# HERITAGE FAÇADE SUPPORT AND EXCAVATION SHORING – A MICROPILE CASE HISTORY

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## ABSTRACT

Originally built in 1927, the distinctive terracotta trim and red brick façade of the Canadian Westinghouse Building in Toronto's entertainment district is preserved in-situ on a temporary frame supported by Case 1 micropiles also employed as vertical members in a temporary excavation shoring system. Two street facing façades of this 6 storey heritage building were supported while the remainder was demolished to make way for development, including two towers and five underground parking levels.

A large diameter soldier pile excavation support system was originally planned around the site, however, proximity of a gas main and the preclusion of street closures due to traffic congestion and light rail tracks, required a hybrid solution with small diameter piles. The façade support frame was founded on two rows of vertical 356 mm diameter piles, designed to act in tension and compression to suit wind loading on the facade. The row of micropiles closest to site were also designed to withstand lateral earth pressures and allow for potential bedrock expansion that is known to develop in Toronto shales following excavation.

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## 1. PROJECT BACKGROUND

Toronto has seen intensive construction over recent decades driven particularly by subway expansion and hundreds of high-rise condominium developments, most of which involve deep excavations for underground structures and basements. The expanding foundation construction industry has been kept very busy. Isherwood Geostructural Engineers (Isherwood) and Deep Foundations Contractors (Deep) have collaborated for more than forty years in executing many excavation shoring projects, including several of Toronto's iconic landmarks.

Driven by the strong natural soils underlying downtown Toronto (glacial tills and shale bedrock) as well as contractor investment in large specialist equipment, shoring practice in Toronto concentrates on drilled soldier pile and lagging and drilled secant caisson walls, typically with rock or soil anchor bracing.

Developers benefit from the City practice of allowing temporary shoring to be located on City Property, thus allowing building of underground structures to the limits of the developer's property.

## 2. EXISITING HERITAGE STRUCTURE

355 King Street West, at the intersection of Blue Jays Way (then called Peter Street) was redeveloped in 1927 for the Canadian Westinghouse Company as a show room, warehouse and district office. The structure was designed in two phases such that the first three levels were built first; then in 1935 three more levels were added to complete the building as shown in figure 1.

The building is designated by the City of Toronto (1992) under the Ontario Heritage Act for architectural reasons citing "its two-part design, restrained Classical detailing and the application of terra cotta trim on brick, a combination rarely used in the City of Toronto".


**Figure 1. Canadian Westinghouse Building** ***Source: KingBlueCondos.com***

## 3. PROPOSED NEW DEVELOPMENT

The Canadian Westinghouse Building Toronto forms part of the site of a condominium development by Greenland Group including two residential towers of 48 and 44 storeys. In order to maintain the streetscape, the two street facing façades of the heritage warehouse are being preserved in situ and will be incorporated into a podium of the same height – see figure 2.

In order to achieve this, a temporary steel frame located on the two sidewalks was required. Once installed, and the facades secured, the remainder of the building could be demolished to clear space for the new construction. Foundations for the façade support frame would have to allow for (the then proposed) seven underground basement levels immediately adjacent.

**Figure 2. Proposed Development** ***Source: KingBlueCondos.com***

# 4. LOCATION

The site, highlighted in blue in figure 3, is three blocks north from Toronto's Roger's Stadium and CN tower (both Isherwood/Deep projects). The building faces King Street West, a major commercial thoroughfare with Toronto's busiest street car line carrying 64,000 passengers daily (TTC, 2014).

