Concrete Pavement: Rehabilitation Applications, Options & Performance

Purdue Road School

March 10, 2004

Concrete Pavement Basics

Basic Components of a Concrete Pavement

- Longitudinal joint
- Transverse joint
- Surface Texture
- Subgrade or subbase
- Tiebars
- Dowel bars
- Surface smoothness or rideability
- Thickness Design
- Concrete materials

Concrete Pavement Types

- Jointed Plain
  - Undoweled
  - Doweled
- Jointed Reinforced
- Continuously Reinforced

Jointed Plain

Plan

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<td>3.5-6.0 m</td>
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Profile

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Jointed Plain
Load Transfer

- The slabs ability to share its load with its neighboring slab
  - Dowels
    High Traffic Volumes
    (Pavements > 8 in.)
  - Aggregate Interlock
    Low Traffic Volumes
    (Pavements < 7 in.)
Continuously Reinforced

Plan

0.6-2.0 m

Profile

Different Pavement Types

Concrete Section

Asphalt Section

Subbase

Subgrade

Subbase

Base

Concrete’s Rigidness spreads the load over a large area and keeps pressures on the subgrade low.

Pavement Performance

Concrete Performance Curve

Asphalt Performance Curve

Traffic or Years

How Pavements Carry Loads

3000 kg.

3000 kg.

Concrete

Asphalt Layer

Subbase

Subgrade

pressure ≈ 0.2 MPa

pressure ≈ 2.0 MPa
I-40 in Oklahoma
Survival Analysis Results

Cost - Performance Balance

Law of Diminishing Returns

Concrete Pavement Design Requires Selecting Appropriate Features
- Subgrade modification
- Drainage system
- Subbase
- Joint Spacing
  - 6.1 m
  - 4.3 m
- Dowels
- Thickness
  - 200 mm
  - 250 mm
  - 300 mm
- Reinforcement
- Joint Sealant
  - None
  - Hot pour
  - Silicone
  - Preformed
- Surface Texture
  - Transverse tine
  - Burlap drag
- Shoulder
- Asphalt
- Concrete

Optimize

Concrete Pavement Rehabilitation
Rehabilitating Concrete Pavements using CPR³
- Restoration
- Resurfacing
- Reconstruction

Note: Over 50% of PCCP Sections Have Not Failed (>30 Years)
Rehabilitation Strategies

- Three categories:
  - Restoration
  - Resurfacing
  - Reconstruction
  Together, known as CPR³
- Which is used depends on existing condition.

Concrete Pavement Rehabilitation

- Improves structural and/or functional condition of pavement.
  - Structural condition - the ability to carry traffic.
  - Functional condition - the ability to serve the user comfortably.

Concrete Pavement Rehabilitation

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Pavement Condition

- Original Pavement
- Terminal Condition
- Rehabilitation
- Increase due to Rehabilitation
- Min. Acceptable Rating

Rehabilitation Timing

- Restoration
- Resurfacing
- Reconstruction
- Min. Acceptable Rating

Restoration (CPR)

- Used early when pavement has little deterioration.
- Repairs isolated areas of distress.

Restoration Techniques

Concrete Pavements

- Full-depth repair
- Partial-depth repair
- Diamond grinding
- Joint & crack rescaling
- Slab stabilization
- Retrofitting dowels
- Retrofitting concrete shoulders
- Cross-stitching long cracks/joints
Full Depth Repairs
- Repairs distresses greater than 1/3 the slab depth.
- Consists of removing and replacing at least a portion of the existing slab to the bottom of the concrete.

Completed Patch

Patch under Construction

Partial Depth Repairs
- Repairs deterioration in the top 1/3 of the slab.
- Generally located at joints, but can be placed anywhere surface defects occur.
Carbide-Milling

Longitudinal Milling

Transverse or Longitudinal Joint/Crack

Near vertical edge.

Transverse Milling (Half-moon)

Transverse or Longitudinal Joint/Crack

TYPICAL SPALLS

REMOVAL

• Milling machine

MILLING IN PROGRESS
Load Transfer Restoration

- Reestablishes load-transfer at undoweled joints or cracks
- Used to limit future faulting

\[ \Delta U = x \]
\[ \Delta L = x \]

Good Load Transfer

\[ \Delta U = 0 \]
\[ \Delta L = x \]

Poor Load Transfer

- Use curing compound
Concrete Pavement Restoration

Concrete Pavement Restoration

Concrete Pavement Restoration

Concrete Pavement Restoration

Diamond Grinding

- Improves ride by removing:
  - Faulting at joints
  - Slab warping
  - Surface deformations caused by studded tires
- Reestablishes skid resistance
- Corrects cross-slope
Joint and Crack Resealing

- Minimizes water & incompressibles into pavement system.
- Reduces:
  - Subgrade softening
  - Pumping
  - Erosion of fines
  - Spalling

