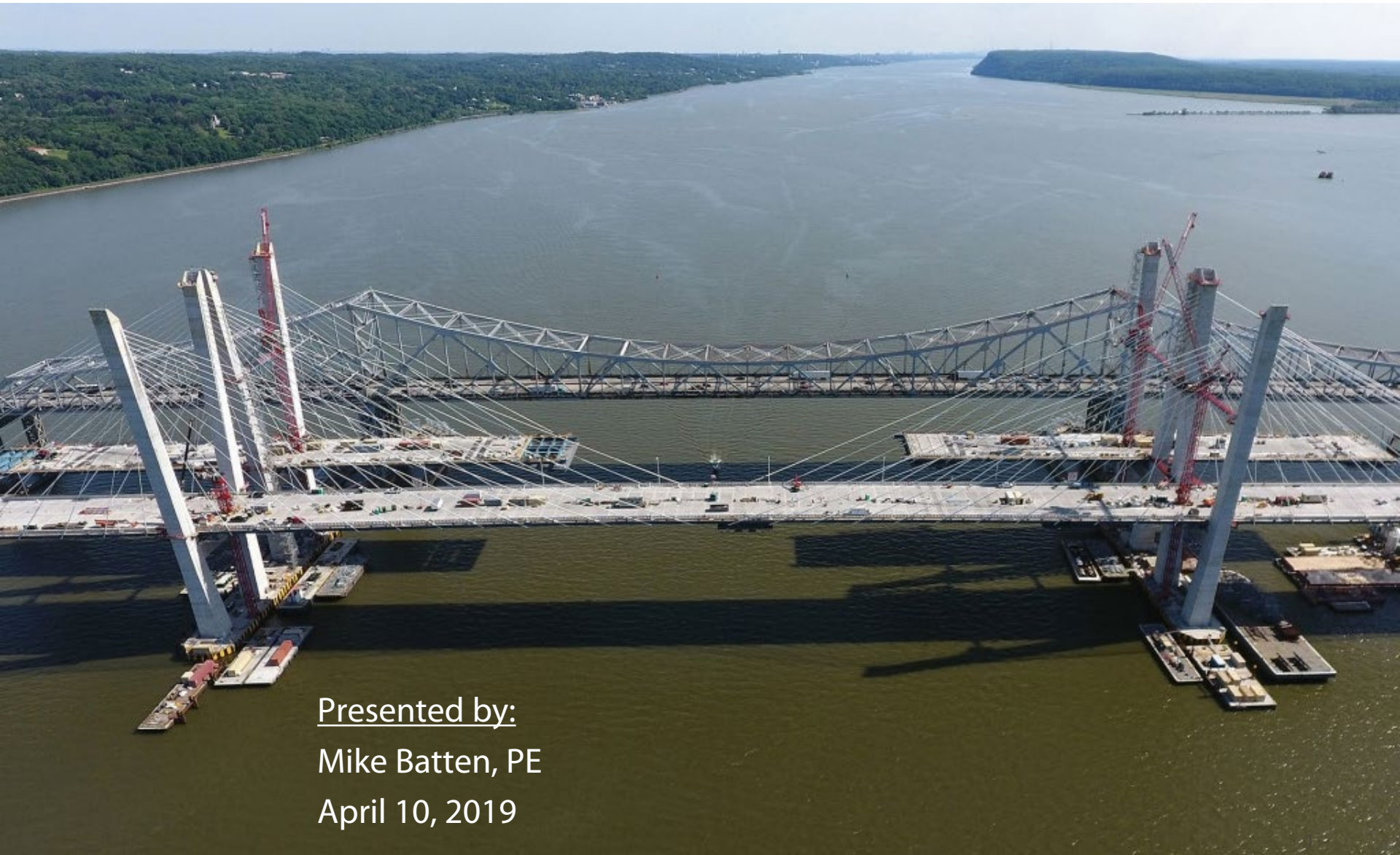
LRFD Micropile Design and Testing for Major Urban Bridges



Presented by:

Mike Batten, PE

April 10, 2019

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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

LRFD Micropile Design and Testing for Major Urban Bridges

Use of Micropiles in Bridge Design

Use of Micropiles in Bridge Design

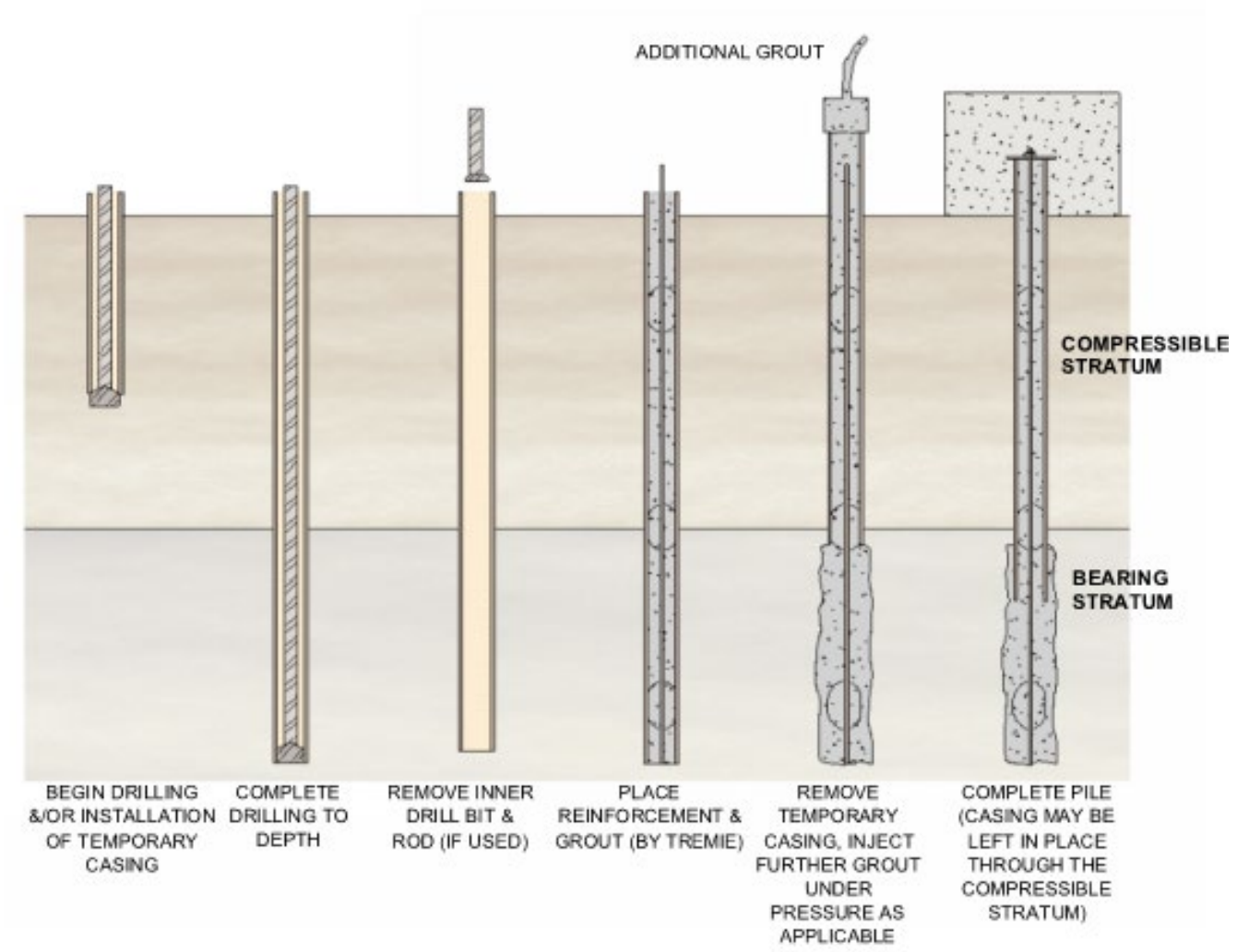


Figure 1-1. Micropile Construction Sequence.