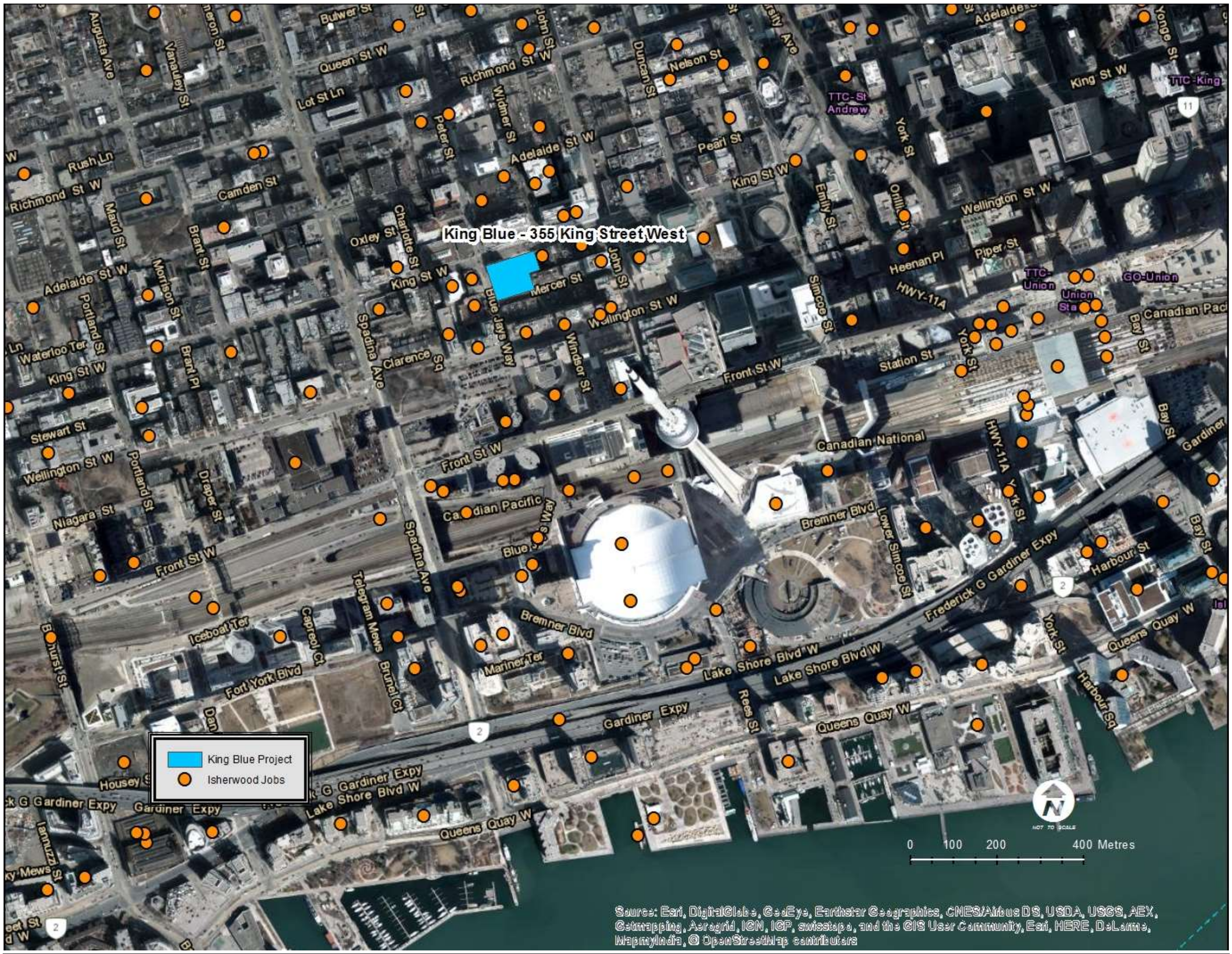

**Figure 3. Location Map**

## 5. STRUCTURAL STEEL FRAME

A temporary external frame, shown in figure 4, was designed by Structural Engineers Jablonsky, Ast and Partners to support the two historic facades.

Diligent coordination between Isherwood and Jablonsky was required throughout to ensure the geometry and foundation design could properly accommodate the loads.

It is worth noting, the authors understand that this is Toronto's tallest façade support project to date.


**Figure 4. Facade Support Frame**

# 6. GROUND CONDITIONS

## a. Geology

The bedrock underlying downtown Toronto is Georgian Bay Shale; which was deposited in an ancient sea 450 million years ago and is interbedded with limestone and siltstone (Sharpe, 1980). This deposit was compressed for over a millennium under an average one kilometer of ice, consolidating it into shale. As this ice melted the vertical stresses in the rock were relieved, but high locked-in horizontal stresses remain and must be considered in any deep rock excavation.

Current overburden (laid down in the last 2.5 million years) consists mainly of glacio-lacustrine till, and is about 6 m thick at the site. The native overburden is overlain by up to 3 m of man-made fill.

## b. Geotechnical Properties of Soil and Rock

The silty clay till has excellent stand up time well suited to wood lagging (see figure 10). High clay content in this soil reduces the effectiveness of grout/soil bond in post grouted tieback anchors. Tieback performance tests with single grout anchors indicated a working soil adhesion of 50 kPa.

Georgian Bay shale encountered at around 9 m below street grade is generally sound rock (5000 kPa SLS foundation bearing capacity) with 600 kPa working adhesion for tiebacks. It provides an excellent foundation for the CN Tower and many other tall buildings in downtown Toronto.

## c. Seasonal Effects

Toronto’s winter lasts from November to March and temperatures dip as low as -25 $^{o}$C (-13 $^{o}$F). Freezing water in unprotected soil can cause forces several times greater than the shoring system is designed to withstand. Isherwood has seen frost movements of up to 40 mm in one week and 90mm over a winter.

# 7. RESTRICTED SPACE CHALLENGES

Incorporation of heritage facades into new developments has become increasingly popular in many world cities. In Toronto, it is usual to employ a drilled soldier pile or secant caisson shoring wall immediately outside the façade with cantilevered brackets to support its weight, and an external steel frame to resist lateral and eccentric loads. A previous Isherwood/Deep project supported a four-storey façade on St. Joseph Street in this way, where we could occupy the sidewalk and curb lane for the duration of construction.

At King Blue a similar approach was contemplated. However, a study of existing utility records revealed a large electrical transformer vault occupying 7m of the sidewalk on Blue Jays Way prohibiting drilling and construction traffic access. Of more consequence were existing gas lines along both streets encroaching into the planned space for the caisson wall. The long delay and cost of relocating these services was prohibitive to the developer.

The distance between the King façade and gas line appeared to be about 800 mm. The gas line company required 300mm minimum clearance between the gas line and any drilled holes, leaving a 500mm strip in which to fit a smaller shoring system. With this consideration, the idea of using micropiles was born. Moreover, the City would not allow occupancy of a traffic lane on King Street for drill operation, because of the streetcar tracks and heavy traffic, small drills that could work within the limits of the sidewalk would be required.

## 8. MICROPILE DESIGN

Micropiles were needed to provide foundations for the steel frame and act as soldier piles for the shoring system. Based on the narrow strip available a standard HSS 356 dia x 13 section pipe was selected for all micropiles. Replacing the planned W610 soldier piles with these smaller sections required that the pile spacing be reduced from 2400 to 1500.

To convert the micropiles to act as soldier piles supporting lagging, structural steel tees were welded to their near edge as shown in figure 5. These were installed during excavation in stages to suit each lift of lagging.

