“MSE WALL DESIGN AND GROUND IMPROVEMENT IN KARST TERRAIN”

BIRMINGHAM NORTHERN BELTLINE - RAMP “J”
ALABAMA DEPARTMENT OF TRANSPORTATION (ALDOT)

BY: LUTHER H. BOUDRA, P.E., D.GE
ALDOT BIRMINGHAM NORTHERN BELTLINE (BNB) PROJECT:

- 52 miles.
- Six-lane Corridor.
ALDOT BIRMINGHAM NORTHERN BELTLINE (BNB) PROJECT

- First section under construction from SR-79 to SR-75.
- Approximately 1.34 miles.
Alignment is near the contact between the Cumberland Plateau and the Valley and Ridge geologic physiographic provinces.

Transitions from Pennsylvanian-aged sandstones and shales to Cambrian-aged limestone and dolomite.
BIRMINGHAM NORTHERN BELTLINE - RAMP “J” WITH GEOLOGY & STRUCTURE SECTIONS OVERLAY

**Legend**
- **Areas Most Susceptible to Subsidence by Sinkhole Collapse**
- **Sinkhole Area Disturbed by Slope Failure**

**Geological Layers**
- Oc ALLUVIUM AND LOW TERRACE DEPOSITS
- OcC CHICKAMAUGA LIMESTONE
- OcK KNOX GROUP UNDIFFERENTIATED
- Mb BANGOR LIMESTONE
- Srm RED MOUNTAIN FORMATION
- Pgw PARKWOOD FORMATION
- Mpm PRIDE MOUNTAIN FORMATION
- Mhp HARTSELLE SANDSTONE

**Map Features**
- **Ramp J**
- **B’ham Northern Beltline**
- **Project Area**
BIRMINGHAM NORTHERN BELTLINE - RAMP “J”

ALIGNMENT FROM EARLIER THIS YEAR
Estimated top of rock from SPT and CPT prior to 2014

Original Top of Wall Profile

Final Top of Wall Profile

Revisions to top of rock profile based on additional borings in 2014

“Z” Boring Locations

Analysis at 2211+00

Analysis at 2225+85

BIRMINGHAM NORTHERN BELTLINE – RAMP “J” WITH GEOLOGY & STRUCTURE SECTIONS OVERLAY
CROSS SECTION AND STABILITY ANALYSES
STATION 2211:

- Stability analyses – note that the alluvial soils extend a significant distance behind the wall.
Sta. 2211+00
Drained Analysis

Existing Soil
\( \phi'(1) = 29 \) degrees
\( c'(1) = 0 \)
\( \phi'(2) = 19 \) degrees
\( c'(2) = 350 \) psf

Embankment
\( \phi' = 32 \) degrees
\( c' = 0 \)

Effective Bedrock Zone

Aggregate Base
CROSS SECTION AND STABILITY ANALYSES
STATION 2225:

- Stability analyses – note that the presence of the hillside improves the global stability.
BIRMINGHAM NORTHERN BELTLINE – RAMP “J”
RETAINING WALL - SLIDE GLOBAL STABILITY

2225+85

Diagram showing a retaining wall with slide global stability analysis at 2225+85.
Sta. 2225+85
Drained Analysis

Upper Alluvium
\( \phi' = 30 \text{ degrees} \)
\( c' = 0 \)

Alluvium/Slot - Upper
\( \phi' = 25 \text{ degrees} \)
\( c' = 0 \)

Alluvium/Slot - Lower
\( \phi' = 30 \text{ degrees} \)
\( c' = 0 \)

MSE Wall
Aggregate Piers

Embankment
\( \phi' = 32 \text{ degrees} \)
\( c' = 0 \)

Hillside (Residuum)
\( \phi' = 36 \text{ degrees} \)
\( c' = 0 \)

Effective Bedrock Zone
BIRMINGHAM NORTHERN BELTLINE – RAMP “J”
RETAINING WALL - SLIDE GLOBAL STABILITY

Sta. 2225+85
Undrained Analysis

Upper Alluvium
cu = 800 psf
phi = 0

Alluvium/Slot - Upper
cu = 400 psf
phi = 0

Alluvium/Slot - Lower
cu = 800 psf
phi = 0

Embarkment
cu = 1500 psf
phi = 0

Hillside (Residuum)
cu = 2200 psf
phi = 0

Effective Bedrock Zone

MSE Wall
Aggregate Pier Area
(drained parameters for soil around agg. piers)
After reviewing several options for stabilizing a MSE wall in the western 1200 feet of wall, it became apparent that a bridge is more cost effective.