Use of Micropiles in Bridge Design

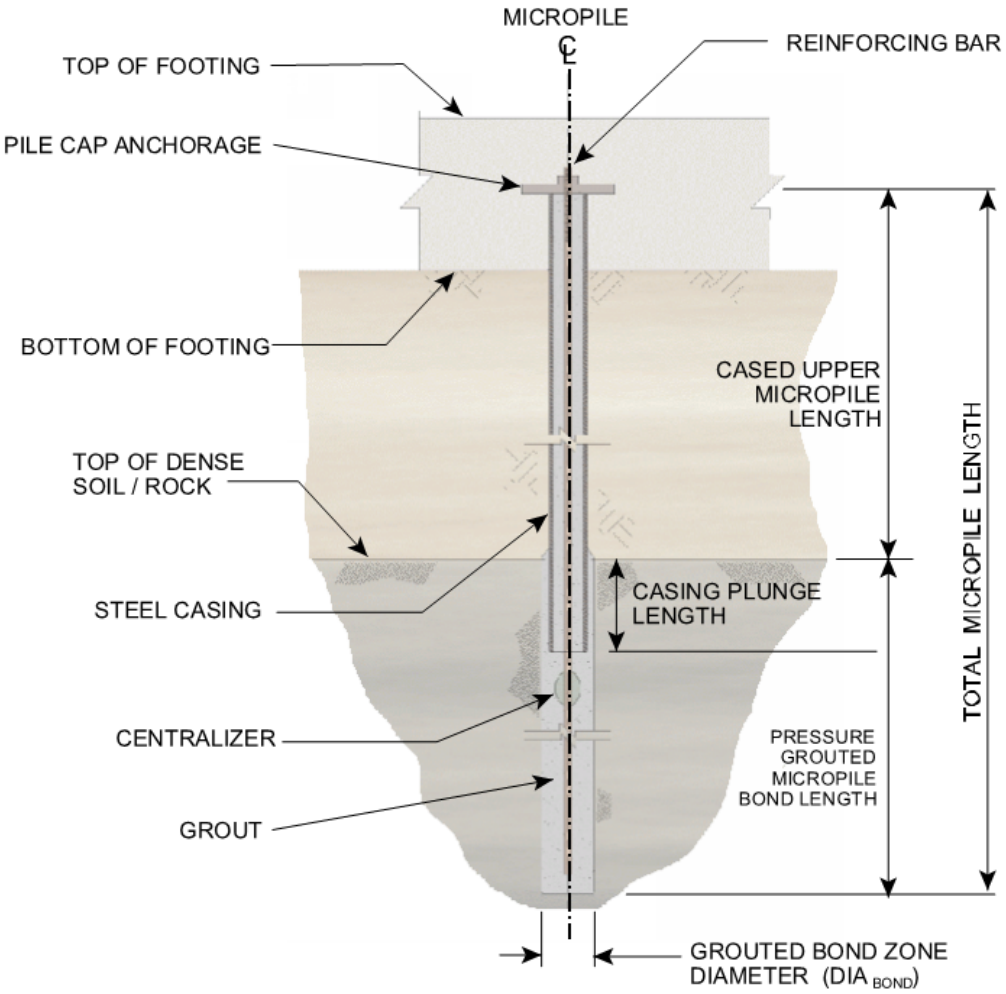
- Micropiles require significantly less head room to install
- Casings are standardized (typically flush joint)
- Minimal reinforcing required (centralized bar or bars)
- Cost effective when welded splices are costly
- Allows for easy installation when access is an issue (especially for battered piles)

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



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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

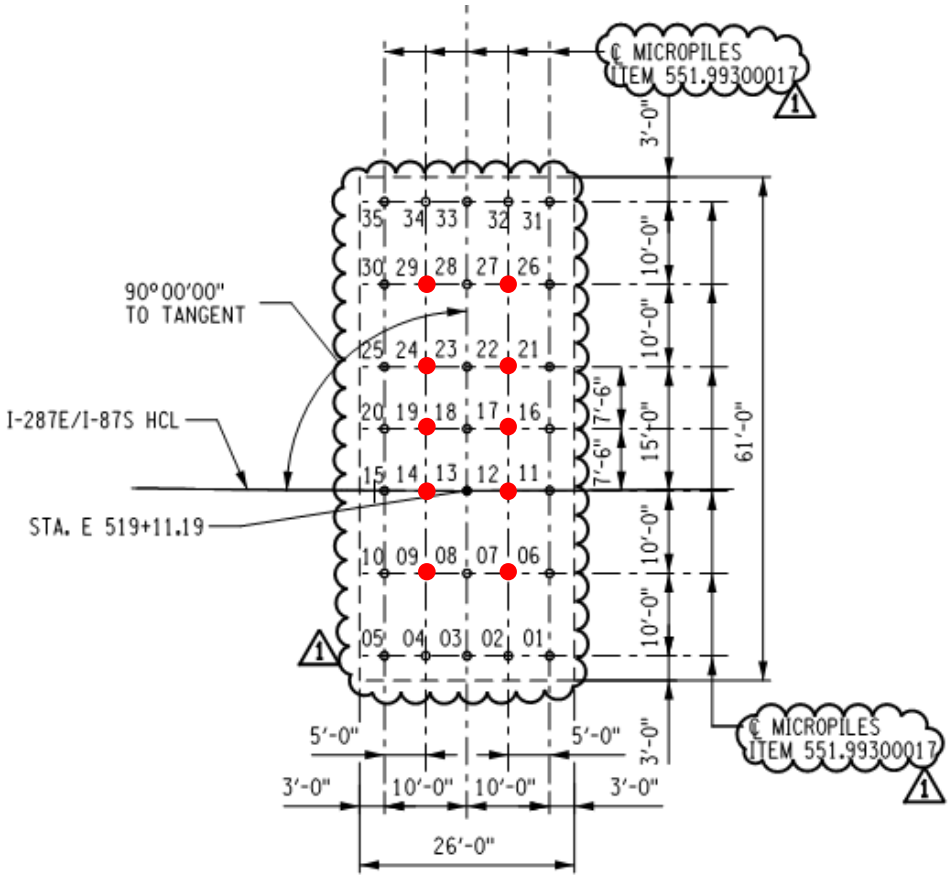
- Demolition of the existing bridge was on the critical path to substantial completion
- Project schedule would see benefit from constructing new bridge foundation at Pier 1 Eastbound prior to demolition of the existing bridge
- Low headroom conditions on the existing landing at Pier 1 Eastbound prevented 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

