Design and Construction of Concrete Overlays

WCPA 2016 Annual Pavement Workshop
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Jerod Gross - Snyder and Associates, Inc. Representing CP Tech Center
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

Improve surface characteristics
add structural capacity
Bonded and Unbonded

Bonded

Unbonded
History

• First bonded concrete over concrete overlay
  – Warsaw Street in Toledo, Ohio in 1913.
  – Typical applications have been:
    ▪ to correct construction deficiencies
    ▪ to correct surface problems relating to wear or loss of skid resistance

• First unbonded concrete over concrete overlay
  – Grand River Road, Wayne County MI in 1916.
    ▪ Only lasted 7 years
  – 2nd overlay was constructed in 1920 and was overlaid in in the 1980’s

• First concrete overlay of asphalt (Whitetopping)
  – 3–4 in. reinforced concrete overlay on South 7th street in Terre Haute, Indiana in 1918
  – Used to upgrade military & civil airports during 40’s and 50’s
  – Highway use started approx. 1960
  – Bonded concrete overlays of asphalt (UTW) started in 1990’s.
General Applicability of Concrete Overlays

Existing pavement condition before repairs:
- Excellent
- Good
- Fair
- Poor
- Deteriorated
- Failed

Time

Preventive maintenance
Minor rehabilitation
Major rehabilitation
Reconstruction

Bonded on Concrete
Unbonded on Concrete
Bonded on Asphalt
Unbonded on Asphalt
Types of Concrete Overlays

Bonded

- 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

- 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
BONDED OVERLAY OF CONCRETE - FULL DEPTH CUT & WIDTH OF CUT
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.
Bonded Overlay on Concrete: Keys to Success

- Bond is critical
- 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
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Bonded Over Asphalt/Composite

Keys to Success

- Bonding is critical
- Small square panels reduce curling, warping, & shear stresses in bond.
- Mill to remove surface distresses, or improve bonding.
- Be sure to leave 3” of HMA after milling.
- Joints in the overlay should not be placed in wheel paths, when possible.
- Application of curing compound is critical.
How Do Bonded Overlays over Asphalt Work?

• Concrete bonds to the asphalt
  – Lowers the neutral axis
  – Decreases stresses in the concrete

• Short joint spacing
  – Controls cracking
  – Slabs act as paver-blocks

• Fibers improve concrete toughness
Effects of Asphalt Thickness

Concrete

\[ \text{Tension} \quad \text{Comp.} \quad \text{Asphalt} \]

\[ x \]

Concrete

\[ \text{Tension} \quad \text{Comp.} \quad \text{Asphalt} \]

\[ 2x \]
Structural Fibers Considerations

- Does not increase the concrete’s strength
- Increases toughness
- Increases post-crack integrity
  - Helps control plastic shrinkage cracking
  - Steel fibers not recommended where deicing salts may be used.
EXCESSIVE MILLING OF EXISTING ASPHALT BEYOND ASPHALT LIFTS (TACK LINE)

- 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)
JOINTING BONDED CONCRETE OVERLAYS ON ASPHALT

• 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

Outer Shoulder

Traffic

2 ft x 2 ft

3 ft x 3 ft

4 ft x 4 ft

6 ft x 6 ft

12 ft
Types of Concrete Overlays

Bonded

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Bonded Concrete Overlays of Composite Pavements

Unbonded

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—previously called conventional whitetopping—

Unbonded Concrete Overlays of Composite Pavements
Unbonded Overlay of Concrete Pavements

Keys to Success

- Full-depth repairs – isolated only where structural integrity is lost
- Separation 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
- No need to match joints with those of the underlying concrete pavement
UNBONDED OVERLAYS PLACED OVER POOR PAVEMENTS

D35-Kansas City Metro Area-9000 ADT- 5” Unbonded Overlay Excellent Condition
SPOT REPAIRS FOR BONDED OVERLAYS OF CONCRETE

Joint Patching
DRAINABLE ASPHALT SEPARATION LAYER
ASPHALT STRIPPING CAN BE A PROBLEM, but . . . . .
Geotextile (Separation) Interlayer

Existing Pavement

Overlay

Geotextile Interlayer
What is it?

