Concrete Pavement: Rehabilitation Applications, Options & Performance

Purdue Road School

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Concrete Pavement Basics

Basic Components of a Concrete Pavement

Concrete Pavement Types

• Jointed Plain
  – Undoweled
  – Doweled
• Jointed Reinforced
• Continuously Reinforced

Jointed Plain

Plan

| 3.5-6.0 m |

Profile

or
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.

Jointed Plain

Jointed Reinforced

Plan

7.5-9.0 m

Profile

Jointed Reinforced
Continuously Reinforced Plan
0.6-2.0 m

Continuously Reinforced Profile

Different Pavement Types

Concrete Section
- Subbase
- Subgrade

Asphalt Section
- Asphalt Layer
- Base
- Subbase
- Subgrade

How Pavements Carry Loads

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
I-40 in Oklahoma Survival Analysis Results

Cost - Performance Balance

Law of Diminishing Returns

Concrete Pavement Design Requires Selecting Appropriate Features

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.

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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.

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 edges

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

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

Poor Load Transfer

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

Good Load Transfer

Curing

- Use curing compound
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>
</tr>
</thead>
<tbody>
<tr>
<td>NC I-26</td>
<td>CPR</td>
<td>11.3 km</td>
<td>$77,640</td>
</tr>
<tr>
<td>NC I-26</td>
<td>Crack/Seat and AC Overlay</td>
<td>4.2 km</td>
<td>$232,920</td>
</tr>
<tr>
<td>WA I-90</td>
<td>DBR</td>
<td>53.1 km</td>
<td>$73,800</td>
</tr>
<tr>
<td>WA I-90</td>
<td>110 mm AC Overlay</td>
<td>53.1 km</td>
<td>$118,300</td>
</tr>
</tbody>
</table>

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**

- **Restoration**
- **Resurfacing**
- **Reconstruction**
- **Min. Acceptable Rating**

**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.

**Unbonded Overlay**

- 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.

**Unbonded Overlays**

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

**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.

**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.

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
- I – 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

Bonding Effects on Edge Stress

Unbonded Bonded
8.49 Mpa (1230 psi) 2.90 Mpa (420 psi)

75 mm Concrete, 100 mm AC, K=81 Mpa/m, Ec = 27,580 Mpa, Eac = 2,758 MPa

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

**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
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

Allisonville Road

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
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

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

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

Summary

- CPR³ 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.

Questions?