HCM OVERCOMES ENCROACHMENT RESTRICTIONS FOR 25M DEEP EXCAVATION

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HCM OVERCOMES ENCROACHMENT RESTRICTIONS FOR 25M DEEP EXCAVATION

BY KAILEY DENBRABER, NICK WARREN, JASON WECK

PROJECT SUMMARY

HC Matcon Inc. (HCM) and RWH Engineering Inc. (RWH) teamed up to provide a design-build shoring solution for the development of a 22-story condo with seven levels below grade in the Port Credit neighborhood of Mississauga, Ontario. Supporting a 2-story residential building to the north, city right-of-ways to the east and south, and a 3-story above-ground parking garage to the west, this was a seemingly straightforward project at first. However, due to various site constraints including tieback anchor encroachment agreements with neighboring properties and limited shoring clearances along city and private property lines, this development would prove to be an example of how conventional excavation support can become complicated by external factors.

HCM and RWH worked with the developer to determine a design solution that would stay within the site limitations while still providing a system to minimize the impact to the below-grade foundation construction. The final design was a perched shoring system in the rock, which included soldier piles and lagging, and a secant caisson wall with a total of seven highly loaded, large diameter HSS pipe struts spanning 30 m (100 ft) across the site. Where permitted, two rows of tiebacks were installed to

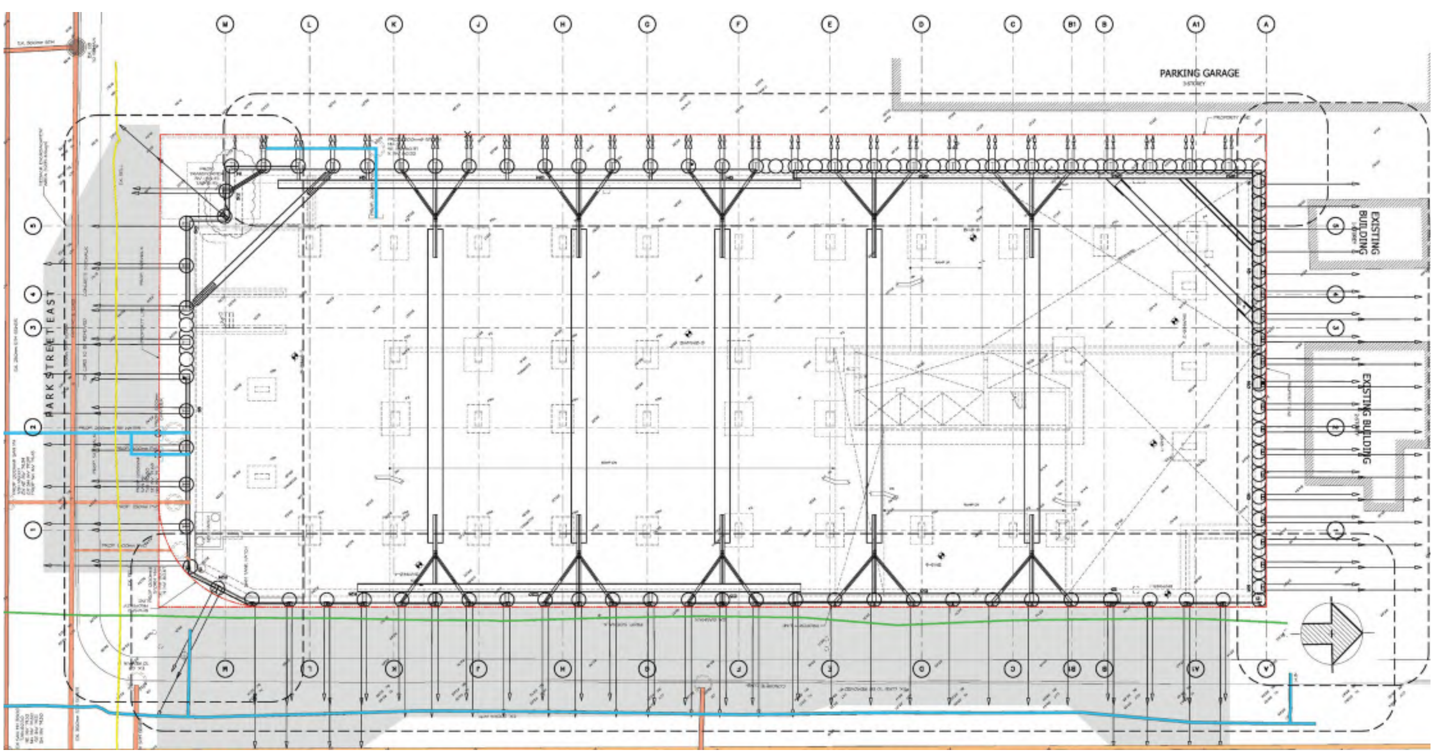
rock, and the perched pile toes were pinned back with rock bolts.

