Large Diameter Open-End Pipe Piles at TUS-36-12.05

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June 21, 2016
TUS-36-1205 Bridge

US 36 WILL BE CLOSED 03/07/16 FOR 260 DAYS
OHIO DEPT OF TRANSPORTATION
EXISTING STRUCTURE

TYPE: STEEL THROUGH TRUSS SPANS WITH STEEL BEAM APPROACH SPANS, CONCRETE DECK AND CONCRETE SUBSTRUCTURES

SPANS: 30’-0”±, 220’-0”±, 220’-0”±, 30’-0”± C/C BEARINGS

ROADWAY: 28’-0”± T/T CURBS

ORIGINAL DESIGN LOADING: TRUSS & APPROACH SPANS: S-15-40
DECK: HS20-44 & ALT. MILITARY

ALIGNMENT: TANGENT

SKEW: NONE

WEARING SURFACE: 1”± MONOLITHIC CONCRETE

CROWN: 0.0156±

APPROACH SLABS: AS-1-81 (15’± LONG)

YEAR BUILT: 1949 ORIGINAL CONSTRUCTION
1995 MAJOR REHABILITATION

STRUCTURE FILE NUMBER: 7900333

DISPOSITION: TO BE REPLACED

TUS-36-1205 Bridge
PROPOSED STRUCTURE

TYPE: CONTINUOUS STEEL PLATE GIRDERS (A709, GR50W) WITH COMPOSITE CONCRETE DECK ON SEMI-INTEGRAL ABUTMENTS AND CAP AND COLUMN PIERS

SPANS: 92′-0″, 115′-0″, 115′-0″, 115′-0″, 92′-0″ C/C BEARINGS

ROADWAY: 36′-0″ T/T PARAPETS WITH 8′-0″ BIKEWAY

DESIGN LOADING: HL-93

0.60 KSF FUTURE WEARING SURFACE

ALIGNMENT: TANGENT

SKEW: NONE

WEARING SURFACE: 1″ MONOLITHIC CONCRETE

CROWN: 0.016

APPROACH SLABS: 25′ LONG, AS-1-15 (MODIFIED)

COORDINATES: LATITUDE N 40° 21′ 41″

LONGITUDE W 81° 26′ 41″

STRUCTURE FILE NUMBER: 7900334
Design 500-Year Scour

- Predicted 15.8 feet of scour
- Pier Top Elevation = 833.30 feet
- River Bottom Elevation = 809 feet
- Design Scour Elevation = 793.2 feet

- Piers must stand 40.1 feet cantilever in the Extreme II Limit State!

- Scour Controls the Design!
Bridge Foundations: Drilled Shafts
Bridge Foundations: Conventional Pile Cap Piers
Bridge Foundations: Large-Diameter Open-End Pipe Piles
Restrictor (Plug) Plate Details
Restrictor (Plug) Plate
Restrictor (Plug) Plate
2 Previous Projects:

- TUS-TUSAV-0505 over Tuscarawas R.
  - Originally open-ended with no restrictor plate
  - Low dynamic testing results at Rear Abutment
  - Added restrictor plate and increased length 11’
  - Still did not reach 1448 kips capacity!
  - Revised FS from 2.0 to 1.53: now 1075 kips
  - Equivalent of changing $\varphi_{\text{dyn}}=0.70$ to $\varphi_{\text{dyn}}=0.915$
  - Revised capacity achieved at 7-day restrike
2 Previous Projects:

- STA-21-0525 over Tuscarawas R.
  - Originally open-ended with no restrictor plate
  - EOID = 470 to 890 kips; BOR = 660 to 810 kips
  - This is only 37% to 45% of 1778 kips capacity
  - Added restrictor plate at top of driven piles
  - Increased length 20’; delay to order materials!
  - Now achieved only 1020 to 1310 kips!
  - This is FS of only 1.14 (equivalent to $\varphi_{\text{dyn}} = 1.22$)
  - No more room for tinkering with FS!!!
2 Previous Projects:

- **STA-21-0525 over Tuscarawas R.**
  - Major Design Changes:
  - Added **FULL restrictor plate** to Pier 2 piles
  - This only achieved 1049 to 1290 kips!
  - This is FS of only 1.17 (equivalent to $\varphi_{\text{dyn}}=1.19$)
  - Connected pier columns w/ **Load Transfer Beam**
  - Drove **8x 60-ft 16-inch CIP Pipe Piles** per pier
  - No static analysis or capacity verification
TUS-TUSAV-0505 Soil Profile
TUS-36-1205 Soil Profile
Current Project:

