Unbonded CRCP Overlays

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• Mike Plei
  – CMC Group

CRCP CRACKING PATTERN

Presentation Overview

• CRCP in heavy traffic areas in Illinois
• CRCP Unbonded Overlay Basics
• Review of CRCP Overlay Projects
• Key design issues for CRCP overlays
• Illinois Experience with Unbonded CRCP
• Summary

Example Urban CRCP

• Illinois experience:
  – I-90/94 Dan Ryan Expressway – Chicago
  – Other projects

• I-95 Georgia experience
**Extended -Life CRCP Design**

**Illinois DOT (2005)**

- CRCP
  - 40 Year
  - 0.8% Steel Epoxy Coated
- Bituminous Base
- Aggregate Working Platform

**Dan Ryan Expressway, I-90/94 (2007)**

- 6 in.
- 40 Year CRCP

**I-90/94 Dan Ryan Expressway Chicago**

- Original CRCP design (1961)
- 2006-2008 reconstruction for 500 million ESALs and 40 year life.
  - Slab thickness = 14-in
  - Steel content = 0.80%
  - Steel depth = 4.5-in
  - Tied JPCP shoulder
  - 4-in dense graded HMA
  - Min. 12-in granular subbase
  - Fine grained subgrade (A-6 soil)

**CRCP – Dan Ryan Expressway 40 Year**

**Illinois State Toll Highway Authority**

**I-294 Chicago (2005)**

- 5 mile project (I-80 to Indiana)
- CRCP design ESALs= 175 million (40 yrs)
  - 12-in CRCP
  - 0.75% steel
  - Depth of steel = 3.5-in
  - Tied JPCP shoulder
  - 4-in dense HMA base
  - 12-in granular subbase (PGE)
  - Fine grained subgrade (A-6 soil)
Illinois State Toll Highway Authority  
**I-294 (2008-2009)**

- 12.5 mile project (I-80 to 95th)
- CRCP design ESALs = >60 million (40 yrs)
  - 13-in CRCP
  - 0.75% steel
  - Depth of steel = 3.5-in
  - Tied JPCP shoulder
  - 3-in dense HMA base
  - 24-in recycled concrete aggregate subbase
  - Fine grained subgrade (A-6 soil)

Other Illinois DOT CRCP Projects  
“Extended Life”

<table>
<thead>
<tr>
<th>Route</th>
<th>Location</th>
<th>Year</th>
<th>Overlay Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-70*</td>
<td>Marshall</td>
<td>2002</td>
<td>12in CRCP, 5in HMA, 8in CRCP</td>
</tr>
<tr>
<td>I-80*</td>
<td>Morris</td>
<td>2003</td>
<td>14in CRCP, 6in HMA, 12in CRCP</td>
</tr>
<tr>
<td>I-290</td>
<td>Schaumburg</td>
<td>2003</td>
<td>14in CRCP, 6in HMA, 24in Aggregate</td>
</tr>
<tr>
<td>I-74</td>
<td>Peoria</td>
<td>2006</td>
<td>11.5in CRCP, 6in HMA, 12in Aggregate</td>
</tr>
</tbody>
</table>

Continuous Reinforced Pavements

- No man-made “joints”
- Steel reinforcement bars
- Numerous transverse cracks

Unbonded Concrete Overlay

- Asphalt Concrete Interlayer

Unbonded CRCP Overlay Objective

- Isolate excessive movement of existing pavement from concrete overlay
- Limit concrete distress reflection into concrete overlay
- Provide uniform support to overlay

Concrete Overlay Stress Distribution

Khazanovich et al. 2002
CRCP Unbonded Overlays

General Overview

- Existing pavement condition is fair to poor
- Asphalt separator layer or “bond-breaker”
  - Friction layer that provides uniformity
  - Durable, moisture insensitive layer
  - Allows deflection profiles of two concrete layers to be independent
- Roadway & roadside geometrics
  - shoulders, ramps, guardrail modifications

Overlay Comparisons

<table>
<thead>
<tr>
<th>Bonded Concrete Overlays (BCOs)</th>
<th>Unbonded Concrete Overlays (UBOLs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Overlay on Intact CRCP</td>
<td>HMA Overlay on Rubblized CRCP</td>
</tr>
</tbody>
</table>