Elected to go with aggregate pier ground improvement.

Geopier® was the successful bidder, and they developed a detailed design.

Slight differences in the Geopier® design and ours.

Additional borings (Z-borings) were drilled in areas Geopier® was unsure about.

Geopier® elected to use a combination of their replacement “conventional” and displacement “combo pier” designs.
Displacement vs. Replacement Geopier® Equipment
Probe and Plates Used to Install “Impact” Geopiers®
GEOPIER® LAYOUT:

- Note the different pier designs.
- Color coded installed depth of piers.
BIRMINGHAM NORTHERN BELTLINE – RAMP “J”
RETAINING WALL - GEOPIER LOCATION PLAN

Depth of Geopiers

- 0-5 FEET
- 5-10 FEET
- 10-20 FEET
- 20-40 FEET
- >40 FEET

2220+00

2220+75

15+00

2218+49

ALDOT NORTHERN BELTLINE RAMP "J"
JEFFERSON COUNTY, ALABAMA

GEOPIER®

Legend:

1. All existing and proposed utilities within and adjacent to the area shall be clearly marked by the general contractor and coordinated with the designer. Installation of geopiers ahead of demolition and utility relocation shall proceed with caution.
2. Plan view geopier location shall be adjusted to avoid all utility lines.
3. Geopier elements, under wall footings and/or miscellaneous foundation elements shall be located by survey of control points established from the survey documents.
BIRMINGHAM NORTHERN BELTLINE – RAMP “J”
RETAINING WALL - GEOPIER LOCATION PLAN

Depth of Geopiers

- 0-5 FEET
- 5-10 FEET
- 10-20 FEET
- 20-40 FEET
- >40 FEET

FIRST ROW OF PIERS SHALL BE ALIGNED UNDER CENTER LINE OF WALL.

2223+00

2224+22

GEOPIER LOCATION PLAN

GEOPIER® Foundation Plan Notes:

1. All existing and proposed utilities within and adjacent to the MSE wall shall be located prior to the final construction and coordinated with the geopier installer before geopier element installation shall proceed.

2. Plan for geopier location only. Please refer to AMEC Final Plan for grading details.

3. Geopier element locations shall be based on the field by field dimensions from control points established from civil plans.
Depth of Geopiers

- 0-5 FEET
- 5-10 FEET
- 10-20 FEET
- 20-40 FEET
- >40 FEET

Impact Piers ("Displacement Method")
Depth of Geopiers

- 0-5 FEET
- 5-10 FEET
- 10-20 FEET
- 20-40 FEET
- >40 FEET
BIRMINGHAM NORTHERN BELTLINE – RAMP “J”
RETAINING WALL - GEOPIER LOCATION PLAN

Depth of Geopiers

- 0-5 FEET
- 5-10 FEET
- 10-20 FEET
- 20-40 FEET
- >40 FEET

LEGEND

1. ALL EXISTING AND PROPOSED UTILITIES WITHIN AND ADJACENT TO THE MSE WALL SHALL BE TREATED IN ACCORDANCE WITH THE REQUIREMENTS OF THE CONTRACTOR AND CONSIDERED PART OF THE MSE WALL.
2. GEOPIER LOCATION SHOWN ON PLANS AND PLAN SHEETS REFER TO SHEET 'AL-261 PLAN'.
3. GEOPIER ELEMENTS UNDER WALL TYPING AND/OR FOUNDATION ELEMENTS SHALL BE LOCATED IN THE FIELD AT SUBSEQUENT TIMES FROM CONTROL POINTS ESTABLISHED FROM ON-SITE PLANS.
SUMMARY:

- When dealing with karst conditions, there is no such thing as “too much” subsurface information.
- Be prepared to modify plan based on subsurface conditions encountered.
- Aggregate piers are a useful tool for ground improvement in karst areas, but (with apologies to Santa) “No Virginia, aggregate piers are not suitable in all conditions.”
- The particular installation technique utilized, e.g., vibroplacement, vibrodisplacement, rammed aggregate piers, etc., will depend on the soil strength, soil type, depth the piers are required to extend, groundwater conditions, etc.
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QUESTIONS?