Restoration Cost Comparisons

<table>
<thead>
<tr>
<th>Location</th>
<th>Rehabilitation Technique</th>
<th>Project Size</th>
<th>Cost/Lane km</th>
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<tbody>
<tr>
<td>NC I-26</td>
<td>CPR</td>
<td>11.3 km</td>
<td>$77,640</td>
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<tr>
<td>NC I-26</td>
<td>Crack/Seat and AC Overlay</td>
<td>4.2 km</td>
<td>$232,920</td>
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<td>WA I-90</td>
<td>DBR</td>
<td>53.1 km</td>
<td>$73,800</td>
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<td>WA I-90</td>
<td>110 mm AC Overlay</td>
<td>53.1 km</td>
<td>$118,300</td>
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CPR in NC and dowel bar retrofit followed by diamond grinding

Restoration Performance

- Provides 10 or more years of service.
- Preliminary engineering & timing are critical.
- Overall effectiveness is highly dependent on design adequacy, construction quality, and other restoration activities.
Rehabilitation Timing

Resurfacing

- Used when pavement has medium to high levels of distress.
- Used when restoration is no longer effective.

Resurfacing Activities

- Concrete overlays for concrete pavements:
  - Bonded Concrete Overlays
  - Unbonded Concrete Overlays
- Concrete overlays for asphalt pavements:
  - Conventional Whitetopping
  - Ultra-Thin Whitetopping

Bonded Overlays

- Consists of a thin concrete layer (100 mm or less) on top of an existing concrete surface.
- Specific steps are taken to bond the new concrete overlay to the existing concrete.

Bonded Overlay

- The major use of Bonded Overlays is structural enhancement of the pavement.
- Cracks in the underlying pavement will reflect into the resurfacing.
- Most often used where the underlying pavement is in reasonably good condition.
**Bonded Overlays**

**Performance**

- **Good when:**
  - Placed correctly and at the right time.
- **Poor when:**
  - Placed on deteriorated pavements.
- **Loss of bond does not necessarily constitute failure.**

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**Unbonded Overlays**

**Separation Interlayer:**

- Allows layers to act independently.
- Prevents distresses from reflecting into overlay.
- Typical Interlayer:
  - 1-1 ½ “ Asphalt layer

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**Unbonded Overlays**

**Separation Interlayer:**

- Consists of thick concrete layer (125 mm or greater) on top of an existing concrete.
- Uses a “separation interlayer” to separate new overlay and existing concrete.

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**UNBONDED CONCRETE OVERLAYS**

**Advantages**

- Can Place on Pavement in Bad Condition.
- Less Pre-Overlay Repair Needed Than Other Overlay Designs.
- No Future Reflective Cracking.
- Avoid Reconstruction Problems.
- Maintain Traffic.

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**UNBONDED CONCRETE OVERLAYS**

**Job-Site Considerations**

- Overhead Structures.
- On-line Bridges.
- Shoulders.
- Fill for Slope Flattening.
- Traffic Control.
UNBONDED CONCRETE OVERLAYS

Payment

Cubic Yard  Square Yard

NOTE: Divided payment is the most equitable and economic.

Unbonded Overlays

Performance

• Very Good
• Can be expected to perform for 20+ years.
  – Most failures are due to the use of inadequate separation layers.

Conventional Whitetopping

• Consists of thick concrete layer (100 mm or greater) on top of an existing asphalt pavement.
• Behaves as a new pavement on a strong base.

Whitetopping Engineering Bulletin

• New for 1998
  – Conventional Whitetopping
    • Design
    • Construction
    • Performance
  – Ultra-thin Whitetopping
    • Design
    • Construction
    • Performance

Whitetopping - History

• First Whitetopping
  – South 7th street in Terre Haute, Indiana - 1918
  – 4” concrete overlay of existing asphalt pavement
• During 40’s & 50’s used to upgrade military & civilian airports
• Highway use started approx. 1960
  – Types have included JPCP, JRCP, CRCP, FRC

Whitetopping History

• Modern usage began in Iowa in 1960’s where heavy loads from farm trucks created a need for a durable pavement.
• Performance was excellent
• Over 500 miles of whitetopped roads since the 1960’s
• Now used for Interstates, highways, airports, and parking lots
**Typical Whitetopping Thickness**

- Depends on expected traffic load.
  - City streets, county roads, and small airports
    - 100 to 175 mm (4 to 7 in.)
  - Primary roads and interstate highways
    - 175 to 280 mm (7 to 11 in.)
  - Large airports
    - 200 to 460 mm (8 to 18 in.)

**Whitetopping - Advantages**

**Construction**

- Can place on pavement in bad condition.
  - Little or no pre-overlay repair needed.
- Avoid reconstruction problems.
  - Minimal rain delays.
  - Maintain traffic on existing surface.

**Improved structural capacity.**

**Maintains high level of serviceability.**

**Low maintenance.**

- No seasonal weakening (spring breakup).
- Concrete slabs bridge problems asphalt cannot.
- Light reflective, safe riding surface.

