Lesson 2 & 3
Definitions, Background, Classification, Applications and Costs

Learning Outcomes

- Define a micropile
- Describe the characteristics, advantages and limitations of micropiles
- Describe the micropile classification system
- Identify factors influencing the choice and cost of micropile systems

Background Definitions

Two basic types of piles:
- Displacement piles: driven or vibrated into the ground thereby displacing the soil laterally during installation.
- Replacement piles: placed within a previously drilled borehole thus replacing the excavated ground.
Micropiles are replacement piles of small-diameter (typically less than 12 inch) that are drilled, grouted and reinforced. The reinforcement supports all or most of load.

Typical Micropile Capacities
- Over 500+ tons in rock
- 20 to 200 tons in soil
- Structural capacity usually governs design
- Micropile lengths are usually less than 100 ft

Typical Micropile Construction Sequence Using Casing
- 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)
- Bearing stratum
Typical Micropile Working Conditions

Typical Working Conditions

Advantages of Micropiles

- High capacity and relatively high stiffness
- Minimal disturbance to adjacent structures, soil and the environment by noise and vibrations
- May be installed in access-restrictive environments
- May be installed in all soil and fill conditions
Advantages of Micropiles (cont.)

- Installed at any angle below horizontal
- Installed using same equipment as for anchor and grouting projects
- May be installed through existing foundations and close to existing structures
- Can resist compression, tension, and/or lateral loads

Limitations of Micropiles

- Lateral capacity limitations for vertical micropiles
- Because of high slenderness ratio (length/diameter), may not be appropriate for seismic retrofit (vertical micropiles)
- High lineal cost relative to conventional piling systems

Original Micropile (Palo Radici)
High Capacity Bars

High Capacity Micropile
USA 1980’s and Onwards

Micropile Classification Systems

- A large number of historical/national/proprietary names for micropiles
  - pali radice
  - micropali
  - mini piles
  - pin piles
  - root piles
  - needle piles
- This highlights the need for international standardization i.e., “micropile”
Classification System

1) Based on Design Concept
   - designated by Case 1 or Case 2
2) Based on Grouting
   - method of grout placement defines the
ground bond capacity
   - designated by a letter A through D
   - To form a 2-part designator, e.g., Type 1A or Type 2B

Micropile Classification System
Based on Design Concept

Case 1
- Micropiles are loaded directly (either axially or laterally)
- Reinforcement resists the majority of the
applied load and transfers load to the soil via
grout-ground bond
- Piles can be installed individually or in groups

CASE 1 Micropile Arrangements
Micropile Classification System Based on Design Concept

Case 2
- Networks of micropiles circumscribe and internally reinforce a soil mass to make a reinforced soil composite
- Load is resisted by the soil mass internally strengthened by lightly reinforced elements

CASE 2 Micropile Arrangements

Micropile Classification System Based on Grouting
- Type A: Gravity
- Type B: Pressure grouting through casing
- Type C: Single, global post grout
- Type D: Multiple, repeatable post grout
- Type E: Injection bore bars (hollow bar)
**Type A Micropile**
- Grout is placed under gravity head only
- Neat cement grouts and sand-cement mortars used occasionally (Europe)
- Hole may be underreamed to increase capacity, although not now common

**Type B Micropile**
- Grout is placed under pressure as casing or auger is withdrawn
- Neat cement grout used
- Injection pressures of 75 to 150 psi used

**Type C Micropile**
- Primary grout placed under gravity head
- Secondary grout placed prior to hardening one time via sleeved grout pipe without packer at pressure of at least 150 psi ("only" in France)
- Neat cement grout used
Type D Micropile
- Primary grout placed under gravity head or pressure
- Secondary grout placed after hardening via a sleeved grout pipe at pressure of 300 to 1,200 psi.
- Double packer used and secondary grouting may be repeated several times.
- Neat cement grout used

Structural Support Application

In-Situ Reinforcement Application
Micropiles for Foundation Support of Transportation Applications

A) BRIDGE FOUNDATION SUPPORT

B) MICROPILE FOUNDATION SUPPORT FOR SOFT GROUND TUNNELING BENEATH EXISTING STRUCTURES

Micropiles for Foundation Support of Transportation Applications

C) FOUNDATION SUPPORT FOR CAST IN PLACE REINFORCED CONCRETE RETAINING WALLS

D) FOUNDATION SUPPORT FOR HIGHWAY SOUNDWALLS

Micropile Drilling in New York

Williamsburg Bridge, NY (Nicholson)

