PERFORMANCE OF THREE UNIQUE SHORING SECTIONS FOR BLOCK 75 SHORING

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The Block 75 portion of the City Creek redevelopment project in Salt Lake City required multiple shoring walls surrounding the 6 acre site constructed to depths ranging from sixty-five to ninety feet below original street grade. Shoring for the project was challenging due to site soils consisting of cobbles, sands and gravels, interlayered lakebed silty clay and fine sandy silt with incised stream deposits of silty/clayey sand and gravels combined with a high groundwater table. Moreover, several abutting structures each with a unique foundation system would be directly or indirectly supported by the shoring system.

Three sections of interest are the shoring walls constructed at Main Street, Deseret Trust Building and Eagle Gate Tower. Main Street shoring extended to as much as sixty-five feet below street grade and utilized existing basement walls anchored in place in the upper zones with soil nail walls with pre-installed vertical elements for face stabilization below. Data are presented which illustrates the effect dewatering had on the settlement of the Main Street Shoring. The Deseret Trust Tower shoring supported a 12 story, historical masonry building. Site conditions dictated a separate design for the east side and the north side of the building allowing comparison of relative performance between these walls. Settlements of this structure were controlled by installing micropiles through the 90 year old structures spread footings. Shoring for the Eagle Gate Tower was to be constructed immediately adjacent to a mat supported 22 story high rise structure. This shoring system combined secant piles, ground anchors and incorporated existing abandoned-in-place pipe piles with infilling high pressure jet grouting to create a cutoff wall and eliminate the adverse impacts of dewatering below this sensitive foundation.

Project Summary

The City Creek Project commenced in 2007, as a broad-based, multi-use development intending to revitalize the central downtown blocks of Salt Lake City. The main focus of the project is the redevelopment of two city blocks (Blocks 75 and 76).

“Figure 1” shows an overview of the project site. The ZCMI center mall and parking lot occupied the majority of the block, and fronted 3 major streets. The mall and parking structure were demolished under the redevelopment program, while five other office buildings were retained at the corners and eastern side of the project. The project schedule required that the ZCMI food court, located at the north end of Block 75, be maintained in operation during construction on the south and east sides of the project, until a new facility could be opened. This project constraint resulted in two separate phases for construction – Phase I and II.

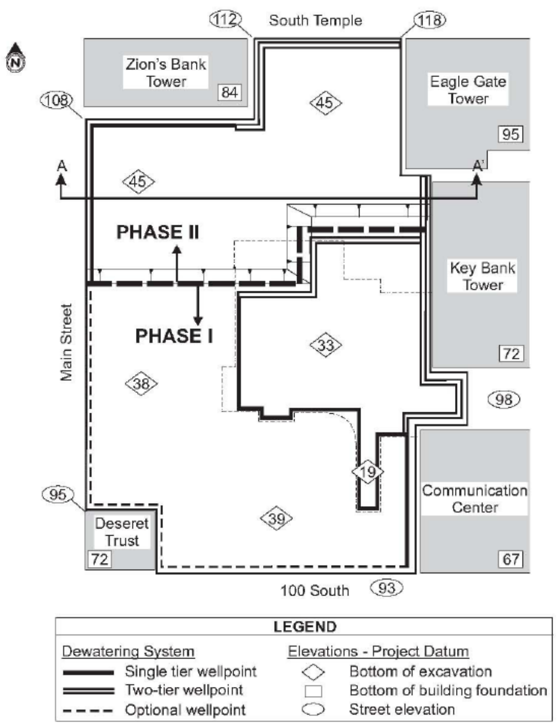

Figure 1 – Site Plan

Soil Profile

Block 75, located adjacent to Temple Square, has been continuously occupied since the founding of Salt Lake City during the 19th century. Several prior developments on the site have left behind buried foundations and construction debris. The site, along with the native soil layers slopes significantly downhill from northeast to southwest. Fill materials consisting of silty and clayey sand and gravel are present from the surface to depths varying from five to 25 feet. Underlying the fill, native soils comprising dense silty sands and gravels with cobbles (deposited by nearby City Creek) extend to varying depths, as much as 55 feet below the surface. Zones of weak, interlayered silty and clayey fine sand, intermittently incised with zones of silty sand and gravel occur beneath the granular deposits throughout much of the site. These soils extend from 40 to 65 feet below the surface. The basal soils encountered during construction comprise medium stiff to stiff layers of clay and medium dense silty sand (Lake Bonneville Deposits). Groundwater was found at depths as shallow as 40 feet from the surface.

