THE BENEFITS OF AN EARLY CONTRACTOR INVOLVEMENT FOR A MEGA PROJECT IN SAN FRANCISCO

Robert Small, Malcolm Drilling Co., Inc., Hayward, CA, USA, 510-780-9181,
rsmall@malcolmdrilling.com
Ihab Allam, Malcolm Drilling Co., Inc., Hayward, CA, USA, 510-780-9181,
iallam@malcolmdrilling.com
Amshu Chappa, Brierley Associates, Moraga, CA, USA, 925-247-9000,
achappa@brierleyassociates.com

ABSTRACT

San Francisco Public Utilities Commission (SFPUC) is a department of the city that provides drinking water and wastewater services to San Francisco. The $2 Billion Biosolids Digester Facilities Project (BDFP) will upgrade and modernize the existing facilities at their Southeast Treatment Plant (SEP), which services over 80% of the city's wastewater, by reducing odors in the surrounding neighborhoods, designing for future earthquakes and sea level rise, and ensuring operational redundancy and efficiency for decades to come.

The project required participation of Local Business Enterprises (LBE) and Disadvantage Business Enterprises (DBE) therefore helping the local economy and its residents.

SFPUC decided to use an alternate delivery method to leverage the expertise of the entire construction industry by engaging Trade Core partners at a very early stage in the design process. Malcolm Drilling was chosen to be the Foundation Core Trade partner after an intense pre-qualification process. Our expertise for various deep foundation and support of excavation methods helped the designer to optimize two large excavations in difficult ground conditions and in close vicinity to an active railroad. Our scope of work included the installation of Cased Drilled Shafts, Continuous Flight Auger Piles (CFA), Cutter Soil Mixing (CSM), Diaphragm Walls, Tie-Downs, Tiebacks, Internal Bracing, Mass Excavation, Shotcrete, Demolition and Dewatering. We were also responsible for site access and the required logistic to handle up to 80 concrete trucks coming into the site and the same amount of spoil trucks leaving the site on a daily basis with only one entry and one exit point.

This paper highlights the benefits of early involvement of a specialty contractor in a very complex project. The interaction with the owner's design and management team during the pre-construction phase enabled the project team to apply the most modern and efficient construction techniques proposed by the contractor. Significant cost and schedule savings made this a very successful project for all stakeholders.

Keywords: core trade partner, shoring design, diaphragm walls, tiebacks, construction, young bay mud

INTRODUCTION

The Biosolids Digester Facilities Project (BDFP) is located in the southeast part of San Francisco, CA, at 1800 Jerrold Avenue. The jobsite is bounded by the active Caltrain and Union Pacific Railroad tracks on the west side and the existing Southeast Treatment Plant (SEP) on the north, south and east sides, as shown in Fig. 1 below. The existing SEP was constructed in the 1950s and portions of the facility have reached their operational life. The $2 Billion BDFP will replace and relocate the outdated existing solids treatment facilities with more reliable, efficient, and modern technologies and facilities. In addition, the nearby Bayview and Hunters Point neighborhoods will benefit from the improved odor control.

