Learning Objectives

By the end of this presentation, the students will be able to:

• discuss the types of bridge foundations commonly used by VDOT and understand the factors used by designers in selecting a particular foundation type

• understand the QA/QC methods used during construction that will help ensure that the foundation will perform as designed

• complete the documentation (paperwork) that is required for the more common types of deep foundation systems
**Two General Types of Foundations**

**Shallow Foundations**
- Spread Footings

**Deep Foundations**
- Driven Piles
- Drilled Shafts
- MicroPiles
- Others

**Shallow Footings**

- *(Embedment)* $D_f < 2B$ (Twice the Footing Width)... Somewhat arbitrary definition
- The terms Shallow Footings and Spread Footings tend to be used interchangeably.
- Typically, Spread Footings are the most cost-effective foundation type when competent material is “close” to the proposed ground surface. (Close ~ 10 feet)
- VDOT historically only uses shallow foundations when they can bear on bedrock or weathered bedrock. However, spread footings can bear on soil, provided the bearing capacity of the soil is adequate and settlements are tolerable.
- When bearing on soil, settlement almost always controls.
### Spread Footings – Typical Configurations

<table>
<thead>
<tr>
<th>Type of Bearing Material</th>
<th>Consistency in Place</th>
<th>Bearing Resistance (lb)</th>
<th>Recomended Value of Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very dense</td>
<td>180</td>
<td>6</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Medium dense</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Loose</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very loose</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Medium dense</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very dense</td>
<td>180</td>
<td>6</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Medium dense</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Loose</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very loose</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Medium dense</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very dense</td>
<td>180</td>
<td>6</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Medium dense</td>
<td>90</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Loose</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>Marine silt and siltstone, sandstone, gravel, and similar materials</td>
<td>Very loose</td>
<td>20</td>
<td>2</td>
</tr>
</tbody>
</table>

Reference: GEOTECHNICAL ENGINEERING CIRCULAR (GEC) NO. 6, FHWA-SA-02-054, Sept. 2002
Spread Footings – Typical Configurations (con’t)

Figure 2-3: Spread Footing with Curvilinear Stemwall at Bridge Abutment

Figure 2-4: Semi-Gravity Curvilinear Retaining Wall

Reference: GEOTECHNICAL ENGINEERING CIRCULAR (GEC) NO. 6, FHWA-SA-02-054, Sept. 2002

Spread Footings – Typical Configurations (con’t)

Figure 2-5: Combined Footing

Reference: GEOTECHNICAL ENGINEERING CIRCULAR (GEC) NO. 6, FHWA-SA-02-054, Sept. 2002
Spill-Thru Abutment on a Combined Footing

Reference: GEOTECHNICAL ENGINEERING CIRCULAR (GEC) NO. 6, FHWA-SA-02-054, Sept. 2002

Rte. 130 over Pedlar River, Amherst County
Abutment A – Stepped Spread Footing
Rte. 130 over Pedlar River, Amherst County
Abutment A – Stepped Spread Footing

Rte. 130 over Pedlar River, Amherst County
Abutment A – Stepped Spread Footing
Rte. 130 over Pedlar River, Amherst County
Abutment A – Stepped Spread Footing

Deep Foundations

- Typically used if competent material is located a significant distance below the ground surface. (Usually > 20 feet)

- If a deep foundation is necessary, driven piles are typically used in the Staunton District.
Conditions requiring Deep Foundations

Deep Foundations – General Types

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume I
Sept. 2016
What is a pile

Vertical or battered long, slender, structural members which at top are embedded into the substructure, at bottom into the soil, transferring the total load of the bridge to the soil or rock.

References

- Section 403 of the VDOT Specs. - P. 392, 2007 VDOT Road and Bridge Specs.
  P. 442, 2016 VDOT Road and Bridge Specs.


Pile Foundations
Examples of different steel piles

- Steel H-Pile (can be end bearing or friction piles)
- Steel shells for cast-in-place friction piles
- Steel sheet piling (Typically used for shoring)

Miscellaneous Pile Information

- Steel – H Pile, example - HP 14 X 73

- General Note information pertaining to piles:
  - Factored axial resistance - Design Load
  - Nominal axial resistance – as measured during driving
Driven Piles (Pros/Cons)

- **Pros:** Economical (No sub-contractor needed usually)
  High Capacities Possible
  Versatile (Can be used in a wide variety of ground conditions)

- **Cons:** May refuse above scour line
  Short piles may have low lateral resistance/capacity
  Creates Noise and Ground Vibrations during installation

