Innovative Underpinning Systems

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Presentation Outline

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- Helical Pile and Micropile Underpinning
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Background

- Underpinning is usually performed to transfer the building loads to a lower level.
- Depending on the reason for lowering the foundation, underpinning may be considered either *remedial* or *precautionary*.
- The key design aspect to innovations in underpinning is *understanding* the intended purpose of the system. This is not always an obvious task! No understanding means no innovation!
- Innovations in underpinning may be grouped into the following general categories:
  - Combining the functions of deepening foundation support and permanently supporting the excavation.
  - Utilizing easy to install helical piles, micro piles or jet grouting in lieu of the labor-intensive approach pit underpinning.
  - Increasing the capacity of existing foundations through ground improvement techniques or soil-structure interaction analyses.



Background

Top: approach pit and pit below foundation. Right: dry packing the underside of the footing.

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Traditional Delivery of Underpinning

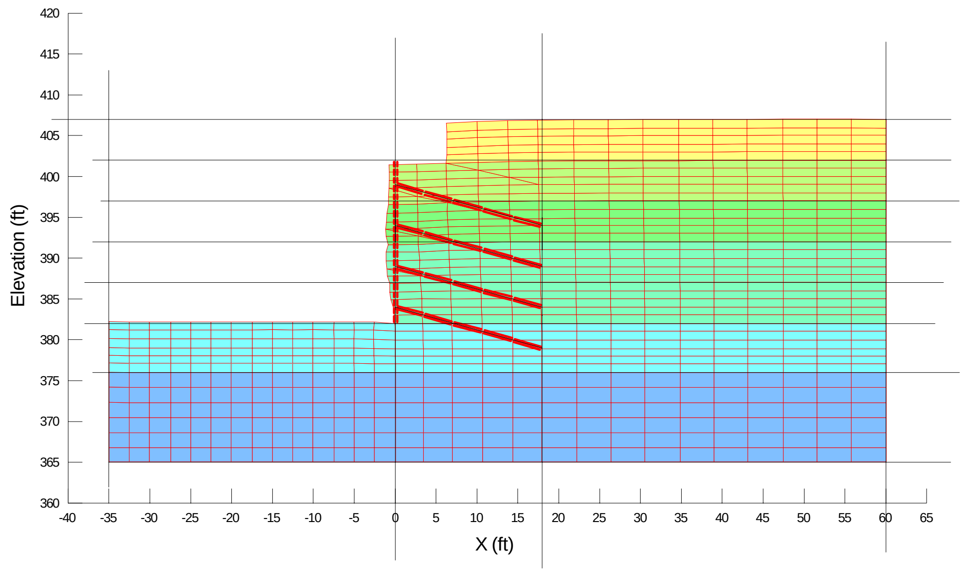
- Specialty designers/contractors carry out the work during the construction phase of the project.
- The design is performed under very tight schedule (one to two weeks).
- Very little communication, if any takes place between the designer/underpinning contractor and the geotechnical or structural engineers.
- On few complicated projects, the design conceptions may not be clearly understood by the project structural and/or geotechnical engineers—a recipe for problems even if communication with the underpinning contractor takes place.
- In rare occasions, the new structure cannot be feasibly separated from the underpinning system. This creates considerable problems in the lines of responsibility for the adequacy of the entire structure.
- The FHWA divides underpinning work into such categories: (1) integral part of final structure; and (2) final structure is intended to handle all loads independent of the system.
- FHWA recommends that *category 1* be designed by the project's design team while a specialty contractor may be selected to design *category 2*.

Combining Foundation and Permanent Excavation Supports

- Underpinning system must be capable of supporting the foundation loads.
- Must not yield laterally.
- Must be applicable to the site conditions and construction sequence.
- Input from the entire project team including the construction manager is desirable during the design phase.
- Specialty contractors should be consulted during the design phase for input and consideration.
- The system must be flexible to accommodate site-specific features and utilities.