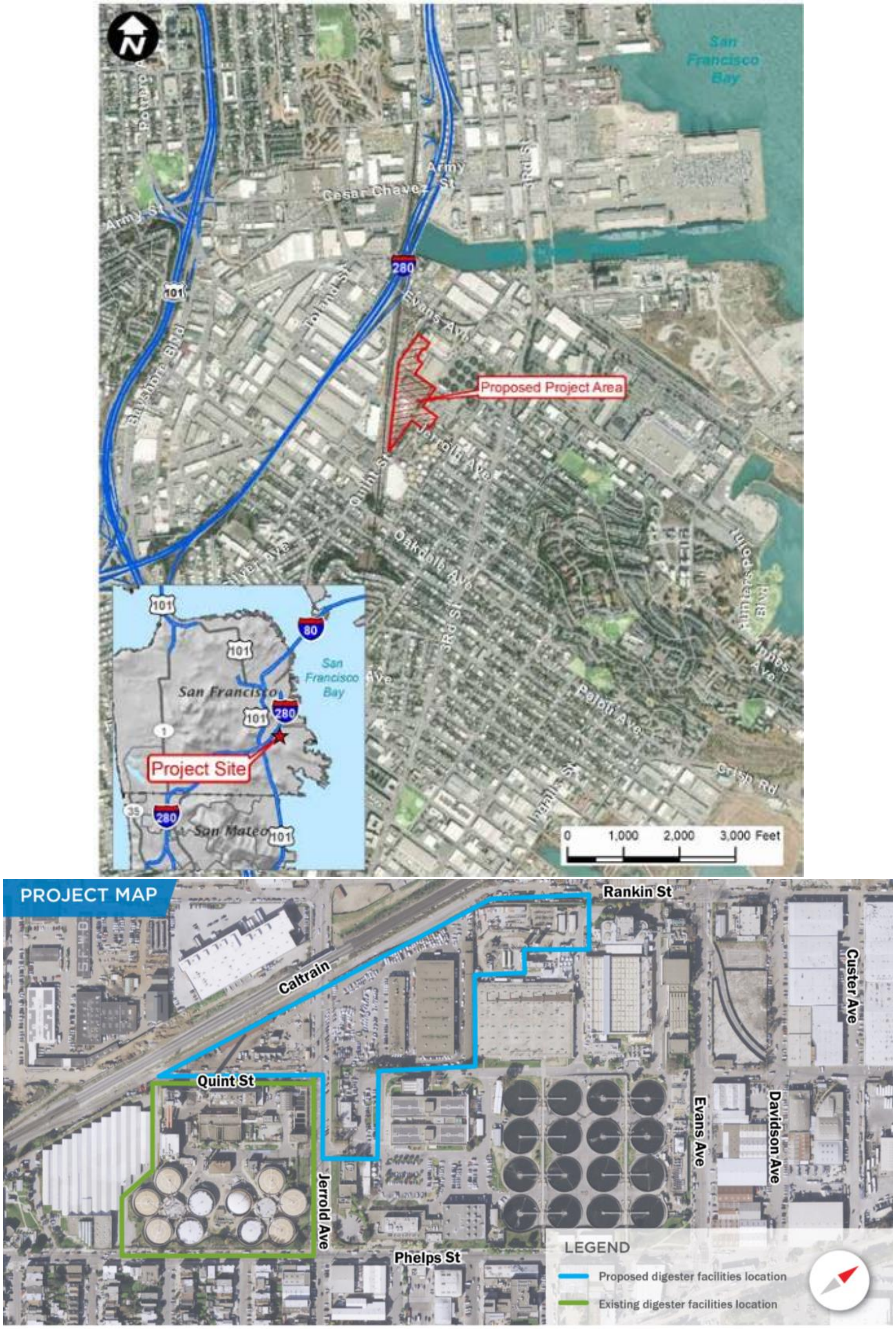

Fig. 1. Jobsite Location Maps

CORE TRADE PARTNER

In 2017, the San Francisco Public Utilities Commission (SFPUC), the owner of the project, selected MWH/Webcor, a Joint Venture, as the Construction Manager General Contractor (CMGC) for the project. As part of an alternate delivery method set forth in the prime contract, the CMGC was permitted to propose the use of a Core Trade Subcontractor Partner for the SFPUC's approval to provide pre-construction services. The CMGC identified three major scopes (Electrical, Mechanical & Foundation) where a Core Trade Partner would be able to assist the project in design-build, design-assist, value engineering, and/or other necessary pre-construction activities. In 2018, Malcolm Drilling Co., Inc. (Malcolm), was approved by the SFPUC and brought on board as the Foundation Core Trade Partner.

Malcolm participated in weekly meetings with the CMGC, SFPUC, and the SFPUC's Design Team to provide value engineering on several major scopes of work. Malcolm proposed Continuous Flight Auger (CFA) piles at certain structures, in lieu of the more traditional drilled shafts, which brought immediate schedule and cost savings to the project. In order to verify the capacities of the CFA piles and drilled shafts, Malcolm performed an early-work onsite load test program, which gave the SFPUC Design Team confidence in the pile foundation selection.

Malcolm also provided guidance on the selection of temporary shoring systems to be utilized at the two major excavations (Facility 610 and Facility 600). Several Cutter Soil Mix (CSM) shoring wall options utilizing Deep Soil Mixing or even Jet Grouting Plugs as well as deeper Secant Piles walls were considered. Initially, a 70 ft deep CSM shoring wall was envisioned for both excavations, however after reviewing the available geotechnical information it was uncertain if the wall would be deep enough at the Facility 610 to provide effective groundwater cut-off. As part of another early-work onsite test program, Malcolm installed and performed a pump test program to provide the Design Team with more information about the groundwater conditions. It was discovered that two underground aquifers (one at 40 to 60 ft below grade and another at 80 to 100 ft below grade) were connected and that a 70 ft deep CSM wall would not provide an effective cut-off to control groundwater drawdown outside the excavation.