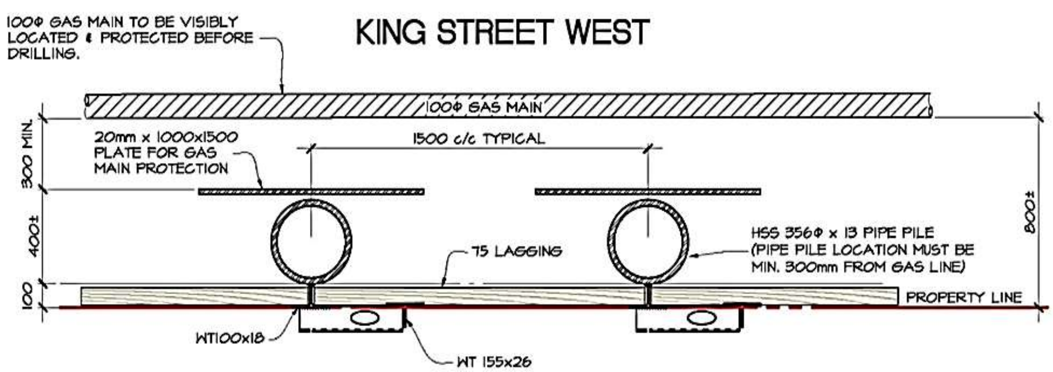


**Figure 5. Micropile/Lagging Detail**

For the outside frame support, near the curb, each leg generally required a pair of micropiles to resist wind load as illustrated on the Partial Plan (figure 6).

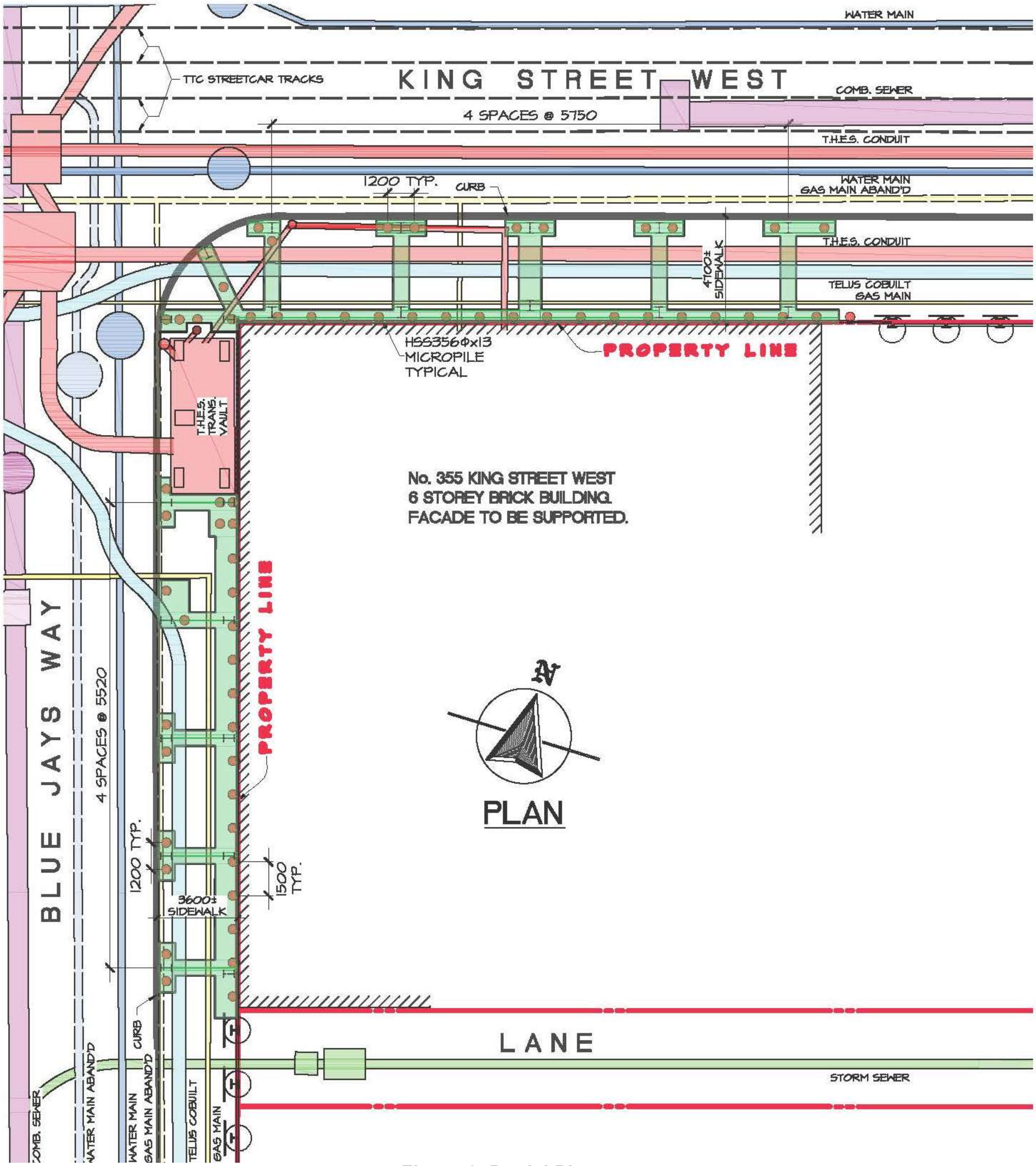


Figure 6: Partial Plan

In a case 1 micropile system, as used on this project, each pile is loaded directly and this load is resisted using the steel members and geotechnical resistance of each separate micropile (FHWA, 2005). Due to the site's high clay content, the micropile grout was gravity fed with no post grout, i.e. Type A micropiles.

The inner row of piles supporting the façade were designed for up to 390 kN of compression load due to the weight of the façade and wind loading, plus the vertical component of the soil and rock anchors. This vertical load was resisted by the 350 MPa steel casings (micropile type A2), and adhesion over the 8.5 m minimum length of the rock socket toe.

The outer row of piles at the curb were designed for up to 250 kN of compression and tension, due to wind loading on the façade, employing the same casing in a 3 m deep socket in sound rock, and then a #18 DYWIDAG Threadbar (517 MPa) advanced down another 3 m to resist tension through rock/grout adhesion. These are type A3 micropiles per FHWA (2005) and were fully encased in the ground, supporting the street side of the façade support frame.

