I-65 over the Wildcat Creek
Emergency Repair

Anne Rearick
Bridge Director, INDOT

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Bridge Design Manager, INDOT

March 8, 2016
Background

- Bridge was built in 1968
- 25,000 AADT
- 5 spans 67’-6, 85’, 85’, 85’, 67’-6
Background

- Piers are founded on spread footings
- Artesian conditions present
Background

- The bridge was undergoing a deck replacement and widening
- Piles had been driven at Bent 1, Pier 2 and Pier 3
Background

H-Piles

Pier 3

Coffer Dam

Sand and Gravel

Impermeable Layer (Loam)

Sand w/Artesian Features

Spread Footer

Rock
Timeline

- August 3rd Pier 3 production piles completed
- August 4th Cofferdam dewatered
- August 4th Bridge closed after bearings fell out at Pier 3
- August 5th Bridge re-opened after jacking and temporary grillage installed
- August 6th Cofferdam dewatered
Timeline

- August 7th Bridge closed
- August 14th Micropile solution chosen
- August 18th Purdue installs monitoring system
- August 19th Test pile installation begun
- September 2nd Concrete Mix and Thermal Control Plan Approved and Thrust Block Poured
Timeline

- September 2\textsuperscript{nd} Jacking procedure approved
- September 5\textsuperscript{th} Required Concrete Strength reached and Jacking operations completed
- September 6\textsuperscript{th} Bridge Inspection and Load Tests Completed
- September 6\textsuperscript{th} Bridge re-opened
Cofferdam
Timeline

- Bridge Closed August 7, 2016
Why was the Bridge Closed?

It was observed Aug 7th that Pier 3 was sinking
Why was the Bridge Closed?

10” down on the East, 9” down on the West and rotated 7” uniformly to the north
Why was the Bridge Closed?

Photo Courtesy Bob Fisher, Parsons
Plan to address the Pier

- Perform Additional CPT and SPT borings
- Develop a remediation plan that provides for a 30 year bridge life, assures the stability of the pier and safe construction activities for both NB and SB Pier 3
- Develop a monitoring plan
Options Considered

- Compaction grouting
- Pressure grouting
- Micropiles
- Drilled shafts
- Load Testing
- Or a combination of all of the above
Potential Repair Solutions

- **Pressure Grouting**
  - Concept: Pump flowing grout into artesian layer to densify the material and stabilize subsurface under the spread footing

- **Foundation Underpinning**
  - Concept: Substitute a deep foundation for the failed spread footing
Proposed Repair Solution

- **Foundation Underpinning**
  - **Micropiles**
    - Core holes through existing spread footing
    - Install casing through holes
    - Install reinforcing bar
    - Pressure grout through the casing
Test Pile Installation

Photos Courtesy Bob Fisher, Parsons
Micropile Installation

Photo Courtesy Bob Fisher, Parsons
Transfer Block

Photos Courtesy Bob Fisher, Parsons
Thermal Control Plan

- Temperature sensors installed
- 35 degree temperature limit
- Max 115 degrees
- PVC cooling pipes installed to draw water from the creek if necessary
- Insulation Blanket
Thermal Control Plan

Sensor Control Locations
Thermal Control Plan

Photos Courtesy Bob Fisher, Parsons
Jacking

Photo Courtesy Bob Fisher, Parsons
Post Jacking

Photo Courtesy Bob Fisher, Parsons
Temporary Support

Photo Courtesy Bob Fisher, Parsons
Opening Requirements

- Full Hands on Fracture Critical Inspection
- Load Tests to be done 24 hours following the re-establishment of final elevations
- Acceptable analysis of leaving the tilt in the pier
- 3500 psi in the transfer block
Proof Testing

- **Monitoring**
  - Bridge Inspectors in place to monitor the pile cap and the superstructure for movement
  - Purdue Sensors
    - Inclinometers on pier cap to measure lateral movement
    - Strain Gages on the bottom flange adjacent to the pier to indicate vertical movement
  - 3D Automated Survey System
Proof Testing