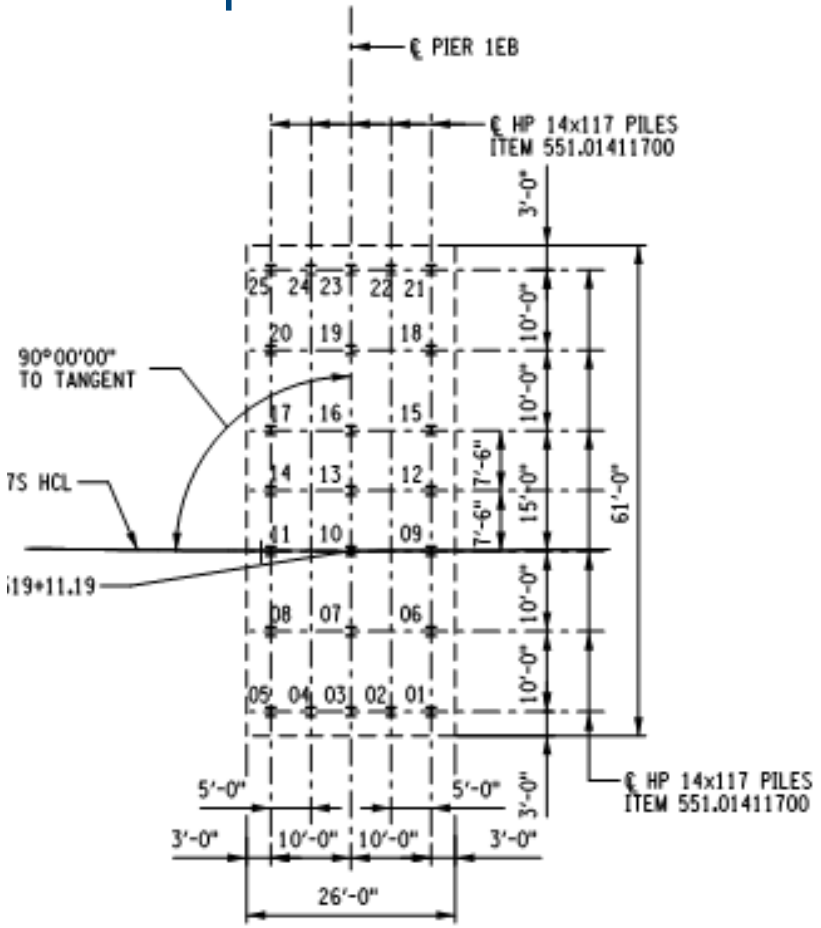
Design & Detailing

Design & Detailing

Pile Layout: 21 H-Piles replaced by 35 Micropiles



NDC0137 PILE LAYOUT



RFC PILE LAYOUT

Design & Detailing

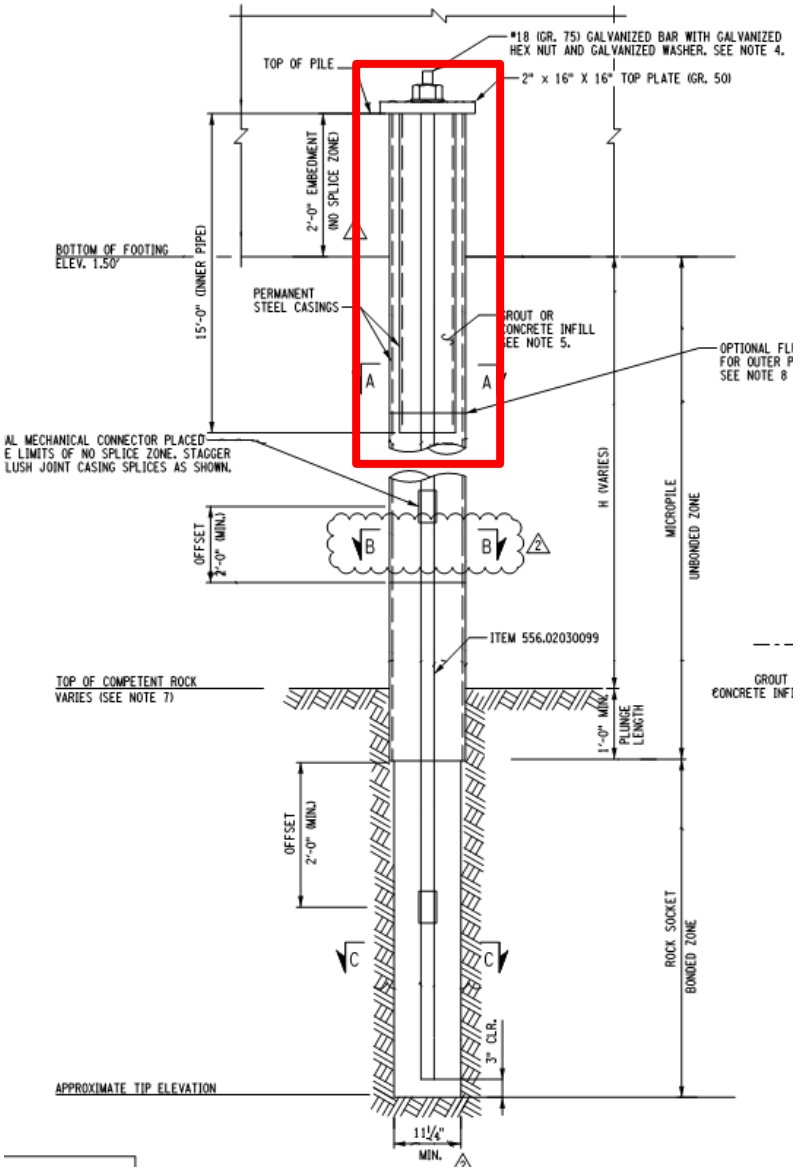
Micropile Details

- 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

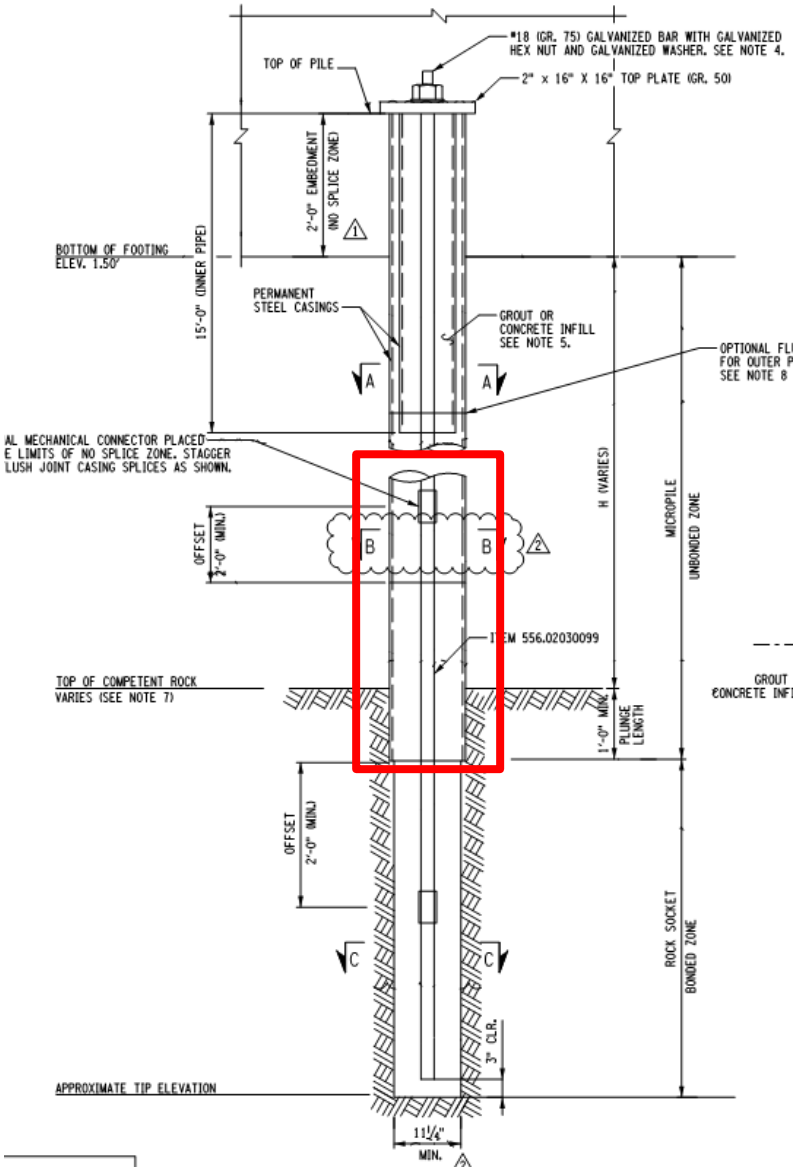


