Unbonded Concrete Overlay Design: Thickness and Other Considerations

Presented at:
PennDOT/ACPA Penn Chapter Bus Tour Roundtable Discussion
August 6, 2015

Mark B. Snyder, Ph.D., P.E., Engineering Consultant

Acknowledgments

- Tom Burnham, Minnesota DOT
- John Donohue, Missouri DOT
- Federal Highway Administration
- Dale Harrington and the National Concrete Pavement Technology Center
- Todd LaTorella, ACPA – MO/KS Chapter
- Randell Riley, ACPA – IL Chapter
- Dr. Shiraz Tayabji (Applied Research Associates)
- The Transtec Group
- Dr. Julie Vandenbossche, Univ. of Pittsburgh
Concrete Overlay Design

Design Balances Several Factors

- Desired service life, load-carrying capacity
- Costs
- Existing pavement condition, preoverlay repairs
- Design (thickness, etc.)

Thickness Design Procedures

- **Empirical Design Procedures**
  - Based on observed performance
    - ’72, ’86/’93 AASHTO Design Procedures

- **Mechanistic-Empirical Design Procedures**
  - Based on mathematically calculated pavement responses
    - Pavement-ME (MEPDG)
    - PCA Design Procedure (PCAPAV)
    - ACPA Ultrathin Whitetopping Design Procedure
    - StreetPave (ACPA Design Method)
    - BCOA-ME (Univ. of Pittsburgh, 2013)
  - Allows new and innovative designs and materials (e.g., smaller panels and wider lanes with lower stresses)
Family of Concrete Overlays

Bonded Family
- Bonded Concrete Overlay of Concrete Pavements
- Bonded Concrete Overlay of Asphalt Pavements
- Bonded Concrete Overlay of Composite Pavements

Unbonded Family
- Unbonded Concrete Overlay of Concrete Pavements
- Unbonded Concrete Overlay of Asphalt Pavements
- Unbonded Concrete Overlay of Composite Pavements

Bond is integral to design
Old pavement is base

Bonded versus Unbonded (intent)

- **Bonded:**
  - Overlay and existing pavement behave as one integral paving layer.
  - Use to eliminate surface defects; increase structural capacity; and improve surface friction, noise, and rideability

- **Unbonded:**
  - Overlay and existing pavement act as two separate and independent layers.
  - Use to restore structural capacity and increase pavement life equivalent to full-depth pavement. Also results in improved surface friction, noise, and rideability
**Unbonded Cement Concrete Overlays**

(of existing AC, PCC or composite pavement)

**Common items**
- **Thicker**
  - > 6 inches over AC
  - > 4 inches over PCC or composite
- **Joint spacing**
  - 6 ft x 6 ft for t < 6 inches
  - Conventional for t > 6 inches
- **All placed directly over AC surface (or fabric interlayer)**
- **Bonding discouraged (or at least “not encouraged”)**

---

**Unbonded Overlay of Concrete Pavements: Uses and Benefits**

- >4-in thickness (up to 12-inch) have been used
- Use when existing pavement is in poor condition, including with material-related distress such as D-cracking and ASR., 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 provide long-life rehabilitation solution.
- Results in improved surface friction, noise and ride.
Structural Deficiency Approach to Overlay Design (1993 AASHTO Guide)

Unbonded on Concrete / Composite 1993 AASHTO

Slab Thickness Design

Unbonded overlay design equation:

\[ D_{ol} = \sqrt{D_f^2 - D_{eff}^2} \]

where:

- \( D_{ol} \) = Required PCC overlay thickness
- \( D_f \) = Required thickness of new PCCP
- \( D_{eff} \) = Effective thickness of existing PCC
Unbonded on Concrete / Composite
1993 AASHTO

Determination Of Effective Slab Thickness ($D_{eff}$)

$$D_{eff} = F_{jcu} \times D$$

Where

$F_{jcu}$ = Joints and Cracks Adjustment Factor
$D$ = Thickness of Existing Slab, in.

Unbonded Concrete Overlay
Joints & Cracks Adjustment Factor, ($F_{jcu}$)

Adjusts for PSI loss due to unrepaired joints, cracks, and other discontinuities

- Number of deteriorated transverse joints per mile
- Number of deteriorated transverse cracks per mile
- Number of existing expansion joints, exceptionally wide joints (>1 in.), or AC full-depth patches

Very little reflective cracking has been observed in unbonded overlays
Unbonded Concrete Overlay
Joints & Cracks Adjustment Factor, \((F_{jcu})\)

UBOL Design using Pavement-ME

Same process as for new pavements...