Driven Piles: End Bearing Pile vs. Friction Pile

We generally classify piles based on the predominant manner in which it carries the loads. If the resistance (capacity) is achieved predominantly at the tip of the pile, we call it an **end-bearing pile**. If the resistance (capacity) is achieved predominantly along the sides of the pile, we call it a **friction pile**. In reality, all piles have both side friction capacity and end-bearing resistance.
Deep Foundations (Driven H-piles)

- Driven piles (east of the Fall Line) = Prestressed Concrete Piles (Friction piles completely embedded within soil)

- Driven piles (west of the Fall Line) = Steel H-piles (End bearing piles driven to weathered bedrock or competent bedrock)

Pile Driving Equipment – Swinging Leads

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016
Pile Driving Equipment – Fixed Leads

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016

Swinging Leads restrained by chaining leads to a track hoe
Types of Pile Driving Hammers

Seems to be the most common

Single-Acting Diesel Hammer (aka Open-ended Diesel Hammer)

With OED hammers, the ram freefalls under gravity. Stroke can be visually estimated or calculated.
Double-Acting Diesel Hammer
(aka Closed-ended Diesel Hammer)

With CED hammers, the ram falls under gravity and is propelled downward by pressure that builds up in the bounce chamber. Stroke cannot be visually estimated or calculated; an "equivalent" freefall stroke must be correlated from the bounce chamber pressure reading.

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016

Completed Pile Group for a Stage constructed Abutment
Pile Tips

Pile Foundations
Installing a pile into driving leads
Positioning pile into head block

Positioning pile for driving
Pile Driving Tolerances

Definition - Center of Gravity (CG) of a Pile Group – a unique point that represents the central location of all of the piles in the group. The CG can be determined for the entire pile group, or it can be determined for a subset of the entire group (a single row, for example).

Table IV-1--- p. 402 – 2007 VDOT Road and Bridge Specs.
P. 454 - 2016 VDOT Road and Bridge Specs

<table>
<thead>
<tr>
<th>Pile Type</th>
<th>Condition</th>
<th>Tolerance for Single Pile (in)</th>
<th>Center of Gravity for Pile Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Steel Concrete</td>
<td>and Column supports for bent caps and integral abutments</td>
<td>3</td>
<td>About long axis of 3% of distance between footing platens or 1 1/2 in., whichever is greater</td>
</tr>
<tr>
<td>2. Steel Concrete</td>
<td>and (a) Footing supports for box culverts</td>
<td>6</td>
<td>About both major axes of distance between platens or 1 1/2 in., whichever is greater</td>
</tr>
<tr>
<td></td>
<td>(b) Footing supports for column piers</td>
<td>6</td>
<td>About both major axes of distance between platens or 1 1/2 in., whichever is greater</td>
</tr>
<tr>
<td></td>
<td>(c) Footing supports for abutments, retaining walls, and piers other than column piers</td>
<td>6</td>
<td>About long axis of 3% of distance between footing platens or 1 1/2 in., whichever is greater</td>
</tr>
</tbody>
</table>

WEAP or Dynamic Pile Test will be used to determine refusal.
Method of Grouping Piles for Abutments and Retaining Walls

Staunton District Modifications to the 2005 Construction Manual (rev. 2016) for the grouping of piles in Abutments and Retaining Walls for the determination of the group location tolerances from plan center of gravity.

Generally, because the front or toe row of piles are the most critically loaded piles and the most critical for the structural stability, the piles should be grouped as shown. (This does not apply to piles in Piers.)

- Pile group (typ.)

Distance Between Extremes

SHELF ABUTMENT OR SHORT RETAINING WALL

Structures and Bridge Division
Method of Grouping Piles for Abutments and Retaining Walls

Shelf Abutment – showing approximate location of resultant force (all forces combined) on the abutment
Example illustrating why we want to evaluate the two rows of piles separately rather than together

As designed $S = 10 \times 1 \times (1.25)^2 \div 1.25 = 12.50 \text{ ft}^3$

As driven $S = 10 \times 1 \times (0.75)^2 \div 0.75 = 7.50 \text{ ft}^3$

$S =$ Section Modulus (a factor pertaining to the strength of the pile group

Section Modulus reduced by 40%, this will result in significant increase in load to the piles in the front row

How would the computed deviation of the center of gravity for the as-driven pile group check out?

