PCC Overlay Design and Construction

Tomorrow’s High Performance Concrete Pavements Today Workshop, Concord NC, February 28, 2012

Michael E. Ayers, Ph.D., Global Pavement Consultants, Inc. Representing - National Concrete Pavement Technology Center
County Road D-38 from Sergeant Bluff east 0.7 miles
Constructed in IA in 1960
Overlay Type: Unbonded on Asphalt
Application: Highway
Overlay Thickness: 6 in.
Click for more details...
Concrete Overlay Guide second edition

Contents
1. Overview of Overlay Families
2. Overlay types and uses
3. Evaluations & Selections
4. Six Overlay Summaries (11”x17 “sheets”)
5. Design Section
6. Miscellaneous Design Details
7. Overlay Materials Section
8. Work Zones under Traffic
9. Key Points for Overlay Construction
10. Accelerated Construction
11. Specification Considerations
12. Repairs of Overlays

Guide to CONCRETE OVERLAYS
Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements
A practical approach to understanding and successfully using concrete overlays, from selection to opening
Design of Concrete Overlays Using Existing Technologies

• Listing and explanation of current and recommended software programs for specific overlays

• Background of recommended overlay design techniques

• Detailed examples of how to use the existing design techniques

• Learn by example – then apply to your situation!
Types of Concrete Overlays

**Bonded**

*2” – 5”*

- Bonded Concrete Overlays of Concrete Pavements
  - previously called bonded overlays –

- Bonded Concrete Overlays of Asphalt Pavements
  - previously called ultra-thin whitetopping –

- Bonded Concrete Overlays of Composite Pavements

**Unbonded**

*4” – 11”*

- Unbonded Concrete Overlays of Concrete Pavements
  - previously called unbonded overlays –

- Unbonded Concrete Overlays of Asphalt Pavements
  - previously called conventional whitetopping –

- Unbonded Concrete Overlays of Composite Pavements
Concrete Overlays
Service Life Expectations

• Thickness of 2 to 6 in. – 15 to 25 years
• Thickness > 6 in. – 20 to 30+ years

Overlay service life is dependent upon:
• Sound overlay structural design - compatible with expected traffic and site conditions, and
• Good construction practices
Bonded and Unbonded

Bonded

Unbonded
Pavement Evaluation to Determine if Existing Pavement is a Candidate for a Concrete Overlay

- Poor Choice
  - 4” Bonded Overlay over 50 yr pavement

- Poor Choice
  - 4” Concrete Overlay over “D” cracked aggregate
Evaluations of Existing Pavements for Overlays

- Evaluation is also used to determine:
  - Required repairs where needed
  - Establish the concrete overlay design thickness
  - When combined with an overlay can the existing pavement help carry anticipated traffic as:
    - an integrated part of the pavement (bonded)
    - or serve as a base or subbase
What are We Building the Overlays On?

1 Pavement History and Performance Goals

- Pavement material (including aggregate CTE), design, age, thickness, layers
- Existing traffic and performance level
- Design life
- Remaining life
- Desired traffic and performance level
- Desired design life
- Elevations and grade restrictions
- Other historical information

2 Visual Examination

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Asphalt / Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Fair</td>
<td>Fair</td>
</tr>
<tr>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Deteriorated</td>
<td>Deteriorated</td>
</tr>
</tbody>
</table>

(Images of pavement conditions)
3 Core Analysis

- Type of distress
- Depth of distress
- Verification of thickness for pavement base/subbase
4 Optional Analyses

(depending on extent of problems)

4-a. Material-Related Tests

(indicated by core analysis)

Conduct if (a) material or durability issues are indicated or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- Petrography analysis
- Concrete material-related distress (MRD)
- Poor air-void system
- Asphalt stripping
- CTE

4-b. Subsurface Tests

Conduct if (a) pavement or subgrade support issues are indicated or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- FWD tests
  - Subgrade/subbase support (k value)
  - Subgrade/subbase variability
  - Pavement properties
  - Load transfer efficiency
  - Presence of voids
  - Asphalt stiffness
  - Concrete flexural strength
- Subgrade tests
  - Freeze-thaw characteristics
  - Shrink-swell characteristics
  - Soil strength (dynamic cone penetration or standard penetration test)

4-c. Surface Texture Tests

Conduct if (a) materials or durability issues are indicated, or (b) roadway provides service for high levels of traffic, especially if a bonded overlay is being considered.

