HCM INSTALLS INNOVATIVE DESIGN-BUILD BYPASS SHOTCRETE SYSTEM

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COVER STORY

HCM INSTALLS INNOVATIVE DESIGN-BUILD BYPASS SHOTCRETE SYSTEM

BY DAVID STEINMANN, PROJECT ENGINEER, EIT, KAILEY DENBRABER, PROJECT ENGINEER, EIT AND JASON WECK, PRESIDENT, P.ENG., RWH ENGINEERING INC.

PROJECT SUMMARY

The first new-build condominium project in downtown Hamilton in 20 years, the City Square development will be comprised of three separate towers at the corner of Robinson Street and Park Street South. The third phase tower, at 17 stories, will be the tallest of the three in comparison to the 9 and 11 story towers built in the first two phases.

HC Matcon Inc.* (HCM) and RWH Engineering Inc. (RWH) were selected by the developer to provide a Design-Build shoring solution for City Square Phase 3. HCM working with RWH provided a tailored solution by utilizing their knowledge of the site gained during the shoring for City Square Phase 2, adjacent to Phase 3. The result was a shoring system that took advantage of the soil conditions for an efficient design and construction approach.

The 14,000 square foot project consisted of three sides of shoring to a depth of 36ft (11m) to tie into the existing Phase 2 parking garage which bordered the west side of the site. Soldier piles with concrete lagging across the face of the pile, known as bypass shotcrete, was installed. The north and east walls were designed with one row of double tiebacks using a specialized anchor connection developed by HCM. The south wall design, which supported a neighboring property as well as the City Square Phase 1 parking garage, required the use of raker supports which were pre-loaded to mitigate deflections of the shoring system. The precision monitoring was completed by RWH to review the performance of the shoring and verify the design.


INSTALLED BYPASS CONNECTIONS.


FIGURE 1. BYPASS SHOTCRETE CONNECTION.

SHORING APPROACH

The soil stratigraphy of the site varied from very stiff to hard native silty clay till overlaying Queenston Shale bedrock at 75ft (23m) below grade. The geotechnical investigation presented that the upper 6 to 10ft (2 to 3m) of the silty clay till had standard penetration test (SPT) "N" values ranging from 20 to 30 but dropped to approximately 15 blows throughout the remaining excavation depth. The clay posed a design obstacle as the low adhesion values would require long tieback anchors while the depth of the shale was not feasible for rock anchor installation.

In the second phase of the project, HCM also installed shotcrete with tiebacks, however, the average cut was 20ft (6m) to a maximum cut of 28ft (8.5m) in comparison to 36ft (11m) for Phase 3. RWH used design parameters that were proven during the previous phase and applied them to the larger excavation depths to result in a comprehensive shoring design and construction approach that capitalized on HCM's labor and equipment strengths.

The limiting factor of the design was determining a balance between the tieback loads and pile spacing. The advantage of tiebacks and bypass shotcrete is HCM's own tieback connection which is cast into the shotcrete lagging and eliminates the need for welding conventional tieback angle connections and walers between the piles. This allowed for quicker installation and reduced welding requirements. Typically, on piles and lagging the waler location is excavated out and each end of the waler is welded to the pile. After the tieback is installed, the tieback connection is constructed and the tieback stressed. With shotcrete bypass, the tieback is installed and the area around the tieback is locally built up with additional rebar, thickened shotcrete, and an HSS pipe with clips. This connection has significant time savings and reduced labor requirements for installation. Given the depth of the excavation, the single row system required double tiebacks at the same elevation to split the load for manageable anchor lengths and to remain within the limits of the soil to grout bond. **Figure 1** shows a 3D representation of the tieback connection. The tiebacks were angled at 15 and 20 degrees on either side of the pile for adequate separation to ensure there was no interaction of the bond zones in order for the tiebacks to act independently. The versatility of bypass shotcrete allowed the bay size to be modified from classical timber lagging spacing and maximize the capacity of the bypass connection. Typical bay spacing was 8ft (2.4m) but was reduced to 7ft (2.2m) as the existing grade rose.