Elevation

Design & Detailing

Structural Details

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

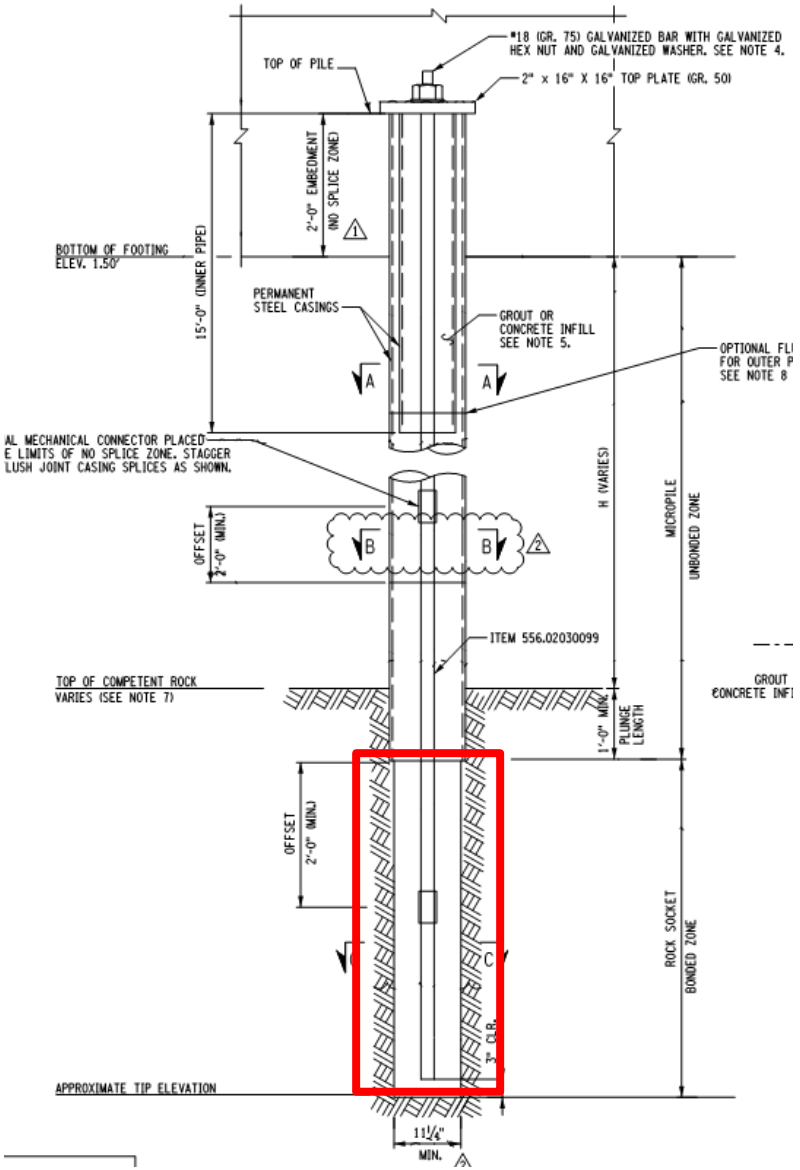


Elevation

Design & Detailing

Structural Details

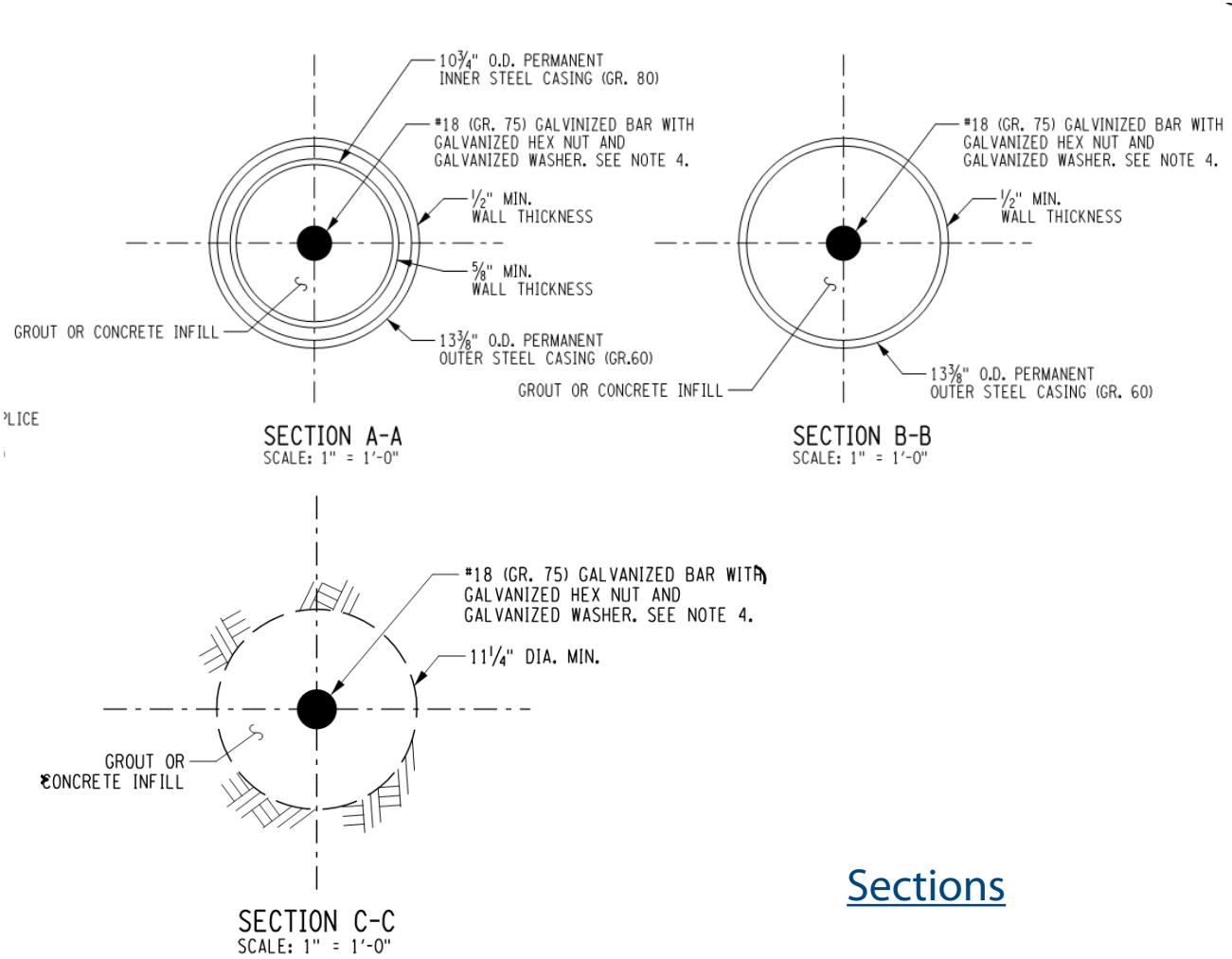
- Pier 1 Eastbound
- Section A-A: double casing
- Section B-B: single outer casing
- Section C-C: uncased bonded zone



