Webinar on:
Concrete Overlay
Design Details and Joints

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March 5, 2015
System of Concrete Overlays

Concrete Overlays

Bonded Overlay System
- Concrete Pavements
- Asphalt Pavements
- Composite Pavements

Unbonded Overlay System
- Concrete Pavements
- Asphalt Pavements
- Composite Pavements

Bond is integral to design
Old pavement is subbase
# Bonded vs. Unbonded Overlay Considerations

<table>
<thead>
<tr>
<th>Concrete Overlay</th>
<th>Bonded (4”)</th>
<th>Unbonded (4”-6”)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>Primarily a preventive maintenance or minor rehabilitation strategy to improve surface characteristics and/or load-carrying capacity</td>
<td>Primarily a minor and major rehabilitation strategy</td>
</tr>
<tr>
<td><strong>Condition of Existing Pavement</strong></td>
<td>Pavements in good to fair structural condition or made into that condition.</td>
<td>The underlying pavement can be poor to deteriorated but must be, along with the base and/or subgrade, stable and uniform</td>
</tr>
</tbody>
</table>
| **Resulting Improvements to the Pavement** | • Long-term wearing surface added  
• Surface defects eliminated  
• Surface characteristics like smoothness, friction, and/or noise improved  
• Load-carrying capacity added  
• Pavement life extended | • Load-carrying capacity restored and increased  
• Pavement life extended  
• Surface defects eliminated  
• Surface characteristics like smoothness, friction, and/or noise improved |
### 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>
</tbody>
</table>

| **Structural Deficiencies** | **Structural Deficiencies** |
| • Corner breaks | • Fatigue (alligator) cracking |
| • Joint deterioration (severe) | • Depressions |
| • Tented panels | • Heaves |
| • Longitudinal cracking | • Longitudinal cracking |
| • Pumping/faulting | • Potholes |
| • Punchout | • Transverse thermal cracking |
| • MRD (medium to severe) | • Rutting/shoving |
| • Transverse cracking | • Subgrade/subbase condition |
| • Subgrade/subbase condition | • Other |
| • Other | |
Plan Development of Overlays
Plan Development

- For agencies that are inexperienced with the design of concrete overlays, the approach should be similar to that of designing an asphalt overlay.

- The location, geometrics and maintenance of traffic requirements should dictate the level of design detail that is required in the plans.
Plan Development

- Oklahoma example
- 5 mile county road – 5” concrete overlay
- 12 plan sheets (4 are structure details)
Required PCC Overlay Plan Items

• Items to include:
  - Title sheet and System Map.
  - Typical Cross Sections.
  - Estimate of Project Quantities & References
  - Special Drawings & Tabulations.
  - Pollution Prevention Plan.
  - List of Road Standards & Drawings.
  - Traffic Control Plan Notes & Limitations.
  - Tabulation of Repairs, Subdrains, Special Events,
Required PCC Overlay Plan Items Continued

• Items to include:

  - Vertical/Horizontal Control Points \((x,y,z)\).
  - Profile Tabulation w/Vertical & Horizontal Curve Data Tabulation.
  - General Staging Notes & Limitations.
  - Intersection Jointing Plans.
  - Plan and Profile (Not always necessary as long as you have reference layout)
Design Decisions Required
Concrete Overlays - Design

• Design Constraints

Vertical and horizontal constraints need to be accounted for in the design phase

- Existing structures
- Overhead clearances – overpasses, signs and utilities
- Barrier rails
- Existing cross-slope variability
- Drainage structures
- Existing foreslopes
- Intersections, driveways and field entrances
Overlay for Two Lane Roadway with Paved Shoulders (Conventional Paver)

**COmmenced Overlay**

- Pavement marking
- Rumble strip
- Finished shoulder
- Existing pavement
- Concrete overlay
- Separation layer (for unbonded overlay)

**Base shoulder widening**
- Surface repair and overlay surface preparation
- Separation layer (for unbonded overlay)

**Construction area**
- Traffic control device
- Vehicle traffic 11 ft (3.35 m) min.

**Stage 1**

- Typically less than 0.25 mi (0.40 km) without pilot car

- Overlay for Two Lane Roadway with Paved Shoulders (Conventional Paver)
Overlay for Two Lane Roadway with Paved Shoulders (Conventional Paver)

Stage 2

Stage 3
Overlay for Four Lane Roadway with Paved Shoulders (Conventional Paver)
Typical Paving Clearance Zone

• The minimum clearance zone needed for a standard concrete paver operation is 4 ft. (1.22 m) per machine side:
  ▪ This allows 3 ft. (0.91 m) for the paver track/worker
  ▪ 1 ft. (0.30 m) or paver control string line
1. Tailor design to meet performance and budget
2. Include appropriate design details
3. Define maintenance of traffic requirements
4. Allow the contractor to sequence within those requirements
Edge Drop Off Fillets