The south shoring wall bordered a residential property on the east end and the existing City Square Phase 1 on the west end. Rakers were required for the south wall as tieback encroachment was not permissible on the residential property and geothermal boreholes beneath the Phase 1 parking garage did not allow for tieback installation without a high risk of damaging the geothermal system. Similar to the approach of the north and east walls, pile spacing on the south wall was set to 7.5ft (2.3m) along the residential property but was then reduced to 5ft (1.5m) due to the increased building loadings where the Phase 1 structure was in the influence. This allowed an efficient raker and waler design as spacing was set to utilize the full capacity of the steel sections and the allowable bearing of the soils. To minimize deflections of the shoring system in front of the existing buildings, all rakers were pre-loaded to 50% of the design load to ensure settlement of the raker pads in the clay material was reduced from the system and support load locked-in adequately.

Utilizing only one row of tiebacks and rakers allowed for simplified construction and accelerated excavation. HCM and RWH proposed this approach to minimize delays as the site was comprised of cohesive material which would have required the construction of additional working platforms and ramps for the tieback equipment at each level. Eliminating a row of tiebacks reduced both the installation time and the associated grout curing time of the tiebacks. While eliminating the ramp flip, as well as being able to remove the tieback equipment offsite after approximately one third of the cut was completed,

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CAT 321 WITH TEI DRILL.

allowed for continuous and unobstructed excavation to the bottom of the shoring. Without the information from the tieback testing and monitoring results from completing the previous phase, the design of Phase 3 would have included multiple tieback levels and heavier steel sections for the piles.

CONSTRUCTION

HCM’s* Watson* 4400 commenced piling on February 27, 2017. Similar to traditional pile and lagging systems, soldier piles were installed with 15MPa toe concrete with a lean mix concrete to grade. Portions of existing footings obstructed several pile locations, requiring revised pile layout as they could not be excavated due to their depths. The bypass system allowed for the pile spacing to be easily adjusted for the site conditions and as drilling progressed RWH reacted, working to address concerns and revise the design for the large spans between the piles.

By the end of March, the shotcrete crew mobilized to install shotcrete for the first lift of excavation. HCM applied 30MPa concrete 100mm thick as a wet gunite mix shot onto mesh and rebar reinforcement installed on the face of the excavation. The Hamilton clay proved to be satisfactory material for shotcrete application as the cohesive soils allowed large portions of the site to be open cut and prepared prior to shotcrete installation. Excavation and installation of shotcrete in this material was able to be installed via ribbon cutting procedures, not in sequenced panels as is often required, and as result the excavation and shotcrete advanced quickly and efficiently. To address the larger bays which were a result of obstructions, RWH used concrete walers to provide additional strength and stiffness between piles. On each lift of the excavation concrete walers were constructed with a horizontal trench dug across the bay with rebar tied on site and installed to span between the piles and then shot in place. Once the void was filled with shotcrete it formed a reinforced concrete beam which acted similar to an internal waler.

After two full lifts of shotcrete were completed tieback drilling and waler installation for the rakers commenced. HCM used R51 hollow bars for the tiebacks, which allowed for quick installation as the drill steel is left in the ground and becomes the threadbar reinforcement. Furthermore, the utilization of hollow bars eliminated the need for post-grouting of the anchors, saving additional time on project schedule. The hollow bars were installed with a TEI Rock Drill's Inc.* mounted on a CAT 321 excavator. Proof testing of all anchors was important to ensure the anchors engaged the clay material. After stressing of tiebacks, excavation continued on the north and east walls simultaneously with raker and corner strut installation on the south wall.

An unknown factor for the Phase 3 shoring was the condition of the backfilled Phase 2 shoring completed in 2013. The design required the new shotcrete to tie into the existing shotcrete at the north and south corners of the Phase 2 parking garage. Lift-off testing of all exposed existing tiebacks was completed to prove capacity to ensure they could be incorporated into the current shoring system on the north wall, while a corner strut system was installed to the existing piles on the south wall.

The project progressed quickly after the single row of supports were in place as excavation could continue to the bottom without delay from an additional row of tiebacks at a lower elevation. August 18th saw the last of the HCM’s equipment loaded on float trucks heading out of Hamilton.

