Video or photography is not allowed during this presentation. The information (electronic or hardcopy) contained in this presentation is intended for the exclusive use of this presentation and may contain information that is confidential or sensitive. Dissemination, forwarding, printing, or copying is strictly prohibited. Information regarding the New NY Bridge Project that can be circulated is available on NewNYBridge.com

Photos courtesy of New York State Thruway Authority.
Agenda

- Use of Micropiles in Bridge Design
- Use of Micropiles on Governor Mario M. Cuomo Bridge
- General Design & Detailing
- Structural Design
- Geotechnical Design
- Pier 1 Eastbound Installation
- Static Load Testing
Use of Micropiles in Bridge Design

LRFD Micropile Design and Testing for Major Urban Bridges
Use of Micropiles in Bridge Design

Figure 1-1. Micropile Construction Sequence.
Use of Micropiles in Bridge Design

- Micropiles require significantly less head room to install
- Casings are standardized (typically flush joint)
- Minimal reinforcing required (centralized bar or bars)
- Cost effective when welded splices are costly
- Allows for easy installation when access is an issue (especially for battered piles)
Use of Micropiles in Bridge Design

- FHWA Micropile Design and Construction is an important reference to consider all design elements.

- Non-battered micropiles (in the case of Pier 1EB) resist large lateral loads and bending moments

- Location of flush joints and central bar splice locations must be evaluated

- Section loss due to corrosion to be considered (Structural/Geotechnical coordination)
Use of Micropiles in Bridge Design

- General Details of a Micropile
Use of Micropiles on Governor Mario M. Cuomo Bridge
Use of Micropiles on Governor Mario M. Cuomo Bridge

Project Overview

- Existing Tappan Zee Bridge in New York replaced by Governor Mario M. Cuomo Bridge
- Design-Build Contract awarded to Tappan Zee Constructors, LLC
  - HDR – Lead Designer
- New eastbound bridge abutment was coincident with the existing bridge on the western approach for the first four spans
- New Pier 1 eastbound located entirely underneath the existing bridge
Use of Micropiles on Governor Mario M. Cuomo Bridge

**Benefit of Micropiles**

- Demolition of the existing bridge was on the critical path to substantial completion
- Project schedule would see benefit from constructing new bridge foundation at Pier 1 Eastbound prior to demolition of the existing bridge
- Low headroom conditions on the existing landing at Pier 1 Eastbound prevented the use of driven piles as planned
- Micropiles could be installed in low headroom condition underneath existing bridge prior to demolition, expediting the new bridge construction schedule
LRFD Micropile Design and Testing for Major Urban Bridges

Design & Detailing
**Pile Layout:** 21 H-Piles replaced by 35 Micropiles
Micropile Details

- 13.375” outer diameter of outer casing - ½” thick permanent steel casing (Spliced)

- 10.75” outer diameter of inner casing – ½” thick permanent steel casing

- 1/8” corrosion loss for outer surface (full length)

- #18 – 75 ksi galvanized all thread rod (Spliced)

- Minimum rock socket = 13 feet (not including plunge length)

- Minimum plunge length = 1 foot
Design & Detailing

Structural Details

- Pier 1 Eastbound
- Section A-A: double casing
Design & Detailing

Structural Details

- Pier 1 Eastbound
- Section A-A: double casing
- Section B-B: single outer casing
Design & Detailing

**Structural Details**

- **Pier 1 Eastbound**
- **Section A-A:** double casing
- **Section B-B:** single outer casing
- **Section C-C:** uncased bonded zone

Elevation
Design & Detailing

Structural Details

Sections
Bar Centralizers: Corrosion Protection

(a) GEWI – PILE with Standard Corrosion Protection
(b) GEWI – PILE with Double Corrosion Protection
Flush Joint Threaded Connection

- When Micropiles are designed to resist significant flexure, the flush joint threaded connection must transfer moment capacity of pipe.
- Due to corrosive soils at the site, the section loss showed that the threaded splice would see a loss in force transfer.
- Location of splices were moved to be outside areas of maximum moment.
Flush Joint Threaded Connection

- Reverse Angle Torque Shoulder
- External Metal-to-Metal Seal
- Machined Inside Diameter
- Hooked Thread Form with Flank-to-Flank Contact
- Internal Metal-to-Metal Seal
- True Flush Outside Diameter
Design & Detailing

**Design Steel Grade for Casing**

- API Grade N80 casing widely available at economical cost using mill secondary steel
- API Grade N80 casing has minimum 80 ksi yield strength
- Mill secondary casing is unused but rejected for use as oilfield pipe because it does not mean one or more API N80 specification requirements -> typically it is out of spec for geometrical tolerance
- Mill certifications for mill secondary casing not always available
Mill Secondary vs. Prime Casing