- Nonwoven
- Woven
Color of Fabric

Black vs. White

- **Black** - carbon molecules which absorb Ultra-Violet energy
  - Requires damping to reduce heat below 110 F.
  - Use in spring and fall

- **White** - pure polypropylene resin and reflects Ultra-Violet energy
  - Does not require damping to reduce heat
  - Use in summer months
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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
- Partial bonding between the overlay and the existing asphalt pavement is acceptable and may even improve load-carrying capacity
Evaluation Steps

1. Pavement History (Records)

2. Field Review of Distresses

3. Coring Pavement

4. Field Tests Where Necessary

5. Condition Assessment Profile
1. Pavement History

- Age of Different Thickness Layers
- Estimate Remaining Life
- Mixture materials,
- Design & construction date and method,
- Performance Grades of Lifts (records)
- Type and Amount of Traffic Now and in the Future
- Pavement Management Records
- Desired Design Life
- Elevations and Grade Restrictions
Evaluations of Existing Pavements

• 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 (unbonded)
2. Field Review of Distress/Limitations

- Identify distress:
  - Type
  - Amount
  - Severity

- Evaluate uniformity of distress conditions

- Identify areas for further testing/evaluation

- Document repair quantities
3. Coring

- Layer confirmation
- Layer thicknesses
  - Variability
  - Minimum requirements for thin overlays
- Subsurface conditions
  - Stripping
  - Delaminations
- Samples for laboratory testing
  - Material properties
Concrete Overlay Thickness Design & Design Details
• 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, geometry 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)

Don’t make it complicated
The Principal Factors of Concrete (Overlay) Pavement Design

- Geometry
- Thickness
- Joint Systems
- Materials
Identify and Quantify Constraints

- Vertical and horizontal constraints need to be identified during the pavement evaluation
  - Existing structures
  - Overhead clearances – overpasses, signs and utilities
  - Barrier rails
  - Existing cross-slope variability and new cross-slope requirements
  - Drainage structures
  - Existing foreslopes
  - Intersections, driveways and field entrances
Important Considerations in Overlay Design

- Required Future Design Life of the Overlay
- Traffic Loading (ESALs)
- Pre-overlay Repair
- Reflective Crack Control
- Subdrainage
- Recycling Existing Pavement (PCC & AC)
- Durability of aggregate for new concrete
Important Considerations in Overlay Design (cont.)

- Shoulders/Widening
- Existing PCC Slab Durability
- PCC Overlay Joints
- PCC Overlays Bonding / Separation Layers
- Overlay Design Reliability Level & Overall Standard Deviation
- Traffic Disruptions and Delay Costs
Design Balances Several Factors

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

Traffic management for concrete overlay projects is no more challenging than for any other paving project, particularly under traffic, as long as straightforward practices are followed.
Traffic During Paving

• Maintenance of traffic
  – Depends on concrete overlay thickness
    • If edge drop-off criteria is exceeded, then MOT is just like full depth PCC reconstruction
    • Otherwise, similar to MOT for asphalt projects
  – Options include:
    • Construction adjacent to traffic (lane at a time)
    • Positive separation or cones
    • Pilot car operation for two lane roadways
    • Crossovers and construct full width
    • Staged intersections or full closure with accelerated opening (48 to 72 hr)
  – All concrete overlays are accelerated construction!
Work Zone - Cost Effectiveness

• Traffic strategies can significantly affect project costs

• Traffic control costs and construction costs should be balanced against the impact on the public

• Many urban intersections have been overlaid with concrete utilizing only weekend work hours

• Agency sets the criteria regarding staging, contractor proposes staging that meets criteria
2 Lane Roadways: Open or Closed for Overlay Construction?

- Always analyze the option of closing road where feasible.
  - Partly or completely closing a work zone to traffic can help minimize traffic management costs.
  - Projects closed to traffic can save time and cost of 25% to 35%.

- Concrete overlays can be successfully and cost-effectively constructed without closing the roadway to traffic.

- Contractor is responsible for maintaining local access for residents and businesses.

