S.R. 60 Bridge – Birmingham, Ohio
Design, Construction, Instrumentation
and Long Term Monitoring

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Overview

Initial embankment construction

Old S.R. 60

Severe Deterioration

Original Design

Old S.R. 60
July 2001, a new structure was designed

**Contractors Input in Design**

- Design Consultant - Richland Engineering Limited, Mansfield, OH
- General Contractor - S.E. Johnson Companies, Inc., Maumee, OH
- Geotechnical Consultant - BBC&M Inc, Dublin, OH
- Drilled Shafts - Millgard Corp., Livonia, MI
- Rock Anchors - Schnabel Engineering, Chicago, IL
- Instrumentation and Monitoring - E.L. Robinson, Columbus, OH
Subsurface Investigation and Field Observations

- A total of 34 soil borings were performed over multiple phases for this project by BBCM
- Installation of 5 inclinometers and monitoring
- Slope stability analyses
- Evidence of slope movement
  - Cracking at surface - Measured crack widths
- Sloping bedding planes in bedrock at exposure on north side of river within upper bedrock unit
Soil Borings and Inclinometers

• Several distinct layers of bedrock were encountered within all of the borings
• Inclinometers indicated significant movement near the interface of the reddish brown Bedford Shale and the gray becoming dark gray Ohio Shale
• Direct shear testing—residual strength
• Residual Friction Angle for Design = 10°
Slope Stability Analyses

• The intention was to determine if deep failure surface was possible or if likely only shallow
• Provided an indication of the relative factors of safety for various failure surfaces
• Considered residual strength of shale
Conclusions of Subsurface Investigation

- Instability appeared to be in upper bedrock layer known as Bedford Shale
- Foundations on the slope would either need to resist applied earth loading or else would need to stabilize entire slope
- Several general options were discussed to allow for construction of the bridge
Proposed Structure

- The decision was made to utilize a relatively long structure spanning the entire valley supported by 4 high capacity piers
- The piers would be supported on drilled shafts designed to carry any applied earth load with tolerable deflection at the top
PIER 1  PIER 2  PIER 3  PIER 4

S.R. 60 Over Vermilion River

PLAN

203'  254'  254'  230'  190'

ELEVATION
Determination of Shaft Load

• Intent was to have shafts resist applied soil loads which would likely occur over time; not to stabilize the entire slope

• Based on presence of slickensides, inclinometer data, and shear strength, change from loading to resistance taken as the interface of Bedford and Ohio Shale
Long Term Shaft Loading Caused by Moving Earth

- Magnitude based on at rest condition, insufficient movement to consider active
- Residual shear strength of shale used for computations
- Zone of influence taken into account by computing load over 3 shaft diameters
Pier No. 1

Very-soft reddish-brown shale

$\Phi'(\text{residual}) = 10^\circ$

$\gamma_{\text{dry}} = 135 \text{pcf}$

Soft becoming medium-hard gray becoming dark-gray shale
Design of Shafts

• Iterative procedure using the computer program LPILE
• Stiffness of the shaft for geotechnical models considered all reinforcement
• Analyzed two general conditions
  1) Long term with earth loading shafts
  2) Short term with shafts loading earth
Structure Design

- Vertical cantilevered beam with lateral load
- Column with vertical eccentric loading
- Rock socket for fixity
- Analyzed as a reinforced concrete column with vertical and lateral loading
12’ Diameter Drilled Shafts

• Single shaft to minimize applied load
• High strength 5 ksi concrete to minimize shaft diameter
• Larger diameter resists more load, requires more reinforcing
• Smaller diameter does not have enough space for reinforcing
Shear Resistance in Shaft

- Shear load determined shaft diameter
- 12’ diameter required to contain enough reinforcing steel for shear resistance
- H piles used for shear reinforcement
- H piles small in size in proportion to concrete area
Section Through Drilled Shaft Rock Socket

12'-0" DIAMETER DRILLED SHAFT

52-#18 BARS

18-HP12x53

10-HP12x53

STEEL CASING

INCLINOMETER TUBE (TYPICAL)
Refine Foundation Design

• Rock anchor tiebacks to reduce bending moment and deflection
• Reduce ground elevation to reduce load and lower tieback connection point
• Contractor input in design
Pier 1 Elevation