The micropiles were capped by a grid of buried reinforced concrete grade beams set flush with the sidewalk as shown in plan on figure 6 and in section on figure 7. Those grade beams adjacent to the facades were poured directly against the exposed existing foundation walls, and connected by shear pins and pre-stressed tie rods to provide the bonding load transfer mechanism.

## 9. MICROPILE INSTALLATION

Utilities near each of the pile locations were exposed in advance by hydrovac for accurate location. Steel plates were inserted to protect the gas main, and all the holes backfilled with unshrinkable fill.

Deep Foundations chose suitable hydraulic drill rigs using a Hutte HBR 504FTW and Casagrande C7NG, both of which are capable of swiveling the drill head to work outside the tracks (see figure 8), allowing just a 100mm offset from the façade to outside of micropile holes.

Each rig worked on a separate street, with access to King via the east and Blue Jays via the south, since the large hydro vault near the corner blocked access. A Klemm KR 806-2D short-mast hydraulic drill rig was also brought in to drill underneath TTC overhead wires (4.5m headroom) at the corner of King Street and Blue Jays Way. All three drills used duplex drilling (advancing casing and drill rods simultaneously).

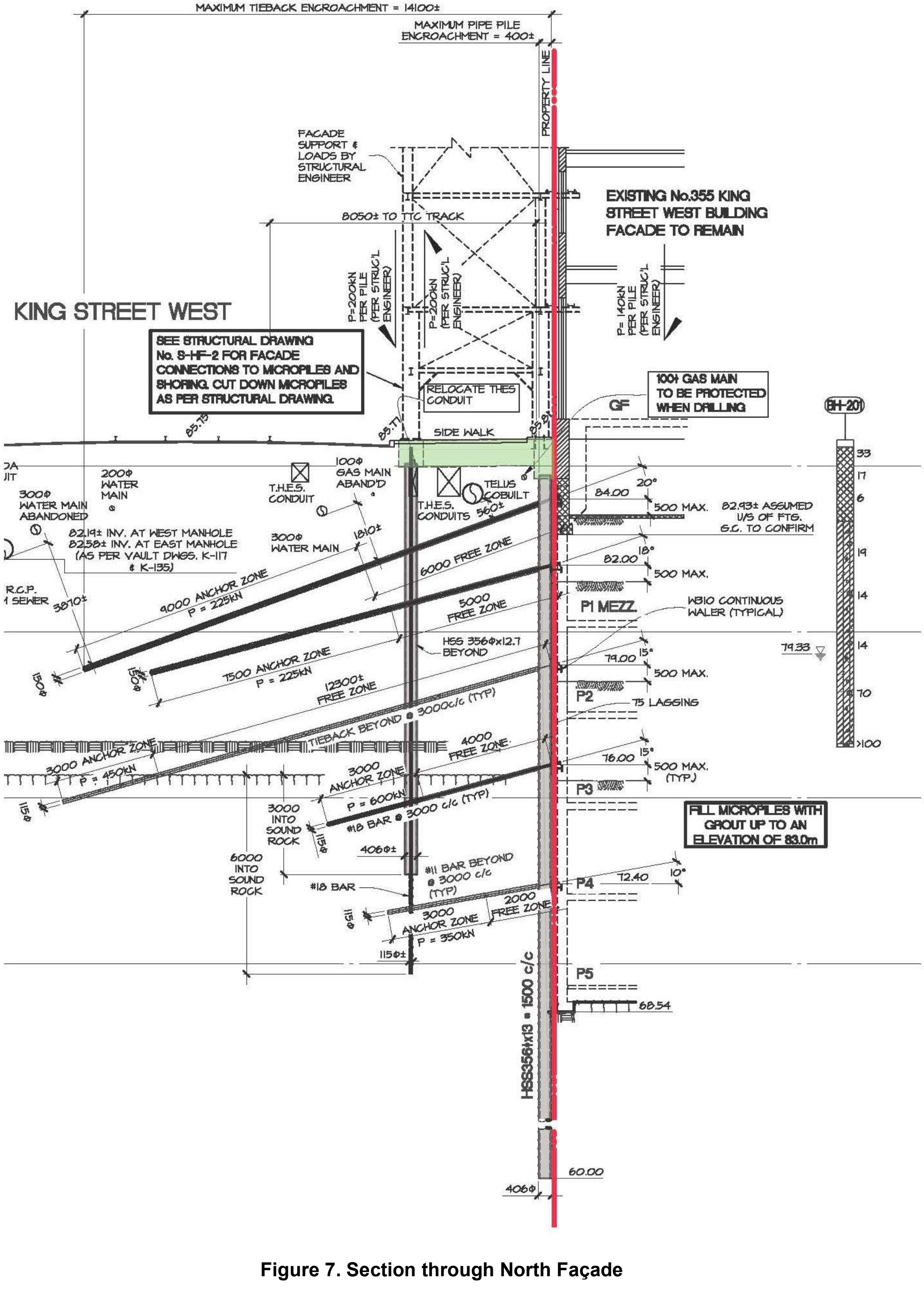


**Figure 7. Section through North Façade**

A wing bit and/or button bit (depending if the casing was to be advanced into the rock) was attached to a down the hole hammer (DTH) with a shock absorber. This tool measured over 3m in length. The Hutte and Casagrande rigs utilized 3m stainless steel single use HSS 356 dia x 13 starter casing with RH male and female threads, and 2m similar casing thereafter to the specified depths. Drill rods, HSS 219 dia (8 5/8”), were used to advance the DTH.

The Klemm utilized 1m long casing similar to above, and similar drill rods, but only 1m long, to advance the DTH. Casings were threaded together using the dual jaws of the rigs.

The tension threadbar in the curbside micropiles was installed in 3m lengths and connected by coupler.

A platform was constructed with timber mats to protect the utilities and accommodate the mobility of the rigs. Tarping of both the façade and the curbside hoarding provided protection from drilling fluids, which were collected and disposed off-site by means of hydrovac (see figure 9). Concrete was pumped to the drillhole locations due to tight site constraints.