Initial project borings were performed around the perimeter of the block since existing structures precluded access to the interior of the site. After start of demolition, additional borings were completed providing more detailed geotechnical profiles which disclosed several zones of the weaker, layered silty and clayey fine sand which had not been identified during initial project design. These materials provided shoring challenges due to limited stability when exposed during excavation and concentrated flow of groundwater at unpredictable locations. Dewatering was extremely challenging due to the fine grained structure of these soils (Jameson, 2010). Several segments of shoring required redesign using a variety of specialty construction techniques to overcome difficulties and maintain project progress. These are presented in the following sections.

Shoring Summary

Shoring for the perimeter of Block 75 was to support three different streets and multiple sides of five separate buildings ranging from five to 22 stories tall. Total exposed shoring face area was approximately 96,000 square feet. There were ten separate design sections, many of which had distinct subsections.

Construction difficulties were consistent throughout all of the design sections, notably: the presence of highly loaded structures with and without deep foundations; soil that was known to present problems with face stability (Bishop, 2009); known and suspected obstructions including foundation elements of existing structures and existing basement walls; small clearance (often less than two feet) between the face of shoring and existing structures; and variable groundwater conditions affecting dewatering plans.

These unique challenges precluded the possibility of either using a single shoring system throughout the site or even the use of standard shoring techniques such as conventional soldier pile and lagging, slurry walls or secant piles. Rather, these standard shoring techniques required modification and combination to fit the project's challenging conditions.

Three of the design areas will be discussed herein, and are designated as follows:

Main Street – This segment used existing foundation walls from demolished buildings as the face for the upper section of the 65-foot cut.

Deseret Trust Building – A hybrid system of shoring was required for two sides of a 90-year old historic masonry building, supported on concrete plinth foundations.

Eagle Gate Tower – In this area excavation support was designed as a hybrid shoring system to function as a cut-off wall along the west side and southwest corner of the 22 story tower that is supported on a mat foundation.

Contract specifications limited lateral movement at all areas of the project to no more than one inch. The final shoring design identified areas where it would be prudent to achieve lower deformation limits. These are discussed individually for each shoring section.

The prevalent cohesionless soil conditions in the Salt Lake Valley can cause migration of material into the excavation, potentially leading to settlements behind the shoring wall and excessive quantities of shotcrete in soil nail systems. The sensitivity of structures within the influence of the shoring system required that unique methods be utilized to control ground loss.

Installation of the shoring system required many construction techniques including Hollow Bar Soil Nails and Micropiles, Cased Soil Nails, Tiebacks, Micropiles and Vertical and Battered Small Diameter Shoring Elements, Cased Large Diameter Soldier and Secant Piles and Jet Grout Columns and utilized a wide array of foundation drilling equipment.

Shoring performance was measured by contractor installed instruments, such as inclinometer casing, differential leveling, piezometer nests, strain gages and tiltmeters. Additionally, the owner installed an extensive automatic survey system which allowed real-time monitoring to various extents of all shoring wall movements in each direction.

Main Street

The entire length of the Main Street shoring system was lined with existing structures consisting of the old ZCMI Center buildings (constructed around 1965), and subgrade parking structures extending to varying depths to a maximum of 35 feet. Structures planned for Block 75 required typical excavation depth of 58 feet and locally to depths of 65 feet. Granular fill and natural soil deposits generally extended to a depth of 40 feet below street grade, and were underlain by the weaker interlayered silty and clayey fine sand soil to a depth of about 65 feet. Groundwater was encountered coincident with the interlayered silty and clayey sand, which was higher than expected during preconstruction.

Main Street supports several utility systems and a major light rail line with a station immediately adjacent to the excavation. Pre-construction estimates for settlement were ½-inch to 1-inch, which was considered acceptable for this shoring segment. This estimate (0.1+/- percent of wall height) was based upon local experience of soil nailing in these conditions with hollow-bar anchors.

In order to prevent ground loss of the upper, loose fill layers associated with demolition of existing foundation walls, the basement walls of the original structures were left in place as they did not encroach into the footprint of the new structure. Cored holes were drilled through the existing walls and the walls were then supported in place with self grouting hollow-bar soil nails installed with a hydraulic top hammer drill. The plate and nut connection for the soil nails were tightened with 200 foot-pounds of torque to secure the existing wall in place.