Due to the close proximity of two nearby active railroad lines, the project could not utilize a shoring system that might allow uncontrollable drawdown outside the shored excavation. Options for a drilled secant shoring wall and a temporary diaphragm shoring wall were evaluated since they could both reach greater depths than the CSM wall option. Ultimately, a temporary diaphragm shoring wall was selected for the shoring system at Facility 610 due to the faster install time, greater depths it could penetrate, and its ability to meet strict deformation criteria.

EXISTING SITE AND SUBSURFACE CONDITIONS

The project site is located within the Hunters Point Shear Zone. The project site is generally level at about elevation +3 ft and the ground water level was observed at a depth varying between 7 to 12 ft below existing grade, although the piezometric head in the deeper soil strata is generally higher than the unconfined near surface groundwater level. In general, the geologic units encountered at the project site consisted of Artificial Fill (af) extending to a depth ranging from 10 to 18 ft. The fill includes boulders, cobbles, rubble, concrete and existing foundation piles extending to a depth of approximately 40 ft.

The fill is underlain by Young Bay Mud (Qybm) that extends up to 55 ft below ground surface. The Young Bay Mud is a primarily soft to very soft clay with scattered organics and is highly compressible.

Upper Layer Sediments (Quls) are located below the Young Bay Mud and extend to a depth of up to 180 ft and consist of interbedded sands and clays.

Old Bay Clay (Qobc) is stiff to very hard fine-grained soil that underlies the Upper Layer Sediments and extends to as much as 230 ft below ground surface.

Older Colluvium (Qoc) and Franciscan Complex (Kjf) are found at great depth below the site. Fig. 2 is a representative subsurface profile.