DRILLED SHAFT

ROCK ANCHORS

BEDFORD SHALE

ROCK ANCHOR SOCKET = 40'

OHIO SHALE

14'

39'-4 1/2"

DRILLED SHAFT CAP = 7'

DRILLED SHAFT ABOVE BEDROCK 41'

DRILLED SHAFT BEDROCK SOCKET 40'
Pier 1, Trial 6 – Strong Rock Model – Passive Load Case
Rock Anchors

- 45 degree angle from vertical to stay within right of way
- Multiple anchors for redundancy and to limit size (14 strand, 490 kips/each)
- Fanned to allow for variation in direction of applied load
- Redundant corrosion protection
Pier 1 Plan

Section Through Drilled Shaft Cap

CONSTRUCTION S.R. 60

ROCK ANCHOR (TYPICAL)

INCLINOMETER TUBE

PIER STEM

ROCK ANCHOR SLEEVES

ANCHORAGE

E.L. ROBINSON ENGINEERING
Construction Methods

- Auger drilled through Bedford shale in one day, 12’-6” diameter (40’ deep)
- Steel casing installed above bedrock, 12’-0” diameter
- Core barrel drilled through hard shale in 5 days, 11’-6” diameter (40’ deep)
Instrumentation, Monitoring, and Testing
Objectives

- Plan and execute instrumentation and monitor load testing of Piers 1 and 2.
- Study the temperature effect on massive pours
- Determine the soil and bedrock p-y curves.
- Determine load-deformation characteristics of the drilled shaft.
- Measure the actual lock off load in the anchors.
- Monitor the Piers and the slope during service life.
Pier 1
50 Sisterbar Strain Gages
2 inclinometers
1 Biaxial Tiltmeter

Pier 2
2 inclinometers
Pictures of Instrumentation Installation
Pictures of Concreting the Pier
Instruments locations

- Old ERI-60 Road
- B0+
- A0+
- A0+
- B0+
- Direction Downslope
- B0+ Direction 90 Degrees Clockwise from A0+ Direction

#1
#2

0 degrees
270 degrees
90 degrees
180 degrees
Temperature monitoring in Pier 1

Mass Pour

E.L. ROBINSON ENGINEERING
Temperature monitoring in Pier 1

Client:  S.E. Johnson Construction Companies, Inc.
Project:  ODOT 5(01) SR 60 Birmingham, Ohio

Report Date: May 15, 2002
CTL Project No. 026002EV

Temperature vs Time Caisson #1, 60.5 ft from bottom

Date/Time

Temperature, °F degrees

12" from center
36" from center
Outside
Outside ERI
Strains in Pier 1 (East-West)
3/13 ~ 5/28/02
Anchor Tensioning- Pier 1
Deflection with depth during Tensioning of Pier 1
Strains during anchor tensioning in Pier 1

Measured Strain in Pier#1 upslope 0 degrees (East)

Distance from bottom of shaft (ft)

Strain (μ)

-300 -250 -200 -150 -100 -50 0

Measured Strain in Pier#1 Downslope 180 Degrees (West)

Distance from bottom of shaft (ft)

Strain (μ)

-50 0 50 100 150 200 250

Anchors: Anchor 5 (1), Anchor 4 (2), Anchor 6 (3), Anchor 3 (4), Anchor 7 (5), Anchor 1 (6), Anchor 9 (7), Anchor 2 (8), Anchor 8 (9)
Long Term monitoring Results
5/30/2002 ~ 8/21/2002
After opening Bridge to Traffic
Deflection in Pier 1
Load Cell Measurements in Pier 1 Anchors

ERI-60: Load Cells Monitoring at Pier#1

Load (Kips)

Time in Days since 5/30/2002

Average Load
Long Term monitoring Results

5/30/2002 ~ 6/21/2014

4 Earth Inclinometers were added near the Rear Abutment and Piers 1 and 2
Conclusions

- The instrumentation and monitoring added a valuable input in understanding the behavior of the piers during construction and over the 13 years of monitoring.
- The deflection and strain build up is still going on as shown in the time plots.
- The monitoring is helping ODOT decide on the status of the structure and how safe it is.
Thank you

Questions?