Local ordinances for Salt Lake City prevent the installation of shoring elements from extending beyond the curb line (~20' from the face of shoring in this case) for a depth of 20'. Soil nail lengths were limited to 20 feet in the top row; while the lower two to four rows were 48 feet long and steeply angled to avoid this utility envelope. "Figure 2" details a typical shoring section along Main St.

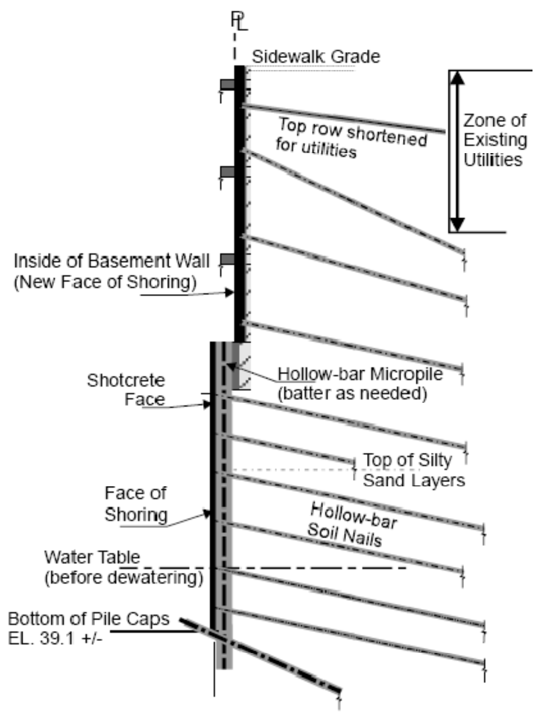

Figure 2 Cross Section along Main St. (typ)

Obstructions, not readily identifiable, were encountered in one area, which caused refusal of the hollow bar nails approximately 15' behind the face of the wall. Since all utilities had been positively located, it was decided to drill through the obstructions. Fully cased holes were drilled using a double rotary drill method utilizing a downhole hammer, which penetrated through the obstructions. The holes previously cored through the basement walls were enlarged to accommodate the increased drill casing diameter.

Prior to installation of shoring below the existing basement walls vertical and battered micropiles were placed from the base of the original basement walls to the bottom of the excavation at 3'-6" centers. Micropiles were used to support the old walls (grouted into the old footings where they could be left in place) and to provide some measure of face stability during excavation. Ideally, the micropiles would be installed vertically directly behind the planned shotcrete face. However, a batter was required to maintain clearance for the drill head. The lower half of the excavation was finished with a shotcrete facing.

Since the groundwater level along the Main Street shoring wall was located approximately 10 feet from the bottom of excavation, the primary plan was to use trenching as a dewatering method with a contingency to utilize a well point system in the event the trenching proved insufficient to control the groundwater. As the excavation was extended below the groundwater level, work conditions became increasingly difficult. The wellpoint dewatering option was implemented along this wall which allowed construction to continue without causing a delay to the shoring schedule.

Significant settlements (in tenths of an inch), were recorded by the real-time survey system as the excavation progressed down through the last twenty feet. Figure 3 shows measured lateral movements of the Main Street Wall. Sudden jumps in lateral movements correlated with settlement jumps, which generally coincided with excavation and placement of nails and shotcrete for each lift. When final grade was reached, the movement continued. The data showed that the shoring wall was deflecting into the excavation and settling. Deep stability was questioned and reanalyzed, but it was later determined that dewatering induced consolidation settlement was occurring. Ultimately, alternate wellpoints were shut down, halting the settlement while still maintaining a dry site.