RWH completed the precision monitoring program to review the performance of the shoring system throughout the excavation and foundation construction using precision survey equipment, inclinometers, and strain gauges on the pipe struts.

SHORING APPROACH

The soil conditions in this area consisted of a sandy silt fill overlying various native materials generally ranging from sandy silt till to clayey silt. The overburden was approximately 9 m to 10 m (30 to 35 ft) deep and situated over shale bedrock of the Georgian Bay Formation interbedded with limestone. The project site was located close to Lake Ontario and often the groundwater table is at a similar level to the lake. This was found to be true on this project in which the groundwater was observed within the native silts and top layers of weathered bedrock.

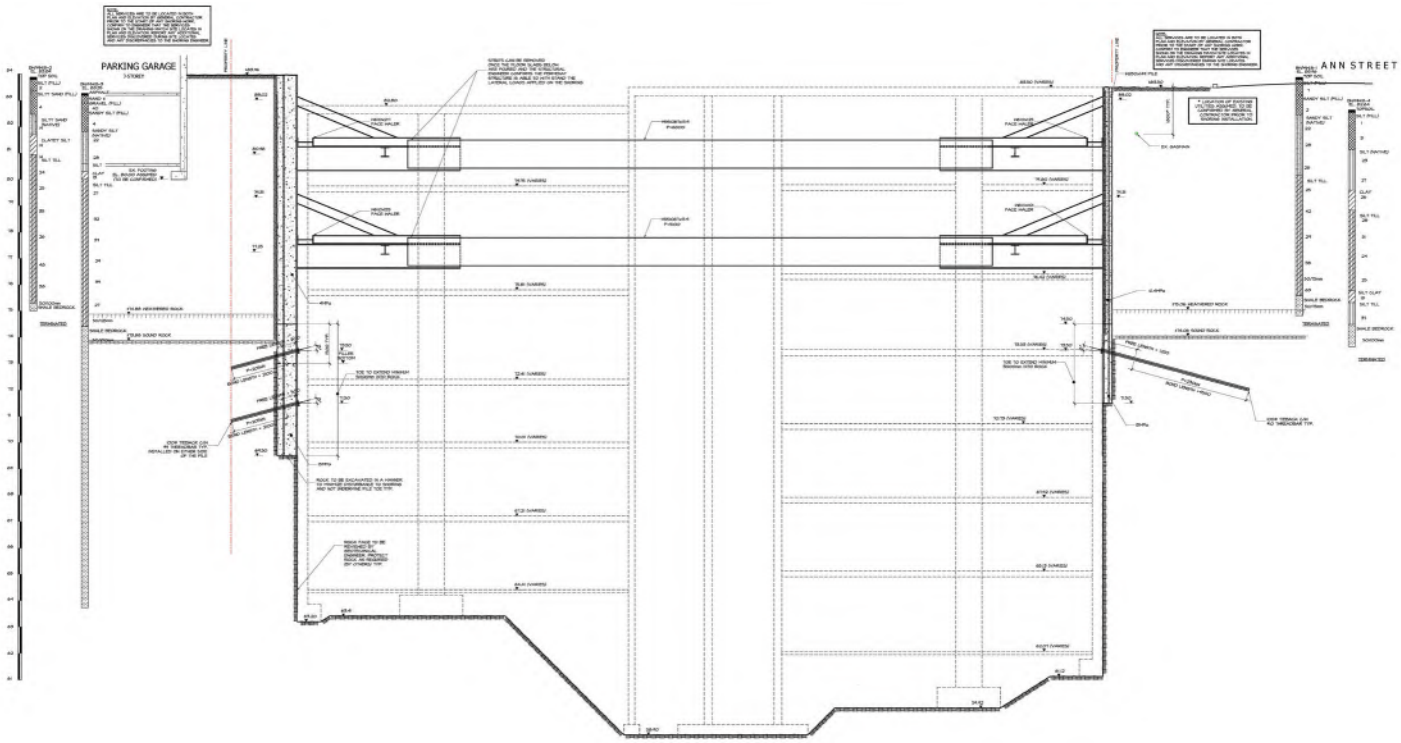
The challenges faced on this project were not from difficulties with the ground conditions, but those encountered during the permitting and design process. The design required a high level of coordination with the City as well as the developer



