SCHNABEL DESIGNED & INSTALLED SHORING AROUND THREE ADJACENT SENSITIVE & HISTORIC STRUCTURES IN WASHINGTON, D.C.

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GEOSTRUCTURAL DESIGN & CONSTRUCTION

Shoring Around Sensitive Structures

Schnabel was hired to design and install the temporary shoring for the Scottish Rites Apartments (SRA) project early in the design development phase. The project will facilitate the construction of the five-story SRA development behind the historic Freemason's Scottish Rites House and adjacent to two other sensitive and historic structures in Washington, D.C.

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Shoring and Deep Foundations Around Sensitive Structures in Washington, D.C.

The Freemason's Scottish Rites House of the Temple is a historic and sensitive structure built in the early 1900s in the DuPont Circle neighborhood. The House of the Temple and its manicured lawns are nestled between European architecture and tight streets of brick townhouses. The developer, Perseus TDC, partnered with the Scottish Rite to build the five-story Scottish Rites Apartments (SRA) in the open space behind the House of the Temple. The development consists of 158 units, which envelope the existing carriage house into the new structure. The new structure includes two English basement levels with below grade units and 110 underground parking spaces.

Schnabel Geostructural Design & Construction was hired to design and install the temporary shoring for the project early in the design development phase. During the preconstruction phase, it recommended that deep foundations be installed instead of footing steps at the building transition from two levels below grade to four levels below grade.

Carriage house and House of the Temple

FEATURE ARTICLE

Site Geology

The soils at this project site are typical for northern downtown Washington, D.C. Upper soils consist of man-made fill overlaying alluvium deposits. The alluvial river deposits consist of loose to medium dense sands, silts and gravels, and are approximately 25 ft (8 m) thick with blow counts in the single digits. Below the alluvial layer, Cretaceous age marine deposits from the Potomac Formation are present. The Potomac Formation deposits are stiff to hard clay and medium dense to very dense sand and gravel with blow counts exceeding 100 blows per foot at a depth of around 45 ft (14 m) below the ground surface.

Q5: Gravel, sand, silt and clay. af: Artificial fill

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This high blow count zone includes gravel, clay and sand in addition to occasional boulders. The groundwater table is roughly at the Alluvium-Potomac interface and varies throughout the year.

The site geology for the project made for a challenging shoring design and installation. The abrasiveness of the Potomac Formation sands and gravels resulted in excessive wear to drill tooling. Cobbles and boulders obstructed drilling and installation of structural components of the shoring. As the excavation progressed, loose sands and silts were prone to running during placement of lagging. Groundwater management was difficult due to the fine grained soils present limiting the effectiveness of dewatering efforts.

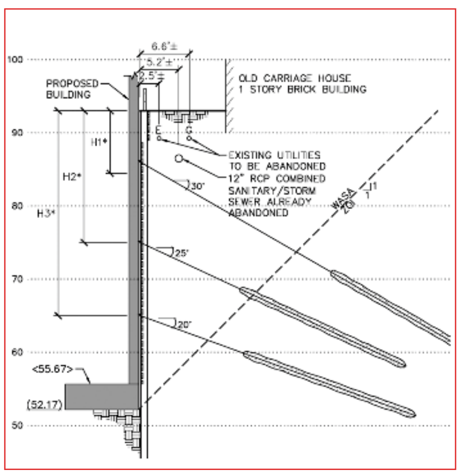
Three Adjacent Sensitive and Historic Structures

The House of the Temple is very sensitive to any movement from construction activities because the northwest corner of the structure was damaged in a 2011 earthquake. Even though the House of the Temple is located outside the influence of the excavation, construction-related vibrations were not permitted. In addition to vibration impacts, there were concerns that differential settlement due to dewatering at the project site would negatively impact the structure.

The carriage house is a one-story brick structure with no continuous footing as is typical for similar structures built in the 1800s. The carriage house was located approximately 8 ft (2.5 m) away from the 40 ft (12 m) deep shoring excavation. Project plans detailed incorporation of the carriage house into the SRA building with interior steel façade reinforcement and new footings constructed to support three additional floor levels. Existing cracks in the carriage house were documented prior to the start of any construction work and monitored during construction.

New apartments adjacent to existing buildings

A four-story brick townhouse (Campbell townhouse) to the south of the project site was built in 1925 with a one-story below grade basement in addition to three stories above grade. The Campbell townhouse is a privately-owned structure located across a 15 ft (4.5 m) wide public alley. It was assumed that the Campbell townhouse foundation consisted of an unreinforced concrete footing as is typical for similar structures in the area. Interior pre-construction surveys indicated the townhouse was in good condition without major cracks or deterioration prior to the start of construction. The exterior of the townhouse was brick with minor cracks in the mortar joints.



Cross section at carriage house

Shoring Design

The temporary shoring chosen for this project consisted of soldier piles, wood lagging and tiebacks. This type of earth retention is considered a flexible shoring system, as compared to a stiffer concrete secant pile or slurry wall. Flexible systems allow for the small amount of movement required for active earth pressures to develop.

Based on tight settlement thresholds for the carriage house and Campbell townhouse, a movement-based design was checked against the typical apparent earth pressure diagram design. A semi-empirical method after Cording (1981) was used to evaluate the excavation induced movement of the shoring by evaluating the relationship between the volume of lateral wall displacement and the soil/wall stiffness. This method emphasizes the importance of the soil modulus and the vertical distance between lateral supports. Use of the method leads to the conclusion that stiff or dense ground will limit movement of the shoring regardless of its flexibility with the most important factor for reducing movement being the number of tiers of lateral support and the distance between them. Adding an additional tier of tiebacks or braces has a greater influence on limiting movement of the shoring than reducing the soldier pile spacing or using a larger soldier pile section.