Detailed Analyses Essential

- Traditional analyses such as empirical or even limit equilibrium procedures do not provide input on the magnitude of the lateral deflection of the underpinning system.
- To ensure that the lateral deformations remain in check, detailed analysis including FEM is essential.
- Construction sequence or stages play a key role in the overall performance of the system and cannot be typically modeled with detailed analyses.
- Subsurface variations are easily captured.



Deformed Mesh (magnified 30 times)

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Ground Anchors/Tiebacks vs. Soil Nails

- Tiebacks (fewer, larger, longer) are prestressed while soil nails (many, smaller, shorter) are not, providing on-demand reinforcement.
- Tiebacks have negligible lateral movement while soil nails typically deform by 1 to 3% of the height of retained soil.
- Tieback loads are greater than 100 kips while soil nail loads are less than 30 kips.
- Wall facing is extremely important for tiebacks and spacing of tiebacks is mostly large and depends on the rigidity of the facing while spacing of soil nails is less than 10 ft.

Key Construction Aspects

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Helical Pile Underpinning

- Helical piles consist of specially made augers or helical sections which are drilled and left in place to form the pile.
- Their capacity is proportional to the installation torque and typically ranges between 10 and 30 kips.
- They can be installed with minimal site disturbance and under low headroom conditions.

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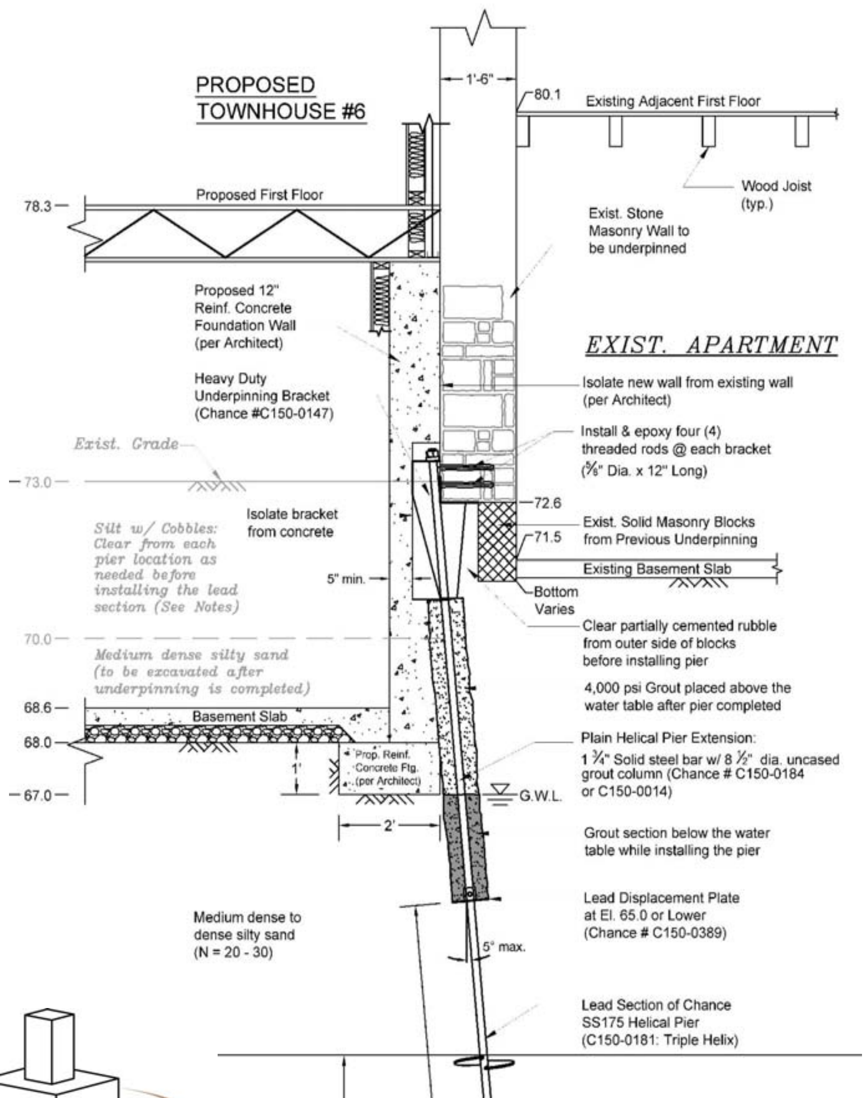
Helical Pile Underpinning