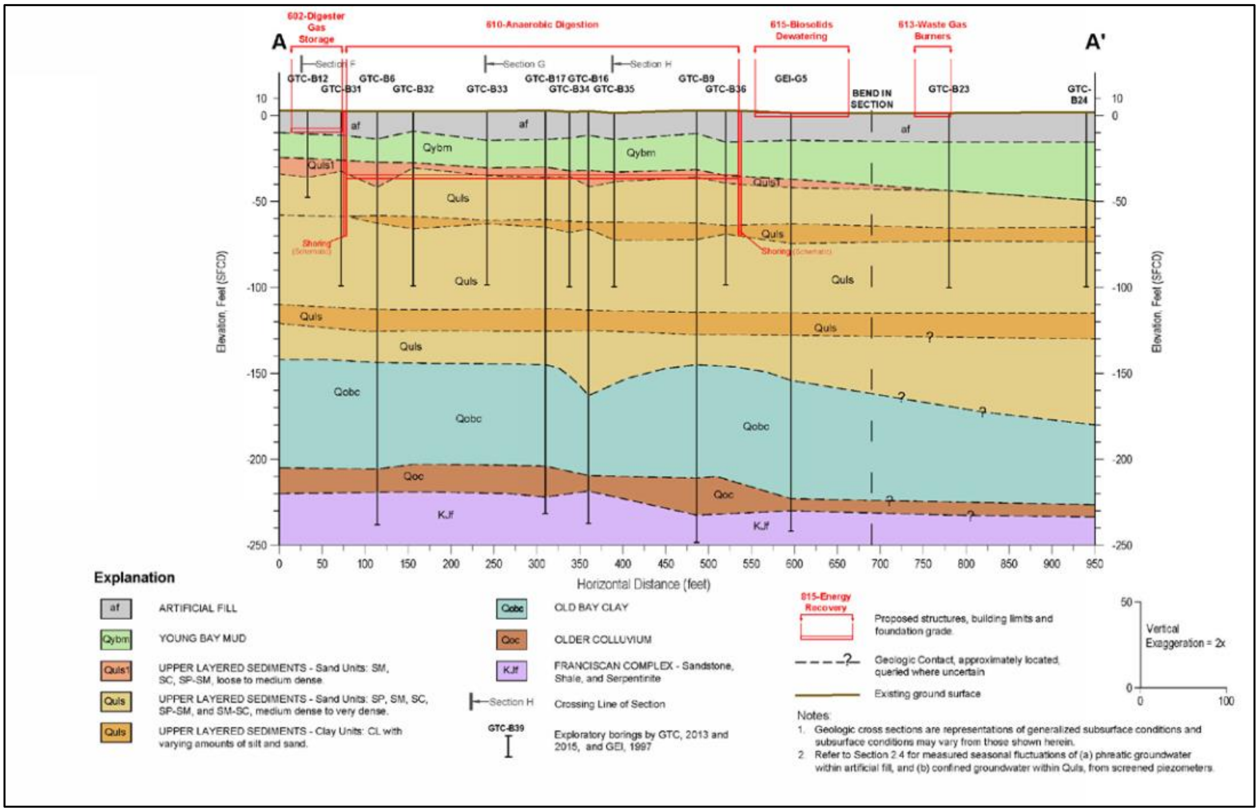

Fig. 2. Subsurface Profile

DESIGN AND CONSTRUCTION CONSIDERATIONS

Facility 610 Shoring and Excavation

The Facility 610 Anaerobic Digestion structure consists of five digestion tanks which extend from a lower basement level that is approximately 34 ft below grade to maximum height of approximately 65 ft above grade (see Fig. 3). Because the excavation is approximately 40 ft deep with numerous site constraints, including two adjacent railroads that could not be impacted by the construction, a rigid shoring system was required. Excavation extended through the artificial fill and Bay Mud and bottomed out in the Upper-Layered Sediments. In order to ensure bottom cutoff, the perimeter shoring wall was extended 160 ft below grade to penetrate into the relatively impermeable Old Bay Clay for a bottom seal.

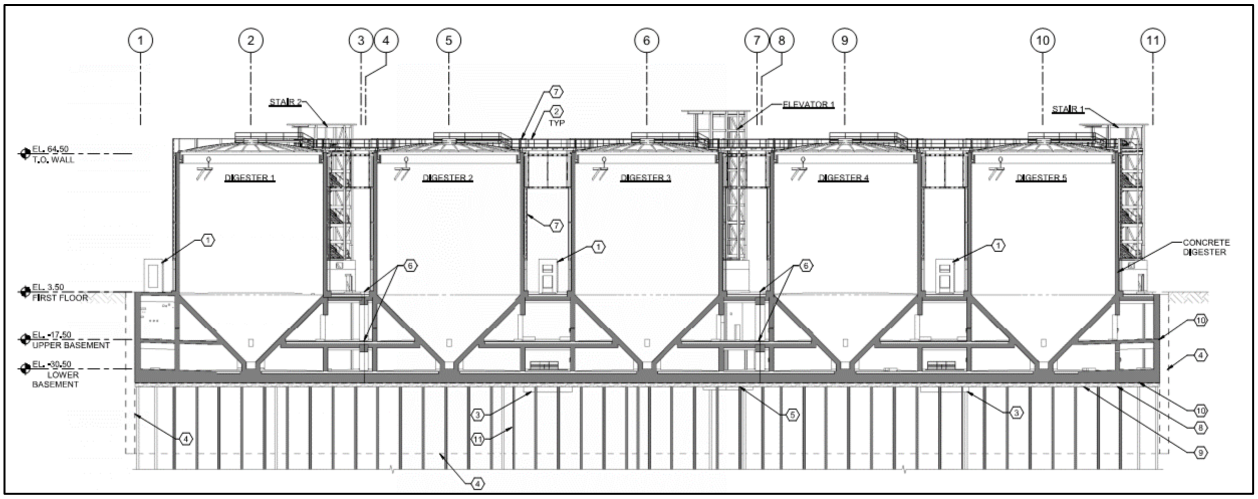

Fig. 3. Profile view of Facility 610

Design and Construction of Excavation Support System

The design and construction of the shoring system navigated several site constraints to ensure the constructability of the tieback/bracing system and the ability to perform the excavation efficiently. The geometry of the excavation would have been ideal for an internally braced shoring system to avoid possible tieback conflicts beyond the structure. However, block-outs through the cast in place digester tanks were not allowed, and the size and shape of the tanks would have required excessively large spans for the internal bracing that could not meet the tight deformation criteria. Other challenges included: high groundwater levels (excessive drawdown outside the excavation was not permitted), very soft and compressible Young Bay Mud, and protecting the active rail lines to the west. The support of excavation system had to be coordinated with existing and new adjacent structures including the existing sewer vault and a forest of piles for new structures and improvements surrounding the Facility 610 excavation. The tieback locations and orientations had to be coordinated to address these constraints.