The movement-based design method assumes good workmanship and limited loss of ground during the installation of the shoring. For the movement-based design method to provide valid results, sound construction procedures that limit loss of ground and excessive ground movements need to be used during construction of the shoring. The method of soldier pile installation can greatly influence overall movements if ground is lost during drilling or vibrations densify soils during driving. Lagging installation has the potential to allow for ground loss if not performed under control and with consideration of soil conditions. The granular soils at this project site generally had enough silt and clay content for a 5 ft (1.5 m) vertical lift to stand without unraveling. Drilling tiebacks may result in ground loss if positive pressure is not kept inside the hole or if full depth casing is not used and the drillhole collapses.

Drilling first tier tiebacks

Shoring Installation

Initially, soldier pile installation by drilling was specified due to concern over vibrations. Schnabel proposed driving soldier piles using a variable moment hammer to limit installation vibrations. The design team, including design consultants for the House of the Temple, permitted all 115 soldier piles to be driven with real-time continuous vibration monitoring performed at all adjacent buildings. At the House of the Temple, vibrations were minimal with readings of 0.01-0.05 in/sec (0.25-1.27 mm/sec) recorded at distances of 50-100 ft (15-30 m) from the soldier pile operation. The vibrations peaked at the carriage house and Campbell townhouse structures while the soldier piles were penetrating a stiff layer of soil. During these peaks in vibration, the existing cracks on the structures were monitored in real time. Installation proceeded while closely observing the penetration rate of the pile and the existing conditions of the structures. Schnabel allowed piles that hit refusal

Piles hit refusal at 35 ft (10.5m)

Piles driven to final depth

to sit overnight and drove them to design depth with less difficulty and lower vibrations the next day. One possible explanation for this phenomenon is that groundwater was able to percolate along the sides of the soldier pile and loosen the salt bonds in the cemented sands allowing additional driving the next day. No new cracks developed on the existing structures and existing cracks did not propagate or widen during soldier pile driving.

Change in strata at cemented sands

All 175 tiebacks were installed using double-head rotary drilling and a down-the-hole hammer where necessary to penetrate the gravel, cobbles and boulders at depth. The sands and gravels were extremely abrasive and the casing shoes were replaced every few days. The tiebacks were bonded in the silty sand layer and regrouted to ensure design bond capacity was achieved. The soil was very dense as most of the tiebacks only accepted a few bags of grout during regrouting. Every tieback on this project was tested to at least 120% of the design load per the recommendations of the Post-Tensioning Institute.

Shoring Performance

Movements of soldier piles and adjacent buildings were monitored using automated optical prisms with all movements staying within established thresholds with very little lateral or vertical movement. Typical values of up to 0.5 in (13 mm) of lateral movement were observed at the top of the soldier piles corresponding to 0.1% - 0.15% of final excavation cut height (.001H - .0015H). This relatively small amount of movement can be attributed to the movement-based design, the good workmanship during construction, the equipment used during installation and the relative density and stiffness of the ground itself.

Soldier pile settlement was minimal with most experiencing less than 0.25 in (6 mm). Soldier piles that experienced more than 0.25 in (6 mm) of settlement were located near a leaky existing sewer. Existing building movement was negligible. The House of the Temple and the Campbell townhouse did not experience any measurable settlement or tilt. The carriage house experienced up to 1/32 (0.03) in (0.76 mm) of settlement. No creep movement was noted with time and most importantly no visible signs of stress or existing crack propagation in the sensitive structures themselves was observed.

Deep Foundations

The project structural drawings showed 28 micropiles spread out over five pile caps in the English basement

Soldier beam installation

level. The micropile design load was up to 171 kip (760 kN) in compression. Micropiles were installed using the same method used to install the tiebacks. As with the tiebacks, a down-the-hole hammer was used to penetrate through cobbles and boulders and the micropiles were regrouted to ensure bond capacity. The micropile design load was carried by a solid bar tendon in the center of a 7 in (179 m) diameter hole. Permanent casing was used in the upper 20 ft (6 m) of the micropile to locate the bond zone of the micropile below the lowest subgrade elevation for the project.

To aid in the design of the micropile bond length, an eight-strand "tieback" was installed vertically and tested in tension to its maximum structural capacity of more than two times the micropile design load. Based on this preliminary test, an allowable bond stress of 30 psi (0.2 MPa) was assumed for micropile bond design resulting in a bond length of 25 ft (8 m). In accordance with ASTM D3689, a nonproduction micropile load test was performed to two times the micropile design load with satisfactory results.

Micropile set up

Conclusion

The soils at the project site consisted of two main layers — fill and alluvial river deposits of silt, sand, clay and gravels — in the upper 25 ft (8 m) of excavation and underlying dense marine deposits of the Potomac Formation consisting of sands, silts and clays, cobbles and boulders. Although challenging from both a design and installation perspective, the shoring was successfully installed without causing damage to the three adjacent sensitive and historic structures. This was achieved utilizing a movement-based design, equipment that minimized vibrations and quality workmanship that did not allow for ground loss. Micropiles were successfully installed in the dense, cobbly soils to serve as permanent foundation elements. The relatively small drill diameter and ability to use a down-the-hole hammer made installation through the cobbles and boulders possible. The preliminary load test proved that the load transfer rate was higher than published data and allowed for efficiencies in both design and construction.

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Joanna Mason, P.E., is a senior project manager at Schnabel Geostructural Design & Construction. She has 16 years of experience in the heavy civil industry specializing in the design and construction of excavation support systems and deep foundation elements. In her current position at Schnabel, she manages large projects and assists in the business development of the mid-Atlantic market.