- GeoStructures prepared design drawings, specifications, and details for the project, and conducted settlement monitoring during construction.
- 20-ton capacity, helical steel piers were connected to the base of the wall using heavy duty steel brackets.
- No other connections were necessary, as the helical piers were spaced about every 32 in., the wall was capable of bridging between the brackets.
- The contractor installed the piers into the ground using a terminal torque of 8,000 ft-lb to achieve their design capacity of 20 tons.
- Even with the close pier spacing, this system ended up being about half the cost of conventional concrete underpinning piers.

In order to construct the new wall in contact with the existing one and maximize available space, the underpinning bracket was set into the new basement wall.

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Helical Pile Installation Steps

Clockwise from top left: pre-augering through cobble zone; helical pile segments; attaching driver to pile; spinning piles into ground.

Micropile Underpinning

- Micropiles are a small diameter, drilled and grouted displacement piles which are typically reinforced.
- They are installed by drilling with minimal disturbance to the adjacent structures and under low headroom conditions.
- They can be installed through existing foundations
- Their capacity is significantly dependent on the installation technique.
- Vertical resistance is primarily due to friction between grout and ground (soil or rock).
- High capacity can be achieved by increasing the cross section area or using steel casing, and by anchoring (soketing) into rock.

Micropile Installation

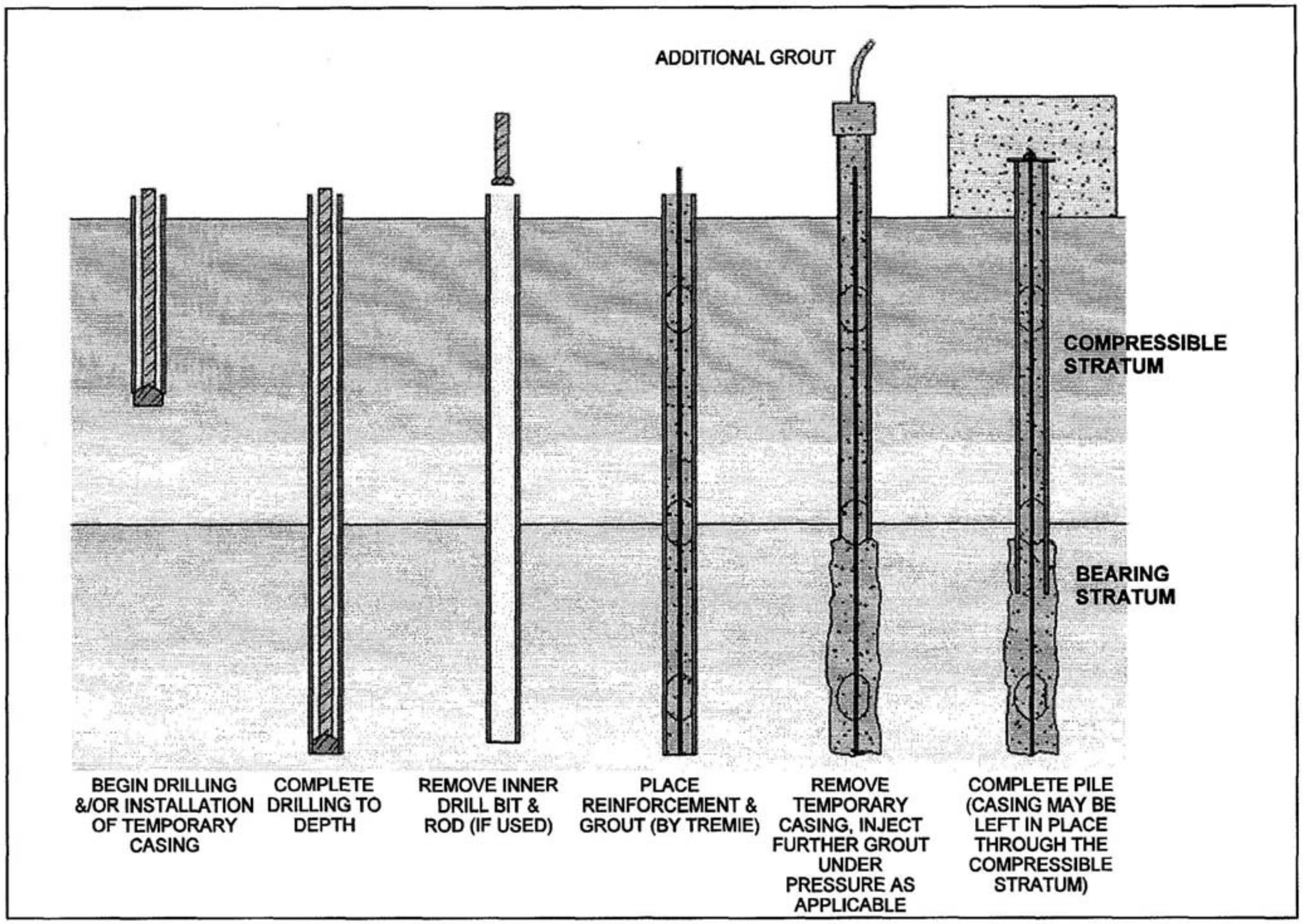
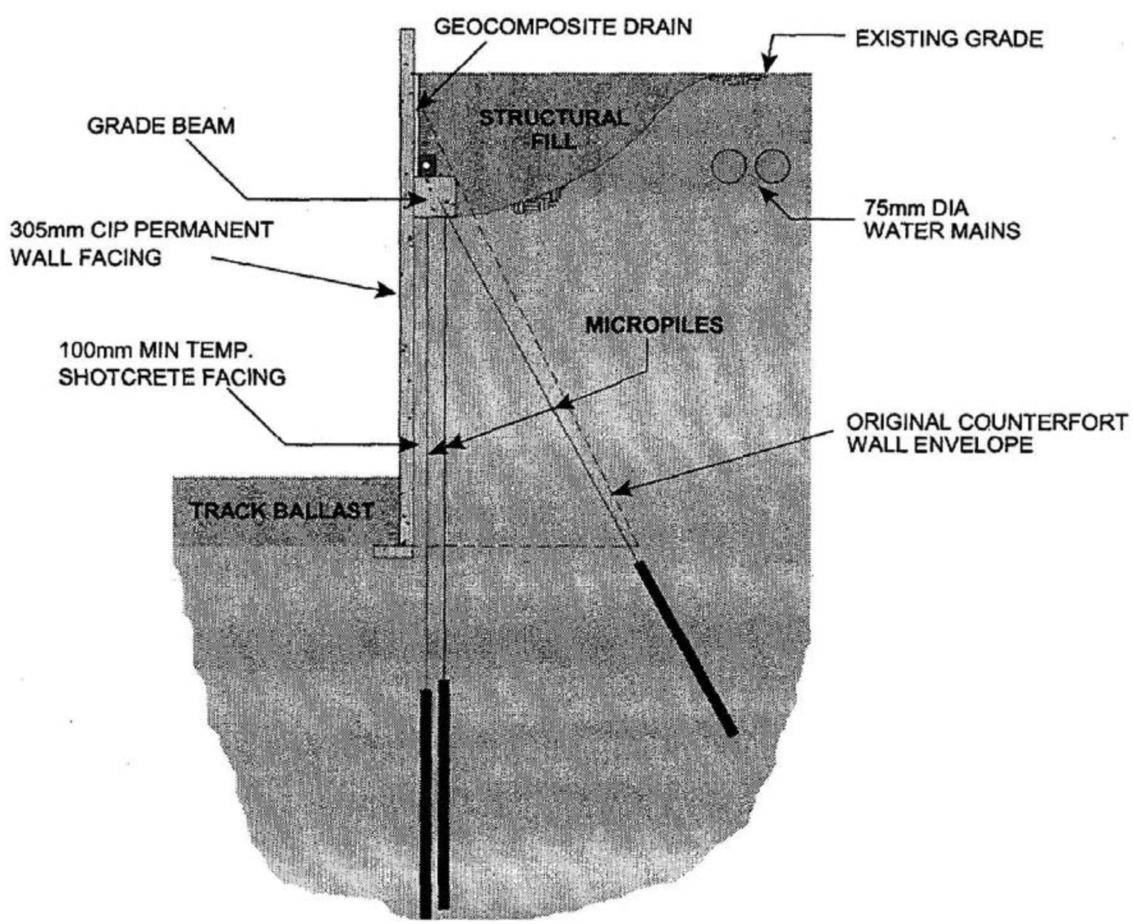