- Tests
  - Vertical Load
    - Trucks Beside Each Other
  - Negative Moment on Superstructure
    - Trucks front to back with gap
  - Longitudinal Force
    - Single truck braking from highway speed to a stop
  - Eccentric Load on Pier Foundation
    - Single truck along outside shoulder
Load Test

Following Test

Braking Test

Static Load Test

Photo and video Courtesy Bob Fisher, Parsons
Load Test

- Trucks Beside Each Other - Max Vertical Load
- Trucks front to back - Negative Moment on Superstructure
- Single Truck Braking from Highway Speed to a stop
- Single truck along outside shoulder - eccentric load on pier and foundation
Bridge Re-opened September 6, 2016
What happens next?

- A plan is being developed that will address the construction at the remaining piers such that another foundation settling event will not be initiated.
- Bridge monitoring system will be in place for the remainder of the construction.
Thank you to:

- FHWA
- Parsons
- Purdue University
- RQAW
- ATC
- Walsh/CHA/SME Design Build Team
I-65 Wildcat Creek Bridge
Artesian - Geotechnical/Structural

Mir A. Zaheer, P.E.,
Geotechnical Design Engineer, INDOT

March 08, 2016
Objective

- Improve understanding of foundation design and construction.
- Improve understanding of geotechnical investigations, designs, plans and specifications.
- Improve understanding of artesian conditions.
Outline

Foundation Issues - I-65 over Wildcat Creek, Tippecanoe County

- What Happened
- How Was it Investigated
- What Were the Findings
- What Was the Solution
- How Can These Problems Be Avoided in the Future
Outline

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What Happened

- Pier #3NB Spread Footer settled.
  - Vertical Settlement = 10 inches
  - Lateral Deflection = 7 inches
Artesian Aquifer - General
Cofferdam Construction
Outline

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Investigation

- At INDOT’s direction DB team installed Piezometer & did SPT borings and CPT soundings
- Artesian water conditions were noted at the interior piers of the Interstate 65 Bridge over Wildcat Creek.
- Ground water was noted flowing adjacent to the existing interior piers adjacent to Wildcat Creek.
- Heaving sands were encountered within the augers during sampling in Boring S5-TB-WC-2 and S5-TB-WC-5.
Spread footings are not recommended for support of the interior piers due to the presence of artesian ground water conditions, potential differential settlements between new and existing footings, the risk of undermining the existing spread footings, causing a “quick” condition during construction excavations to reach the existing spread footing bearing elevations and the projected scour depth.

Significant dewatering will likely need to be performed prior to excavations for the proposed interior pile caps.
Piezometer Post Failure Pier 3
Piezometer installed after failure of Pier #3 Foundations
Soil Profile At Pier #3 Cofferdam

Sheet Pile Wall
bottom Elevation 511.00
CPT Soil Profile at Pier #3
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Findings

- Artesian conditions loosened soils below the existing footing causing settlement

**Probable Mechanism**

- Seepage of water and piping of fine sand from beneath the loam layer around the piles and the sheet piles via preferential pathways
- Heaving of soil inside cofferdam, and movement of sands from underneath the footing toward the voids formerly occupied by heaved soils.
Findings

- Penetration of the sheet piles through the loam layers and subsequent movement of sand towards the voids created by the possible heave.
- Water was flowing into the cofferdam along the north side from sheet piling abutting the west end of NB pier to the pump location at the southwest corner.
- Top of loam layer may be below the bottom of the footing. Sands placed during the 1968 construction scoured from under the footing.
Findings

- Seepage, could occur in the case of a sandy foundation or in the case of preferential flow paths.
- The process of excavating, which relieves confining pressure coupled with the high gradient and driving of sheetpiles and/or piles may have fractured the confining layer that was serving as the aquitard.
- A combination of all of the mechanisms caused the failure.
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Solution

Multiple options were investigated

- Compaction Grouting
- Drilled shafts
- Micropiles

Micropiles were ultimately chosen as the most feasible alternate to support the existing spread footer & also the rest of the piers
Solution

- **DB’s Team Assessment**
  - Drilled shafts, while technically feasible, were considered uneconomical due to the difficult constructability issues associated with the deep granular soils and the high artesian water pressure.
  - Therefore, a micropile type foundation system, was recommended for support of the interior piers.
Solution
Solution