- **Constructability**
  - Vertical Clearance
    - Bonded: Not a problem (typically 50 to 100 mm (2-4 inches) thick)
    - Unbonded: May be a problem (typically 180 to 250 mm (7 to 10 inches) thick)
    - Unbonded depends on overlay thickness
  - Traffic Control
    - Bonded: May be difficult to construct under traffic
    - Unbonded: May or may not be a problem, depends on the overlay thickness
  - Construction
    - Bonded: Special equipment and experienced operators needed
    - Unbonded: No special equipment required

- **Performance**
  - Existing CRCP Condition
    - Bonded: Good condition with no MRD
    - Unbonded: All conditions, good to bad
  - Extent of Repair
    - Bonded: Repair all deteriorated joints and cracks
    - Unbonded: Repair limited to severe damage
  - Future Traffic
    - Any traffic level
  - Historical Reliability
    - Bonded: Fair to Poor*
    - Unbonded: Good, Good to Poor, depending on the support

- **Cost**
  - Initial Cost
    - Bonded: Depends on pre-overlay repair, but usually high
    - Unbonded: Higher than conventional HMA overlay
  - Life Cycle Cost Analysis (LCCA)
    - Bonded: Competitive if future life is substantial
    - Unbonded: Cost-effective unless the pavement is in poor condition

Unbonded CRCP Overlays

**Abridged History**

- 600 miles of CRC Overlays (6 to 9-inches) since 1959 (CRSI 1988)
  - Waco, TX first CRCP overlay (CRSI 1973)
  - IN, MD, MS, TX, OR, IL, PA, ND, IA, CT (PCA 1976)
- Oregon DOT (e.g., 1970 to 1975)
  - 4 projects (29.6 miles)
- TxDOT (e.g., 1972-present) > 10 projects
- Illinois DOT (1967-present) - 7 projects

Oregon I-5 CRCP Overlay

(1970-1975)

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>Original</th>
<th>Fatigue</th>
<th>Joint Design</th>
<th>Actual Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oregon</td>
<td>1970</td>
<td>6-in</td>
<td>3.7 (truck of 5-39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>1970</td>
<td>6-in</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>1970</td>
<td>6-in</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>1970</td>
<td>6-in</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TxDOT Experience**

- I-35W Johnson County (1965)
  - 6-inch CRCP over 9-inch JPCP
  - ADT=22,000 w/ 14% trucks
  - 8.78 mile section
- I-45W Galveston area (1972-1976)
  - 6-inch CRCP over JPCP
  - ADT=50,000
  - 15.5 mile total section (4 projects)
Recent TxDOT Projects
CRCP Overlays

1. IH-30 in Paris District: existing pavement is JPCP
2. IH-45 in Dallas District: existing pavement is JPCP.
3. IH-35 in Wichita Falls District: existing pavement is CRCP.
4. IH-45 in Houston District: existing pavement is JPCP.
5. IH-20 in Fort Worth District: existing pavement is CRCP.
6. IH-20 in Tyler District:
7. IH-20 in Beaumont District: existing pavement is JRCP.
8. IH-35W in Fort Worth District: existing pavement is JPCP.

from Moon Won

Arkansas DOT Experience

- I-40/55 West Memphis (1972)
  - 6-inch CRCP over 9-inch JPCP
  - ADT=27,000 w/ 25% trucks (1986)
  - 1.7 mile section
- I-55 West Memphis (1980)
  - 6-inch CRCP over 9-inch JPCP
  - ADT=26,600 w/ 28% trucks (1986)
  - 2.2 mile section

Unbonded CRCP Overlays
Issues

1. Assessing existing pavement conditions
2. Interlayer type and thickness
3. Overlay structural design
4. Pre-overlay repairs (?)
5. Construction specifications and details

Condition Survey Information

- Failures / mile
- Deflection or PSI
- Drainage condition
  - Interlayer or subbase erosion