Figure 4 - 1. Typical Micropile Construction Sequence Using Casing

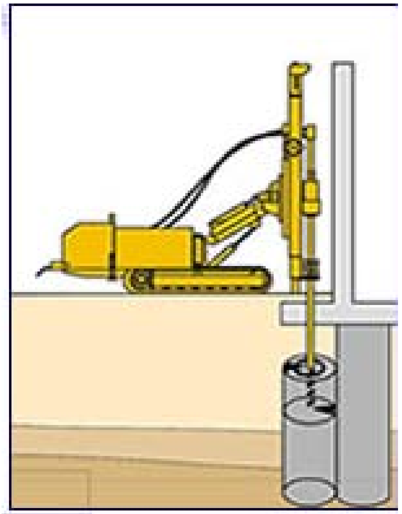
After FHWA (2000)

Micropile Underpinning Application



After FHWA (2000)

Jet Grouting Underpinning



From Illustration by Hayward Bake http://www.haywardbaker.com/services/jet_grouting.htm
photo by Nicolson Construction at http://www.nicholsonconstruction.com/groundTreatment/jetGrouting.aspx

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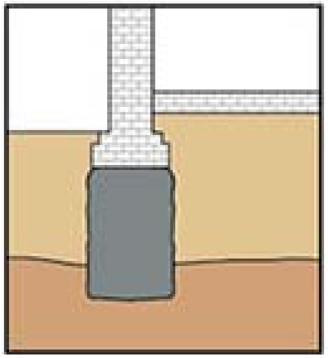
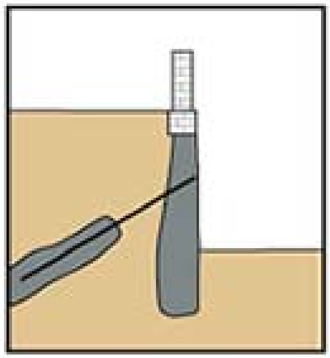
Jet Grouting Underpinning

- Jet grouting use ultra high-pressure fluids or binders (grout) that are injected into the soil at high velocities. This energy breaks down the soil matrix and replaces it with a mixture of grout slurry and in situ soil (soilcrete).
- It is installed by drilling and causes minimal disturbance to adjacent structures at the ground level.
- Requires specialty contractors and is relatively expensive.
- Vertical resistance is due to end bearing and side friction of the soilcrete column.
- It can provide lateral resistance as a gravity wall system or by using anchors.



