UHPC Overlays for Bridge Preservation – Lessons Learned

New Jersey Department of Transportation

Jess Mendenhall
Samer Rabie
Bureau of Structural Engineering
Structural Value Solutions (SVS)
• Pilot project to investigate UHPC overlay
• Ultra-High-Performance Concrete (UHPC) as a thin-bonded overlay
• Focus on rehabilitation and increased service life of bridge decks.
• 4 Bridges
• ~48,000 SF deck area
• 2 Contracts (North/South)
Background

- Thin overlays are suitable to seal existing or new decks as surface treatment without a major change in the roadway profile.
- Concrete overlays not often used by NJDOT in recent years.
- UHPC overlay is high cost but offers potential life cycle cost benefits ($$)
- NJDOT is in the Demonstration and Assessment phases with pilot projects.
Advantages of UHPC overlays published include superior bond strength, compressive strength, lower permeability, more resistant to freeze thaw-damage, good abrasion resistance, rapid cure times, etc...

..Many ideal properties for a deck surface.

Disadvantages:

• Material cost for UHPC is high; Bids for this project yielded an average cost of $270 to $410/SY or $35 to $46/SF (overlay only)

• Fresh UHPC does not bond well to hardened UHPC - careful consideration for joint construction is needed, including reinforced staging joints.

• Limited test data for construction materials to determine their ability to perform well with UHPC

• The NJ construction force is not familiar with the use of UHPC as an overlay.
Bridge Selection Process
Bridge Selection Process

- Considerations: condition ratings (good condition), load ratings, deck chloride content, construction staging and traffic volumes, existing overlay depths
- Eight (8) structures fully evaluated/tested, four (4) were advanced
- Deck slab ages from 10 years up to 40 years
- Deck slab areas from 800 SF to over 20,000 SF
- All bridges had asphalt overlay
- Structures were eliminated due to load ratings (unexpected asphalt thicknesses discovered), heavy traffic volumes and/or difficulty in limiting number of stages
Initial Conditions & Testing

- Concrete cores were taken at each bridge:
  - overlay thickness
  - chloride contents
- Chloride Content:
  - ensure deck concrete to remain isn’t overly contaminated
  - provide baseline data for future testing
  - NJDOT consider the threshold to initiate corrosion based on chloride content to be 2.0 pounds per cubic yard (PCY).
- Ground penetrating radar (GPR):
  - estimate area of deck repairs
  - increase confidence in the overall condition of the deck.

### Chloride Content Test Results (Maximum Chloride Content)

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Structure Name</th>
<th>Acid Soluble Chloride (PCY) 0.75”-1.25” Depth</th>
<th>Acid Soluble Chloride (PCY) 1.75”-2.25” Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NJ 49 over Cohanseay River</td>
<td>Eliminated</td>
<td>Eliminated</td>
</tr>
<tr>
<td>2</td>
<td>I-295 NB &amp; US 130 NB over Mantua Creek</td>
<td>3.062</td>
<td>2.983</td>
</tr>
<tr>
<td>3</td>
<td>I-195 EB over S. Broad St WB (CR 524) &amp; Arena Dr.</td>
<td>Eliminated</td>
<td>Eliminated</td>
</tr>
<tr>
<td>4</td>
<td>I-78 EB over Tributary to Dead River</td>
<td>Eliminated</td>
<td>Eliminated</td>
</tr>
<tr>
<td>5</td>
<td>NJ 57 over Hances Brook</td>
<td>0.529</td>
<td>0.438</td>
</tr>
<tr>
<td>6</td>
<td>I-280 WB over Newark Turnpike (CR 508)</td>
<td>3.794</td>
<td>3.821</td>
</tr>
<tr>
<td>7</td>
<td>NJ 24 Over Park Avenue</td>
<td>Eliminated</td>
<td>Eliminated</td>
</tr>
<tr>
<td>8</td>
<td>NJ 159 WB over Passaic River</td>
<td>0.438</td>
<td>0.407</td>
</tr>
</tbody>
</table>
Project Details

- Maintain grades (limit impacts, environmental impacts/permits)
- Staged construction (2-stage)
- **Sequence:** 1.) Existing overlay removal 2.) Hydrodemolition (¾“) 3.) Deck Patching 4.) Reconstruct deck joints (UHPC headers) 5.) UHPC Overlay (1-1/2” to 2-1/2”) 6.) Overlay or Diamond Grind
Contract Documents

- Structure Plans
- Performance Specifications
- Submittals
- Details
- Deck survey after existing overlay removal and after UHPC overlay installation
- Contract Pay Items
Material Testing

- The UHPC mixes consisted of a partial premix made by the supplier, sand, water, liquid admixtures, and steel fibers (3.25% of the total dry volume).

- To ensure the consistency of each UHPC batch, a procedure of overlay flow testing in accordance with ASTM C1437 was followed.

- With 3.25% steel fibers, the values of static and dynamic flows were 4-6 inches & 6-8 inches, respectively.