CRCP Structural Evaluation

<table>
<thead>
<tr>
<th>Component</th>
<th>Current Status</th>
<th>Excellent</th>
<th>Good</th>
<th>Fair</th>
<th>Adequate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punchouts</td>
<td>&lt; 10/100</td>
<td>&lt; 10/100</td>
<td>&gt; 10/100</td>
<td>&gt; 10/100</td>
<td>&gt; 10/100</td>
</tr>
<tr>
<td>Patch failures</td>
<td>&lt; 20%</td>
<td>&lt; 20%</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
</tr>
<tr>
<td>Interlayer</td>
<td>&lt; 15</td>
<td>&lt; 15</td>
<td>&gt; 15</td>
<td>&gt; 15</td>
<td>&gt; 15</td>
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<tr>
<td>Primary</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
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<tr>
<td>Secondary</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
<td>&gt; 20</td>
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<tr>
<td>Masticated joint</td>
<td>&lt; 10</td>
<td>&lt; 10</td>
<td>&gt; 10</td>
<td>&gt; 10</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>Materials related</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resurfacing Threshold Values

- TxDOT
  - < 1.2 failures/km/yr (2 failures/mi/yr) allowed for thin HMA overlay used
  - 1.2-1.9 failures/km/yr (2-3 failures/mi/yr) allowed for BCOs
  - > 1.9 failures/km/yr (3 failures/mi/yr) allowed for UBOLs

(MEPDG 2004)
CRCP Pre-overlay repairs

<table>
<thead>
<tr>
<th>Distress Types</th>
<th>Repair Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide transverse cracks with significant</td>
<td>FDR</td>
</tr>
<tr>
<td>differential deflection</td>
<td></td>
</tr>
<tr>
<td>Pavement</td>
<td></td>
</tr>
<tr>
<td>Unstable slabs with large deflections</td>
<td>FDR, slab stabilization</td>
</tr>
<tr>
<td>Placing/stabilization</td>
<td></td>
</tr>
<tr>
<td>Punishing/Fauling (&gt; 6 mm (0.25 in))</td>
<td>Retrofit edge drains</td>
</tr>
<tr>
<td>Settlement</td>
<td></td>
</tr>
<tr>
<td>Settlement</td>
<td></td>
</tr>
<tr>
<td>Materials related durability problems:</td>
<td></td>
</tr>
<tr>
<td>D-cracking or reactive aggregate</td>
<td></td>
</tr>
</tbody>
</table>

Interlayer or Separation Layer Properties

- Dense-graded HMA
  - Provide interface friction for crack development
  - >1 inch thickness to level up
  - Greater distress requires > interlayer thickness
- Interlayers with performance issues
  - PE sheeting, chip seals, slurry seal, or curing compound, open-graded AC
  - Erodible/stripping, not resistant to reflective cracks, insufficient friction

Separation Layer, con’t

- Geotextile layer
  - Nonwoven used for JPCP unbonded overlays
    - Germany & Missouri
  - Not used for CRCP, yet
  - If distress is high then GT probably is not useful to stop reflection cracking
  - Doesn’t level up surface

Structural Design Methods

- Darwin M-E (MEPDG)
  - Results in better thickness values
- IDOT
  - Modified-AASHTO JRCP/CRCP Method
  - Subtract 1-inch for overlay
- TxDOT
  - Uses AASHTO 1993 for thickness design


<table>
<thead>
<tr>
<th>Thickness</th>
<th>ESAL, Millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 in.</td>
<td>5</td>
</tr>
<tr>
<td>10 in.</td>
<td>20</td>
</tr>
<tr>
<td>12 in.</td>
<td>100</td>
</tr>
<tr>
<td>14 in. (max)</td>
<td>300+</td>
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</table>

*CRCP overlay design minus 1-inch*
Construction Issues

- Pre-overlay repairs
  - Punchouts!
  - High severity spalling
  - Subgrade/Drainage problems
- Concrete Material Selection
- Steel Content
  - Minimum 0.60%
- Interlayer provides friction
  - Erodibility test of interlayer
    - Hamburg Test
  - Whitewash surface (?)

IDOT CRCP Unbonded Overlays

History

- Constructed Unbonded overlays since 1967
  - Unbonded CRCP overlay of JRCP
- I-74 Knox County - 1995
- I-88 Whiteside Country – 2000-01
- I-70 Clark County – 2002
- I-57/I-64 Mt. Vernon - 2011

I-55 CRCP Overlay Sections

- 8-inch CRCP Overlay (1970)
  - Springfield, IL (MP 89-92)
  - 9-inch JRCP
  - Steel content= 0.6%
  - 4 inch HMA interlayer + 8 inch HMA overlay
  - ADT = 24,600 w/ 15% trucks
  - CRS=6.5 & R.I. = 85 (1986)
  - Crack Spacing = 2.9 ft (1986)
  - Percent patching= 0.1% (1986)
  - Total ESALs=9.2x10^6