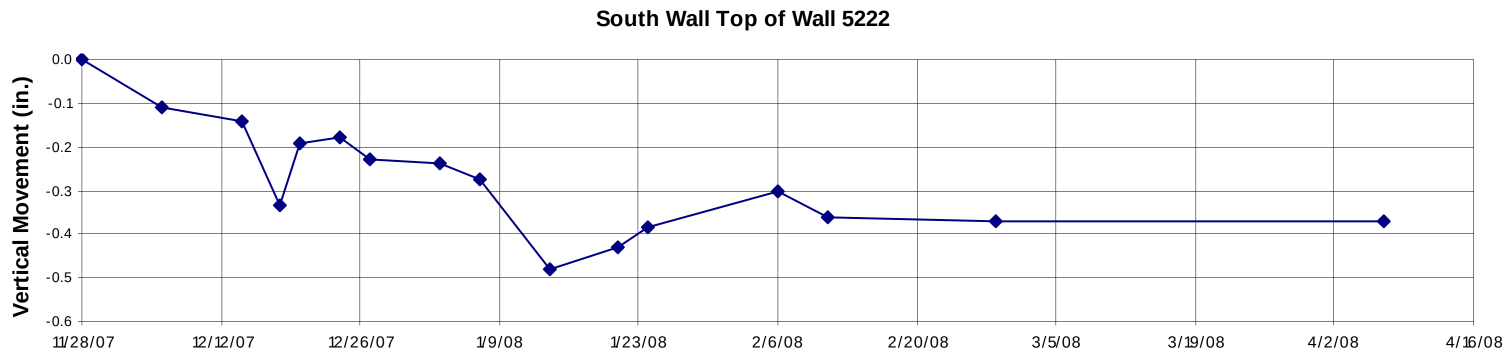


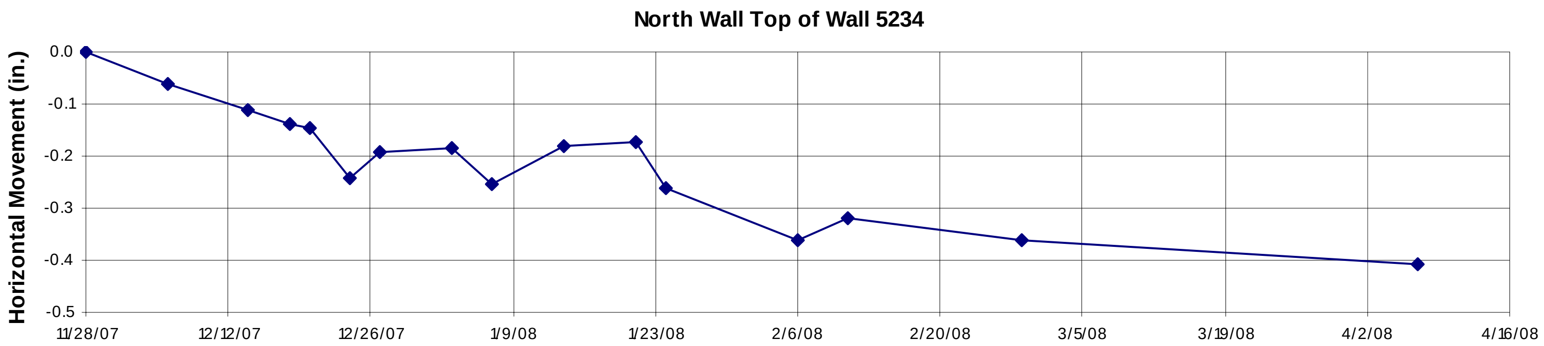
From Illustration by Hayward Bake http://www.haywardbaker.com/services/jet_grouting.htm

Verification and QA/QC Testing

- Verifying capacity by load test is essential—applicable to soil nails, anchors, helical piles and micropiles.
- Standard material testing requirements is needed.
- Monitoring of grout mix, grouting pressure, and grout sampling and testing is necessary.
- Installation supervision and monitoring are very important since the end products are technique dependent.
- Settlement monitoring of adjacent structures must be implemented.

Verification and QA/QC Testing





Conclusions

- Significant advantages can be gained by early coordination and understanding of the specific requirements that must be met by the underpinning and excavation support systems.
- Incorporating the design of the underpinning system into the overall project deliverables has the potential of resolving unforeseen problems during construction.
- One must distinguish between innovations in pile foundations and ground improvement techniques from innovations due to addressing site-specific conditions.
- Proper QA/QC testing programs are essential to every projects and their importance cannot be overemphasized. Even the best designs can be derailed by improper QA/QC or improper implementation.

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