Under the BQE, NY
Dulles Airport

Foundation Seismic Retrofit

Old Court House San Juan, PR

Seismic Retrofit for Bridge

Seattle, Washington
Seismic Retrofit of Richmond /San Rafael Bridge, CA

New Foundation for Lewistown Bypass, PA

Micropile Stabilization Mandalay Bay Hotel, Las Vegas, Nevada
Foundation Upgrading

Expansion of Exton Mall, Pennsylvania

Old PR-156 Bridge, Caguitas River, PR

Linn Cove Viaduct, NC
- Deliver the Project ‘Top-down
- Limited exploration
Linn Cove Viaduct

- Two uses for ‘Microshafts’
  - Pier foundations
  - Sliding resistance

In-Situ Reinforcement

- Slope stabilization and earth retention (most common)
- Structural stabilization
- Ground strengthening and settlement reduction (least common)

State Road 4023 Slope Stabilization

Armstrong County, PA
(Case 1 Design)
Case 1 Micropile Wall for Slope Stabilization

Case 1 Micropile Wall Construction

Wall 600 Permanent Earth Retention,

Portland, OR (Case 1 Design)
Slope Stabilization

FH-7, Mendocino National Forest, CA (Case 2 Design)

Reticulated Micropiles for Slope Stabilization

Mendocino County, California

Structural Stabilization

Mosul, Iraq (Case 2 Design)
Factors Influencing Micropile Selection

Physical Considerations
- restricted access
- remote areas
- close pile proximity to existing structures

Subsurface Conditions
- difficult and variable geologic conditions
- susceptibility of ground to liquefaction during pile driving
- obstructed soils or fills
- existing foundations
- high water table

Environmental Conditions
- vibration/noise sensitive areas
- hazardous or contaminated soils

Existing Structure Adaptation
- micropiles can be added to an existing pile cap

Typical Micropile Prices
- Mob/demob $10,000 to $50,000/rig
- Testing
  - Sacrificial test $10,000 to $30,000 each
  - Proof test $2,000 to $10,000 (if tension)
  - $10,000 to $20,000 (if compression)
- Typically $75 to $150 per linear foot of pile
Typical Micropile Prices

Typically $75 to $150 per lineal foot of pile

- If more expensive, may well not be cost effective
- alternative technology
- If cheaper, be very suspicious
- recalculate price!

Cost Breakdown

- Labor 30 – 50%
- Equipment 20 – 30%
- Materials 25 – 40%

Micropile Budget Cost Estimating

<table>
<thead>
<tr>
<th>Cost Factor</th>
<th>Influence Range</th>
<th>Cost Influence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical and access conditions</td>
<td>Very easy to very difficult</td>
<td>0% to +100%</td>
</tr>
<tr>
<td>Geology/ground conditions</td>
<td>Very easy to very difficult</td>
<td>0% to +50%</td>
</tr>
<tr>
<td>Pile capacity</td>
<td>Very low to very high</td>
<td>-30% to +30%</td>
</tr>
<tr>
<td>Pile lengths</td>
<td>Very short to very long</td>
<td>-25% to +25%</td>
</tr>
<tr>
<td>Pile quantities</td>
<td>Very high to very low</td>
<td>-50% to +100%</td>
</tr>
<tr>
<td>Testing requirements</td>
<td>Very low to very high</td>
<td>-10% to +10%</td>
</tr>
<tr>
<td>Mobilization/demobilization</td>
<td>One to multiple</td>
<td>0% to +10%</td>
</tr>
</tbody>
</table>

SEE TABLE 10-4 IN MANUAL

Drill Rigs
Specialized Equipment - Low Head-Room Conditions

Modular Drill Rig for Difficult Working Access

Specialized Equipment for Restricted Access Conditions
Yet Further Subsurface Challenges

Economic Considerations

- Factors affecting final cost:
  - right-of-way acquisition and agreements
  - utility realignment
  - excavation, shoring and backfill requirements
  - footing construction
  - hazardous material handling
  - dewatering
  - erosion control
  - access restrictions
  - ground improvement
  - owner and neighbor disruption
  - testing/verification experiments

- Clearly define true final cost - not just the item cost of the piling system

Learning Outcomes

- List the different classifications of micropile applications
- Identify factors influencing the choice and cost of micropile systems
- Define a micropile
- Describe the characteristics, advantages and limitations of micropiles