- 9-inch CRCP Overlay (1974)
  - Springfield, IL (MP 105-108)
  - 10-inch JRCP
  - Steel content= 0.6%
  - 4 inch HMA interlayer
  - ADT = 17,000 w/ 22% trucks
  - Crack Spacing = 3.2 ft
  - Percent patching= 0% (1986)
  - Total ESALs=9.1x10^6

I-70 CRCP Overlay Sections

- CRCP Overlay (1967) – MP 31-35
  - 8,7, and 6-inch CRC with 0.6, 0.7, & 1.0% steel
  - 6-inch HMA interlayer
  - 10-inch JRCP
  - ADT = 14,000 w/ 34% trucks
    - 17 million (1986)
  - CRS = 5.7 (1986) & R.I. = 86
    - 7.3% patching for 6-inch CRCP & 0% for 8-inch
    - Overlaid in 1989
  - Minimum req’d = 7 inches

I-74 Knox County (1995)

Existing

- MP 54-62 Westbound only
  - East of Galesburg
- Existing pavement cross-section (1969)
  - 3 to 4.5 inches HMA overlay
  - 7-inch CRCP
  - 4-inch HMA base
- Severe D-cracking and punchouts
  - Transverse and longitudinal cracks in HMA overlay
  - Full-depth concrete patches

Existing pavement cross-section (1969)
- 3 to 4.5 inches HMA overlay
- 7-inch CRCP
- 4-inch HMA base
- Severe D-cracking and punchouts
  - Transverse and longitudinal cracks in HMA overlay
  - Full-depth concrete patches

Lippert & DuBose 1988

McNeal 1996; Heckel 2001
I-74 Knox County (1995)

- 9-inch CRCP overlay w/ tied PCC shoulders
  - Design ESALs = 24 million
  - Crack spacing = 3.1 ft (1997); 2.3 ft (2001)
- 2009 AADT = 14,800 (SU = 550, MU = 3300)
  - Annual ESALs = 1.070x10^6
- Condition Rating Survey (CRS) value
  - 8.3 out of 9.0 (2001)
  - 8.2 out of 9.0 (2009)
- IRI – 70 (2001); 69 (2009)
- Transverse crack LTE = 92% (2001)

I-88 Whiteside County (2000-01)

- IL 78 to west of Rock Falls
- Existing 8-inch CRCP (1975)
  - Crushed river gravel
  - blowups and D-cracking problems
  - HMA overlays in 1988, 1991
  - Recurring blowups and D-cracking

I-88 Whiteside County (2000-01)

- 9.25-in CRCP unbonded overlay
  - 1-inch leveling binder placed on top of the existing 3.25-inch HMA overlay
- 2010 CRS = 8.0
- IRI (in/mi) = 52 EB, 57 WB
- 2009 AADT = 8800 (SU = 300, MU = 2300)
  - Annual ESALs = 0.741x10^6

I-70 Clark County (2002)

General Project Information

- Originally constructed in 1969
- 8-inch CRCP on 4-inch HMA base
- Subsequent bituminous overlays totaling 7-3/4 inches
- Traffic (2-way)
  - Current ADT of 24,000 with 42% trucks
- Location = IL 1 to Indiana Line

Proposed Pavement Cross Section

12 ft. 24 ft. 6 ft.

12" PCC SHOULDERS 12" UNBONDED CRCP OVERLAY 12" PCC SHOULDERS

BITUMINOUS OVERLAY BITUMINOUS OVERLAY

BITUMINOUS SHOULDER 8" CRCP

4" BAM BASE

12" PCC SHOULDERS 12" UNBONDED CRCP OVERLAY 12" PCC SHOULDERS

BITUMINOUS OVERLAY BITUMINOUS OVERLAY

BITUMINOUS SHOULDER 8" CRCP

4" BAM BASE

IDOT CRCP Design (I-70)

- Pavement design = Chapter 54 of BDE manual
  - 30-year design traffic of 116x10^6 ESAL’s (rigid)
  - 13-inch design thickness
- Thickness credit of 1-inch given in areas of unbonded overlay (NCHRP/Corps of Engrs.)
  - 12-inch design thickness w/ 0.80% steel (#7 bars)
  - Nominal 5-inches of HMA interlayer
  - 25 bars at 6-1/4 in. centers-longitudinally
  - #4 bars at 2-ft. intervals-transversely
I-70 CRCP Overlay Warranty