Bonded overlay 2–4 in. (5.1–10.2 cm) thick

Unbonded overlay greater than 4 in. (10.2 cm)
Variable Thickness

- Cross-slope correction for overlay
- Existing crown needs to be superelevated
  - Asphalt separation layer?
  - Concrete thickness?
  - Reconstruction?
- Sawcut depth – maintain T/3
**Crossing Lift Lines**

- Identify HMA lift Lines (thru coring)
- Limit profile milling that crosses lift lines
- Attempt not to mill within one inch from the lift line
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

• Most effective way to make corrections is by utilizing a nominal thickness of asphalt (typically 1”) as a separation layer

• Make cross-slope and smoothness adjustments in the concrete overlay
Cross Section or Grade Correction by Milling

• Milling should be minimized to reducing structural support of the milled pavement.

• Purpose of Milling:
  ▪ Remove distortions 2” or more
  ▪ Reduce significant high spots
  ▪ Increase bond of overlay
  ▪ Meet vertical elevation requirements

• It is preferable to mill to a depth that will minimize the potential for delamination between lifts

• Grade corrections should be made in the thickness of the concrete overlay
Mill Surfaced Resulting In Thin Asphalt Lift Issues
Unbonded Overlay Transitions Tapers

Bridge approach slabs or meet existing Concrete

Bridge approach slabs or meet existing Asphalt

Note: Recompact and reshape existing subbase in area of transition and reconstruction.
Mill and Fill Transitions

Mill and fill transition for concrete overlay of concrete pavement

Mill and fill transition for concrete overlay of asphalt or composite pavement
Milling & HMA Runout at End of Reconstructed Areas
Side Road Transitions

Temporary granular transition to existing side road/driveway

Asphalt wedge transition to existing side road/driveway
Widening Details

• Widening units
Drainage Outlets for Interlayers

Interlayer outlet for concrete overlay shoulder

HMA interlayer outlet for asphalt shoulder

Geotextile interlayer outlet with new paved shoulder (concrete or asphalt)
• Curb treatment
Manholes

- Manhole and utility structures

Diagram:

- New concrete overlay
- Existing pavement
- Subbase material
- Casting (ring and cover)
- Internal chimney seal
- Water-tight mastic (for movement)
- Adjusting rings
- New concrete overlay
- Existing pavement
- Subbase material

Note: Remove existing pavement around manhole and replace with concrete
Joints
(a) Cracks generally do not develop in concrete that is free to shrink.

(b) Slabs on the ground are restrained by the subbase, creating tensile stresses that result in cracks.
Stages of Cement Hydration

From FHWA’s Draft IMCP Manual January 2006

Stages of Hydration

Temperature

Sawing window

Final set

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing</td>
<td>Dormancy</td>
<td>Hardening</td>
<td>Sawing</td>
<td>Densification</td>
</tr>
<tr>
<td>Lasts about 15 minutes</td>
<td>Lasts about 2–4 hours</td>
<td>Lasts about 2–4 hours</td>
<td>Continues for years</td>
<td></td>
</tr>
</tbody>
</table>

Characteristics of concrete mixture

- High heat is generated immediately, followed by rapid cooling.
- Mixture is plastic, workable, and not generating significant heat.
- Hydration generates significant heat.
- Mixture sets, begins to harden, and gains strength.
- Stress begins developing in the concrete.
- Stress development will exceed strength development if stress is not relieved.
- Slab continues to become stronger and less permeable.

What engineers, supervisors, and workers must do to ensure durable pavement

- Ensure adequate mixing.
- Transport, place, and finish the concrete while plastic and workable.
- Begin curing as soon as possible.
- Thoroughly apply curing compound.
- Saw joints to relieve stress and control cracking.
- Insulate the slab if the air temperature is expected to cool rapidly and significantly.
- Protect curing compound as long as possible.
Joints

- Single sawcut
- Fill with hot pour
- Specify the depth
- Require adequate number of saws and blades
# Joint Spacing for Concrete overlays

<table>
<thead>
<tr>
<th>Bonded Overlay of Asphalt / Composite</th>
<th>Restriction</th>
<th>Typical Range</th>
<th>Transverse Joint Depth</th>
<th>Longitudinal Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length &amp; width (in feet) at 1.5 times the thickness (inches)</td>
<td>3’ – 8’</td>
<td>T/3 min.</td>
<td></td>
<td>T/3</td>
</tr>
<tr>
<td>Bonded Overlay of Concrete</td>
<td>Match existing Joints</td>
<td>N/A</td>
<td>Full depth of overlay plus ½”</td>
<td>T/2 min.</td>
</tr>
<tr>
<td>Unbonded Overlay of Asphalt or Concrete</td>
<td>• Overlays ≤ 6” use length &amp; width at 1.5 times the thickness (inches)</td>
<td>6’ – 14’</td>
<td>T/4 min. T/3 max.</td>
<td>T/4 – T/3</td>
</tr>
</tbody>
</table>
Load Transfer