who was working to optimize the structural footprint of the building. The developer was unable to obtain an agreement with the neighboring property to the west of the site to install tieback anchors beyond the property line resulting in the need for an internally braced earth retention system. The challenge being, a conventional raker and waler system was not feasible on this project as the site was 30 m (100 ft) wide and extended up to 25 m (82 ft) deep. With tieback and raker bracing ruled out for lateral support along the west property line, the design-build team opted for cross-lot bracing using multiple large-diameter struts to span across the site from the east to the west.

> ***"This required a holistic approach, with the objective to provide an internally braced shoring system while minimizing the impact to the construction of the below grade structure itself."***

This required a holistic approach, with the objective to provide an internally braced shoring system while minimizing the impact on the construction of the below grade structure itself. The design-build project team was brought on early in the project stages to mitigate issues to other trades down the line of construction. All relevant trades were involved to coordinate construction activities prior to finalizing the design for the success of the project and any impact on cost and schedule. Multiple iterations of strut locations and spacing were reviewed with the project team before designing a system that consisted of five upper, and two lower row 1067 mm (3.5 ft) diameter pipe struts. The struts were spaced at 10.5 m (35 ft), with design loads up to 6000 kN (1,350 kips).


PARKING GARAGE
ANN STREET

The shoring system for this site was split into two halves. A perched caisson wall at the north and northwest ends of the site to support the 3-story parking garage and 2-story residential buildings, and soldier piles and lagging along the east, south, and southeast to support the existing right of ways. The caisson wall shoring was designed with two rows of struts to support the additional surcharge imposed from the existing building and to ensure movements of the shoring were limited. Along the southwest wall where minor movements were allowable, but tiebacks could not be installed, the piles were founded below the bottom of excavation to avoid the requirement for a second row of struts. Where possible, multiple rows of shortened anchors were installed to help reduce the structural design requirements of the piles. At the southeast end of the site, a second row of tiebacks were installed, and the piles perched into the rock. Additional challenges arose along the north and east walls with limited clearances to the property line, as setbacks were approximately 350 mm (13.8 inches) from the edge of the proposed foundation wall. As encroachment restrictions did not allow soldier piles to be installed over the property limits, RWH designed using W250 (W10) steel sections which are less efficient at unsupported lengths, increasing pile weights. This also resulted in tighter pile spacing along the north wall where the secant caisson wall would be shaved back to be only 350mm thick.

To allow for sufficient working room during both the excavation and foundation construction, the struts were spaced approximately 10.5 m (35 ft) apart and were responsible for resisting the lateral load from four piles. To add to the challenge, struts of this length are typically supported at the center with vertical king piles, but these types of systems are more intrusive to the site restricting equipment access and complicating excavation. To limit these challenges, RWH designed the struts to span the site without relying on additional vertical supports.

