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ENGINEERING

Lesson 2 & 3

Definitions, Background, Classification, Applications and Costs

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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.

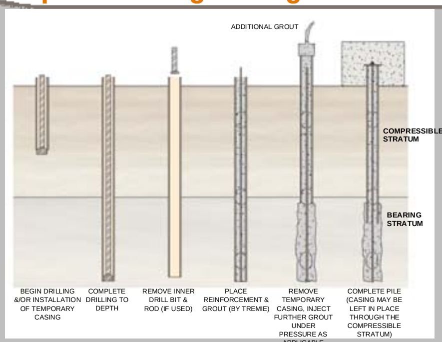
Micropiles Defined

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

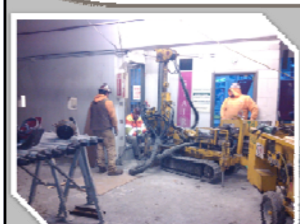
Typical Micropile Construction Sequence Using Casing



Typical Micropile Working Conditions

Courtesy: Nicholson

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

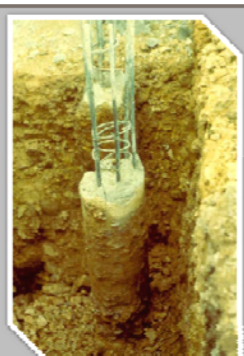
Advantages of Micropiles (cont.)

- 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

Courtesy: Hayward Baker

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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

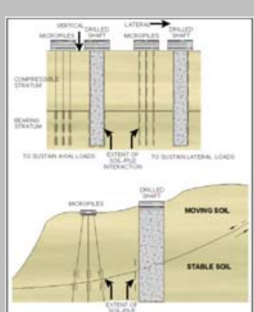
- 1) Based on Design Concept
  - designated by Case 1 or Case 2
- 2) Based on Grouting
  - method of grout placement defines the grout/ground bond capacity
  - designated by a letter A through D
- To form a 2-part designator, e.g., Type 1A or Type 2B

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

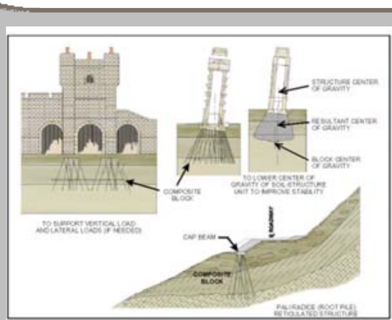


Micropile Classification System Based on Design Concept

Case 2

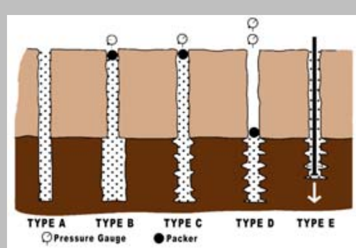
- Networks of micropiles circumscribe and internally reinforce a soil mass to make a reinforced soil composite
- Load is resisted by the soil mass internally strengthened by lightly reinforced elements

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

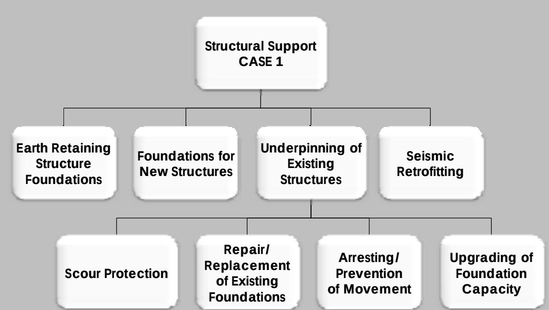
Type C Micropile

- 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

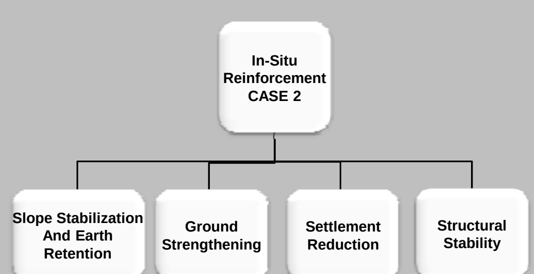
Type D Micropile

- 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

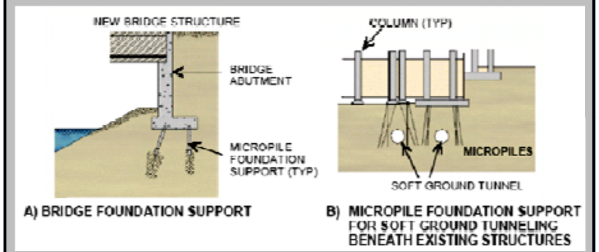
Structural Support Application



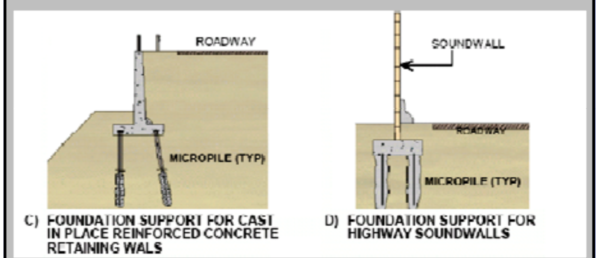
In-Situ Reinforcement Application



Micropiles for Foundation Support of Transportation Applications



Micropiles for Foundation Support of Transportation Applications



Micropile Drilling in New York

Under the BQE, NY

Williamsburg Bridge, NY (Nicholson)