- Putting the bonus on the contractor allows flexibility in their methods for providing local access is a preferred strategy.
Inside Safety Edge Placement
Inside Safety Edge Placement Removal
Clearance Challenges

The primary challenges to maintaining reduced clearances are:

• Equipment Clearances:
  – Physical tracks and frame of the slip-form paving machine
  – Traditional paving controls such as use of a string line

• Adequate working area for workers

• Traffic controls for traffic in adjacent lanes

• Traffic Users (vehicles, bicycles, pedestrians, etc.)
Clearance Challenges

• Adaptation
  – Moving string (ski)

• Innovation
  – Stringless paving
Concrete Overlay Placement

1. Pre-paving activities
2. Design and construction details
3. Paving activities
Pre-Paving

• Stringline
• Stringless – 3D models for existing/milled surface and concrete overlay
• Profiles optimized to balance
  – Thickness
  – Volume
  – Smoothness
Pre-Paving

• Milling
  – Remove distortions of 2” or more
  – Reduce high spots to insure minimum overlay thickness
  – Match adjacent lanes
  – Enhance bond
  – Restore profile

• Bonded on asphalt or composite must maintain a minimum of 3” sound asphalt after milling
Pre-Paving

• Cautions for milling
  – Milling should be minimized to retain structural support of pavement
  – Grade corrections should be made in the thickness of the concrete overlay

Excessive milling of existing asphalt
Pre-Paving

- Surface cleaning
  - Power sweeping
  - Air blasting
Concrete Overlays
Accelerated Construction

• Eliminates exposing subgrade to the weather
• Production is typically (or should be) limited by the capacity to saw joints in a timely manner
• Incentives can be used to motivate accelerated opening
• Normal concrete mixtures can and should be used
Paving

• Maintenance of traffic
  – US-69 Oklahoma
    • Four lane divided
    • One lane at a time
    • Adjacent to traffic
Paving

• Maintenance of traffic
  – US-18 Iowa
    • Two lane roadway
    • One lane at a time with a pilot car
    • Stringless Paver

Pilot car reduced traffic 10%
Paving

• Delivery, spreading, consolidation and initial finishing
Finishing

• Increased Finish Area to Volume placed:
  – 12 inch thick 2350 cy = 7050 sy - 1 lane mile
  – 6 inch thick 2350 cy = 14,100 sy - 2 lane miles
  – 4 inch thick 2350 cy = 21,150 sy - 3 lane miles

• Must use a workable mix design:
  – Well graded mixes with SCM’s are recommended

• Curing
  - Uniform
  - Edges
Sawing

- Volume of saw cuts increased:
- Longitudinal cuts are as critical as transverse
- Increased base friction
- Base temperature control
- Mix Temperature control – set times
Sawing

• Plan for volume of saw cuts

24 foot wide pavement

Conventional 15 foot spacing = 13,728 feet/mile
6’ x 6’ spacing = 36,960 feet/mile

~3 times the saw length
PERFORMANCE HISTORY OF CONCRETE OVERLAYS

Nova Scotia
March 2015

Gary Fick
Leif Wathne
## Concrete Overlay Case Histories

<table>
<thead>
<tr>
<th>Case History #</th>
<th>State</th>
<th>Route</th>
<th>Year Constructed</th>
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Costs

Average Concrete Overlay Cost ($/SY/in.)
Bonded and Unbonded Overlays

- Iowa: $2.52
- Michigan: $2.82
- Missouri: $3.35
- Oklahoma: $3.35
- South Dakota: $3.58
- Minnesota: $4.07
- Illinois: $4.45
THANK YOU!
Short Panels Improve Performance By Decreasing Curling And Warping

Effect of Slab Length on Shrinkage Force

- Curling & warping is produced by the shrinkage force at the slab surface.
  - Due to drying and thermal differential shrinkage on the surface of the concrete.
- The magnitude of this force is dependent on the length of the surface.
  - Shorter slabs have less length, which means that shorter slabs have reduced curling

Effect of Slab Length on Curling/Warping

- All concrete slabs curl / warp so that approximately 1/4 of the slab length is lifted of the subgrade / subbase support
- By reducing slab length, the amount lifted, and the height of the lift is greatly reduced

Cantilever = 1/4 L

Length 12 to 15 ft., cantilever = 3 to 3.75 ft

Cantilever = 1/4 L

Length 6 ft., cantilever = 1.5 ft