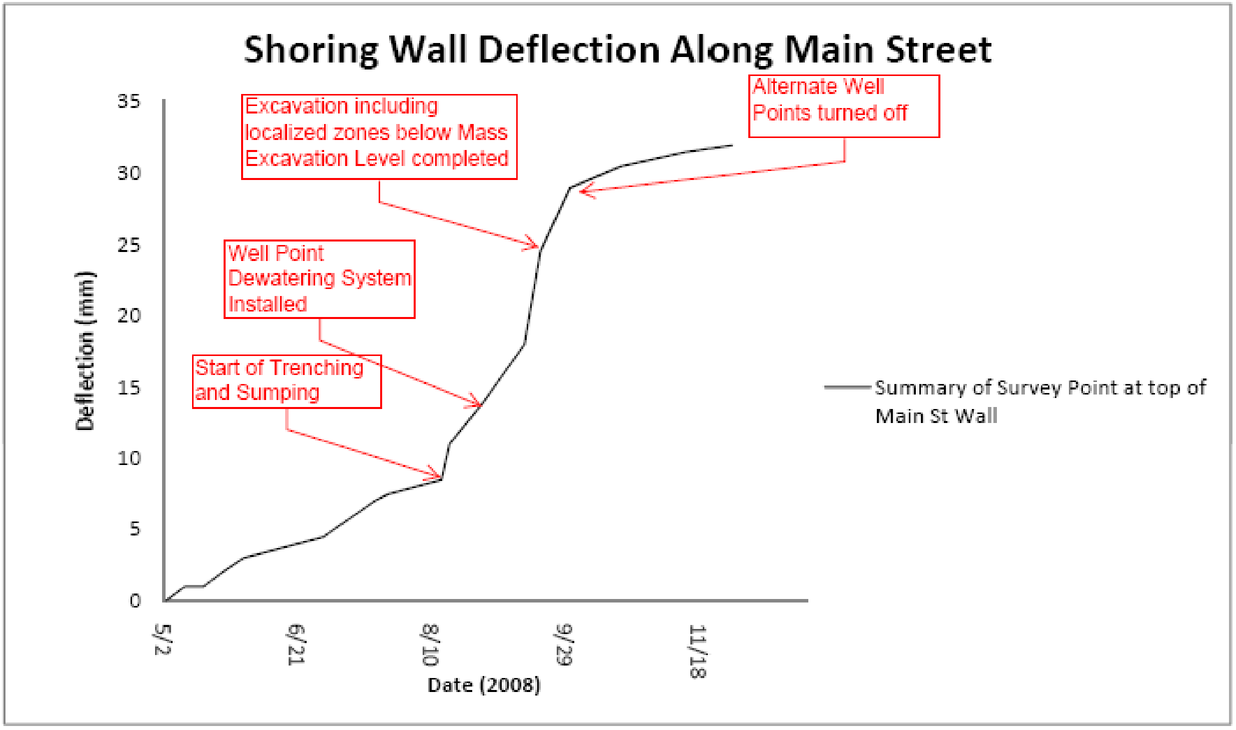

Figure 3 Lateral Movement along Main Street

The Main St shoring wall deflected a total 1-1/2" during construction which was greatly influenced by the dewatering induced settlement of the soils, which occurred largely at the front face of the wall (thereby inducing some lateral movement by 'tilting' outwards). While the movement was enough to damage the inclinometer casing placed behind this wall, no damage occurred to the wall or any facilities along Main Street. The performance of the shoring system on Main Street was not as planned, but through a constant process of monitoring the performance of the wall, minor construction changes were employed to preserve the entire environment surrounding the shoring wall and avoid wholesale design changes.

Deseret Trust

The Deseret Trust building is a 90 year old historical structure located at the southwest corner of Block 75. It is a masonry structure supported by a system of large concrete plinth footings founded on the natural granular soil about 18 to 20 feet below street grade. The structure has a small footprint, on the order of 85 feet by 75 feet; three of its four quadrants being 12 stories high and the fourth quadrant (northeast corner) only 3 stories high. Project structural engineers estimated the average ground pressures to be on the order of 6,000 psf.

Very little information was available regarding the original construction of the structure and it was necessary to expose the plinth foundations, which protruded about four feet beyond the exterior walls. These footings dictated the shoring wall location. The average depth of the shoring around the building was 40 feet with nearby excavations influencing each side of the earth retention system.

To reduce the foundation pressure adjacent to the shoring face, hollow-bar micropiles were drilled through each exposed plinth foundation and designed to support 50 percent of the load from of the outer row of the footing system.

The method chosen for the Deseret Trust shoring was a hybrid soil nail/soldier pile system. Hollow bar soil nails were combined with a structural face to limit ground loss and lateral movements. The face was constructed with fully cased drilled soldier piles placed at five foot centers spanned by shotcrete lagging. The structural face allowed an atypical nail spacing of five feet horizontal by seven feet vertical. Vertical elements (rebar grouted into a six-inch cased hole) were drilled between the soldier piles to limit ground loss during excavation.

