EXCAVATION SUPPORT CONSTRUCTION
IN URBAN ENVIRONMENTS:
CHALLENGES and SOLUTIONS

Presented to:
DELAWARE VALLEY ASSOCIATION OF STRUCTURAL ENGINEERS
April 10, 2013

Foundation Engineering since 1910

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EXCAVATION SUPPORT CONSTRUCTION
How is Excavation Support Defined?

Temporary or permanent structure
that will retain the lateral forces from
soil and/or water in order to permit
excavation for, and construction of
underground permanent structures

Factors that Determine
Selection of Excavation Support

Excavation Support Wall Types
Wall Lateral Support Systems
Waterproofing
Inspection & Monitoring
Relative Costs
Example Projects

Factors that Determine
Wall Type Selection

Excavation Depth and Wash
Proximity to existing structures / roadways
Service life: temporary / permanent
Relative Costs

Flexible Walls
Rigid Walls
Gravity Type Retaining Systems
Excavation Support Construction

Flexible Wall Types:

- Timber Sheeting
- Soldier Pile and Lagging
- Steel Sheet Piles

Excavation Support Construction

Flexible Wall Types: Timber Sheeting - Applications

- Narrow Excavations
- Depth < 20 feet
- Above Water Table
- Installed with hand tools

Excavation Support Construction

Flexible Wall Types: Soldier Pile & Lagging - Applications

- Excavations < 50 ft.
- Above Water Table
- Granular or cohesive soils with stand-up time for lagging installation

Excavation Support Construction

Flexible Wall Types: Soldier Pile & Lagging - Applications

- Pile spacing 5-8 ft. max
- Timber lagging 2-4" thick
- Installed with vibratory or impact hammers
- Voids behind lagging packed with soil

Excavation Support Construction

Flexible Wall Types: Soldier Pile & Lagging - Limitations

- Pre-drilling required through:
  - Man-made obstructions
  - Dense, gravelly soils
  - Till; bouldery soil
  - Problematic in running sands and soft clays
  - Prone to loss of ground and settlements outside wall
  - High-risk use adjacent to sensitive structures not supported on piles or underpinned

Excavation Support Construction

Flexible Wall Types: Steel Sheet Piles - Applications

- Excavations < 55 ft.
- Excavations above or below water table
- Granular or cohesive soils
- Can be used for groundwater cutoff (interlock sealant)
- Installed with vibratory or impact hammers
Excavation Support Construction

Flexible Wall Types: Steel Sheet Piles - Applications

- Combination Shapes
- Various Single Shapes

Flexible Wall Types: Steel Sheet Piles - Limitations

- Not appropriate if buried obstructions or cobbles/boulders are present.
- Common sheet pile length = 65 ft. without splicing, limits their use.
- Prone to settlement in loose granular soils, especially when vibratory hammers are used.
- High risk use adjacent to existing sensitive structures that are not pile supported or underpinned.

Excavation Support Construction

Rigid Wall Types

- Secant Pile Walls
- Soil Mix/Jet Grout Walls
- Slurry Walls

Rigid Walls – Secant Pile Wall

- Drilled overlapped holes reinforced with beams
- Individual 3 ft diameter cased holes in primary/secondary pattern; soil completely replaced with concrete
Excavation Support Construction
Rigid Walls – Secant Pile Wall

Obstructions, cobbles/boulders hinder installation
Wall continuity in deep applications can be a problem (vertically control is critical)

Excavation Support Construction
Rigid Walls - Secant Pile Walls: Limitations

Excavation Support Construction
Rigid Walls - Secant Pile Walls: Practical Applications

Excavation Support Construction
Rigid Walls - Slurry Walls: Practical Applications

Excavation Support Construction
Rigid Walls - Slurry Walls: Practical Applications

Excavation Support Construction
Rigid Walls – Slurry Walls

Excavation Support Systems
Rigid Walls – Slurry Walls

Typical construction sequence

Slurry walls are most economical when the following uses are combined:
- Provides temporary excavation support
- Becomes the permanent foundation wall
- Carries permanent vertical load of the structure
- Provides permanent groundwater cutoff