Elevation

Design & Detailing

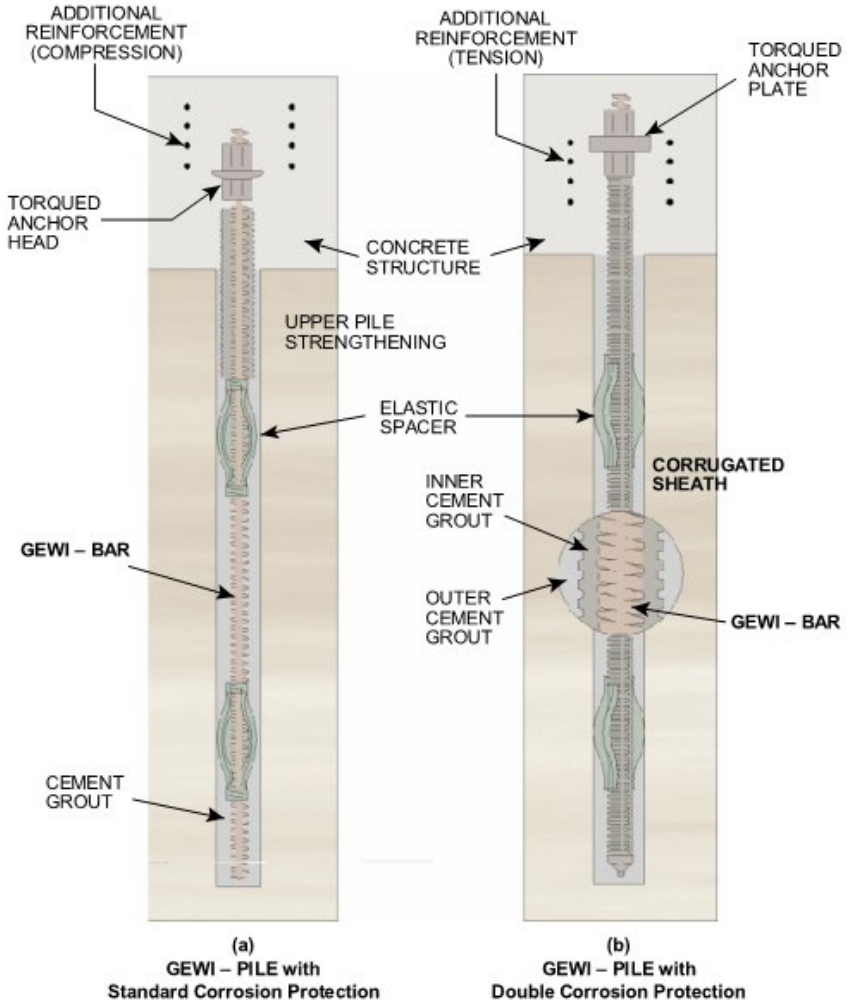
Structural Details



Sections

Design & Detailing

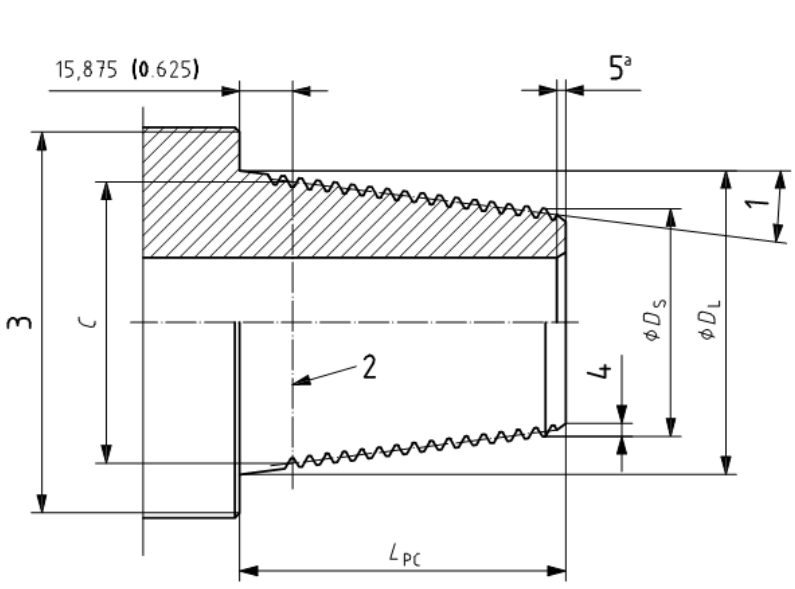
Bar Centralizers: Corrosion Protection

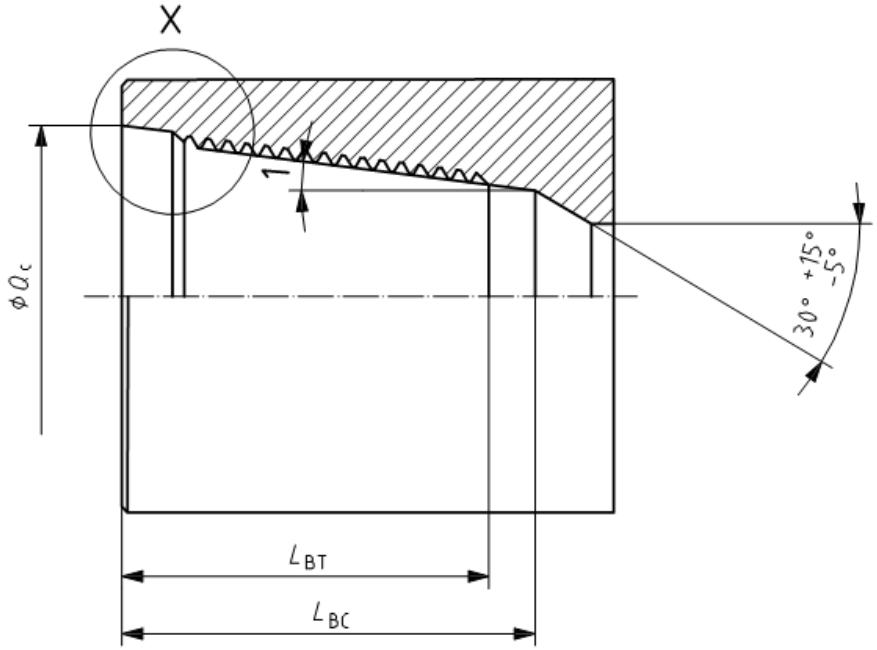


Design & Detailing

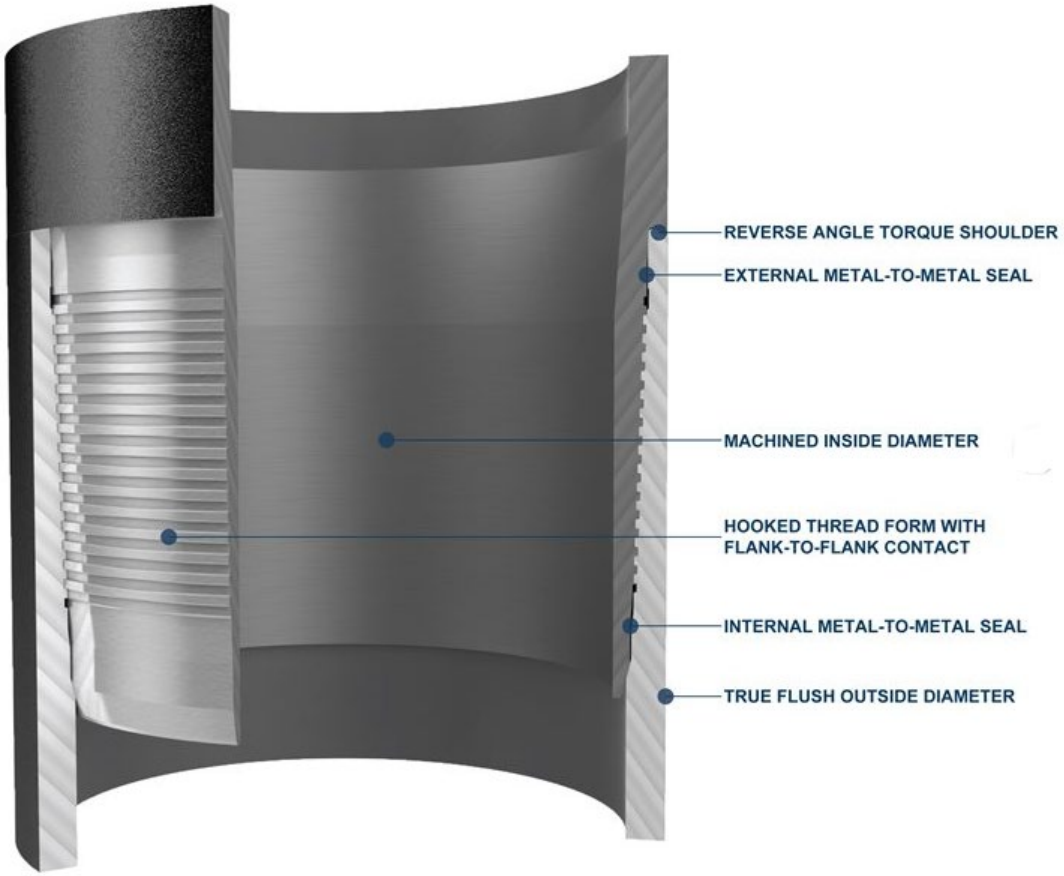
Flush Joint Threaded Connection

- 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



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

Design & Detailing

Mill Secondary vs. Prime Casing

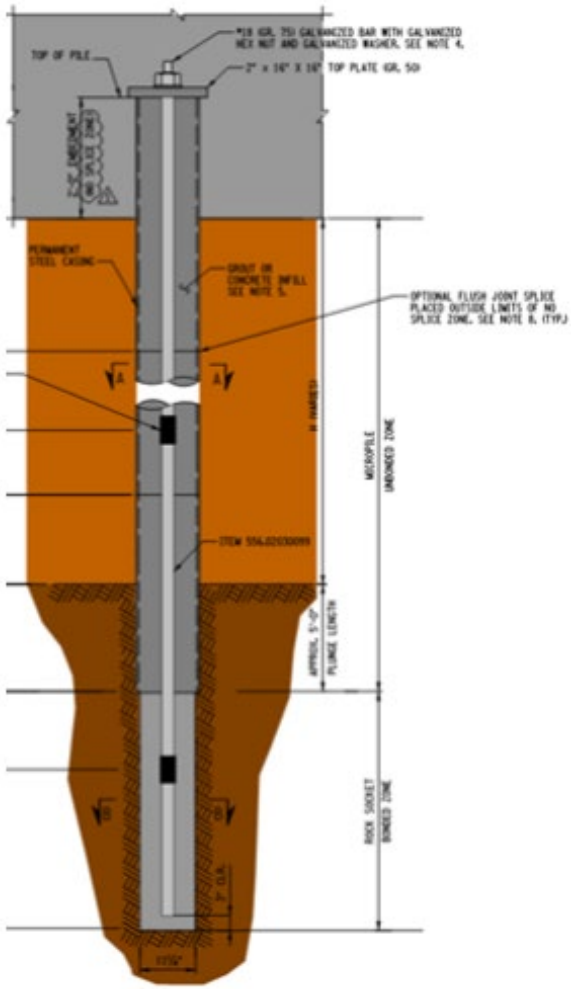
- Buy America provisions for federally funded projects may prevent use of mill secondary casing if the casing cannot be traced to a US steel mill
- If mill certifications are not available, coupon tests on each lot of casing can be done to verify grade of steel
- 50 and 60 ksi prime casing is more readily 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