- Buy America provisions for federally funded projects may prevent use of mill secondary casing if the casing cannot be traced to a US steel mill.
- If mill certifications are not available, coupon tests on each lot of casing can be done to verify grade of steel.
- 50 and 60 ksi prime casing is more readily available and can be specified according to ASTM A252 (Modified) rather than API N80 for comparable pricing.
LRFD Micropile Design and Testing for Major Urban Bridges

Structural Design
Structural Design

- Pile
  - Required Embedment Length
  - Top Plate Size and Thickness
  - Plate to the Casing Connection
  - Casing Portion of Pile
  - Bonded Zone
Structural Design

- Casing Portion of Pile
  - Design based on moment and axial forces per AASHTO Sections 5 and 6
  - Use ½ thickness at threaded joints
  - Consider corrosion
  - Need to specify “No Splice Zone” or Double Casing
Structural Design

- Bonded Zone
  - Start of bonded zone -> Zero moment in micropile
Structural Design

- Bonded Zone
  - Length of bonded zone
    - Min. length to satisfy axial force
    - Adequate bond length for center bar
  - Plunge length -> embedment depth of casing into bearing strata (typically rock) -> reduces bending stress on weaker uncased section at soil/rock interface
  - Simple concrete column design
LRFD Micropile Design and Testing for Major Urban Bridges

Geotechnical Design Criteria
Geotechnical Design Criteria

Geotechnical Resistance Factors

- **Strength Limit State**: Resistance factor of 0.7 (corresponding to static load testing) for geotechnical axial compressive resistance in accordance with AASHTO Table 10.5.5.2.5-1.
  - Bond length preliminary estimates based on AASHTO presumptive values. Resistance factor of 0.55 used for presumptive bond values.

- **Extreme Limit State**: Resistance factor of 1.0 was selected for axial geotechnical compressive resistance in accordance with AASHTO Section 10.5.5.3.2.
Geotechnical Design Criteria

Geotechnical Resistance

- Type A micropiles as defined by AASHTO Section 10.9.1 (tremie grout placement under gravity, no pressure grouting).

- Axial resistance from side friction in the rock socket only.

- End bearing resistance ignored for geotechnical resistance.
Geotechnical Design Criteria

Geotechnical Resistance

- A best estimate value of 150 psi used for grout-to-ground bond nominal resistance for Type A micropiles in Sandstone which ranges from 75 psi to 250 psi according to AASHTO Table C10.9.3.5.2-1.

- Required nominal geotechnical axial resistance verified in the axial load testing program.

- Lateral loads resisted by overburden soils above top of rock socket as determined with FB MultiPier modeling.
LRFD Micropile Design and Testing for Major Urban Bridges

Pier 1 Eastbound Installation
Limited Overhead Room
Installation

Rotary Duplex Casing
Installation

Lead Casing with Cutting Teeth
Installation

Air Hammer Drilling
LRFD Micropile Design and Testing for Major Urban Bridges

Static Load Testing
Static Load Testing

Static Axial Load Testing

- AASHTO requires at least 1 verification test, and 5% of all micropiles to be proof tested for axial compression.

- Performance test requires longer hold increments to evaluate creep potential and testing to the required nominal resistance at a minimum.

- Proof testing is only required up to the max factored design load.

- Uplift load testing often planned instead of compression due to simplicity of operation and no need for end bearing resistance.

- Uplift and compression load tests were done at Pier 1 EB.
Static Load Testing

Static Axial Uplift Load Testing

P01 EB-18 Axial Uplift Verification Load Test

- Elastic Deflection (in)
- Gage 1 Displ. (in)
- Gage 2 Displ. (in)
- Gage 3 Displ. (in)
- FHWA .025 in/kip
- Wire Displ. (in)
Static Load Testing

Static Axial Compression Load Testing
Static Load Testing

Static Axial Compression Load Testing

P01 EB-17 Axial Compression Proof Load Test

Applied Compressive Load (kips)

Axial Downward Deflection (in)

Notes:
1. Irregularities in Wire Displ. readings assumed to be due to readings not being taken at every load increment with assumed values being used instead.
Static Load Testing

Static Lateral Load Testing

- Lateral load testing was performed to meet contract requirements, not often done in practice.

- The goal of the test was to verify that pile head displacement was similar to the predicted pile head displacement in a free head condition in FB MultiPier, and the prediction was very good based on the Sand (O’Neill) p-y curves.

- Testing performed by pushing apart two micropiles, very simple load frame.
Static Load Testing

Static Lateral Load Testing
Static Load Testing

Static Lateral Load Testing

P01 EB-3 and P01 EB-4 Lateral Load Test

Applied Lateral Load (kips)

Lateral Deflection of Micropile Head (in)

- MP 3 Predicted Deflection (in)
- MP 4 Predicted Deflection (in)
- MP 4 Dial Gage 1 (in)
- MP 4 Dial Gage 2 (in)
- MP 4 Dial Gage 3 (in)
- MP 3 Dial Gage 1 (in)
- MP 3 Dial Gage 4 (in)
- MP 4 Wire Line 1 (in)
- MP 3 Wire Line 2 (in)
QUESTIONS?