Black = as designed
Red = as driven - all piles driven 6" toward center of group - each is within allowable individual tolerance

Exercise to determine the deviation of the center of gravity for two row Abutment Pile Group

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Pile No.</th>
<th>Deviation Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.08 ft.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>+0.17 ft.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.06 ft.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-0.33 ft.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-0.42 ft.</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>+0.25 ft.</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-0.49 ft.</td>
<td></td>
</tr>
</tbody>
</table>

$-0.49/6 = 0.08 \text{ ft.} < 0.125 \text{ ft.} --- OK$

<table>
<thead>
<tr>
<th>Group 2</th>
<th>Pile No.</th>
<th>Deviation Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>+0.33 ft.</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-0.08 ft.</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>-0.42 ft.</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>-0.25 ft.</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>+0.17 ft.</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>-0.17 ft.</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>-0.42 ft.</td>
<td></td>
</tr>
</tbody>
</table>

$-0.42/6 = 0.07 \text{ ft.} < 0.125 ---- OK$
Group Exercise!

Pile Driving Criteria

403.08—Driving Criteria:

(a) Bearing: Bearing resistance values for concrete and steel piles shall be determined by the loading tests specified in 403.07(a). In the absence of loading tests, nominal pile resistance may be determined using a dynamic pile test during pile driving specified in 403.07(b) or results of wave equation analysis in 403.07(c). In the absence of loading tests, wave equation analysis, or a dynamic test, the nominal pile resistance may be approximated by using the pile formula specified in 403.07(d). The character of the soil penetrated, conditions of driving, followers, size, length, and weight of the piles, and computed load per pile shall be given due consideration in determining the nominal pile resistance.

Bearing piles shall be driven until the blow count determined to produce the required nominal pile resistance has been continuously maintained for 2 feet or to practical refusal, whichever occurs first.

(b) Practical Refusal: Practical refusal is defined as twice the blow count required to produce nominal pile resistance. In the case of driving to a very dense or hard stratum, the driving criterion should be based on blows per inch criterion and should address limiting the blows following an abrupt refusal to prevent damage. In no case shall driving continue for more than 3 inches at practical refusal driving conditions.

Based on the results of the wave equation, dynamic analysis and/or the driving test, the Engineer may elect to adjust the criteria for practical refusal but in no case shall practical refusal be greater than 20 blows per inch.

(c) A pile shall not be driven above the blow count where wave equation analysis or dynamic testing results indicates that maximum stress levels will be exceeded.

Ref.: 2016 VDOT Road and Bridge Specifications, Sec. 403.08
Pile Driving Criteria

Driving criteria will always consist of two values:
1. Blow count [Blows per foot, BPF, or Blows per inch (BPI)]
2. Stroke (Feet)

There might be several different sets of criteria that vary with the hammer stroke, for example:
1. 6 bpi at a min. stroke of 8’ maintained for 2 consecutive inches
2. 4 bpi at a min. stroke of 9’ maintained for 2 consecutive inches

Hammer Energy

Energy = Weight of the Ram/Hammer X Stroke/Fall

Example:
4,000lb. Ram X 10 ft. Stroke
= 40,000 ft.-lbs. of Energy
Hammer Size

Too Big!

Too Small!

Just Right!

Hammer size

Too small?
Variable energy?

Hand Held Pile Driver

https://www.youtube.com/watch?v=cFb0nLCKypg&t=1
Hammer Size Too Big?

Things to watch for and document during Pile driving for sake of engineering assessment of pile group

1) Sudden drop of the pile such as when hitting a void or cavern. Note the range of the void on the Pile Driving Record i.e. 15 ft. to 18 ft. BPF should be very low or zero for the range.

2) Change in the vertical orientation of a pile especially if the change is sudden. Note the depth at which the change occurred and how much the orientation changed. Make note if the pile jerked free of the leads when the change occurred.

3) If a pile walks laterally and/or changes vertical orientation keep an eye on adjacent piles. If an adjacent pile moves during driving let the Bridge Office know.

4) Part of observation is listening! When an end bearing pile reaches refusal it develops a distinctive resonance/ringing sound. Pay attention to this when performing the PDA to establish reference. This is not a substitution for measuring the final blows per inch, but is supportive/indicative of the condition of the pile.
Always remember to complete the stroke column on this form, especially near the end of driving.

Extracted Pile – Pile was driving normally when it suddenly leaned over freeing itself of the leads. Note Pile Point is missing.