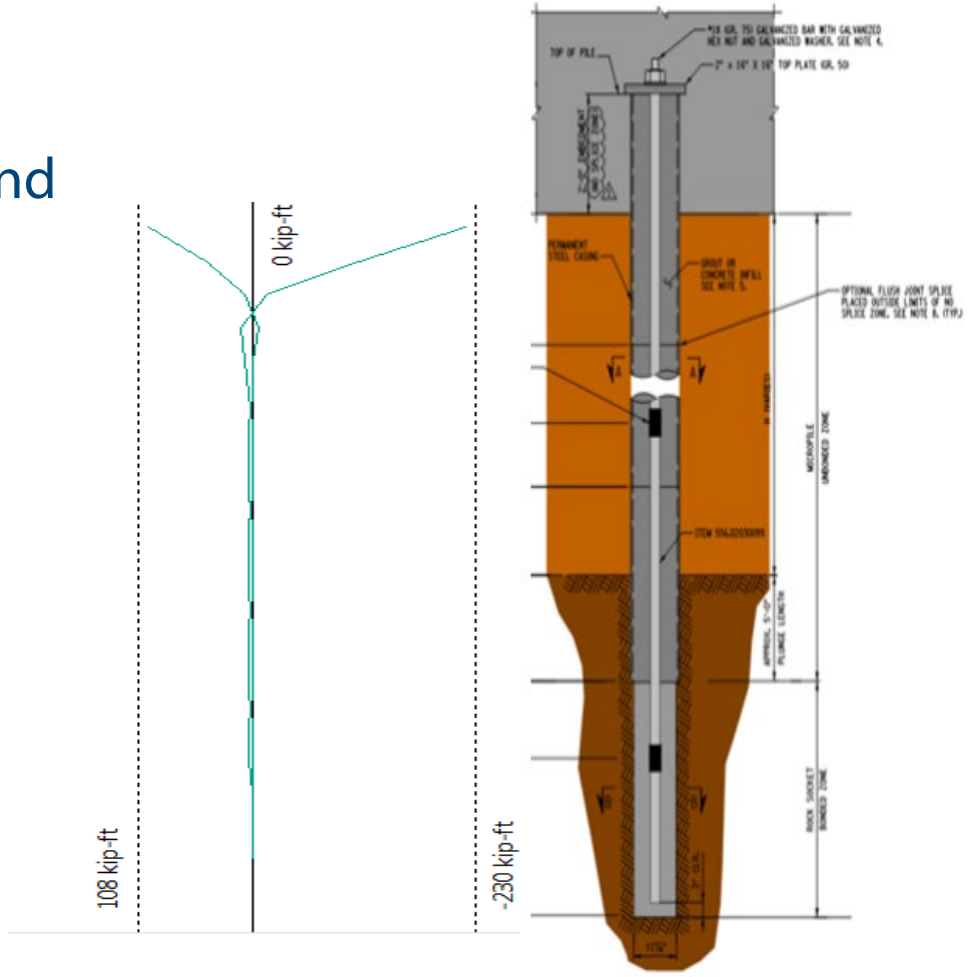
Structural Design

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



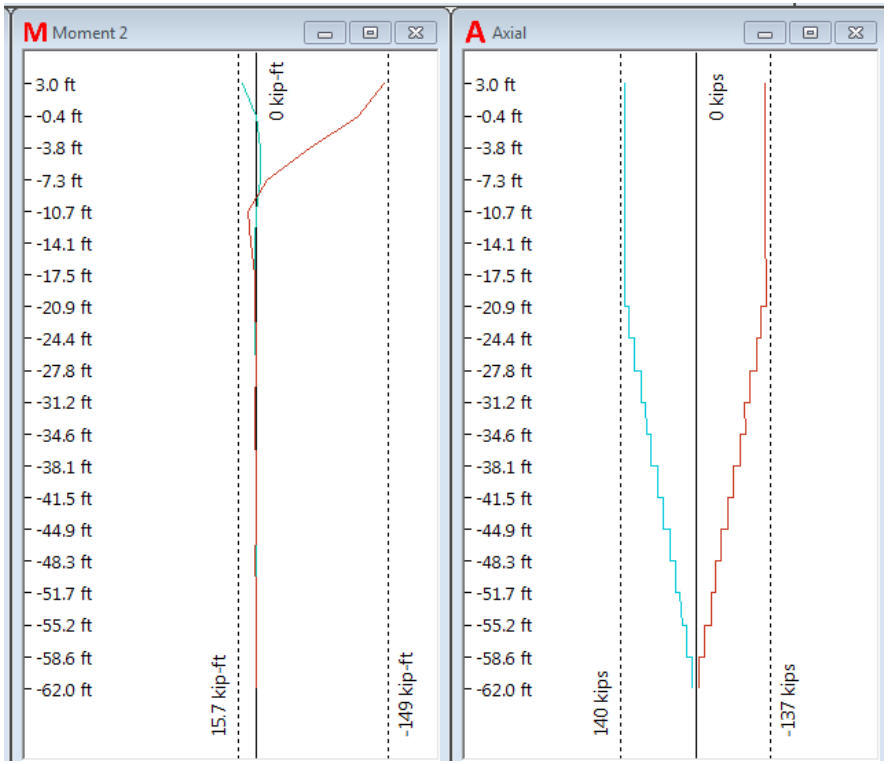
Structural Design

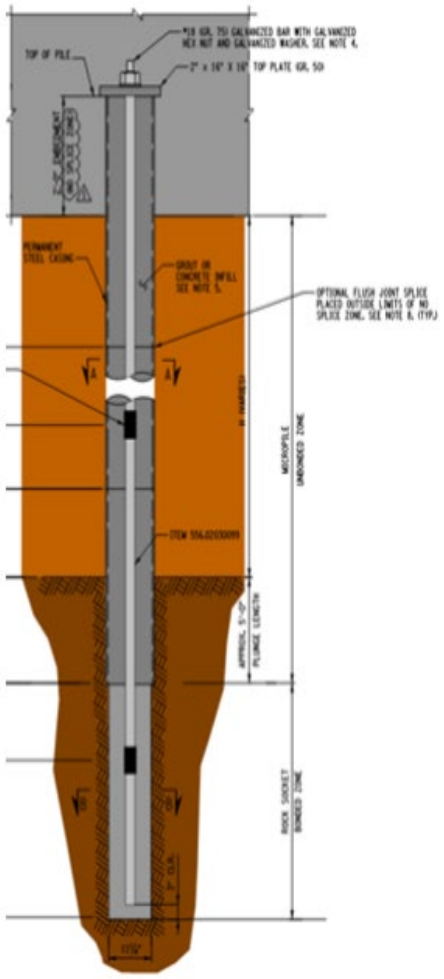
- Casing Portion of Pile
  - Design based on moment and axial forces per AASHTO Sections 5 and 6
  - Use ½ thickness at threaded joints
  - Consider corrosion
  - Need to specify "No Splice Zone" or Double Casing