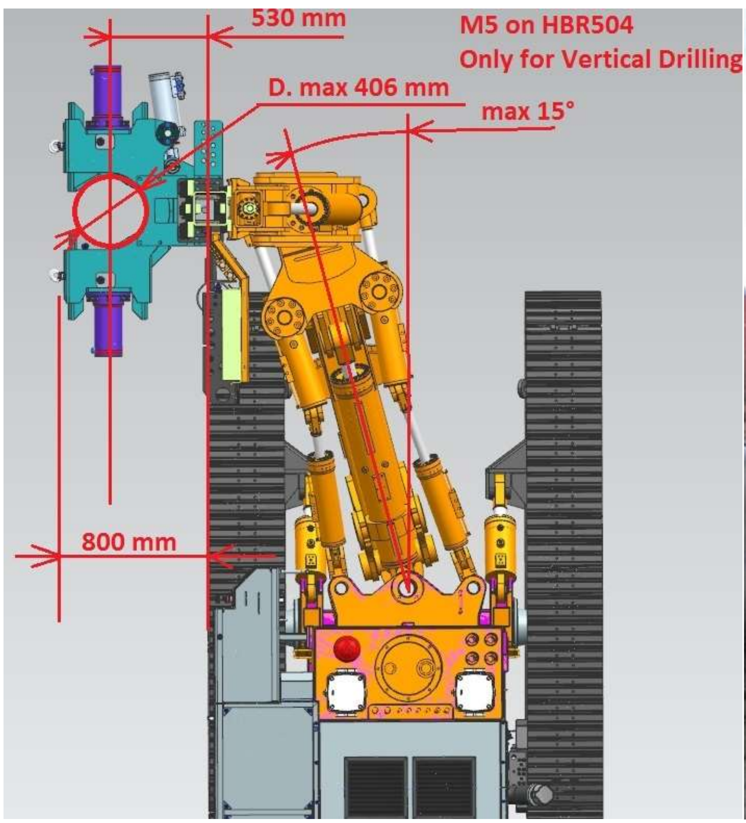


Figure 8. Hutte Swivel


Figure 9. Drilling against the Façade

## 10. EXCAVATION

Concurrent vertical drilling with conventional large diameter rigs operating from within the remainder of the site (beyond the Westinghouse building) was started for soldier pile and lagging shoring at the streets, and secant caisson walls for additional stiffness at existing neighbouring buildings.

Vertical drilling of micropiles and 1 metre diameter shoring piles began in September 2015 and were completed in January 2016, ready for the façade support frame to be installed and demolition to commence.

Originally seven underground parking levels were planned for the site. This was reduced to five levels during further design developments after most of the vertical drilling was complete.

Excavation and anchor installation began in May 2016. Tees welded to the micropiles allowed use of lagging in a shored face indistinguishable in appearance from standard piles and lagging (see figure 10). The narrow bays and stable clay soils permitted deeper than normal lifts for lagging installation.

Lateral bracing was provided by soil and rock anchors at shallow angles to reduce the additional vertical load added to the compression micropiles (see figure 7). The interaction between compression and bending was checked for each unbraced length of pile at each excavation stage.