The constructability at the interfaces of Facility 610 and adjacent facilities (661and 615) and conflict with the existing sewer vault on the western boundary was challenging and special bracing details were developed at these select locations. A supplementary waler detail was added so that tiebacks could be lowered below the deep sewer vault and walers were also added to span the opening at Facility 661.

Fig. 4 shows the shoring system with the excavation at full depth at Facility 610. The 41.5 ft deep excavation is supported by a 3 ft thick, rebar-reinforced diaphragm wall (D-Wall) which is typically restrained by three levels of tiebacks, although localized bracing was used to work around conflicts as noted above. Fig. 5 presents a typical section view of the shoring system at the western side of the site.

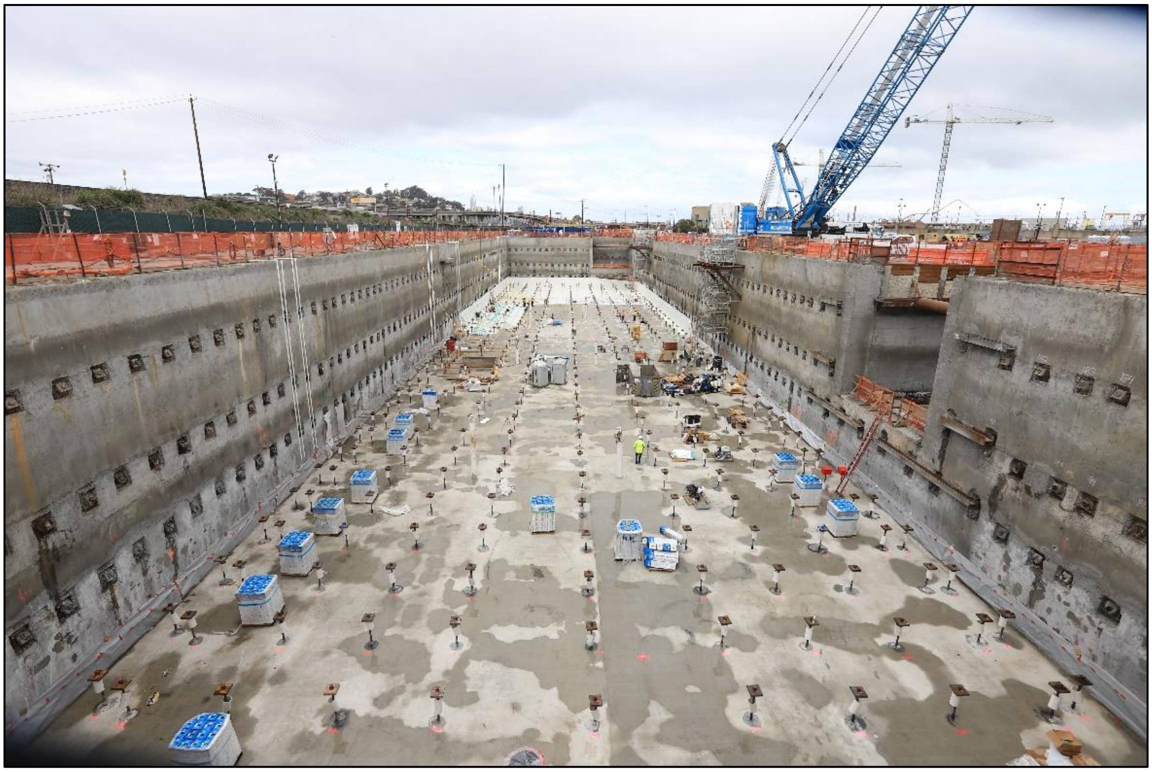

Fig. 4. Shored Excavation at Full Depth

The primary wall panels were excavated by mechanical and hydraulic grab as well as hydro cutters mounted on a Bauer base crane MC96. To ensure verticality and watertight joints, the hydro cutter was used to excavate each secondary panel with real time verticality monitoring. A support fluid processing system maintained the fluid properties required to stabilize the trench excavation and recycle the fluid as concrete was placed. The primary panels were typically 22 ft-4 in long and were excavated in three bites. The one bite secondary panels were cut into the previously constructed primary panels. The diaphragm wall was designed to act both as a structural wall and to provide groundwater cutoff. The wall extended to a depth of 158.5 ft below existing grade.

