USE OF MICROPILES IN TEXAS BRIDGES

by

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Geotechnical Branch
DEFINITION OF A MICROPILE

A micropile is a small diameter (typically less than 12 in.), drilled and grouted non-displacement pile that is typically reinforced.
BEGIN DRILLING &/OR INSTALLATION OF TEMPORARY CASING

COMPLETE DRILLING TO DEPTH

REMOVE INNER DRILL BIT & ROD (IF USED)

PLACE REINFORCEMENT & GROUT (BY TREMIE)

REMOVE TEMPORARY CASING, INJECT FURTHER GROUT UNDER PRESSURE AS APPLICABLE

COMPLETE PILE (CASING MAY BE LEFT IN PLACE THROUGH THE COMPRESSIBLE STRATUM)

ADDITIONAL GROUT

COMPRESSIBLE STRATUM

BEARING STRATUM
MICROPILE APPLICATIONS

IN-SITU EARTH REINFORCEMENT

FOUNDATION STRUCTURAL SUPPORT

~ 95% of the applications worldwide
MICROPILE APPLICATIONS

FOUNDATION STRUCTURAL SUPPORT

Foundations for New Structures
Underpinning of Existing Structures

Repair/Replacement of Existing Foundations
Upgrading of Foundation Capacity
MICROPILES

**ADVANTAGES**

- used in restricted overhead access areas
- used in close proximity to existing structures
- used in difficult ground conditions (karst areas, uncontrolled fill, etc.)
- may be placed on an incline (i.e. battered)

**DISADVANTAGES**

- vertical micropiles may be limited in lateral capacity
- due to their slenderness ratio micropiles are limited in axial capacity
- cost
<table>
<thead>
<tr>
<th>FOUNDATION TYPE</th>
<th>COST ($/LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICROPILES</td>
<td>150</td>
</tr>
<tr>
<td>DRILL SHAFT (18)</td>
<td>41</td>
</tr>
<tr>
<td>DRILL SHAFT (24)</td>
<td>85</td>
</tr>
<tr>
<td>DRILL SHAFT (30)</td>
<td>106</td>
</tr>
<tr>
<td>DRILL SHAFT (36)</td>
<td>112</td>
</tr>
<tr>
<td>DRILL SHAFT (42)</td>
<td>131</td>
</tr>
<tr>
<td>DRILL SHAFT (48)</td>
<td>203</td>
</tr>
</tbody>
</table>

MICROPILES COST = ~ 42 TO 48 inch DRILLED SHAFTS
EXAMPLE OF THE USE OF MICROPILES

- Underpinning of a bridge
Phased Construction

Stage 1 Transverse Section of Proposed Bridge

Stage 2 Transverse Section of Proposed Bridge

Complete Transverse Section of Proposed Bridge
NOTES:
1. DESIGNED IN ACCORDANCE WITH AASHTO LRFD SPECIFICATIONS.
2. BEAM AND CONDITIONING:
   D: DENOTES DOWEL AT EXTERIOR BEAM.
   BLANK DENOTES NO DOWELS.
3. PROPOSED BRIDGE WILL NOT CHANGE THE QUANTITY OR CHARACTER OF FLOW IN THE RAILWAY'S DITCHES AND/OR DRAINAGE STRUCTURES.
4. DRILLED SHAFTS SHALL BE FOUNDED AT THE ELEVATION SHOWN OR DEEPER TO PROVIDE MINIMUM PENETRATION OF 2-SHAFT DIAMETERS INTO HARD LAYER.
PROBLEMS OBSERVED DURING CONSTRUCTION

- Bent 5 showed signs of distress shortly after pouring the slab. The outer column of bent 5 settled 4” the day after the slab pour.

- No cracking of the bridge slab was observed, which indicates the settlement occurred while the deck concrete was curing.
Column – Bent 5
What to do?