- TUS-36-1205 over Tuscarawas R.
  - Now initial design includes restrictor plate
  - Ordered additional 6x 15’ lengths of pile
  - Designed piles by API (American Petroleum Institute) Method
  - FHWA Method (Nordlund/Tomlinson) is uncalibrated for piles larger than 20 inches
  - API is conservative with both design equations and selection of cohesionless soil properties ($\phi$)
Nominal Resistance versus Depth

API Nominal Resistance versus Depth
Pier 4 UBV = 1316 kips = 43.3 feet

- Round up to 45 feet per BDM 303.4.2.1.A
- Order Length 50 feet per BDM 303.4.2.1.B
- Assumes $\phi_{\text{dyn}} = 0.70$ per BDM 202.2.3.2.b
- $\phi_{\text{dyn}} = 0.70$ is typical for ODOT designs with Dynamic Load Testing of 2% of driven piles

Prebid question: “Can’t we use a higher resistance factor? We have 100% Dynamic Load Testing and a Static Load Test.”
Revised Resistance Factor and UBV

Per AASHTO LRFD Table 10.5.5.2.3-1, we can use $\varphi_{\text{dyn}}=0.80$ with a Static Load Test and Dynamic Load Testing of 2% of driven piles.

Since we have a Static Load Test and Dynamic Load Testing of 100% of driven piles, we increased this to $\varphi_{\text{dyn}}=0.85$.

New target UBV = 1090 kips

But we did not revise (shorten) pile lengths.
Pile Instrumentation
C-001-0-16 at Pile 34
C-003-o-16 at Pile 35
C-002-0-16 “at Anchor Pile 1”
C-004-o-16 at Pile 33
C-006-0-16 at Anchor Pile 1
Vibratory Hammer
APE D100-42 Diesel Hammer
Pile Driving
Driven Piles
Driven Anchor Pile (without Restrictor Plate)
Driven Bearing Pile (with Restrictor Plate)
Dynamic Pile Testing

End of Initial Drive (EOID)

- Target UBV = 1090 kips
- Pile 33 EOID = 900 kips (83%)
- Pile 34 EOID = 900 kips (83%)
- Pile 35 EOID = 770 kips (71%)
- Pile 36 EOID = 848 kips (78%)
- Anchor Pile Static Estimate = 560.64 kips
- Anchor Pile EOID = 379 kips (68% of Static)
Dynamic Pile Testing

3-day Restrike Testing (BOR)

- Hammer Malfunction
- Testing Aborted
Dynamic Pile Testing

14-day Restrike Testing (BOR2)

- Target UBV = 1090 kips
- Static Estimate = 1316 kips
- Pile 34 BOR2 = 1290 kips (98% of Static)

- Anchor Pile Static Estimate = 560.64 kips
- Anchor Pile BOR2 = 545 kips (97% of Static)
Nominal Resistance versus Depth

API Nominal Resistance versus Dynamic Test Results
Dynamic Test Results

17 feet + 20 feet = 37 feet
Nominal Resistance versus Depth

API Nominal Resistance versus Dynamic Test Results
Static Load Test
Static Load Test
Static Load Test
Static Load Test Preliminary Results
ODOT 621(15) Pier 4 Pile 34
Load vs. Displacement

Displacement at Top of Pile (inches)

Load (load cells) vs. Displacement
Elastic Compression of Pile
Cavesson Failure Line
Load (pressure gauge) vs. Displacement
Static Load Test Preliminary Results

ODOT 621(15) Pier 4 Pile 34

Load vs. Displacement

Load (kips)

Displacement at Top of Pile (inches)

Load (load cells) vs. Displacement
Elastic Compression of Pile
Drivison Failure Line
Load (pressure gauge) vs. Displacement

1090 kips
1316 kips

Static Load Test
<table>
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<th>AVERAGE PRESSURE PSI</th>
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Static Load Test Results

ODOT 621(15) Pier 4 Pile 34
Load vs. Displacement - all measurements

1120 kips
Static Load Test Results
ODOT 621(15) Pier 4 Pile 34
Load vs. Displacement - all measurements

- Load (kip) vs. Displacement
- Elastic compression of pile
- Maximum capacity failure line
- Load (gross load) vs. Displacement
- Load (load cell) vs. Displacement
- Final load vs. Displacement

Key Points:
- 1090 kips
- 1316 kips
- 1120 kips
- 120%
Thank You

✔️ Questions?

✔️ Comments?