- 5-year duration
- Warranty bond required
- Warrants materials and workmanship
- 95% of pavements expected to not need warranty work
- Evaluated in 0.10-mile sections
- Distress parameters defined in SHRP’s “Distress ID Manual for LTPP” P-338

Warranted CRCP Distresses

- Transverse and longitudinal cracking (moderate and high severity)
- IRI limited to 150 in./mi.
- Spalling of longitudinal joints
- Scaling
- Patch deterioration
- Punchouts
- Corrective actions defined for each distress

I-70 Clark County (2002) Performance

- 12-inch CRCP overlay w/ HMA interlayer
- 5 yr. warranty contract
  - two dozen punchouts in 9 miles of pavement
  - problem (?) = 12-ft. full-depth PCC shoulders tied with #8 bars had punchouts located at jointed shoulder.
- Overall performance very good
  - CRS = 8.1 (2010)
  - IRI = 65 (EB); 69 (WB)
  - 2010 AADT = 20,500 (SU = 650, MU = 8000)
    - annual ESALs = 2.55x10^6
I-70 CRCP Overlay

Example: Early-Age Punchout

I-57/I-64 Alternatives (2010)

• HMA overlay of existing CRCP
  – Rubblization with HMA
  – JPCP and CRCP options
• M-EPDG & IDOT designs
• Milling options vs. rubblization
• Interlayer type
• Thickness options

Poor Section I-57/I-64 NB

Good Section I-57 NB

M-E PDG CRCP Overlay

Inputs

• 20-year design life
  – Mattoon-Charleston, IL Climate
• ESALs
  – 80x10^6
• A-7-6 soil type
  – k=200 psi/in
• Tied concrete shoulder
  – 40 to 80% LTE
• CRCP Steel properties
  – 3.5 inch depth, #6, 0.7%
### MEPDG CRCP Design Results

- **New CRCP = 11 inches**
  - HMA base unbonded = 4 inches
- **Unbonded CRCP = 9 inches**
  - AC base interlayer = 2 inches
  - CRCP (existing) = 8 inches
- **Unbonded CRCP = 10.5 inches**
  - HMA interlayer = 1 to 2 inches
  - CRCP (rubblized) = 8 inches

### I-57 / I-64 Mt. Vernon (2011)

- Mill existing HMA overlay
- Rubblize existing 8-inch CRCP
- Place 3-inch HMA interlayer
- **10.5-in. CRCP overlay w/ 0.7% steel**

### National Performance

![Figure 4.11. Effects of overlay thickness on unbonded CRCP overlay performance](image)

15 sections in GA, IL, ND, WI, AR, MD, PA  
*(Smith et al. 2002)*

### Performance Recommendations

- Concrete Overlay > 7 inches
  - Consistent with IDOT policy
- HMA Interlayer > 1-inch
  - Dense-graded

### LTPP Database

- 4 unbonded CRCP sections
- **Georgia**
  - 20-yr
  - HMA Interlayer = 0.75 inch
  - CRCP overlay 8.25-inch
  - Existing section 8-inch

### CRCP Overlay of JPCP in UK

- Refurbish 6.2km section of M25 London Orbital Motorway during 2000/2001
- Strengthened using hybrid solution of 200mm CRCP overlay for most heavily loaded traffic lanes 1-2, with AC overlays for lane 3 & shoulder
- Existing 3-lane dual carriageway of un-reinforced concrete slabs with contraction joints at 5m centres
  - Road opened to traffic in 1979
  - 10mm AC OL in 1990
  - Large amount of pavement faulting due to underlying clay
  - AADT currently exceeds 120,000 vehicles approximately 15% classified as Heavy Goods Vehicles (HGV’s)
CRCP Unbonded Overlay Summary

- CRCP unbonded overlays
  - 7 to 10 inches
  - Steel content = 0.6 to 0.8%
  - #5 to #7 bars
  - design ESALs from 5 to 100x10^6 ESALs

- HMA interlayer
  - Dense-graded asphalt mixtures
  - >1-inch

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- Harrington, D. et al. (2008), Guide to Concrete Overlays Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements, National Concrete Pavement Technology Center, Iowa State University, Ames, IA.

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