FINITE ELEMENT ANALYSIS

RWH uses finite element (FE) modeling to complete predictive movement and settlements on all excavations that have sensitive infrastructure in the influence of the shoring. A FE analysis does not replace classical calculations and practical knowledge, but it does provide a basis of behavior that can be expected to occur during excavation activities. See **Figure 2** for a diagram of horizontal settlement results for the north wall.

INSTALLED RAKERS PRIOR TO SHOTCRETE.

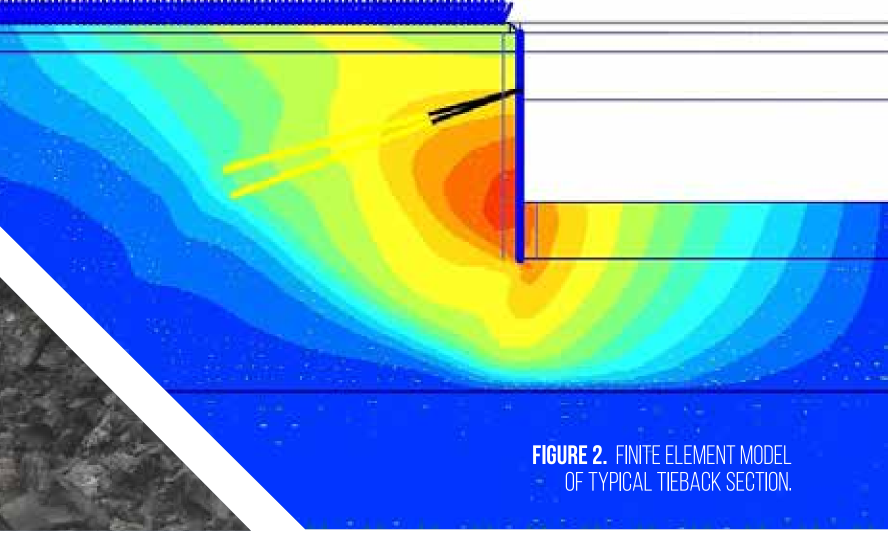

FIGURE 2. FINITE ELEMENT MODEL OF TYPICAL TIEBACK SECTION.

This shoring project is now one of many deep shoring jobs occurring in Hamilton, Ontario. However, Hamilton has only recently been going through extensive growth and large deep excavations are just becoming more prevalent in the city. Because of this, there is limited geotechnical information known and soil parameters provided to use for modelling. Most geotechnical reports only provide SPT values and bearing capacities. Soil strength parameters used in FE modelling have to be derived through correlations and experience from previous excavations nearby and in similar soil conditions.

Using their extensive modeling knowledge, RWH selected parameters and completed a staged excavation model to understand what movements could be anticipated. Completing the shoring for the prior phase and having access to all the precision monitoring data allowed for a back analysis assisting in the selection of appropriate soil parameters. This allowed for the precision monitoring deflections to be reviewed with the predicted deformations at various excavation stages. The results of the modelling yielded confidence that the depth of excavation would have minimal impact on the neighboring buildings.

"RWH completed the precision monitoring on the project which included both survey target and subsurface monitoring using inclinometers."

MONITORING

RWH completed the precision monitoring on the project which included both survey target and subsurface monitoring using inclinometers. Completing both the design and the monitoring through RWH ensured consistent and timely review of the shoring's performance. Targets were attached to the top of every second pile as well as the existing Phase 2 parking garage to monitor both horizontal and vertical movements. An additional row of targets were affixed to the shotcrete face at approximately one third of the final excavation height to ensure excessive toe movements in the softer clays did not occur as the project approached the bottom of excavation. Two inclinometers were secured to soldier piles, one on the north wall and one on the south wall.