All of the soil nails were post-tensioned to approximately 75 percent of their design load, typically 50 to 60 kips. The soldier piles along the east side were extended ten feet deeper to improve global stability to the extent that a tower mat foundation could be excavated 30 feet to the east of the shoring line.

The combined use of soldier piles with the vertical elements to limit ground loss was very positive. Only nominal sloughing occurred during excavation, prior to shotcrete placement.

The pre-construction estimate for settlement ranged from ¼ to ½-inch. This estimate (0.05 to 0.1 percent H) was also based upon local experience, using a post-tensioned hybrid shoring system in these conditions. Site instrumentation data showed about 3/8-inch maximum settlement of the building. There were no cracks or other damage observed in the building and the performance of the Deseret Trust shoring “Figure 4” met or exceeded expectations.

The Deseret Trust Building was able to maintain uninterrupted occupancy throughout the demolition, excavation and new construction for Block 75 extending its 90 plus years of service.

Figure 4: Photo of Shoring at Deseret Trust Building during Excavation

__Eagle Gate Tower__

Shoring design and construction along the Eagle Gate Tower was the most challenging segment of shoring for the Block 75 project. To understand the myriad of challenges involved, existing site conditions and both the pre-construction and final design are reviewed in the following paragraphs.

The Eagle Gate Tower is a twenty-two story structure founded on a five-foot thick, post-tensioned concrete mat foundation. It is located on the northeast corner of Block 75. This building was constructed in the mid-1980s on the site of an old seven story medical office building.

Project requirements dictated that the west side and portions of the south side of the excavation surrounding the building be supported by a shoring system to allow for removal of subgrade structures from the old ZCMI center parking structure and construction of new deeper facilities. Along the west side of the Eagle Gate Tower, shoring extended to 75 feet below street grade, corresponding to 60 feet below the base of the Eagle Gate Tower post-tensioned mat foundation. Only a 3’-6” wide space existed between the existing foundations and the new face of shoring.

The pre-construction design estimated that settlements would range from 3/8” to 7/8” at the Eagle Gate Tower (roughly 0.05 to 0.1 percent H, for hybrid system). Since this corner has the highest elevation on Block 75, it also has the highest groundwater level. During the bidding phase, the shoring team concluded that the shoring system around the Eagle Gate Tower would need to provide a groundwater cutoff to eliminate dewatering induced settlements and loss of ground during excavation to achieve this performance. Consequently, a tied back secant pile system was planned for shoring in this area.

The effect of dewatering induced settlement was later evidenced on the shoring section along Main Street discussed earlier, validating the pre-construction determination to install a cutoff wall at this location in lieu of installing a dewatering system

The narrow corridor provided for shoring installation, limitations created by clearances of a top drive hydraulic drill necessary to fully case the secant piles through the cobbles and sands along with known obstructions led to a unique solution shown in “Figure 5”.