Structural Design

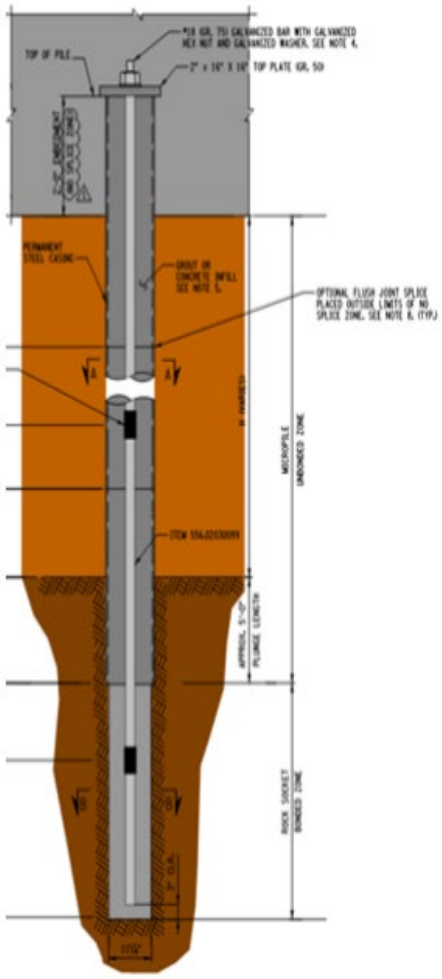
- Bonded Zone
  - Start of bonded zone -> Zero moment in micropile





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

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

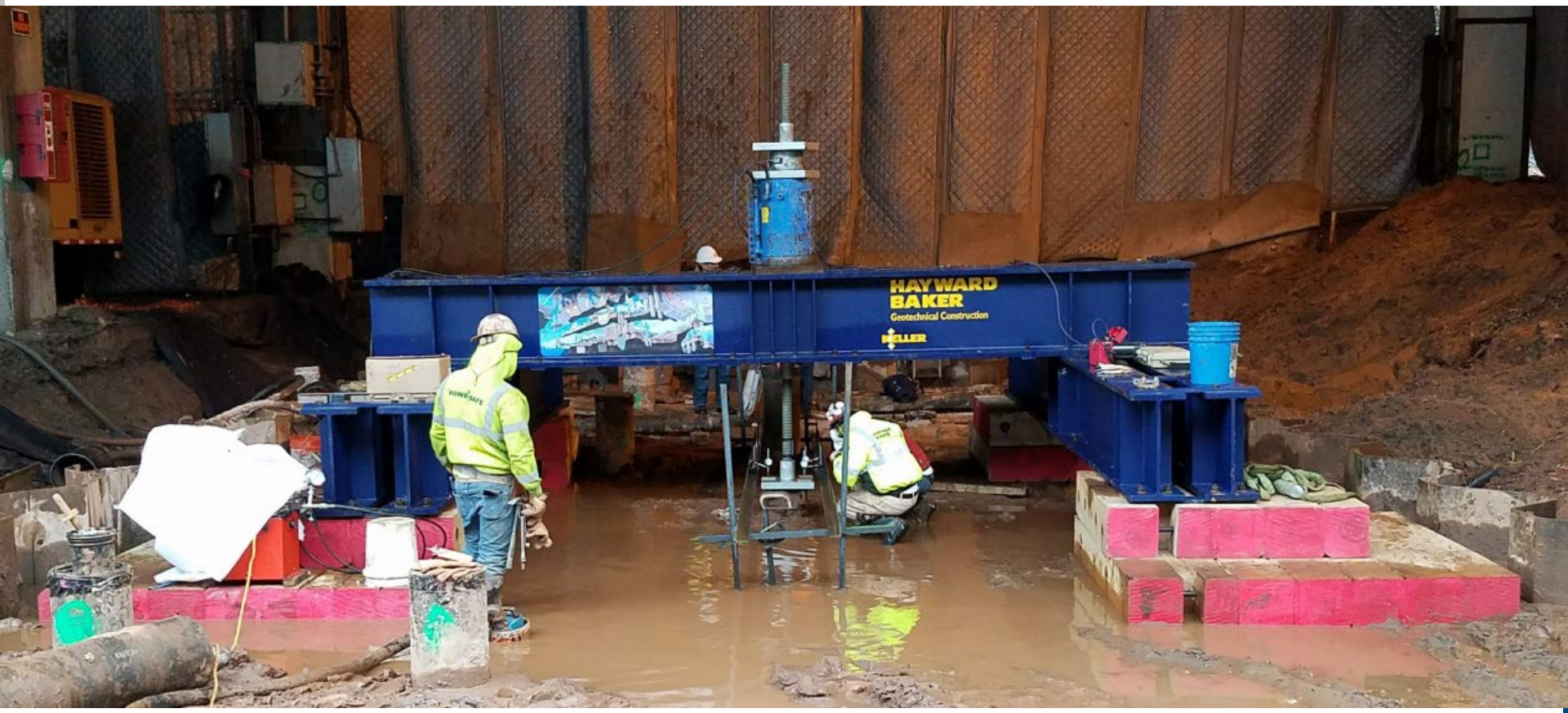
Static Load Testing

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.