With struts of this size and length, it was critical that each strut was installed such that they did not conflict with the proposed structure. This required an in-depth review of the varying slab elevations and parking structure ramps. Further to this, the entire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HCM

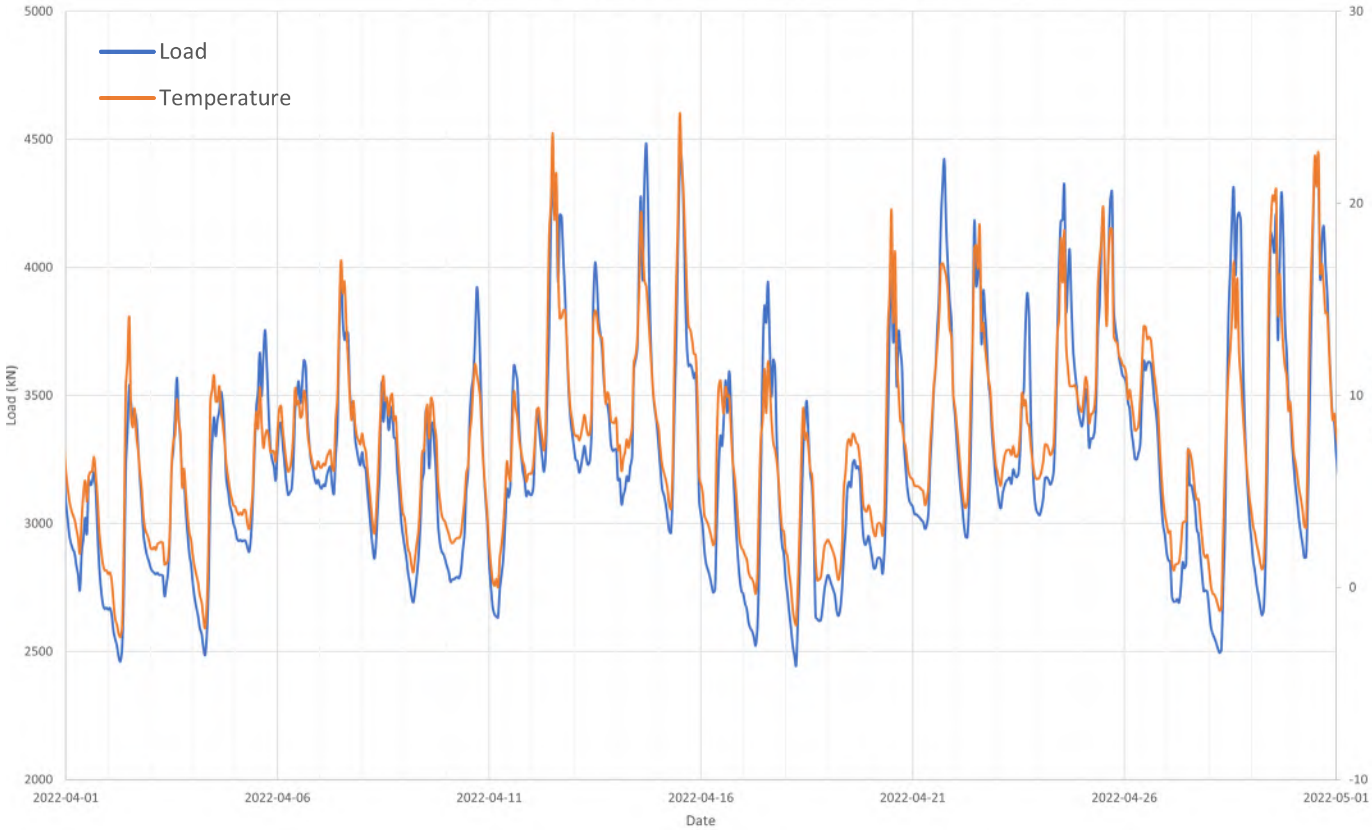
structure including elevator cores and tower crane locations needed to be considered as they could not be interrupted. Due to the complexity, multiple cross sections were prepared throughout the entire site to coordinate the location and elevation of each strut. In addition to avoiding conflicts with the slabs, the struts were designed to be removed in sequence with the installation of the floor slab below. This was successfully achieved by working with the structural engineer to confirm at which stages of the construction process the foundation walls and slabs were self-supporting.