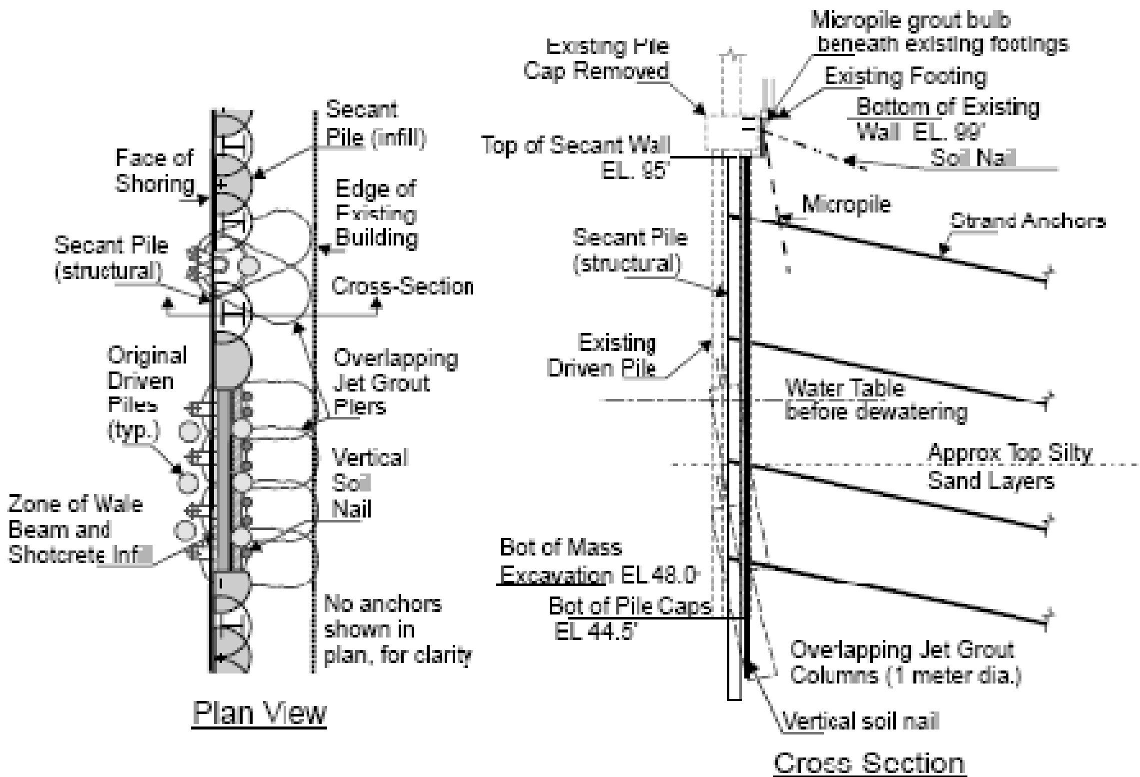

Figure 5 Typical Plan and Cross Section for Eagle Gate Tower Shoring

The determining factor for the secant pile shaft diameter was not the loading of the pile, but the clearance between the drill rig and the adjacent structures. This allowed for the structural member (wide-flanged beam) to be placed towards the back of the cased hole in lieu of the center. The front of the shaft actually encroached beyond the planned face of shoring with the structural element extending right to the plan face of shoring.

During excavation, the front face of the secant piles would be trimmed significantly utilizing a hydraulic grinding wheel outfitted with carbide drill teeth attached to a track hoe. This ground surface would then be made smooth with a thin course of shotcrete to allow for easy placement of a waterproofing membrane.

As the demolition of the food court at the north end of Block 75 was completed, many existing pipe piles were exposed, which interfered with the path of the secant wall system. It was determined that where the driven piles conflicted with the installation of secant piles the existing pipe piles could be incorporated into the cutoff wall by utilizing two rows of battered overlapping jet grout columns to provide structural continuity.

Tieback strand anchors were installed at each new structural secant pile. In between secant pile sections, strand tiebacks were installed through a waler beam. The waler beared on the existing pipe piles and spanned a reinforced shotcrete facing covering the jet grout columns. Each strand tieback was installed utilizing cased holes while maximum performance was ensured through extensive use of post grouting.

The exact location of the existing piles would be required in order to install the secant pile sections. This was complicated by the fact that the tops of the existing driven piles were up to 15’ below the perimeter wall footing for the Eagle Gate Tower.

To allow for the exposure of the pipe piles, battered micropiles were installed below a perimeter footing at the Eagle Gate Tower and a soil nail wall was installed directly beneath this footing. This alignment allowed for maximum clearance of the secant pile drill rig.

At some locations, secant piles could not be installed due to interferences with the existing pipe piles. Jet grouting, shotcrete facing and additional hollow-bar soil nails were installed and supported with wale beams to span these gaps and maintain a continuous cutoff wall.

Several strand tiebacks had to be relocated or deflection angles changed to avoid obstructions, resulting in the destruction of two inclinometer casings. Monitoring was therefore limited to the owner’s real-time survey system. The original estimate for settlement movement of the wall was 3/8-inch to 7/8-inch. Survey results showed approximately 1/4-inch movement.

Conclusions

Urban re-development projects encounter increasingly difficult conditions created by existing structures, and difficult soil conditions. This project illustrates that a large scale and ambitious excavation plan can be completed in a challenging environment. A wide assortment of foundation drilling equipment and designs can be combined successfully to meet almost any project condition, allowing shoring systems which can be modified as construction proceeds.

Communication within the project team was the key to keep this challenging project moving despite frequent changes to the methods and sequence of construction.

Data acquired during construction included additional soil samples, survey and inclinometer readings. This allowed the shoring team to use an observational approach to evaluate and adapt the design as work proceeded.

References

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