Excavation depths: 50 ft. - >100 ft.
Temporary support and permanent foundation walls
Difficult ground conditions and obstructions
Recommended adjacent to sensitive structures
Eliminates need for underpinning
Top-down construction

• Sequenced trench excavation under slurry
• Trench panels: 8 ft - 24 ft.
• Wall thickness: 2 - 4 ft.
• Can be post-tensioned for high capacity
• Can be constructed in various shapes and used as load bearing elements
Excavation Support Construction

Rigid Walls - Slurry Wall Panel Construction Sequence

- Primary (typ)
- Secondary
- Slurry
- Sheet piles

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Excavation Support Construction

Rigid Walls - Slurry Wall

Hydraulic Clamshell Buckets

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Rigid Walls - Slurry Wall Panel Construction Sequence

1. Install guide walls
2. Excavate panel
3. De-sand excavated panel
4. Install rebar cage
5. Place concrete

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Slurry Walls: Limitations

- Requires large laydown area
- Requires slurry plant and bentonite storage facility
- Messy operation
- High costs for slurry containment and disposal

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Slurry Walls: Challenges

- Vertical alignment control
- Problems with horizon
cation
- Overpours
- Leaky joints
- Post finish

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Lateral Wall Supports

- Cantilever Walls
- Internal
- External

- Braces
- Rakers
- Deadman

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Excavation Support Construction
Cantilevered Walls

- No external means of lateral support
- Embedment depth below subgrade is critical
- Performance is sensitive to soil properties
- Limited in Height < 15 ft

Excavation Support Construction
Lateral Wall Supports: Cross-Lot Bracing

- No external easements required
- Orients excavation & construction
- Vertical supports generally required for widths >100 ft.
- Load capacity generally unlimited

Excavation Support Construction
Lateral Wall Supports: Rakers

- Excavation widths > 100 ft.
- Temporary stable soil slopes
- Partial construction of foundation or temporary heel blocks
- Capacity limited by:
  - Bearing capacity of heel blocks
  - Uplift capacity of support wall

Excavation Support Construction
Lateral Supports: Tiebacks

- Unobstructed excavation
- Exterior easements required
- Special seals at wall penetration below water
- Special care below existing structures to prevent settlement
- Capacities:
  - Clay < 45 tons
  - Sands < 250 tons
  - Rock < 500 tons

Excavation Support Construction
Waterproofing

- Blind Side (Membranes)
- Negative Side (Capillary)
- Admixture (Crystalline)

Excavation Support Construction
Waterproofing: Blindside Membrane on Sheet Piling

- Flexibility
- Conformability

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Excavation Support Construction
Waterproofing: Blindside Membrane on Soldier Pile & Lagging
- Detailed around penetrations with accessory products
- Methane barrier

Excavation Support Construction
Waterproofing: Slurry Wall; Drainage Collectors & Finish Wall
- Spray-on/Brush waterproofing
- Horizontal drain board
- Collector pipes
- Block wall partition

Excavation Support Construction
Waterproofing: Slurry Wall; Drainage Chase & Finish Wall
- Continuous trench drain
- Drain board & panel joints
- Collector pipes

Excavation Support Construction
Waterproofing: Slurry Wall; Liner Wall
- Shotcrete finish
- Membrane
- Horizontal drain board
- Concrete liner
- Collector pipe

Excavation Support Construction
Construction Inspection
- Minimum tip elevation is achieved
- Vertical alignment within specified tolerances
- Steel sheet piles interlocked throughout installation
- Bracing properly installed
- Quality Control

Excavation Support Construction
Construction Monitoring During Installation & Excavation
- Vibrations
- Existing Structure Settlement/Movement
- Excavation Support Wall Movement
- Ground Surface Cracks
- Ground Heave/Settlement
- Noise Levels
Excavation Support Construction