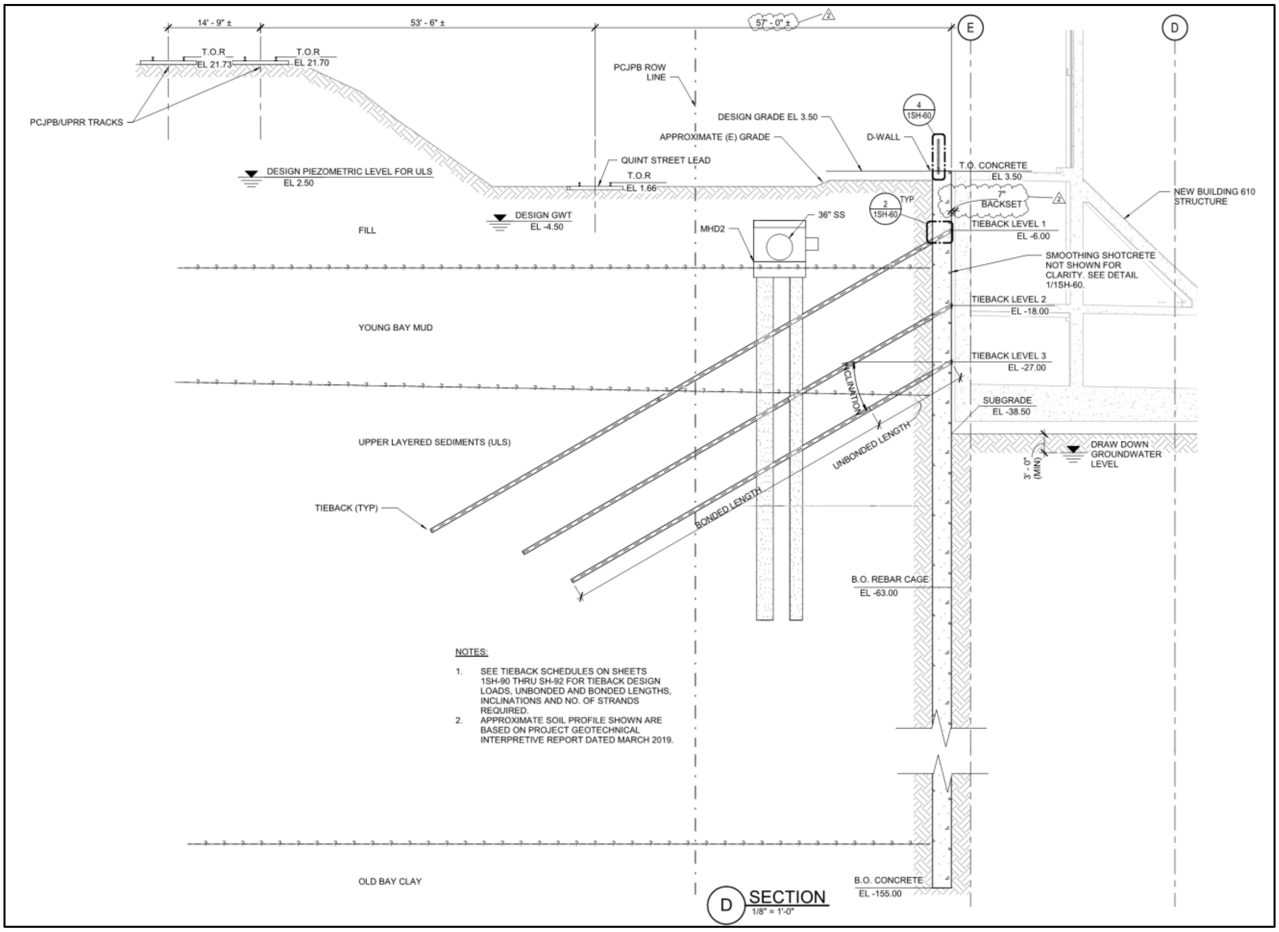

Fig. 5. Typical west wall section of D-Wall Shoring System with tiebacks

Tiebacks were typically installed at 5 ft on center and had design loads of 180 kips at Level 1, 205 kips at Level 2 and 245 kips at Level 3. The tiebacks were installed at 30-degree angles with sufficient unbonded length such that bond zone reached the competent Upper Layered Sediments that are below the Young Bay Mud. Bond capacity was confirmed with field proof tests. The tieback tendons varied from 5 to 10 high-strength strands depending on the tieback design load. The tiebacks were installed through pipe block-outs that were pre-tied in with the diaphragm wall rebar cages. The north-east corner bracing at Level 3 was required to avoid conflict with future permanent piles at the adjacent structure. The typical bracing consisted of HSS20 pipe struts at this location.