The inclinometers were initialized immediately to capture any early movements as targets are initialized once the first lift of shotcrete was complete. Monitoring readings continued weekly throughout the project. The north wall targets showed a maximum movement at the top of pile of 0.71 inches (18mm) and the east and south wall monitoring produced values of 0.79 inches (20mm)

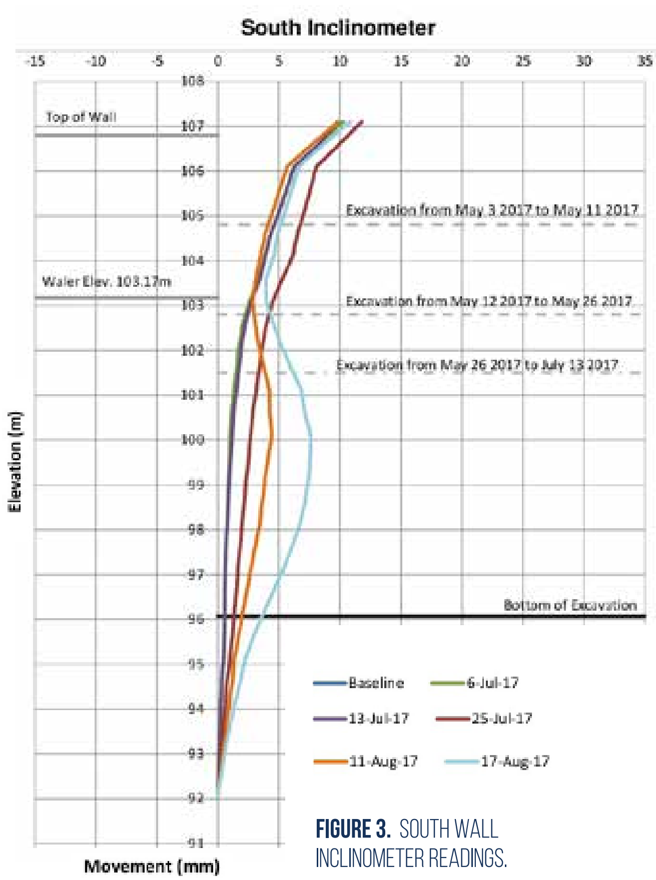

FIGURE 3. SOUTH WALL INCLINOMETER READINGS.

COMPLETED SHOTCRETE BENEATH RAKERS.

CREW AFTER A SUCCESSFUL SHOOT.

PILES READY FOR TIEBACK INSTALLATION.

and 0.51 inches (13mm) of horizontal movement, respectively, with maximum movements occurring the center of the wall. The movement of piles near the corners were approximately 50% to 60% of maximum horizontal movements. Vertical settlement of the shoring system averaged 0.20 inches (5mm) on the north and east walls, but was found to vary between zero and 0.08 inches (2mm) on the south wall. This can be attributed to the jacked raker system on the south wall versus the post-tensioned tiebacks which induced a vertical load onto the piles.

The effect of preloading the rakers in mitigating shoring movement is apparent in the inclinometer readings. **Figure 3** shows the movement of the wall on July 25th at 0.47 inches (12mm) while the piles are in a cantilevered state prior to any supports being installed. The August 11th reading was taken after all rakers had been jacked and shows 0.08 inches (2mm) of movement out of the excavation for the exposed portion of the pile. The August 17th reading, taken once all excavation was complete, produced only an additional 0.06 inches (1.5mm) of movement into the site at the waler elevation.

CONCLUSION

The success of the City Square Phase 3 shoring project can be attributed to the Design-Build teams understanding of the site-specific soil conditions and use of previous knowledge gained from completing the earlier phases of shoring. This project is an example of how applying empirical knowledge can be used to provide the client with both cost and time savings on their project. The soldier pile and bypass shotcrete shoring system developed with specialized connections by HCM, along with a single row of supports, provided a practical construction solution to a tight job site which worked to the advantage of many trades.

Awarding both the design and the precision monitoring to RWH allowed confidence in providing an efficient design. Using an FE model to predict deformations and comparing the staged analysis to the precision monitoring reports provided assurance to all stake holders that the shoring was performing satisfactory.

*Indicates **ADSC** Members.

PROJECT TEAM

PROJECT MANAGER:
Hong Chau
HC Matcon Inc.*

SHORING ENGINEER:
Jason Weck, MESc, P.Eng
RWH Engineering Inc.

David Steinmann, EIT
RWH Engineering Inc.

MONITORING:
Mike Janzen
RWH Engineering Inc.