CONSTRUCTION PROCESS

Construction of the shoring began in January of 2021 with the installation of the secant caisson wall and soldier piles and lagging. Working from an engineered platform designed by RWH, HCM used their Bauer BG24H and Casagrande B300 to install 1000 mm (39 inch) diameter holes consisting of 88 piles and 84 fillers for a total drill length of 2,150 m (7,050 ft) and a total linear shoring length of 212 m (695 ft). Having worked in similar material on previous projects, HCM was well equipped to manage the site conditions.

While piling was ongoing on-site, the pipe struts were prefabricated in shop by HCM. The pipe material was shipped to HCM's yard in 12 m (40 ft) sections and required a splice in the center and knife connections welded to both ends, resulting in each fabricated strut weighing approximately 18,150 kg (40,000 lbs). HCM optimized site constraints by transporting the prefabricated 30 m (100 ft) struts onto the site and used a mobile crane to offload each strut from the delivery float directly into the final location within the excavation. This saved both schedule and cost as prefabricating the struts off-site eliminated double handling material, reduced onsite welding activities, and minimized the required material laydown area that would have obstructed excavation.

Figure 3: Compression Load Fluctuations in HSS Pipe Struts from Thermal Expansion



The excavation of the site was sequenced such that both rows of supports on the north end were installed prior to continuing towards the south end. This allowed for the struts to be installed without limiting the site works for excavation equipment and small-diameter drill rigs. Once each strut was dropped in place, they were fully welded to the piles with additional W-section struts and face walers to help distribute the lateral loads to the shoring wall.

After the connections were welded, the struts were preloaded to 50% of the design load, up to a maximum of 3000 kN (675 kips) to remove any movements that occurred during the initial stages of excavation where the shoring was in a cantilever condition, and to help mitigate and control any future lateral shoring movements. RWH and HCM have previously completed various projects with highly loaded elements including micropiles, preloaded rakers, and synchronized structural jacking, and were able to apply this knowledge and experience when developing customized procedures and details specific to this project. There were significant detailing requirements for the connections and welding which required collaboration between the welders, fabricators, and designers to ensure adequate installation given the high loads.

> **"HCM used their Casagrande C6 and Ingersoll Rand ECM350 to drill hollow bar injection anchors into rock."**

Upon completion of the strutted bracing of the overburden, HCM used their Casagrande C6 and Ingersoll Rand ECM350 to drill hollow bar injection anchors into rock. A total of 78 tiebacks and 168 rock bolts were installed across the project. The west wall alone required 110 rock bolts as the length of each pin was limited due to the proximity of the property line.