**Whitetopping Construction**

- Critical issue is uniform support
- Subgrade / base failures need repair
- Need to evaluate drainage (esp. inlays)
- Address surface distortions
  - Direct application
  - Profile milling
  - Leveling course

**Ultra-Thin Whitetopping**

- Consists of thin concrete layer (4 in. or less) on top of an existing asphalt pavement.
- Specific steps are taken to bond the new concrete to the existing asphalt and to saw short joint spacing.
Ultra-Thin Whitetopping

Short joint spacing allows the slabs to deflect instead of bend. This reduces slab stresses to reasonable values.

Bonding Effects on Edge Stress

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<tr>
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<th>Unbonded</th>
<th>Bonded</th>
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<td>Asphalt</td>
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<tr>
<td>Tension</td>
<td>8.49 Mpa (1230 psi)</td>
<td>2.90 Mpa (420 psi)</td>
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Known Design Considerations

- Bond is critical.
- Slab size (Jointing) is important.
- Underlying asphalt thickness is important.

OVERLAY PERFORMANCE in INDIANA

Specific Concrete Overlay Projects

Indiana Overlays

- I – 69 North of SR 18 – 11” 1986
- I – 65 North of SR 14 – 10.5” 1994
- 1 – 94 West of SR 39 – 13” 1998
- I – 70 at US 27 – Richmond – 12” 2000
- Harding Street – Indianapolis – 6” 1985
- 121st Street – Fishers – 9” 1992
- Indianapolis Bus Lanes – 3.5” 1997
- Allisonville Rd – N. of 96th – 7” 1999
- 56th Street – Brownsburg – 5” 2001
- Market & Columbia – Warsaw – 3.5” 2002

I-69 UNBONDED PCC OVERLAY

FROM SR 18  RM 66.29
to
GRANT COUNTY LINE RM 71.64
I-69 UNBONDED PCC OVERLAY

- OPENED TO TRAFFIC 1964
- RESURFACED (Bituminous) 1975
- NBL RESURFACED (Bituminous) 1978
- UNBONDED OVERLAY 1986

I-69 UNBONDED PCC OVERLAY

Harding Street - Indianapolis

- Old concrete street with patches
- PCC Unbonded overlay placed 1985
- 6" thick over old street
- Widened 6' with 8" PCCP
- Skewed non-doweled transverse joints
- Tied longitudinal joint provided at section thickness change
- Still in excellent condition

I-69 UNBONDED PCC OVERLAY

I-65 UNBONDED PCC OVERLAY
**Project Information**

- Traffic: 26,360 vpd
- Existing 24’ asphalt pavement
- Scope:
  - widen to outside
  - maintain traffic
  - mill & overlay existing

**Pavement Design**

- **PCCP**
  - plain, non-doweled with skewed joints
  - overlay: 7 1/2” PCC
  - widening: 10 1/2” PCC on 4” #53 aggregate base
  - Lime treated subgrade
- **HMA**
  - overlay: 5” HMA
  - widening: 15” HMA
  - Lime treated subgrade

**Allisonville Road Cross Section**

- Commercial and Residential traffic
- 44’ wide, 3500’ long
- 6” concrete overlay with variable depth to 9” as needed
- Center line realignment
- Drainage
- Texture: Turf Drag and Random Tining

**56th Street - Brownsburg**

- Commercial and Residential traffic
- 44’ wide, 3500’ long
- 6” concrete overlay with variable depth to 9” as needed
- Center line realignment
- Drainage
- Texture: Turf Drag and Random Tining
56th Street Brownsburg

City of Indianapolis
Ultra – thin Whitetopping
Bus Lanes

PLACING CONCRETE

PERFORMANCE
• All three sections are performing well

Market & Columbia Streets - Warsaw

Market & Columbia Streets - Warsaw
Reconstruction

- Used when the pavement has high levels of distress.
- Used after overlays are no longer effective.

Reconstruction Activities

- Final stage of rehabilitation.
- Involves removing and replacing existing pavement with a new pavement.
  - Complete removal & replacement
  - Partial removal & replacement (Inlay).
- Can correct:
  - Subgrade / subbase deficiencies, Roadway geometrics, Roadside safety features, Drainage

Reconstruction Activities

- Controls the final elevation
  - Minimizes roadside appurtenances adjustments.
- Can recycle the old pavement

Summary

- CPR^3 repairs structural / functional deficiencies.
- Improves pavement condition to an acceptable level.
- Appropriate activity depends on the existing pavement condition.
  - As condition declines, the optimum activity changes.
  - Applying correct activity at correct time is essential.
Summary

• Restoration
  – Repairs isolated areas of deterioration.
• Resurfacing
  – Repairs a pavement with medium to high severity levels of distress.
• Reconstruction
  – Used at the end of the pavement’s life, when it has very high severity levels of distress.