- International roughness index (IRI)
- Friction (skid resistance) tests
## Initial Evaluation (step 5)

### Condition Assessment Profile

<table>
<thead>
<tr>
<th>Concrete</th>
<th>Asphalt / Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface Deficiencies</strong></td>
<td><strong>Surface Deficiencies</strong></td>
</tr>
<tr>
<td>• Friction loss</td>
<td>• Bleeding/flushing</td>
</tr>
<tr>
<td>• Joint deterioration (low to medium)</td>
<td>• Block cracking</td>
</tr>
<tr>
<td>• Map cracking (non-ASR)</td>
<td>• Friction loss</td>
</tr>
<tr>
<td>• Popouts</td>
<td>• Noise</td>
</tr>
<tr>
<td>• Noise</td>
<td>• Corrugation</td>
</tr>
<tr>
<td>• Scaling</td>
<td>• Joint reflective cracking</td>
</tr>
<tr>
<td>• Roughness (not distress-related)</td>
<td>• Roughness (not distress-related)</td>
</tr>
<tr>
<td>• Plastic shrinkage cracks</td>
<td>• Rutting</td>
</tr>
<tr>
<td>• Thermal shrinkage cracks</td>
<td>• Weathering/raveling</td>
</tr>
<tr>
<td>• IRI</td>
<td>• Shoving</td>
</tr>
<tr>
<td>• Other</td>
<td>• Slippage</td>
</tr>
<tr>
<td><strong>Structural Deficiencies</strong></td>
<td><strong>Structural Deficiencies</strong></td>
</tr>
<tr>
<td>• Corner breaks</td>
<td>• Fatigue (alligator) cracking</td>
</tr>
<tr>
<td>• Joint deterioration (severe)</td>
<td>• Depressions</td>
</tr>
<tr>
<td>• Tented panels</td>
<td>• Heaves</td>
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<tr>
<td>• Longitudinal cracking</td>
<td>• Longitudinal cracking</td>
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<td>• Pumping/faulting</td>
<td>• Potholes</td>
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<td>• Punchout</td>
<td>• Transverse thermal cracking</td>
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<tr>
<td>• MRD (medium to severe)</td>
<td>• Rutting/shoving</td>
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<tr>
<td>• Transverse cracking</td>
<td>• Subgrade/subbase condition</td>
</tr>
<tr>
<td>• Subgrade/subbase condition</td>
<td>• Other</td>
</tr>
<tr>
<td>• Other</td>
<td></td>
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</tbody>
</table>
Concrete Overlay Quantities
- REALITY CHECK -

• Concrete is bid in sq. yards for placement, cu. yards for material

• Profile is not perfect and needs corrected

• Cross slope needs correction
# Engineering Survey

## Cost Comparison of Engineering/Surveying Pre Construction versus at Time of Construction

Base Cost Estimated 3 Line Profile and 10 Mile Project Length

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Estimated Hours 3 Line Profile</th>
<th>Rate</th>
<th>Total</th>
<th>Five Line Profile</th>
<th>Nine Line Profile</th>
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<td><strong>Total</strong></td>
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<td><strong>91,650.00</strong></td>
<td><strong>99,900.00</strong></td>
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</table>

Cost Per Mile: $8,340.00 $9,165.00 $9,990.00

*Note: The estimates show have been generated from six estimates for construction survey that were calculated. We were not the successful bidder meaning someone got the work for less money*
Quantity Estimates

• Estimating plan quantity

- Overlay cubic yard pay item is to adjust the theoretical volume by an appropriate factor that accounts for the non-uniformity of the existing surface

<table>
<thead>
<tr>
<th>Concrete Overlay Thickness</th>
<th>½” Placement Tolerance as a % of Design Thickness</th>
<th>Additional % Adjustment for Gross Surface Irregularities in the Existing Surface</th>
<th>Total Adjustment Factor to be Applied to Theoretical Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>4”</td>
<td>12.5%</td>
<td>5%</td>
<td>17.5%</td>
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<tr>
<td>6”</td>
<td>8.3%</td>
<td>5%</td>
<td>13.3%</td>
</tr>
<tr>
<td>8”</td>
<td>6.3%</td>
<td>5%</td>
<td>11.3%</td>
</tr>
<tr>
<td>10”</td>
<td>5.0%</td>
<td>5%</td>
<td>10.0%</td>
</tr>
<tr>
<td>12”</td>
<td>4.2%</td>
<td>5%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>
Paving with Outside & Inside Stringlines
1st Pass
Paving with Outside Edge Stringline & Ski Combination

1st Pass

US 287

US 69
Paving with Outside Stringline Only & Slope Control 1st Pass
Stringless Paving
Concrete Bonded Overlay of Concrete

2” – 5”
Uses and Advantages - Bonded Overlay of Concrete

2”–5” thickness

- Use when existing pavement is in good structural condition with some surface distress.