• Dowel basket placement
  ▪ $t \geq 7''$
  ▪ Securely anchored
  ▪ Variable thickness HMA interlayer must be accounted for (anchor length and shot force)
Design for Overlay Types
Bonded Concrete Overlays

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
Surface Milling of Asphalt

- Milling AC surface (optional)
  - Remove rutting
  - Restore profile
  - Enhance bond
- Minimum AC thickness remaining after milling: 3 in
- Surface cleaning
Longitudinal Joint Layout

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

Outer Shoulder

Traffic

12 ft
TYPICAL CROSS SECTION AND JOINTING DIAGRAM
PCC UNBONDED OVERLAY
WITH PARTIALLY PAVED SHOULDERS

Notes:
1. Extend existing expansion joints in kind in new pavement.
PCC Joint Sawing

CRITICAL
- Effective curing
- Timely joint sawing
The preferred method of repair is with concrete rather than asphalt (for improved bond).

Cracks can be filled, but generally are not.
Joint Sealing Issues

• Joint sealants are used to keep debris out of joint and to minimize infiltration of water

• Size/shape of sealant reservoir affects sealant performance

Current debate:
TO SEAL OR NOT TO SEAL?
To seal or not to seal ...  
Minnesota findings
Bonded Concrete Overlays

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
Kansas I-35 Bonded Overlay - 2008

- Original PCCP – 1985 – 9 in. JRCP (30 ft slabs), over CTB
- Distress – extensive spalling – 2 in. deep
- Bonded overlay – mill 2 in., shot blast, apply slurry, place 2 in. bonded inlay
Coefficient of Thermal Expansion (CTE)

- Overlay CTE should be similar to underlying pavement
- If not near the same, the overlay CTE should be lower than existing pavement
- Key similar coarse aggregate type

![Diagram showing shear and tensile stress in an overlay pavement system]
Maintaining Bond

- Replaced Asphalt Patch with Concrete Patch
Surface Preparation for Bonded Overlay
Bonding is Critical

Shotblaster

Shot Blasted Pavement

• Sweeping surface followed by compressed air cleaning in front of the paver.
Joint Design—Full Depth Cut & Width of Cut

Within 1/2 inch

New Joints

Existing Joints

Bonded PCC Resurfacing
Existing PCC Pavement

Overlay joint
Concrete overlay

New overlay transverse joint

Sawcut in existing slab

Crack in existing slab
Unbonded Concrete Overlays

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
Jointing

- Unbonded concrete overlay jointing:

- Transverse joints offset from those in existing slab (when possible, BUT NOT NECESSARY)
Unbonded Overlays Can Be Placed Over Poor Concrete Pavements

2007
D35-Kansas City Metro Area- 9000 ADT- 5” Unbonded Overlay Excellent Condition
Spot Repairs for Unbonded Overlays of Concrete

Joint Patching
Separation Layer For Unbonded Concrete over Concrete

• Asphalt separation layer
  ▪ Serves as a good cushion for the overlay
  ▪ Can help prevent keying of the interlayer in faulted concrete pavements
  ▪ Stripping of the asphalt binder can occur due to poor drainage of the interlayer and heavy truck traffic.

• Nonwoven geotextile fabric
  ▪ Easy to place interlayer at less than half the cost of asphalt.
  ▪ Improved drainage but must have outlet
  ▪ Faulting must be minimal to prevent keying of the overlay
**Stripping**

- Stripping occurs in the asphalt interlayer of an unbonded concrete overlay pavement when the interlayer contains trapped water and under repeated heavy truck traffic, results in the water stripping the asphalt binder from the aggregate.

- Prevention
  - Drainage of the interlayer
  - Open-graded interlayer
  - Anti-strip additives
  - Seal Joints
HMA Separation Layer

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ inch</td>
<td>100</td>
</tr>
<tr>
<td>3/8 inch</td>
<td>85-100</td>
</tr>
<tr>
<td>No.4</td>
<td>22-38</td>
</tr>
<tr>
<td>No.8</td>
<td>19-32</td>
</tr>
<tr>
<td>No.16</td>
<td>15-24</td>
</tr>
<tr>
<td>No.30</td>
<td>11-18</td>
</tr>
<tr>
<td>No.50</td>
<td>8-14</td>
</tr>
<tr>
<td>No.100</td>
<td>5-10</td>
</tr>
<tr>
<td>No.200</td>
<td>4-7</td>
</tr>
</tbody>
</table>