<table>
<thead>
<tr>
<th>Description</th>
<th>Test Method</th>
<th>Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive Strength</td>
<td>ASTM C1856</td>
<td>≥14 ksi at 28 days</td>
</tr>
<tr>
<td>Direct Tension Cracking</td>
<td>FHWA-HRT-17-053</td>
<td>≥1100 psi</td>
</tr>
<tr>
<td>Strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Tension Sustained</td>
<td>FHWA-HRT-17-053</td>
<td>≥1250 psi</td>
</tr>
<tr>
<td>Post-Cracking Tensile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>ASTM C1583, bonded</td>
<td>100% failure in substrate concrete with</td>
</tr>
<tr>
<td></td>
<td>to an exposed</td>
<td>concrete compressive strength ≥ 4 ksi</td>
</tr>
<tr>
<td></td>
<td>aggregate concrete</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surface.</td>
<td></td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>ASTM C1856</td>
<td>≥ 6500 ksi</td>
</tr>
<tr>
<td>Long-Term Shrinkage</td>
<td>ASTM C1856</td>
<td>≤ micro-strain</td>
</tr>
<tr>
<td>Rapid Chloride Ion</td>
<td>AASHTO T277 / ASTM</td>
<td>≤ 250 coulombs</td>
</tr>
<tr>
<td>Penetrability</td>
<td>C1202</td>
<td></td>
</tr>
<tr>
<td>Scaling Resistance</td>
<td>ASTM C672</td>
<td>Y ≤ 3</td>
</tr>
<tr>
<td>Freeze-Thaw Resistance</td>
<td>ASTM C1856</td>
<td>Relative Dynamic Modulus of Elasticity ≥</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95%</td>
</tr>
<tr>
<td>Alkali-Silica Reaction</td>
<td>ASTM C1260</td>
<td>Innocuous</td>
</tr>
</tbody>
</table>
Test Slabs

UHPC Overlay Mockup Tests: Per the contract documents, contractors were required to successfully place a 4’x12’x3” deep rectangular test slab of UHPC with a grade of 8% in the longitudinal direction.
Construction : General Contractors vs. Specialized UHPC Contractors

- A specialized contractor brings in prior experience placing UHPC, has established relationships with UHPC suppliers, and has specialized UHPC equipment.

- More contractors are expected to join this industry allowing more competition and competitive bid pricing.

- The most crucial element is the mixing and establishing the correct amount of UHPC fluidity to ensure the UHPC holds the grade of the deck.

- Specialized UHPC pavers are available for purchase by any contractor.

- As long as the documents require the appropriate measures be taken by the contractor along with the quality control requirements, the desired end product should be attainable by a general contractor or a subcontractor.
Construction
Submittals

NJDOT UHPC Overlays
Construction
Joints and Formwork

NJDOT UHPC Overlays
Construction: Headers and Curing

- Ensure proper curing in accordance with the approved procedures to prevent dehydration cracks.
- For UHPC Headers, Contract B used a semithixotropic mix while Contract A used a self-consolidating and self-leveling mix.
- Self-consolidating UHPC is preferred for the full-depth UHPC header placement.
- Consideration of partial depth UHPC headers or HPC headers with UHPC over the top should be included for individual projects.
- Specify water tight forms, top forms, and a minimum ¼" overfill of UHPC followed by grinding the surface per the specifications.
Final Product

- Surface defects were addressed before asphalt paving, out of an abundance of caution, these locations were identified for future monitoring.
- UHPC slurry with no fibers was placed in any identified air voids.
- On one structure the UHPC overlay serves as the final riding surface.
- UHPC overlay surface finish acceptance criteria, beyond the basic rideability requirement, should be added to the specifications to improve the quality of exposed UHPC overlay surfaces.
- An image of the desired surface in the contract documents would help reduce confusion.
- In the contract documents define an overpour thickness as a minimum of \(\frac{1}{4}\)" to \(\frac{1}{2}\)".
- Asphalt overlays on top of UHPC will be avoided especially as the performance evaluation of the material is still on-going.
Future Work

• A long-term testing program is presently being developed to gather performance data in the assessment phase.

• Incorporating UHPC for several applications in the new design manual, including P&R.

• After data collection and lessons learned are finalized, Standard Specifications will be revised.

• Further investigation, performance data, and Life Cycle Cost analysis.

• Additional UHPC overlay applications.
• Contacts for further Questions:
  • NJDOT – Samer Rabie
    (Samer.Rabie@dot.nj.gov)

• Acknowledgements:
  • NJDOT – Ali Najem, Pranav Lathia, Mike Kasbekar
  • FHWA – Zach Haber & Ben Graybeal
  • WSP – Steve Esposito, Andy Foden, Jordy Padilla

• UHPC Overlay Research Projects Awarded FY 2020 Contractors:
  • Agate Construction Co., Inc. of Clermont, NJ
  • Joseph M. Sanzari, Inc. of Hackensack, NJ