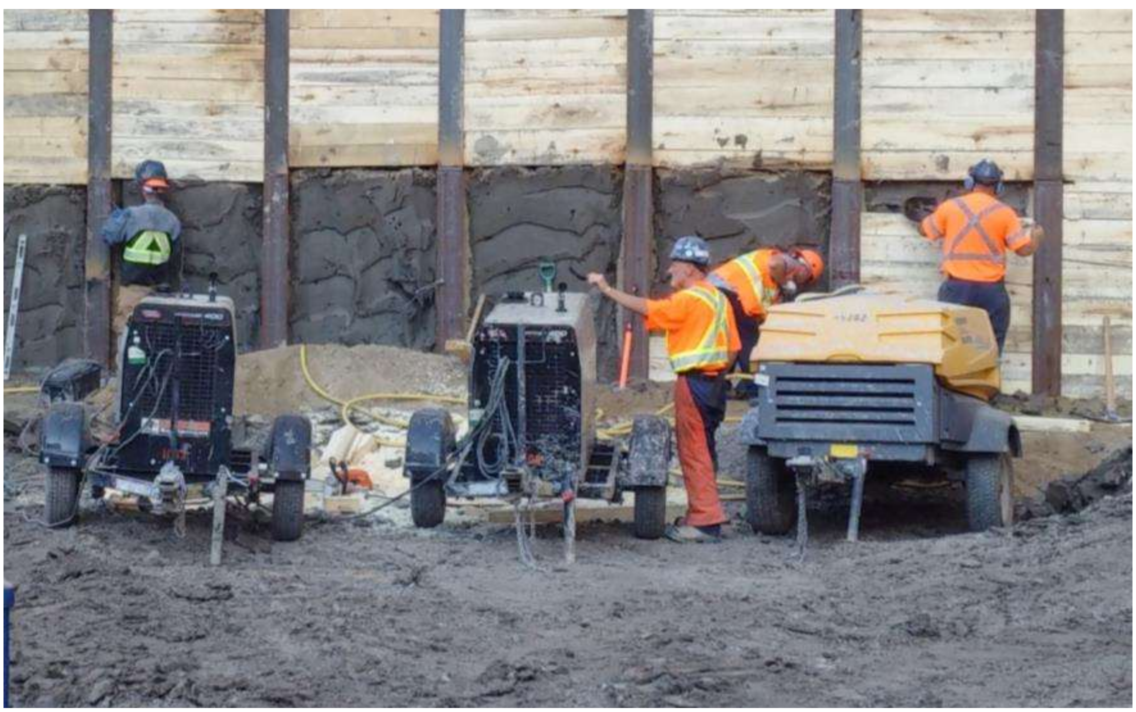

**Figure 10. Silty Clay Till Bays ready for lagging**

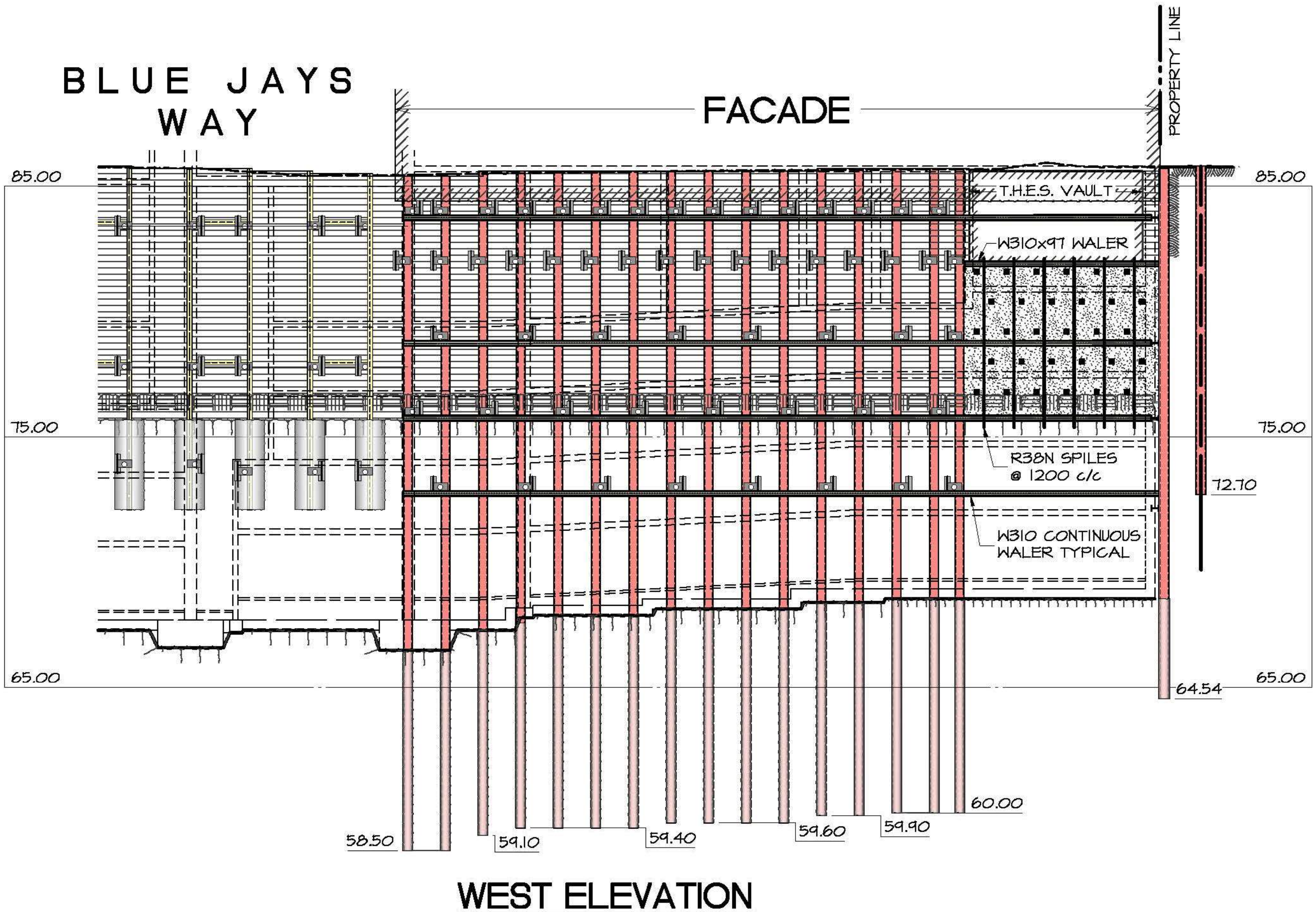


**Figure 11. West Elevation**

## 11. ELECTRICAL VAULT

As micropiles could not be installed at the 7 m long electrical transformer vault this area was bridged by the steel frame. The ground below it was supported with sprayed shotcrete, braced by soil nails at 1200 mm centres horizontal and vertical, and reinforced with inclined spiles, also at 1200 mm spacing, and drilled into sound rock (see figure 11).

The photo below (figure 12), taken when excavation reached the rock surface, shows the final lift of shotcrete being sprayed below the vault and the anchor system used. At the north wall a welder is installing the next section of structural tees, preparatory to lagging installation.