- Use to eliminate any surface defects; increase structural capacity; and improve surface friction, noise, and rideability.

- Typically used directly over concrete without additional repairs except for spot-repairing of severely deteriorated areas.
Bonded Concrete Overlay over Concrete

- Where any of the above distress are present, their severity and extent should be considered to determine if a bonded overlay is appropriate.
- Working cracks to be repaired or sawed since they will reflect through.
Coefficient of Thermal Expansion (CTE)

- Overlay CTE should be similar to underlining pavement
- If not near the same at least overlay CTE should be lower than existing pavement
Poor Bonding: Delamination of Concrete Overlay over Concrete
Maintaining Bond

• Replaced Asphalt Patch with Concrete Patch
Spot Repairs for Bonded Overlays of Concrete

Joint Patching

Full Depth Patches
Bonded Overlay of Concrete - Full Depth Cut & Width of Cut

- Overlay joint
- New overlay transverse joint
- Concrete overlay
- Sawcut in existing slab
- Crack in existing slab

Tech Center
Bonded on Concrete

Keys to Success

• Bond is important
• Concrete aggregate used in overlay should have thermal properties similar to that of existing pavement
• Matching joints with underlying pavement allows structure to move monolithically.
• Existing joints must be in fair condition or be repaired
• Timing of joint sawing is important.
• Cut transverse joints full depth +1/2” and longitudinal joints at T/2.
• Width of transverse joint of overlay to be equal to or greater than underlying crack width of the existing pavement.
• Curing should be timely and adequate.
Concrete Bonded Overlay of Asphalt or Composite
Bonded Overlay of Asphalt or Composite Pavements  

2”–5” thickness

Existing pavement condition
Fair or better structural condition with surface distress

Applications
• To eliminate surface defects such as rutting and shoving
• Improve surface characteristics like friction, noise, and rideability
• To increase structural capacity where traffic loads have or will increase
Feasibility

- HMA pavements with some structural integrity
  - Limited structural (fatigue) cracking
  - No stripping/raveling in HMA layers
  - HMA thickness after milling > 3 in to 4 in. minimum
- Rutting in HMA layers ok
- Non-load associated cracking ok
Typical Uses of Concrete Overlay of Existing Asphalt Pavement

Michigan Intersection

- 300 trucks per day
- 160,000 lbs loading
Typical Uses of Concrete Overlay over Asphalt

Before – Asphalt lasted 3 to 6 months
After- 9 years service of concrete overlay in wheel lines still performing
• A review of the existing profile grade line should be conducted and areas of significant deviation investigated through analysis of core samples in the laboratory.
Purpose of Asphalt Milling for Concrete Bonded Overlay

- Remove distortions 2” or more
- Reduce high spots to insure minimum overlay depth
- Match adjacent lanes
- Help insure good bond
- Meet vertical elevation requirements
- Restore Profile
Cautions on Milling

- Milling should be minimized to retain structural support of pavement.
- Preferable to mill to depth that will minimize the potential for delamination between lifts.
- Grade corrections should be made in the thickness of the concrete overlay.

Excessive milling of existing asphalt beyond asphalt lifts (tack line).
Over Milling Can Result in Structural Failure of Concrete Bonded Overlay over HMA
Joint Design

• Max. spacing of 3 to 8 ft
  – Limit 1.0 to 1.5 times thickness in feet.
  – Some agencies include tie bars at longitudinal joints > 5 in
  – No dowels (aggregate interlock relied upon)
Longitudinal Joint Layout

- 2 ft x 2 ft
- 3 ft x 3 ft
- 4 ft x 4 ft
- 6 ft x 6 ft

Traffic: 12 ft
PCC Joint Sawing

CRITICAL
• Effective curing
• Timely joint sawing
Bonded over Asphalt/Composite
Keys to Success

- Bonding is critical
- Small square panels reduce curling, warping, & shear stresses in bond (1.5 times thickness).
- Mill to remove surface distresses, or improve bonding.
- Be sure to leave 3” to 4” of HMA after milling.
- HMA surface temperature below 120 F before paving.
- Joints in the overlay should not be placed in wheel paths, if possible
- Application of curing compound is critical
Concrete Unbonded Overlay of Concrete
**Uses and Advantages - Unbonded Overlay of Concrete Pavements**

- **4” - 11” thickness**

- Use when existing pavement is in poor condition, including with material-related distress such as D-cracking, when underlying pavement and subbase are stable and uniform except for isolated areas that can be repaired.