- Obtain additional borings along the structure
- Evaluate the foundations using the new borings
Additional Boreholes - Location
Location of Additional Boreholes

B-4A
B-3A
B-3B
B-7
B-8
B-11
Bent 4
Bent 5
# Bore Logs - Bent 5

## Drilling Log - B4A

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>Truncated Penetrometer</th>
<th>Stratigraphic Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>358.8</td>
<td>SAND, red, clay, with gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>354.0</td>
<td>CLAY, red, clay, with gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS Tip = 360.0'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: East side of bridge. Mud rotary was utilized for exploration.

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## Drilling Log - B11

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>Truncated Penetrometer</th>
<th>Stratigraphic Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>358.8</td>
<td>CLAY, red, clay, with gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>354.0</td>
<td>CLAY, red, clay, with gravel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DS Tip = 360.0'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: Mud rotary utilized. Organic materials encountered approximately 3 ft. below ground elevation. Shale encountered at approximately 35 ft. below ground elevation.
### Bore Logs - Bent 5

#### DRILLING LOG

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>LOG</th>
<th>Texas Cone Penetrantype</th>
<th>Strata Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>376.10</td>
<td>1</td>
<td>CLAY, red, clayey, with gravel</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>376.15</td>
<td>1</td>
<td>CLAY, red, gray, with gravel</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>376.20</td>
<td>1</td>
<td>CLAY, gray, with gravel</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>387.35</td>
<td>1</td>
<td>CLAY, red, gray, with gravel</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>387.40</td>
<td>1</td>
<td>CLAY, gray, brown, with shale</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>387.50</td>
<td>1</td>
<td>CLAY, gray, brown, with shale</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>387.60</td>
<td>1</td>
<td>CLAY, red, gray, brown, with shale</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>387.70</td>
<td>1</td>
<td>CLAY, red, gray, brown, with shale</td>
<td>(CL)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DS Tip = 360.0’**

**342.8’**

### DRILLING LOG

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>LOG</th>
<th>Texas Cone Penetrantype</th>
<th>Strata Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Drilled to 48 ft. without sampling</td>
</tr>
<tr>
<td>342.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.70</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>342.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** West side of bridge. Mud rotary utilized.

Any groundwater elevation information provided on this boring log is representative of conditions existing on the day and for the specific location where this information was collected. The actual groundwater elevation may fluctuate due to time, climatic conditions, and/or construction activity.
### Bore Logs - Bent 4

#### DRILLING LOG

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>Depth (G')</th>
<th>Texas Core Parameter</th>
<th>Strata Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>363.5 5</td>
<td>5</td>
<td>CLAY, red, gray (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>363.5 10</td>
<td>10</td>
<td>CLAY, red, with gravel (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>362.5 20</td>
<td>20</td>
<td>CLAY, red, gray (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>378.5 25</td>
<td>25</td>
<td>CLAY, red, gray, brown; hit wood fragments @ 25 ft (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>372.5 30</td>
<td>30</td>
<td>CLAY, gray, brown (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>368.5 35</td>
<td>35</td>
<td>CLAY, red, gray, brown, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>363.5 5</td>
<td>5</td>
<td>CLAY, red, gray, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>362.5 5</td>
<td>5</td>
<td>CLAY, red, gray, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.5 50</td>
<td>50</td>
<td>CLAY, red, gray, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: East side of bridge. Mud rotary utilized. Organic debris (wood) encountered approximately 36 ft. below ground elevation.

The ground water elevation was not determined during the course of this boring.