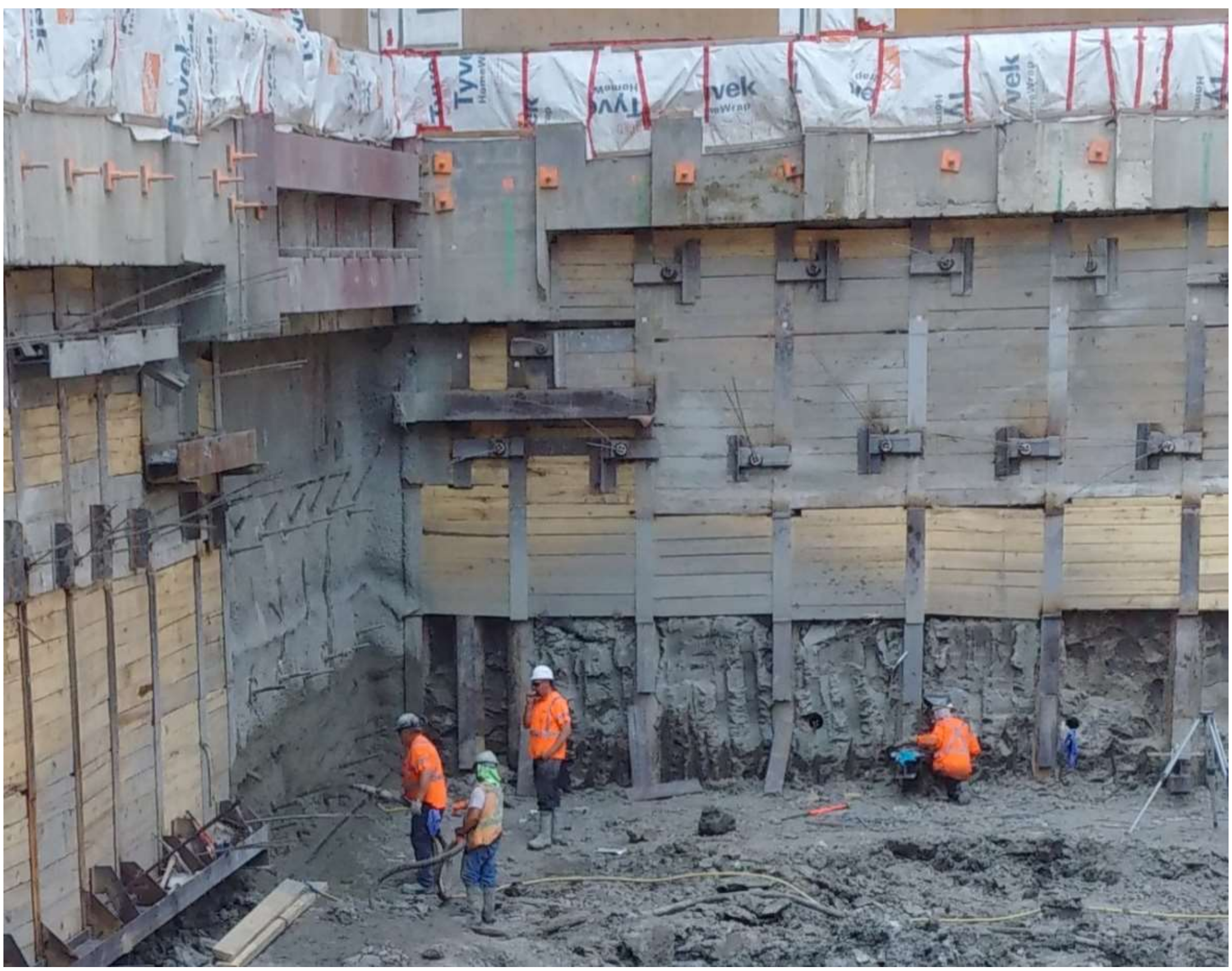

**Figure 12. Welding Structural Tees to Exposed Micropile Casings**

## 12. COMPLETED FAÇADE SUPPORT

Final excavation grade was reached in November 2016. Figure 13 shows the supported facade from inside the site. It also shows the frost protection blankets installed below the façade in early November. Construction of the new basements back to road grade is scheduled for completion in June 2017.

The new basement walls will directly underpin the heritage walls, transferring weight to the new structure. The steel frame will remain in place until construction reaches matching height.


**Figure 13. Frost Protection under the Façade**

## 13. MONITORING

A detailed monitoring plan was developed to verify the shoring and façade support performance including a combination of monitoring types. Inclinometer and Precision Survey Target locations are marked in the Monitoring Plan in figure 14.