- Use to restore structural capacity of the existing pavement and increase pavement life equivalent to full-depth pavement.
Unbounded Overlays Can be Placed over Badly Distressed Concrete Pavements
Existing concrete and its subbase must provide a uniform strength platform.

......if it doesn't, what actions are necessary to achieve uniformity?
Separator Layer

• Required for good performance
  – Isolate overlay from existing distress
    ▪ Prevent reflection cracking
    ▪ Prevent bonding/mechanical interlocking
  – Provide level surface for overlay construction

• Recommended interlayer material:
  – 1-2 in HMA
  – Geotextile (Missouri Demo – Sept 2008)
Need for Adequate Interlayer
Geotextile Separation Layer (Interlayer)

No turns

No wrinkles
Michigan's Porous HMA Separation Layer
Asphalt Stripping
Cross Section or Grade Corrections with Interlayer

- Tendency to utilize the asphalt separation layer as the medium for correcting cross slope & profile
  - Results in variable asphalt thickness and can lead to very thin asphalt sections (less than 1”)
  - When compacted creates variable roll down
  - Varying thickness for fastening dowel bars
- Use constant thickness (typically 1”) as a separation layer
- Make cross-slope and smoothness adjustments in the concrete overlay
Jointing-Load Transfer

• JPCP joint spacing
  – 1.5 times slab thickness in feet ≤ 6 in.
  – 2 times slab thickness > 6 in. (up to 15’)

• Transverse joints offset from those in existing slab (when possible)
Dowel Bars in Wheel Path

Fasteners to Existing Pavement Important
Direct Concrete Placement in Front of Paver

Remove Unnecessary Dowels
Unbonded Overlay of Concrete Pavements
Keys to Success

• Full-depth repairs - only where structural integrity is lost at isolated spots.
• Separator layer (normally 1” asphalt or geotextile fabric)

• Use to restore structural capacity of the existing pavement and increase pavement life equivalent to full-depth pavement.
• Faulting of 3/8 in. or less in the existing concrete pavement
• Shorter joint spacing helps minimize curling and warping stresses.
• To not match joints with those of the underlying concrete pavement.
Concrete Unbonded Overlay of HMA or Composites - Trouble Shooting
Unbonded Concrete Overlay of Asphalt or Composite Pavements

4” - 11” thickness

Existing pavement condition
Deteriorated (severe rutting, potholes, alligator cracking, shoving, and pumping) but stable and uniform

Applications
• To restore or enhance pavement’s structural capacity
• To increase pavement life equivalent to full-depth pavement
• To eliminate deterioration problems
• To reduce urban heat island effect by increasing pavement surface albedo
Semi-Uniform Platform

Remaining HMA severely damaged from trucks hauling away millings

Removed 6 in of existing 9-in HMA Pavement
Iowa 175 Longitudinal Crack
Unbonded Over Asphalt/Composite

Keys to Success

- Milling to eliminate surface distortions of 2 in. or more
- Complete repairs at isolated spots where structural integrity needs restoring
- Concrete patches in the existing pavement should be separated from the overlay
- Surface temperature of existing asphalt pavement should be maintained below 120°F (48.9°C) when placing overlay
- Partial bonding between the overlay and the existing asphalt pavement is acceptable and may even improve load-carrying capacity
**Spring Conditions**

<table>
<thead>
<tr>
<th>Overlay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing pavement (HMA, PCC, HMA on PCC, etc.)</td>
</tr>
</tbody>
</table>

- Cool base; cool nights
  - Slows set throughout depth of overlay (not just the bottom up)

- **Base movement is the controlling factor**
  - Cool ground + warming during day = movement
  - Cooling of base at night (cold above & cold below)

**Countermeasure:** Place concrete overlay during base expansion, not base contraction
  - Start early; consider covering with plastic sheeting
  - Avoid afternoon & evening pours
  - Increase and monitor concrete placement temperature
  - Use minimum amount of required SCM’s
Fall Conditions

- Warm base; cool nights
  - Concrete sets from the bottom up
- Base movement generally not a problem
- May get some random cracks
  - Too green on top to allow for saw cutting, yet stresses building up from bottom of slab

Countermeasures:
- Place early in day; Use heat of day & sunlight to help surface gain strength to allow saw cutting
- Increase and monitor concrete placement temperature; warmer is better
- Cover the slab with plastic sheeting
THANK YOU!

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