- Use low mobility grout, LMG, to fill potential voids and densify loosened soils below footing
- Design and install micropiles to carry all the live and dead loads and the footing loads
- Drill with grout to minimize the impact of artesian conditions
- Perform Tension Load test
- Exclude the contribution of end bearing
Load Test Setup

Diagram showing a test setup with labels for Dial Gauge, Bar, Nuts, Mirror and Piano Wire, Dial Gauge (2 @ 180 Deg Typ.), Independent Reference Frame, Grade, Casing, and Grout. The text at the bottom reads: "RECORD HEIGHT OF BAR DIAL GAUGE ABOVE CASING." The diagram includes a table with the heading "Nicholson Tension Test Dial Gauge Setup."
Load Test Setup
Load Test Setup
Micropile Load Tests

LOAD VERSUS DEFLECTION

Load (kips)

Total Deflection (inches)

TP-1

TP-2
Micropile Load Test TP-2

Strain Gage Loads
Micropile Installation
Pier #3 As Constructed
Piezometer Installation (ATC)
Piezometer Installation (ATC)
Piezometer Data At Pier 4NB

Vibrating Wire Piezometer Water Pressure - Pier 4NB

Equivalent Water Level Elevation (ft)

Date

12/21/2015
1/4/2016
1/18/2016
2/1/2016
2/15/2016
2/29/2016

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Outline

Foundation Issues - I-65 over Wildcat Creek, Tippecanoe County

- What Happened
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- How Can These Problems Be Avoided in the Future
A cofferdam is a structure consisting of sheeting driven into the ground below the bottom of the footing elevation and braced to resist pressure. It shall be practically watertight and be capable of being dewatered.
Standard Specifications

- **Standard Specifications - 701**
  - In general, they shall be carried down well below bottoms of footings, shall be well braced, and as nearly watertight as practicable.

- **Standard Specifications - 206**
  - Cofferdams shall be constructed to protect plastic concrete against damage from a sudden rising of the stream and to prevent damage to the foundation by erosion.
FHWA Guidelines

**FHWA-NHI Pile Guidelines**

- Use solid prestressed concrete pile, tapered piles with sufficient collapse strength or thick wall closed end pipe with flush boot plate depending upon local practice. H-piles without driving shoes may also be viable selection. Do not use mandrel driven thinwall shells, as generated hydrostatic pressure may cause shell collapse. Pile heave also common to closed-end pile.
Subsurface Investigations

- A well developed soil & groundwater profile is necessary to design a cost-effective foundation.

- The best practice to reduce the risk of construction problems is early recognition of geotechnical problems during design stage and designing accordingly.

- Perform an adequate subsurface investigation in advance of final design.
Subsurface Investigations

Should provide the following:

- Depth and thickness of strata (subsurface profile).
- In-situ field tests to determine soil design parameters.
- Samples to determine soil and rock design parameters.
- Groundwater levels including perched, regional, and any artesian conditions.

Any artesian groundwater condition or other unusual groundwater condition should be identified and reported as this often has important impacts on foundation design and construction.
Design Considerations

- Check Basal stability (Piping and Heaving) and overall global stability for all stages of construction for deep excavations.
- Account for construction equipment loads that may increase the live load surcharge. For example; crane loads applied directly behind sheeting. Sheeting adjacent to existing spread footings shall be designed using a uniform surcharge equal to the applied footing pressure.
- Use appropriate sheet pile hammers, vibratory or impact, depending on soils.
Design Considerations

- Even if the structure is confirmed to be stable against uplift, the excavation scheme shall include contingency plans to address potential seepage and movement of material.

- The influence of pore pressure shall be confirmed using a slope stability analysis with pore pressure included. Software commonly used in the field of geotechnical engineering, has a pressure head spatial function that will linearly interpolate pore water pressure.
Design Considerations

- Given the site geology, there are two potential uplift failure modes from the artesian pressures due to excavation. The first is a **mass uplift of the soil** and the second is **seepage via preferential pathways**.
Design Considerations

- For a mass uplift failure to occur, the uplift pressure would need to overcome the cohesive resistance of the foundation. Since the preponderance of the material in the foundation is hard till overlying loose to dense sands, the calculation of factors of safety shall include cohesion.