Types and General Uses

<table>
<thead>
<tr>
<th>Type</th>
<th>Timber</th>
<th>Sheet Piling</th>
<th>Sp &amp; Lagging</th>
<th>Sheet Piles</th>
<th>Secant Piles</th>
<th>Slurry Walls</th>
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<td>0-15' Depth</td>
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</tbody>
</table>

SOIL TYPE

- Granular
- Weak Clay
- Stiff Clay
- Boulder
- Till
- Rock

Depth 0-15'  Y Y Y N N
Depth 15-60' NY Y YY
Depth >60'  N N N Y Y

Groundwater Present NN Y YY
Sensitive Utilities MM M YY
Sensitive Structures NM M YY
Vertical Load Capacity NM M YY

Suitable for Permanent Structure NN Y YY

Example Projects

- Slurry Wall: Top-Down Construction
  - New York Law School, New York, NY
    - Record for excavation support in Manhattan
    - 3' thick x 100' deep slurry wall
    - 65,000 sq ft of slurry wall
    - 44 LBE's

- Slurry Wall: New York Law School
  - Site = 200 x 100'
  - 4 Basement Levels
  - Adjacent Buildings on Spaced Footings
  - Adjacent Subway
  - 60 ft Excavation

- Permanent Applications
  - Slurry Wall
    - NY Law School Manhattan, NY
  - Secant Piles
    - Williams Street Manhattan, NY
  - Steel Sheet Piling
    - Newtown Creek WWTP Upgrade Brooklyn, NY

Relative Excavation Support Costs

- Soldier Pile & Lagging: $200 to $400 per sf
- Baseline: $100 to $125 per sf
- Slurry Wall: $150 to $200 per sf

Excavation Support Construction
Excavation Support Construction
Slurry Wall: New York Law School

- Foundation walls & column foundations installed prior to excavation
- Slurry walls are permanent foundation walls
- Permanent slabs provide lateral support for walls during excavation
- Excavation performed through openings in floor slabs

Excavation Support Construction
Slurry Wall: New York Law School

Guide walls adjacent to buildings

Excavation Support Construction
Slurry Wall: New York Law School

Soil removal through slab opening

Excavation Support Construction
Slurry Wall: New York Law School

Cage delivered by truck

Lowering cage

Excavation Support Construction
Slurry Wall: New York Law School

Congested Site

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**Excavation Support Construction**

**New York Law School: Advantages of Slurry Wall**

- **Shortened construction schedule:**
  - Top-down construction eliminated temporary excavation support walls and bracing.
- **Reduced risk of damage to existing adjacent tunnels and buildings**
- **Groundwater cutoff:** underslab drainage system; no pressure slabs required.

**Excavation Support Construction**

**Williams Street, NY, NY - Secant Pile Wall**

- Buildings on 2 sides
- Supported on timber piles
- Adjacent to subway
- 2 Basement Levels

**Excavation Support Construction**

**William Street, NY, NY – Secant Pile Wall**

- Buried obstructions
- Trimming of existing brick foundation wall
- Cast in place concrete footing for guide wall installation
Excavation Support Construction
Steel Sheet Piling - Newtown Creek WWTP, Brooklyn NY

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Excavation Support Construction
Steel Sheet Piling - Newtown Creek WWTP, Brooklyn NY

Excavation adjacent to existing tanks supported on timber piles

Rakers to Mat Foundation
Excavation Support Construction

Steel Sheet Piling - Newtown Creek WWTP, Brooklyn NY

Excavating below bearing level of adjacent structures without underpinning or installing rigid excavation support walls.

Driving piles with impact or vibratory hammer in granular soils adjacent to existing structures.

Installing soil anchors below existing structures.

Widespread dewatering where fill placed over organic soils.

Excavation Support Construction

Situations To Avoid When Selecting Excavation Support Wall Types

Driving piles with impact or vibratory hammer in granular soils adjacent to existing structures.

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Thank You!

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