Possible scenario depicting why a pile would experience a deviation in vertical orientation.
Driving Battered Piles

Wave Equation and Dynamic Pile Testing

**Wave Equation Analysis of Piles (WEAP)** – a computer model or simulation of the pile driving process. WEAP models the hammer-pile-ground interaction. For VDOT’s purposes, WEAP is mainly used to for hammer approval. Per the 2016 Specifications, the contractor must submit a WEAP model demonstrating that the proposed hammer is capable of driving the piles to the required nominal resistance without overstressing the piles. WEAP is a very approximate model.

**Dynamic Pile Testing** – sometimes referred to by a proprietary name, **PDA** (Pile Driving Analysis). Dynamic analysis, which occurs during the driving of the test pile, uses gauges (accelerometers and strain gauges) attached to the pile that measures force and wave velocity as the pile is driven into the ground. These measurements are used to determine the driving stresses in the pile and estimate the static resistance (capacity) of the pile.

**Signal Matching Program** – sometimes referred to by a proprietary name, **CAPWAP** (CAse Pile Wave Analysis Program). The PDA measurements are input into this program, which provides the pile resistance distribution along the shaft of the pile and at the tip.
WEAP

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016

Figure 12.1 Wave propagation in a pile (adapted from Cheney and Chassie 2000).

WEAP – Pile and Driving Equip’t Data Form
Dynamic Pile Testing - Gauges

Figure 10-2  a) Accelerometer, strain gage, and WiFi transmitter (courtesy Pile Dynamics) and b) combined strain gage and accelerometer (courtesy Alinamics).

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016

Dynamic Pile Testing - Equipment

Reference: NHI Courses No. 132021 and 132022
Design and Construction of Driven Pile Foundations – Volume II
Sept. 2016
Dynamic Pile Testing - Results

At this depth of penetration, we are getting a resistance of about 540 kips...

...and driving stresses are below 45 ksi (0.9Fy)

Methods for Estimating Stroke
(Open-ended Diesel Hammer)

1. Visually (by observing the ram extending out of the body of the hammer, as well as the rings on the ram, when it's at the top of its stroke).

Rings scribed around top of ram can be used to estimate stroke for OED hammers
Single Acting Diesel Hammer

Piston (hammer) is visible as the hammer operates. Rings on the piston will help estimate the stroke of the hammer.

Methods for Estimating Stroke (Open-ended Diesel Hammer)

2. Timing the blow rate, using this chart
(ONLY applicable for open-ended (single-acting) diesel hammers)
4.0 PRODUCTION PILE DRIVING RECOMMENDATIONS

Project 0011-082-713, B620

4.1 General

Based upon field dynamic pile analysis, CTI verbally recommended that initial driving of piles at Abutment A be terminated once approximately 13 blows are required in a 3 inch interval at hammer fuel setting #4 and a stroke height of at least 10 feet.

The test pile was driven in one foot increments and dramatically increased in capacity over the 2 feet of driving. At a capacity of roughly 260 tons or more, the final set of blow counts 4 – 5 blows per inch (bpi).

To maximize productivity and lessen the chance for damage to the piles or hammer, it is recommended that production driving acceptance be based upon the following conditions:

- In addition to one foot marks, also provide six inch markings on the pile for five feet above and below refusal elevation as estimated from boring logs
- Full stroke driving with the ICE I-19 hammer or operating at fuel setting #4 as observed during initial driving of the test piles
- Observe pile response and pause driving when more than 24 blows are required per six inch increment
- Driving should also be paused if the pile begins to rebound, which is indicative of rapid capacity increase and could result in damage if driven to the next blow count demarcation
- Add one inch markings to the pile and resume driving to the following criteria, which should provide a refusal capacity of at least 260 tons

For a stroke height of 10 feet or more, terminate driving when at least 4 bpi are observed.
Pile driven in a seam

Pre-bored Pile
Piles driven to support a shelf Abutment prior to Construction of MSE Abutment and approach fill

Drilled Shafts – Dry Construction Method

Figure 4-5  Dry Method of Construction: (a) Drill the Hole; (b) Clean the Base; (c) Place Reinforcement; (d) Place Concrete

Ref: FHWA-NHI-016, GEC-010,
Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Drilled Shafts – Pros/Cons

Pros:
• Very high axial and lateral resistances/capacities possible
• Can be constructed as deep as necessary for scour resistance
• Usually no cap/footing required
• Low ground vibrations
• Can inspect material coming out of ground
• Applicable to a wide variety of ground conditions, including karst

Cons:
• Expensive
• Quality sensitive to construction procedures
• Requires a high level of knowledge (Engineers and Inspectors)
• Typically no redundancy
Drilled Shafts – Dry Construction Method