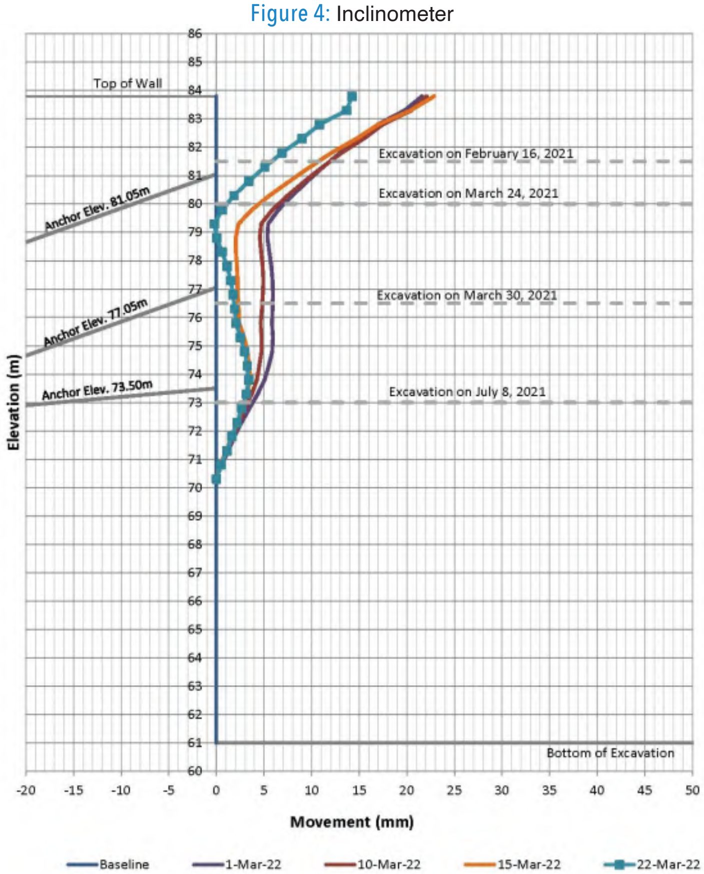
As the below-grade structure was constructed and approached the ground floor level, the pipe struts were removed to avoid forming work boxouts in the foundation walls. Temporary re-shoring inside the structure was utilized as required after the struts had been removed.

SHORING MONITORING AND INSTRUMENTATION

As part of the design-build package, RWH was contracted to provide a precision monitoring program to review the performance of the shoring system and vibration levels at buildings adjacent to the development during shoring installation and excavation activities. Monitoring was completed using precision surveying of the shoring and existing buildings with total stations, as well as inclinometers centered along each wall.

RWH installed arrays of strain gauges on the pipe struts to provide real-time feedback on the loads carried in the struts. This instrumentation was of critical importance in understanding changes in the loading on the system due to environmental conditions, and as excavation progressed. This information proved to be insightful, as it displayed how rapidly the effects of temperature changes and thermal expansion would increase or decrease the loads in the struts as shown in Figure 3. While these were anticipated, the volatility in the fluctuations of the loads throughout a single day was not expected. Furthermore, the shoring became subjected to additional loading brought on by the effects of frost jacking in the colder winter months. This was evident as, unlike typical daily thermal expansion, the loading did not cycle but rather continued to increase until winter protection measures and insulated blankets were placed on the shoring. At this time, the strut loads stopped increasing until the spring in which the ground thawed and the loadings on the shoring wall were reduced. These same effects were evident in the inclinometer behavior along the north wall as seen in Figure 4, where shoring was more prone to movements due to the stiffness of the caisson wall and elongation of the tiebacks.

Figure 4: Inclinometer



CONCLUSIONS

HCM and RWH work together to provide cost-effective shoring solutions for developments across Canada with each project possessing its own set of challenges and opportunities for innovation and experience. Faced with limitations during the early stages of permitting, the project team was able to develop a design-build shoring plan that solved neighboring encroachment limitations, while limiting impacts to the entire construction process within the excavation. This challenge led the teams at HCM and RWH to design and install the largest self-supporting struts on a project to date and in the process develop new connection details, installation methods, and testing procedures. Both HCM and RWH are currently applying this knowledge to new projects, as more developments are experiencing challenges with the permitting process, neighboring properties, and encroachment permissions. While there are often trade-offs in increased shoring costs, it is sometimes easier to maintain the shoring within property limits to avoid costly delays caused by external factors.

PROJECT TEAM

Shoring Contractor

Jason Weck MESC P. Eng	HC Matcon Inc.
Ryan Regier P.Eng	HC Matcon Inc.

Shoring Engineer

Nick Warren BESc.	RWH Engineering Inc.
Kailey DenBraber P.Eng	RWH Engineering Inc.

Precision Monitoring

Rob Mara	RWH Engineering Inc.
Mike Janzen	RWH Engineering Inc.