Drilling the Level 2 and Level 3 tiebacks (see Fig. 6) below the ground water table and risking excessive water and soil inflow to the excavation was a challenging part of the construction. However, Malcolm used a wall mounted preventer system and developed cased drilling and grouting techniques to minimize the amount of soils and water that entered the excavation during the tieback install. Ultimately, hydroactive grout was pumped into the locked-off tieback wedge plate to stop the leaking water.

Fig. 6. Level 3 Tieback Drilling

All the tieback anchors were designed to avoid the future 36-inch sewer line foundation piles on the west side and drilled shaft permanent foundation piles of adjacent buildings around the entire perimeter of the excavation. It was very important that the drilled shaft foundation piles were installed first in order to avoid the risk of drilling through tensioned tiebacks. Fig. 5 above shows a section view of the D-Wall along with west side with tiebacks navigating existing sewer line pile foundations and being drilled below the adjacent railroad embankments.

The process of locating the tiebacks had to be iterated several times to yield an efficient design in conjunction with the ongoing design of the adjacent structure piles. See Fig. 7 below, showing a partial plan view of the diaphragm wall and the 100 ft long tiebacks that had to be drilled straight in order to miss the already existing pile foundations.

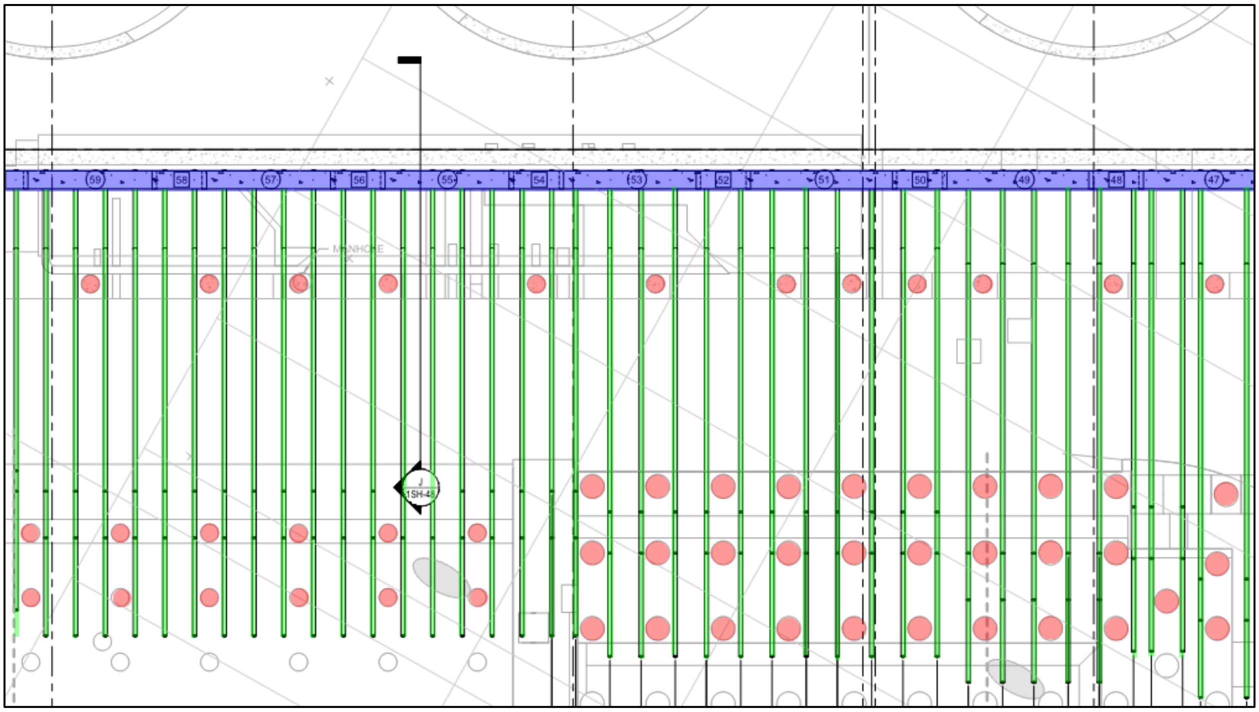

Fig. 7. Plan view of diaphragm wall and designed tieback locations relative to existing pile foundations.