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

Courtesy: Agra Foundations

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New Foundation for

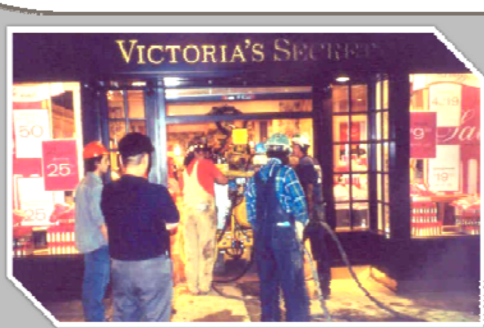
Courtesy: Nicholson

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

Courtesy: Hayward Baker

Linn Cove Viaduct, NC

- Deliver the Project 'Top-down
- Limited exploration

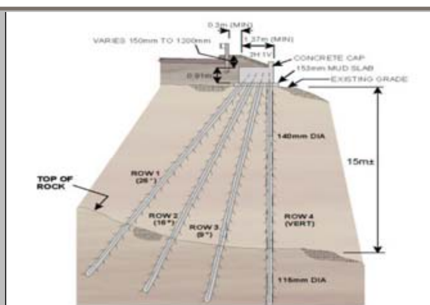
Linn Cove Viaduct

- 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

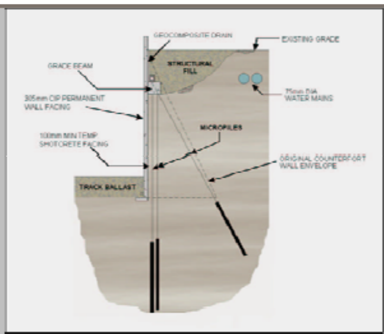


Armstrong County, PA
(Case 1 Design)

Case 1 Micropile Wall for Slope Stabilization

Case 1 Micropile Wall Construction

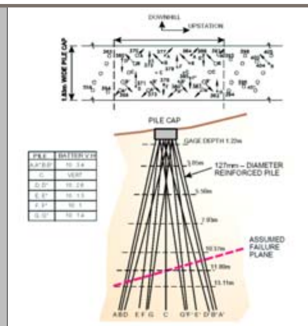
Wall 600 Permanent Earth Retention,



Portland, OR
(Case 1 Design)

Slope Stabilization

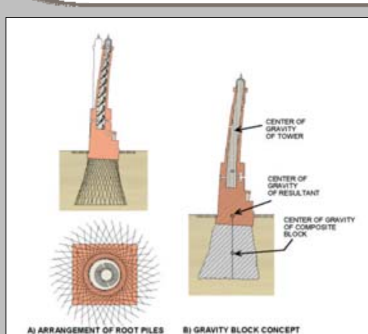
FH-7, Mendocino National Forest, CA (Case 2 Design)



Reticulated Micropiles for Slope Stabilization

Mendocino County, California

Structural Stabilization



Mosul, Iraq (Case 2 Design)

Factors Influencing Micropile Selection

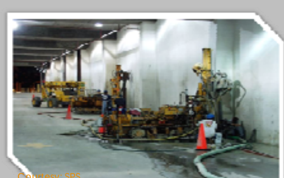
Physical Considerations
- restricted access
- remote areas
- close pile proximity to existing structures

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

Factors Influencing Micropile Selection

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 lineal 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

Cost Factor	Influence Range	Cost Influence (%)
Physical and access conditions	Very easy to very difficult	0% to +100%
Geology/ground conditions	Very easy to very difficult	0% to +50%
Pile capacity	Very low to very high	-30% to +30%
Pile lengths	Very short to very long	-25% to +25%
Pile quantities	Very high to very low	-50% to +100%
Testing requirements	Very low to very high	-10% to +10%
Mobilization/demobilization	One to multiple	0% to +10%
[illegible]	[illegible] not continuous	0% to +25%
[illegible]	[illegible] to very strong	-15% to +30%
[illegible]	[illegible] to very high	-10% to +100%

SEE TABLE 10-4 IN MANUAL

Drill Rigs

Specialized Equipment – Low Head-Room Conditions

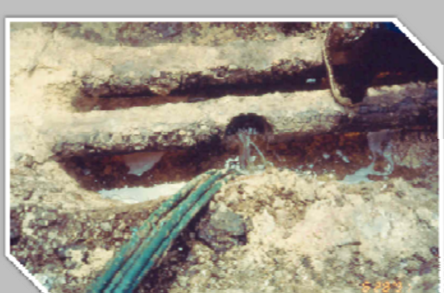
Modular Drill Rig for Difficult Working Access

Specialized Equipment for Restricted Access Conditions

Subsurface Challenges

Further Subsurface Challenges

Even Further Subsurface Challenges



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