- Concerns regarding uplift can be addressed by dewatering. Dewatering shall be performed to lower the water pressure beneath the confining clay layer. The water pressure beneath the confining clay layer can be reduced to a level where it is less than the total weight of the clay layer. Deep wells and/or well point systems shall be used.
Design Considerations

- Seepage via preferential pathways would not likely lead to catastrophic failure because the movement of water and possibly material would be local and could be addressed in the field.
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Questions?

THANKS
Understanding Performance and Service Life for Geotechnical Features

Silas Nichols
Principal Bridge Engineer – Geotechnical
Federal Highway Administration
Office of Bridge Technology
Repair of Bridge Foundations

Recent bridge foundation failures have highlighted primary demands necessary upon closing:

• Procedures to notify and inform public and officials
• Strategies to inspect damage and assess safety and integrity of super- and substructures
• Expedient means for conducting investigations, remediating structure and restoring service
• Establishing roles and responsibilities for personnel that may be involved in solution (contract type dependent)
Repair of Bridge Foundations

Three case histories used to illustrate primary issues:

1. I-43 over the Fox River (Leo Frigo Bridge), Green Bay WI
2. I-495 over the Christina River, Wilmington DE
3. I-65 over Wildcat Creek, West Lafayette IN
I-43 Leo Frigo Bridge

Vitals:
- Built in 1980
- Four lane bridge over Fox River
- ADT of 40,000
- 52 Span bridge
- Total length of 7,983 feet
Pile Deterioration
Pile Deterioration

Decreasing deterioration with distance above kink

Deteriorated but not crushed lower end of section projecting from pile cap (outlined in red)

Top of pile section below heavily deteriorated zone; deformation due to impact from red outlined section above

Position of upper section before vertical pier displacement

Section that deformed/buckled during vertical pier displacement

Position of lower section before vertical pier displacement

Pile at land below water level in good condition
Pile Deterioration

Complete section loss of outer portions of flange

Bottom of upper section is several inches below top of lower section; the sections have cut deeply into each other
Repair Strategy

- BUTTRESS WALL
- EXISTING PIER COLUMN
- EXISTING PIER FOOTING
- FOOTING EXTENSION
- FOOTING POST TENSIONING
- AREA OF CORRODED PILES
- EXISTING STEEL H-PILES
- DRILLED SHAFT (TYP)
- LIMESTONE BEDROCK SURFACE
- CCF RPM SLEEVE (UPPER 30 FT) (TYP)
- ROCK SOCKET (TYP)
Repair Strategy
I-495 over Christina River

Vitals:
• Built in 1974
• Four lane bridge over Christina River
• ADT of 90,000
• 3 Main Spans; 35 Approach Spans
• Total length of 4,804 feet
Failure Mechanism
Failure Mechanism
Temporary Shoring Plan
Final Repair Plan
Final Repair Plan
Temporary Shoring
Drilled Shaft Construction
I-65N over Wildcat Creek

Vitals:
- Built in 19??
- Two lane bridge over Wildcat Creek
- ADT of ??,000
- 5 Span bridge
- Total length of ?,??? feet
Drilled Foundation Solution
Lessons Learned

Through review of these projects, the following was noted:

• While failure mechanisms were different for all three bridges, the repair methodology and approach had commonalities

• There is no circumstance under which a failed foundation will ever be put back into service

• Faster is better
Addressing Needs

FHWA is currently working on a guidance effort based on the lessons learned:

- Developing strategies for assessing initial safety conditions
- Selecting safe investigation methods
- Providing solution alternatives for repair
  - Temporary shoring
  - Permanent repair
Future Impact

The development of guidance includes:

• Review of information (domestic and international)
• Interviews with agencies and contractors
• Development of protocols
  – Identify problem and assess safety
  – Determine cause of damage to foundation
  – Mitigate damage to reopen structure

Final report due in September 2016
Thank You!

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