- Determine basic design parameters (traffic, soil conditions, etc.)
- Develop preliminary designs (thickness, base designs, joint spacing, and other design features)
- Evaluate the predicted performance from Pavement-ME over the analysis period (e.g., 50 years) to determine the life-cycle activity profiles describing “when” and “what” rehabilitation activates will be performed.
- Calculate the Initial and Life Cycle Costs for each pavement design over the analysis period.
- Evaluate designs and modify as needed to develop a pavement section that meets or exceed the required initial performance period and has the lowest life cycle cost.
Guide for the Design of Concrete Overlays using Existing Methodologies

- Background of recommended overlay design techniques
  - 1993 AASHTO Overlay procedure
  - Pavement-ME / MEPDG
  - ACPA Bonded Concrete Overlay of Asphalt pavements
    - (BCOA-ME background on host website)
- Detailed examples of how to use the existing design methodology
- Learn by example – then apply for your situation!

Available online:
http://www.cptechcenter.org/

Summary of Best UBOL Jointing Practices

- Joint spacing (max = 18-to-24 x thickness)
  - For 3 to 6 in. overlay, use 6 by 6 ft
  - For > 6 in. use full width and conventional spacing
  - Avoid longitudinal joints in wheel paths
- Adjust depth of saw cut for actual slab thickness
  - T/3 nominal, T/4 minimum
- Dowel & tie bar use
  - Usually no dowels for overlay thickness < 8 in.
  - For unbonded overlays > 4 in., may use tie bars at longitudinal joints
MnROAD: 3” PCC/10” HMA, 4’x4’

Source: Burnham (MnDOT)

MnROAD: 3” PCC/10” HMA, 6’x6’

Source: Burnham (MnDOT)
Considerations for Using Structural Fibers

- Does not significantly increase concrete strength
- Increases toughness
- Increases post-crack integrity
- Steel fibers not recommended where deicing salts may be used.

Steel

Synthetic Structural

Con Expo Demo
March 2002, Las Vegas
Unbonded on Concrete: 1993 AASHTO

- Separator layer (interlayer)
  - Can significantly affect performance
  - Functions
    - Isolate overlay from underlying pavement
    - Allow differential horizontal movement
    - Provide a level surface for the overlay construction
  - Types
    - Dense- or open-graded HMA, typically 1-1.5" thick
      - Thickness increases with surface irregularities (e.g., faulting)
      - Consolidation and stripping issues increase with HMA thickness
    - Nonwoven Geotextile
    - Other materials have been used with varying success
### Separator Layer

- Isolate overlay from existing pavement
  - Prevent reflection cracking
  - Prevent bonding/mechanical interlocking
- Provide level surface for overlay construction
- Provide a softer interlayer – less curling stresses
- Recommended interlayer material:
  - Dense- or open-graded HMA, typically 1-1.5" thick
    - Thickness increases with surface irregularities (e.g., faulting)
    - Consolidation and stripping issues increase with HMA thickness
  - Nonwoven Geotextile

### Typical Fabric Specs

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement (95% PWL)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fabric Type</strong></td>
<td><strong>Non-woven</strong> Geotextile</td>
</tr>
<tr>
<td>Mass per unit area</td>
<td>≥ 13.3 oz/sq.yd</td>
</tr>
<tr>
<td></td>
<td>≤ 16.2 oz/sq.yd</td>
</tr>
<tr>
<td>Thickness under pressure</td>
<td>0.29 psi: ≥ 0.12 in.</td>
</tr>
<tr>
<td></td>
<td>2.9 psi: ≥ 0.10 in.</td>
</tr>
<tr>
<td></td>
<td>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% (&lt; 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>≥ 96% Polypropylene/Polyethylene</td>
</tr>
</tbody>
</table>
**Unbonded on Concrete: 1993 AASHTO**

- Nonwoven Geotextile Interlayer

www.ConcreteOnTop.com

It is recommended that the design thickness calculated using the 1993 AASHTO Guide be increased by 0.5 in. when a nonwoven geotextile interlayer is used in lieu of HMA.

---

**Pre-Overlay Repairs of Existing PCCP**

- Severe corner breaks, shattered slabs, excessive faulting, settlements
  - Full-depth repair
- Spalling
  - Remove loose material, fill with repair material
- Most cracking or faulting
  - No treatment
- Materials-related distress (F/T, ASR)
  - No treatment (or slab fracturing?)

---
Existing concrete and foundation must provide a platform with reasonably uniform strength and support; repair as required to achieve.

2007 Missouri
5-in UBOL of D-cracked PCCP
Unbonded Overlay of Concrete Pavements: Keys to Success

- Use full-depth pre-overlay repairs at isolated spots where structural integrity is lost.
- Separator layer (normally 1- to 2-inch dense-graded asphalt) to isolate overlay from underlying pavement - minimize reflective cracking.
- Drainage design may be required to prevent stripping in asphalt separation layer.
- Shorter joint spacing helps minimize curling and warping stresses.
- No need to match joints in overlay and original cement concrete.
Performance

- Very good performance – can be designed for 40+ years service life
- Extensive use by many highway agencies
- Key factors affecting performance:
  - Adequate separator layer
  - Adequate structural design (thickness)
  - Effective joint design

Thank You For Your Attention!

Questions?