Driller: E. Wilson  
Logger: M. Williams  
Organization: Apex Geoscience

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#### DRILLING LOG

<table>
<thead>
<tr>
<th>Elev. (ft)</th>
<th>L</th>
<th>G</th>
<th>Texas Core Parameter</th>
<th>Strata Description</th>
<th>Triaxial Test</th>
<th>Properties</th>
<th>Additional Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>363.5 5</td>
<td>5</td>
<td>G</td>
<td>CLAY, red (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>363.5 10</td>
<td>10</td>
<td>G</td>
<td>CLAY, red, with gravel (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>362.5 20</td>
<td>20</td>
<td>G</td>
<td>CLAY, red, gray (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>378.5 25</td>
<td>25</td>
<td>G</td>
<td>CLAY, grey, red, brown, with gravel (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>372.5 30</td>
<td>30</td>
<td>G</td>
<td>CLAY, grey, brown (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>368.5 35</td>
<td>35</td>
<td>G</td>
<td>CLAY, grey, brown, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>363.5 5</td>
<td>5</td>
<td>G</td>
<td>CLAY, grey, brown, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>362.5 5</td>
<td>5</td>
<td>G</td>
<td>CLAY, grey, brown, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>342.5 50</td>
<td>50</td>
<td>G</td>
<td>CLAY, grey, brown, with shale (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: GPS Coordinates: X916464551.0, Y-394538813.6 West side of bridge; mud rotary utilized.

The ground water elevation was not determined during the course of this boring.

Driller: E. Wilson  
Logger: M. Williams  
Organization: Apex Geoscience

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DS Tip = 366.0'  
364.5'  
363.5'  
363.5'
• Based on the new borings the drilled shafts for Bents 4 and 5 were of insufficient length

• Bents 4 and 5 needed to be repaired to restore the capacity of the foundation elements

• Revised drilled shaft tip elevations were provided for Phase 2 construction
Repair Options

- Option 1 - Underpin Bents 4 and 5 by placing drilled shafts along the bent line. Shafts would be connected with a tie beam incorporating the existing columns.

- Option 2 – Underpin bents 4 and 5 by placing drilled shafts perpendicular to the bent line, and installing two shafts per installed drilled shaft. Shafts would be connected with a footing tied into the existing column.

- Option 3 – Underpin bents 4 and 5 by placing micropiles. A footing would be placed on the micropile group and tied into the existing column.

- Option 4 – Remove the superstructure over Bents 4 and 5 and associated bent caps to allow installation of drilled shafts to proper design length. Rebuild bent and superstructure.
Repair Options

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Micropile Repair Option

• The design of micropiles was conducted under TxDOT supervision.

• The allowable design load was 60 Tons/micropile.

• The total length of each micropile was estimated as 70.0’ with a bond zone of 30.0’ min. into stiff strata.

• The reinforcing bar consisted of 1 ¾” (#14) dia, grade 75, equipped with post grout tubing and centralizers.

• Micropiles were 8” diameter (grout filled, post grouted and cased with N80 casing 9’ from surface).

• Grout Strength = 4000 psi.
Micropiles Repair Option

- Four micropiles were installed per drilled shaft and tied to the existing column with a pile footing. The pile footing was designed by TxDOT.

- Prior to installation of production piling, one sacrificial micropile was tested under tension load, in accordance with ASTM D3689 “Quick Test”.

- The test pile performed adequately with a deflection of 0.026” at 60 Ton (design load) and 0.386” at 120 Ton (maximum test load).
Footing Retrofit (Bent 4)
LOAD TEST

Bent Line

Trucks
Load Test Results

• Test Load ~ 90% of Design Load

• Bent 4:
No appreciable movement was measured under a 20 min. hold at the test load.

• Bent 5:
A maximum measured settlement of 0.007” was observed for the sustained test load. Once the load was taken off of the bent, a recovery of 0.003” of elastic settlement was noticed.
Micropiles and the associated footings stabilized the foundations for Bents 4 and 5. The superstructure was restored by jacking it up to the required elevations.
Bridge Deck Prior to Foundation Stabilization and Jacking Up of the Beams
Bridge Deck After Foundation Stabilization and Jacking Up of the Beams
CONCLUSIONS

• Micropiles can be used for foundation support on new bridges and to underpin existing structures

• Micropiles are commonly used:
  - in restricted overhead access areas
  - in close proximity to existing structures

• When used in appropriate conditions micropiles can be cost effective
Questions?