Figure 4-1  Dry Hole in Stable Soil

Ref: FHWA-NHI-016, GEC 010,
Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

Drilled Shafts – Slurry & Casing Method

Figure 4-7  Construction Using Casing Through Slurry-Filled Starter Hole: (a) drill with slurry; (b) set casing and bail slurry; (c) complete and clean excavation, set reinforcing; (d) place concrete to head greater than external water pressure; (e) pull casing while adding concrete

Ref: FHWA-NHI-016, GEC 010,
Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Figure 4-8 Construction Using Casing Advanced Ahead of Excavation: (a) drive casing into bearing stratum; (b) drill through casing; (c) complete and clean hole, set reinforcing; (d) place concrete to head greater than external water pressure; (e) pull casing while adding concrete.

Ref: FHWA/NHI-016, GEC 010,
Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

Figure 4-13 Telescoping Casing
Drilled Shafts – Slurry Method

Figure 4-15  Slurry Drilling Process: (a) set starter casing; (b) fill with slurry; (c) complete and clean excavation, set reinforcing; (d) place concrete through tremie; (e) pull tremie while adding concrete

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

Drilled Shafts - Tools

Figure 5-15  Single Flight Earth Augers

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Drilled Shafts - Tools

Figure 5-16  Double Flight Earth Augers

Figure 5-17  Large Diameter Auger with Double Cutting Edge

Drilled Shafts - Tools

Figure 5-19  Boulder Rooters

Ref: FHWA/NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Drilled Shafts - Tools

Figure 5-21  Typical Drilling Buckets

Ref: FHWA/NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

Drilled Shafts - Tools

Figure 5-22  Clean-out Buckets

Ref: FHWA/NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Drilled Shafts - Tools

Figure 5-33  Downhole Impact Hammers

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

Drilled Shafts - Tools

Figure 6-5  J Slots in Top of Casing for Use with Casing Twister

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
Drilled Shafts – Frictional Resistance and End Bearing resistance

![Diagram of Drilled Shafts](image)

Idealized Geometrical Layering for Computation of Compression Resistances

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010

---

Drilled Shaft Integrity Testing – Crosshole Sonic Logging (CSL)

![CSL Diagram](image)

Reinforcing Cage with Steel Access Tubes for CSL Testing

Ref: FHWA-NHI-016, GEC 010, Drilled Shafts: Construction Procedures and LRFD Design Methods, May 2010
MicroPiles

**Definition** – MicroPiles are small diameter piles that are drilled and grouted into the ground. They are typically 12-inches in diameter or less, and typically use a permanent casing in the upper portion of the pile. The lower, uncased portion (the bond zone) carries the load. Central reinforcement is often used.

**Pros**
- Versatile – can be used in all types of soil and rock, including karst, and in cases where access is difficult.
- High axial and lateral resistances/capacities possible.

**Cons**
- Expensive – can cost between $100 and $200/LF
MicroPiles

Only the resistance/capacity provided by the friction along the bond length is counted on for support. End bearing is not assumed to contribute to resistance.

MicroPiles are classified based on their method of installation:

Figure C10.9.1-1—Typical Detail of Composite Reinforced Micropiles (after Sabatini, et al., 2008)

MicroPiles

Type A micropiles are constructed by placing a sand-cement mortar or neat cement grout in the pile under a gravity head only:

Type B micropiles are constructed by injecting a neat cement grout under pressure (typically 6–21 ksf) into the drilled hole while the temporary drill casing or auger is withdrawn;

Type C micropiles are grouted as for Type A, followed 15–25 min after primary grouting by injection of additional grout under pressure (typically greater than 21 ksf) via a preplaced sleeved grout pipe.

Type D micropiles are grouted similar to Type C, but the primary grout is allowed to harden before injecting the secondary grout under pressure (typically 42–170 ksf) with a packer to achieve treatment of specific pile intervals or material horizons;

Type E micropiles are constructed by drilling with grout injection through a continuous-thread, hollow-core steel bar. The grout injection serves to flush cuttings, achieve grout penetration into the ground and stabilize the drill hole. Often the initial grout has a high water to cement ratio and is then replaced with a thicker structural grout near the completion of drilling.
MicroPiles

Rte. 340 over Compton Creek

MicroPiles

Rte. 340 over Compton Creek
MicroPiles

Rte. 340 over Compton Creek

MicroPiles
MicroPiles

MicroPiles
Questions?