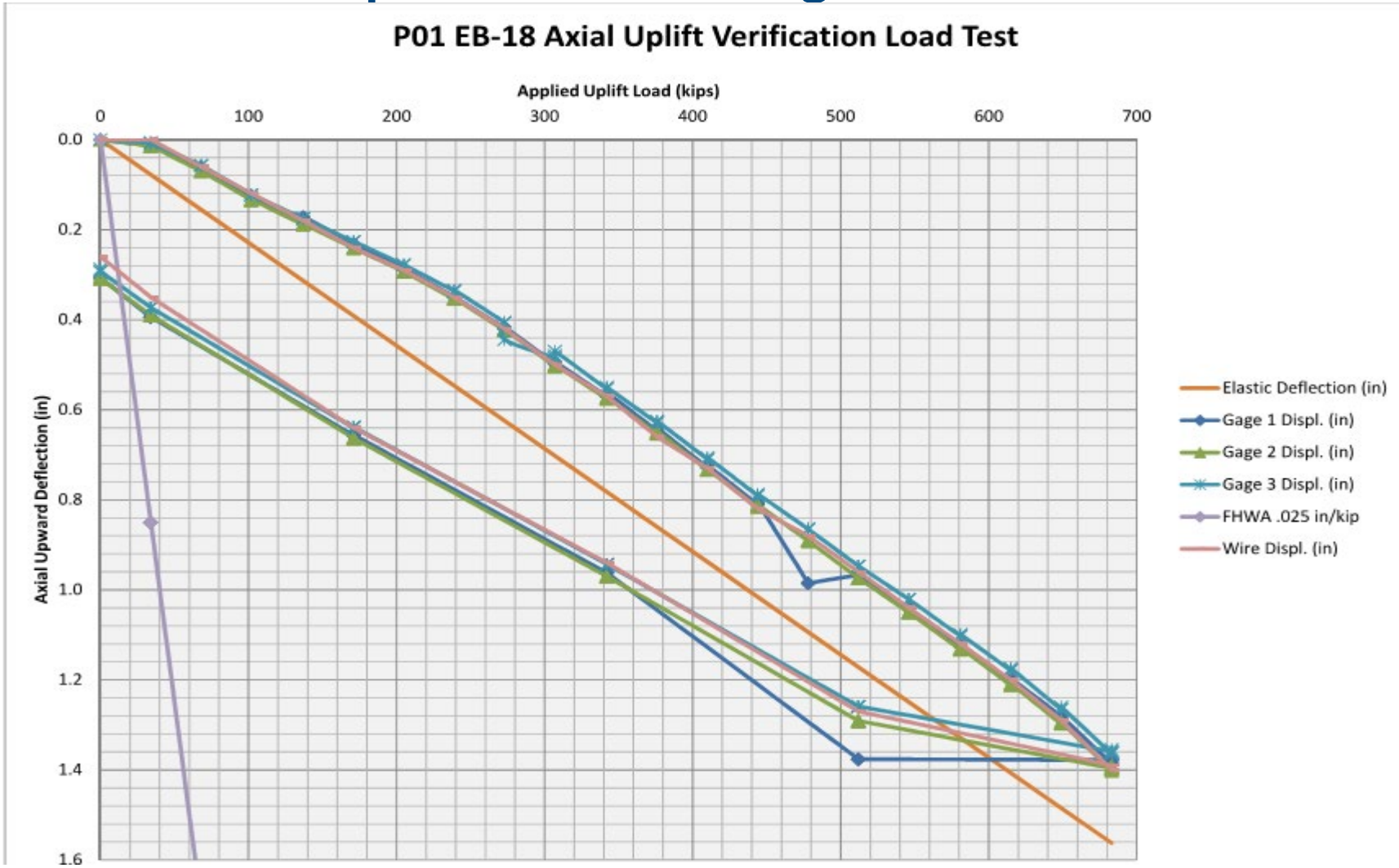
Static Load Testing

Static Axial Uplift Load Testing



Static Load Testing

Static Axial Uplift Load Testing

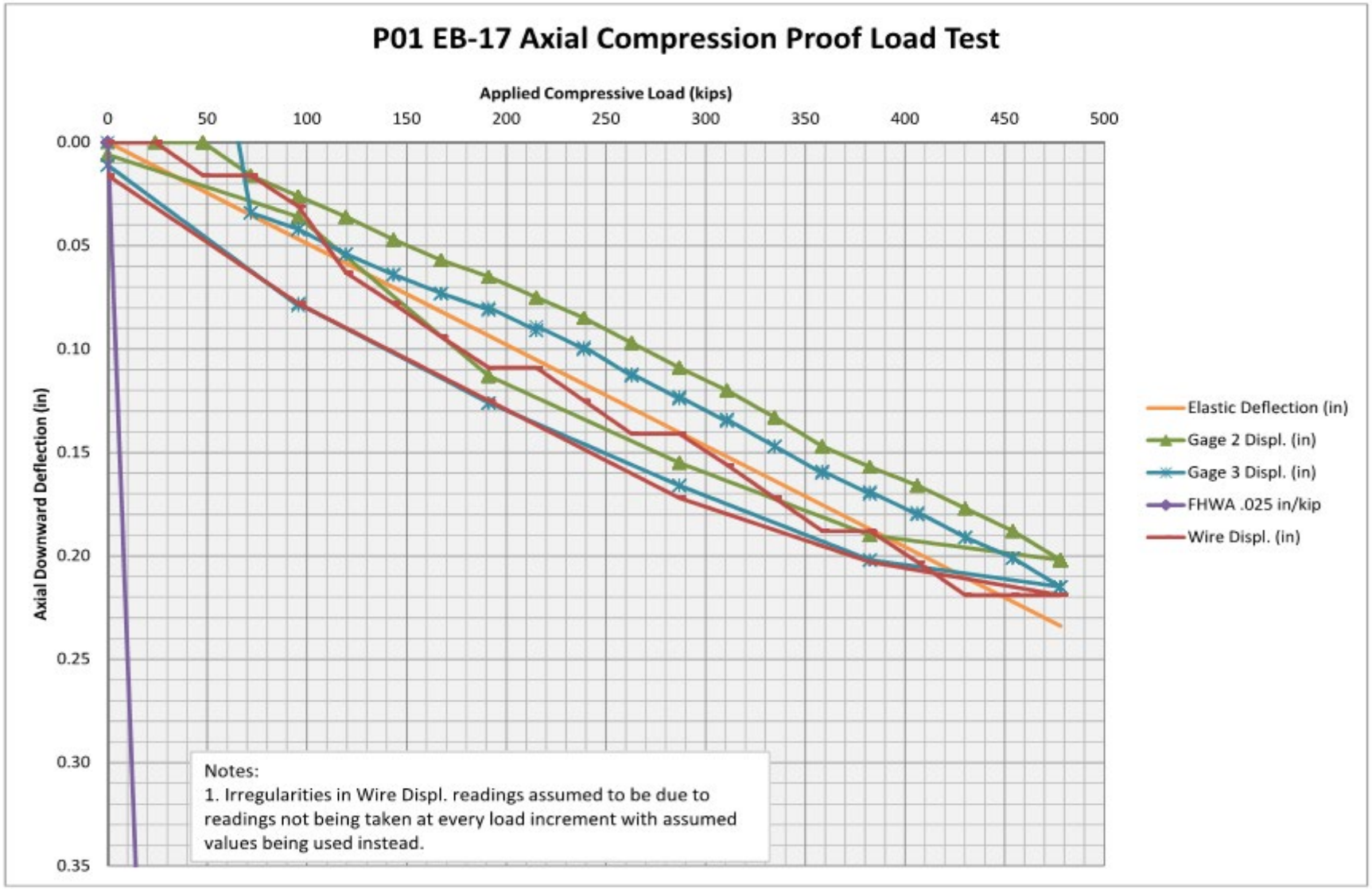


Static Load Testing

Static Axial Compression Load Testing

Static Load Testing

Static Axial Compression Load Testing



Static Load Testing

Static Lateral Load Testing

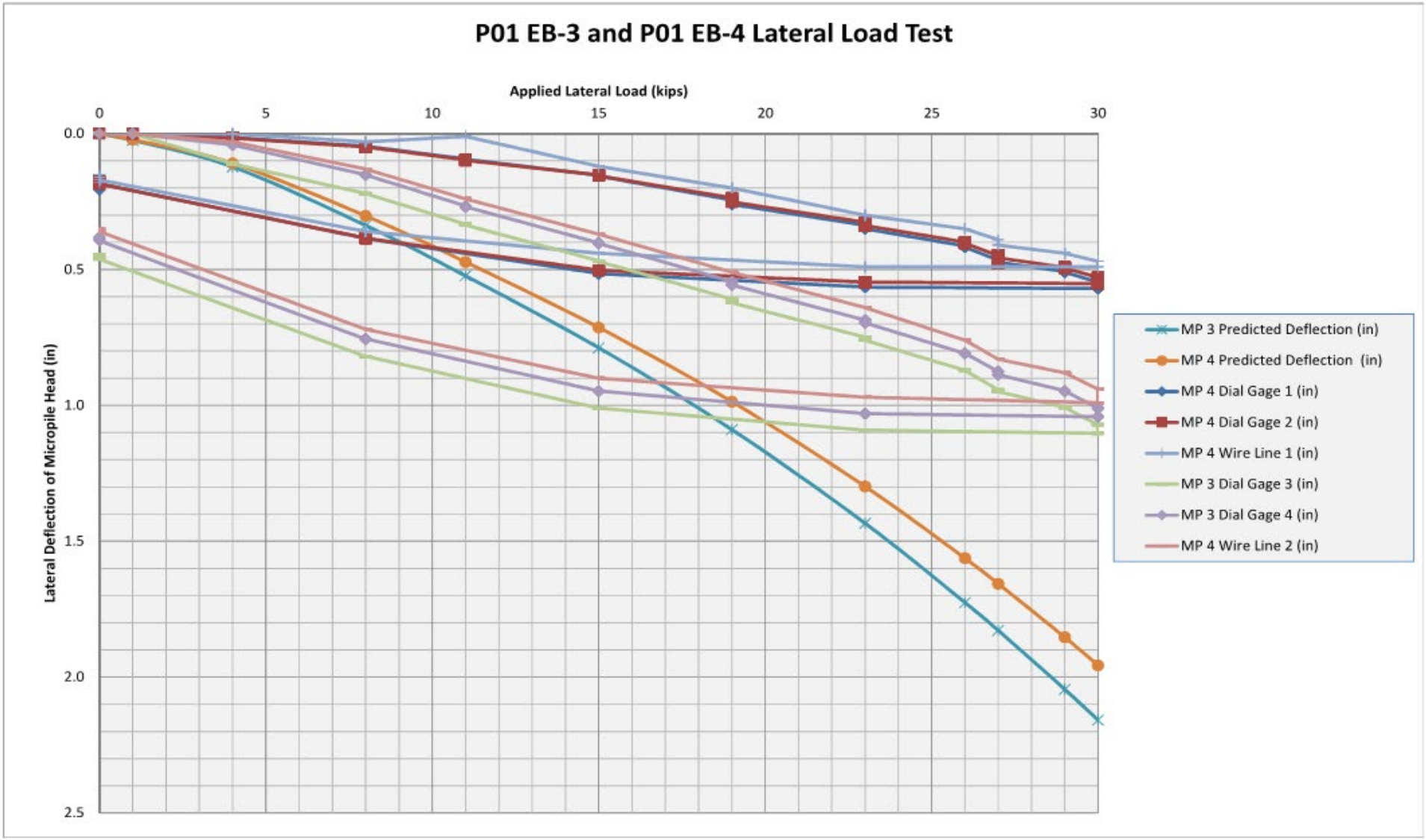
- Lateral load testing was performed to meet contract requirements, not often done in practice.
- The goal of the test was to verify that pile head displacement was similar to the predicted pile head displacement in a free head condition in FB MultiPier, and the prediction was very good based on the 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




QUESTIONS?