress vs displacement for Field 1 and Field 2 with specification line.]
Embedded depth

![Graph showing displacement vs. steel stress for different embedded depths. The graph includes lines for 3 in., 6 in., 9 in., 12 in., and 15 in. embedded depths. The y-axis represents steel stress in psi, ranging from 0 to 100,000, and the x-axis represents displacement in inches, ranging from 0 to 0.5. The lines for each depth show the relationship between displacement and steel stress, with 3 in. having the highest stress at any given displacement and 15 in. having the lowest.](image-url)
Different epoxy
Gage analysis
Existing Pavement

Left  Mid-left  Mid-right

7.5"  11.0"  11.0"  13.0"  11.5"  12.5"  11.0"  14.5"  10.0"  11.0"  13.0"  12.0"  13.0"  10.0"

161.0"

Full depth repair section

■ : SSG
- - - - - : Tiebar with SSG
- - - - - - : Tiebar without SSG
- - - - - - - - : Longitudinal rebar in FDR section

Layout of gage installation
Other Issues with FDRs
Non-Compliance with Specifications

Existing pavement

Transverse joint

Existing rebar

Full depth repair section

Longitudinal rebar in FDR section

New tiebar
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<th>PAVEMENT THICKNESS (INCHES)</th>
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No compaction on loose base
Insufficient epoxy
No transverse tiebars
Use only drilling operations that do not damage the surrounding operations. Place new deformed reinforcing steel bars of the same size and spacing as the bars removed or as shown on the plans.
PARTIAL-DEPTH REPAIR OF CRCP
Partial-Depth Repair of CRCP

• Ideal for distresses that are limited to the top half of the slab in CRCP
• Ensuring good bond between existing CRCP and repair materials is a key to good performance.
SPECIAL SPECIFICATION

Partial Depth Repair of Concrete Pavement

1. **Description.** Repair concrete pavement to partial depth in accordance with the details shown on the plans and the requirements of this Item.

2. **Materials.** Provide materials that meet the pertinent requirements of the following:
   
   - Item 360, “Concrete Pavement”
   - Item 421, “Hydraulic Cement Concrete”
   - Item 440, “Reinforcing Steel”
   - DMS 6100, “Epoxies and Adhesives.”

   If material in Item 421 does not meet the strength requirement, provide material that meets the requirements in DMS-4655, “Rapid-Hardening Cementing Materials for Concrete Repair”

3. **Equipment.** Provide tools and equipment necessary for proper execution of the work that meet the pertinent requirements of the following:
   
   - Item 360, “Concrete Pavement”
   - Item 429, “Concrete Structure Repair”
Summary
- Full-Depth Repairs -

- Establishing solid bond in tie bars
  - Spec requirements: fill holes with epoxy, minimize drain downs using grout retention disks

- Drilling holes
  - Hammer drill, rotary drill, core drill
  - At mid-depth or below the mid-depth if needed, but not above

- Tie bar or longitudinal bar spacing
  - Should be the same as in the existing CRCP.
Summary

- Full-Depth Repairs -

• Establishing solid base
  o Spec requirements: remove loose materials & replace with concrete
Summary

- Partial-Depth Repairs -

• Good candidate for distresses for US 75 and IH 30
  o Still under evaluations

• Establishing good bond bet’n old and new concrete
  o Hook bars

• Other good concreting practices