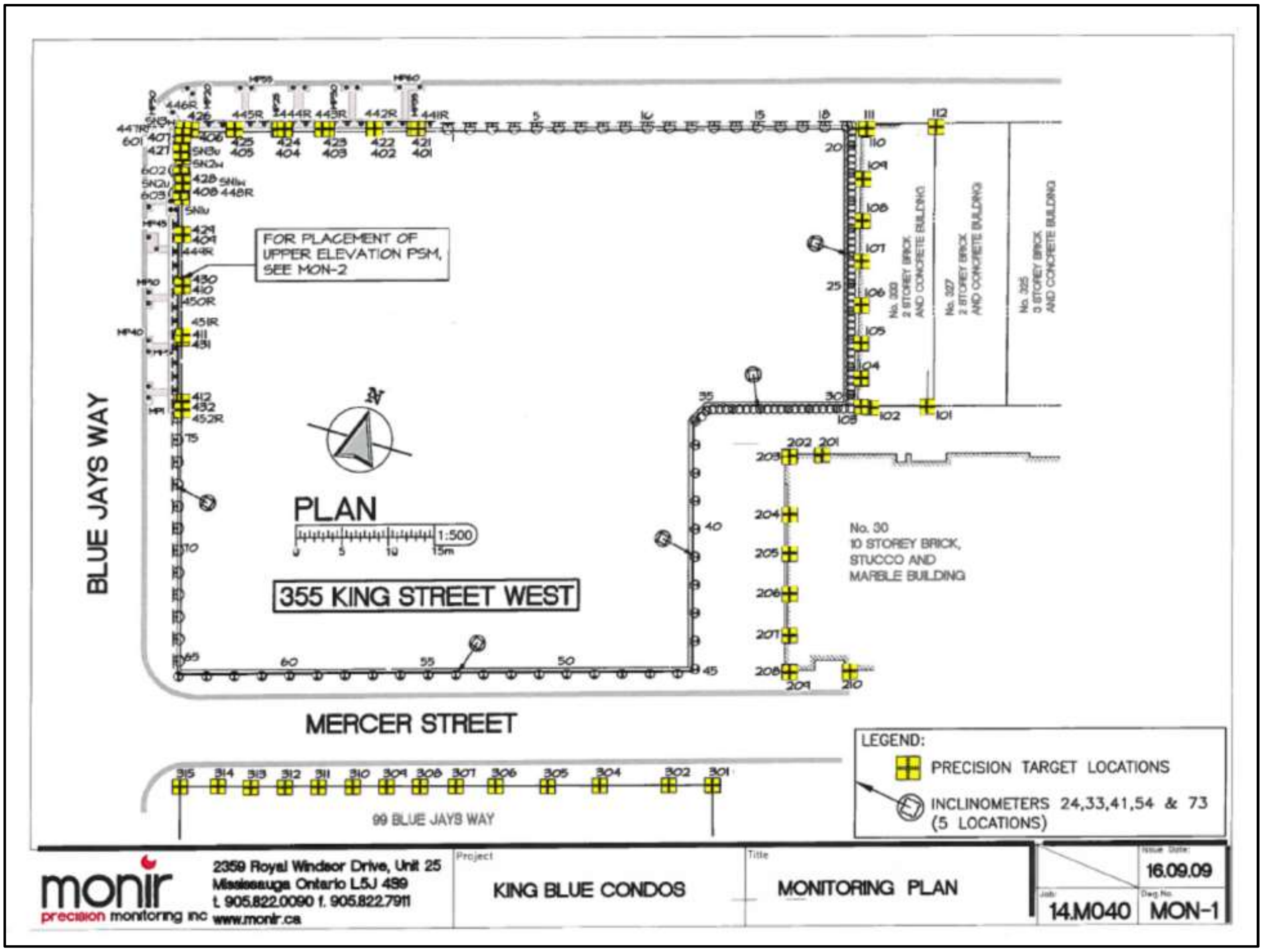


**Figure 14. Monitoring Plan**

### a. <u>Monitoring Types</u>

Precision Survey Monitoring (PSM) targets were placed on the Westinghouse façade at 5 to 6 m spacing to measure horizontal and vertical movements. Targets were located in two rows along the bottom and mid height of the façade. PSM targets were also installed on the transformer vault shotcrete wall and neighbouring structures within the zone of influence.

Pile Target Monitoring (PTM) targets were installed at the top of every shoring pile during the first lift of excavation.

Five Pile Inclinometers were installed on conventional steel soldier piles at various locations around the site but could not be used at the façade support.

### b. Monitoring Performance

At the time of preparing this paper the site had been dug to final excavation grade and build out had reached the third basement level. Figure 15 shows current PTM and PSM readings along the façade. Pile target monitoring indicates acceptable shoring performance with movements within the anticipated range. The façade wall shows the least movement at the site corner where it is naturally stiffest. Into site façade movement increases with distance from the corner, reaching a maximum of 38mm, and appears to be independent of micropile movement. Such movement was not predicted, but was deemed to be acceptable by the Structural Engineer.

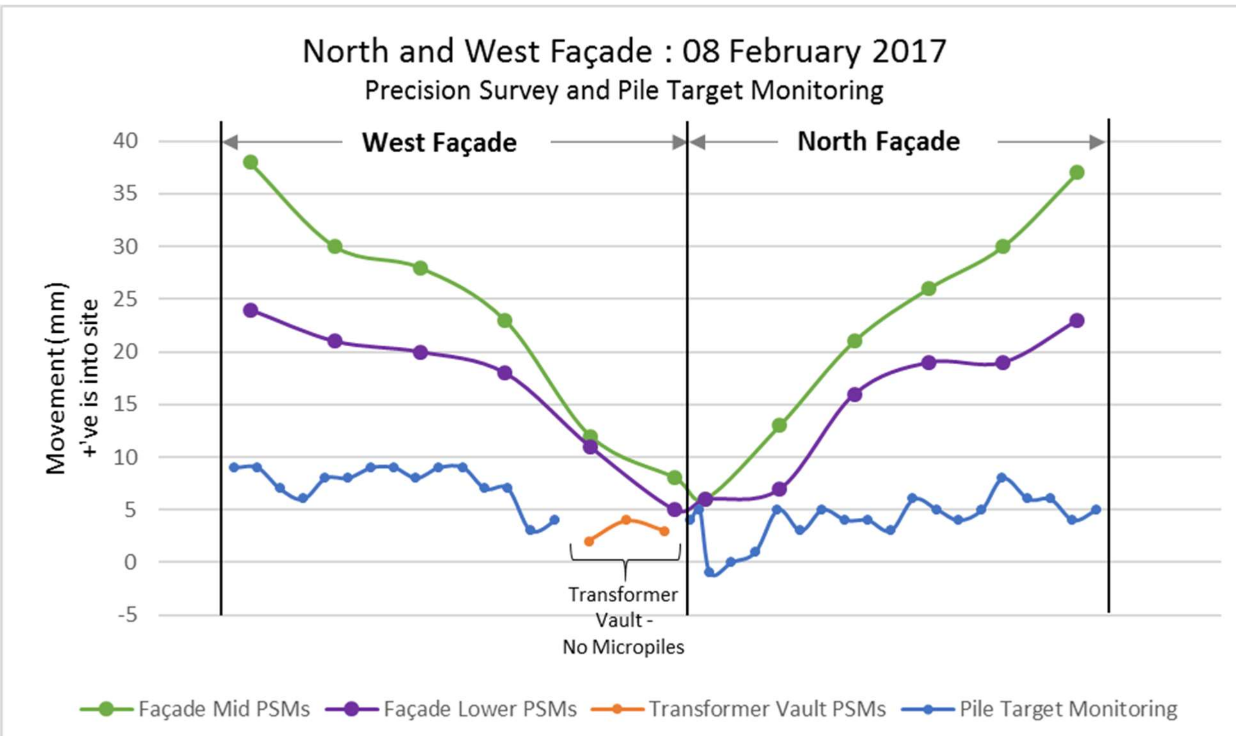


**Figure 15. Monitoring Results**

## 14. SUMMARY

Case 1 micropiles were successfully used to replace traditional shoring when inner city congestion precluded large diameter drilling.

In a hybrid system, these piles were to resist tension and compression loads as a foundation for a temporary steel frame façade support, along with bending moment from lateral earth pressure.

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