Michigan's modified aggregate gradation to address stripping of separation layers
<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement (95% PWL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabric Type</td>
<td>Non-woven Geotextile Uniform color</td>
</tr>
<tr>
<td>Mass per unit area</td>
<td>13.3 oz/sq.yd 16.2 oz/sq.yd</td>
</tr>
<tr>
<td>Thickness under pressure</td>
<td>0.29 psi: 0.12 in. 2.9 psi: 0.10 in. 29 psi: 0.04 in.</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>685 lb/ft</td>
</tr>
<tr>
<td>Maximum elongation</td>
<td>130% (60% recommended as best practice)</td>
</tr>
<tr>
<td>Water permeability in normal direction under pressure</td>
<td>3.3 $10^{-4}$ ft/s) [under pressure of 2.9 psi]</td>
</tr>
<tr>
<td>Alkali resistance</td>
<td>$\geq$ 96% Polypropylene/Polyethylene</td>
</tr>
</tbody>
</table>
Drainage Detail

CONSTRUCT A 12" WIDE x 26" DEEP POROUS DRAINAGE TRENCH ADJACENT TO THE EXISTING SUBGRADE UNDERDRAIN TRENCH (MEASURED & PAID FOR AS: (Misc Excavation, Earth AND (Open-Graded Aggregate, 34R))

EX. SUBGRADE UNDERDRAIN, 6 INCH IN A 1.0' x 1.0' TRENCH, BACKFILLED WITH CL-II GRANULAR MATERIAL (PER CONSTRUCTION REQ)

TYPICAL SECTION TO APPLY ALONG EACH CURB LINE
STA. 41+10.00 TO STA. 147+56.00 (EXCLUDING INTERSECTIONS)
Draining Geotextile Interlayer in Urban Sections
Concrete Overlay Overruns
Issues & Solutions

Most paving projects have some overruns (even new projects)

• Grade (base/subbase variation)
• Handling
  ▪ Mixing
  ▪ Hauling
  ▪ Placement
• Typical 5% on new jobs
Concrete Overlay Quantities
-REALITY SITUATION-

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

• Profile is not perfect and needs corrected

• Cross slope needs correction
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>
</tr>
<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>
Minnesota Department of Transportation (MnDOT) Pay Method

- Set an initial plan quantity based on the theoretical cubic yards
- This quantity is used only for the purposes of bidding and awarding the contract
- After the separation layer has been placed or any milling has been performed, a physical survey is performed
- For a 24’ wide crowned pavement section, lines of survey are taken at the crown point and both edges at 25’ or 50’ centers
- Using this survey information along with the proposed profile grade and design cross-slope(s), a revised cubic yard plan quantity is calculated
- Payment for cubic yards of concrete is then capped by specification at 102% of this revised plan quantity
# Survey Cost Comparison

## Cost Comparison of Engineering/Surveying Pre Construction verses 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>
</tr>
</thead>
<tbody>
<tr>
<td>Project scope development</td>
<td>25</td>
<td>$ 95.00</td>
<td>$ 2,375.00</td>
<td>$ 2,375.00</td>
<td>$ 2,375.00</td>
</tr>
<tr>
<td>Project control establishment</td>
<td>65</td>
<td>$ 150.00</td>
<td>$ 9,750.00</td>
<td>$ 9,750.00</td>
<td>$ 9,750.00</td>
</tr>
<tr>
<td>Topo survey</td>
<td>220</td>
<td>$ 150.00</td>
<td>$ 33,000.00</td>
<td>$ 41,250.00</td>
<td>$ 49,500.00</td>
</tr>
<tr>
<td>Create existing road surface</td>
<td>13</td>
<td>$ 75.00</td>
<td>$ 975.00</td>
<td>$ 975.00</td>
<td>$ 975.00</td>
</tr>
<tr>
<td>Design road profiles</td>
<td>100</td>
<td>$ 88.00</td>
<td>$ 8,800.00</td>
<td>$ 8,800.00</td>
<td>$ 8,800.00</td>
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<tr>
<td>Construction survey</td>
<td>190</td>
<td>$ 150.00</td>
<td>$ 28,500.00</td>
<td>$ 28,500.00</td>
<td>$ 28,500.00</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td>$ 83,400.00</td>
<td>$ 91,650.00</td>
<td>$ 99,900.00</td>
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<tr>
<td>Cost Per Mile</td>
<td></td>
<td></td>
<td>$ 8,340.00</td>
<td>$ 9,165.00</td>
<td>$ 9,990.00</td>
</tr>
</tbody>
</table>

*Note: The estimates show have been generated from six estimates for construction survey that were calculated.*
Questions?

www.cptechcenter.org

Thank You – Dale S. Harrington P.E.