Because the construction sequence for the adjacent buildings was uncertain at the initial phase of the design, the Facility 610 system had to be designed such that all structures could be excavated at the same time, which was extremely challenging due to the complex interaction between the adjacent excavations.

Monitoring and Performance criteria

Movement of the top of slurry wall was monitored on a weekly basis using optical survey techniques. Approximately 40 survey monuments were mounted on top of the diaphragm walls at 40 ft maximum spacing. Six inclinometers were installed around the perimeter of the Facility 610 excavation as shown in Fig. 6. The inclinometers were read manually every week and interpretations of the data was calibrated against deflections measured at the nearby survey monuments.

The contract specifications set threshold horizontal deflections limits of the diaphragm wall at 0.5 inches with a maximum movement limit of 1.0 inches. The baseline measurements were established prior to excavation and monitoring will be continued until the structure is constructed to grade. The survey data was made accessible to the contractors, engineers and other stakeholders.

Groundwater outside the excavation was monitored via manual reading of four multi-level piezometers installed in four boreholes around the entire site with two boreholes closer to Facility 610 that monitored groundwater levels within the Young Bay Mud and Upper-layered Sediments. The dewatering within the excavation footprint did not lower the groundwater more than 5 to 6 ft outside the excavation.

At the time of preparation of this paper, build-out of the basement was underway and lateral deflections had been limited to approximately 0.5 inches or less. The as-built deflection numbers were comparable to estimates made during the design process.

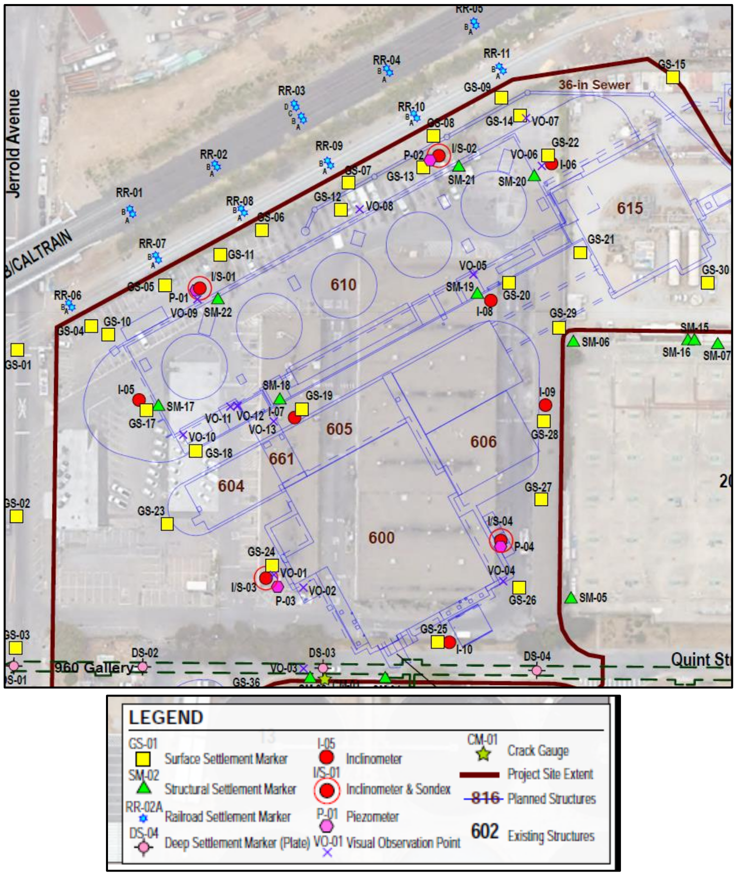

Fig. 8. Instrumentation Plan (Terra Engineers, Inc.)

Construction Verification

The diaphragm wall concrete was specified to have a minimum unconfined compressive strength of 5,000 psi at 28 days. Cylinders were taken from each concrete panel for UCS testing from both pre-production and production wall panels to confirm that the design strength was achieved.

To check the verticality of the excavated wall trench, survey of all the panel excavations was performed using the Koden test. The support fluid properties were monitored during excavation and prior to concrete placement by the field engineers using American Petroleum Institute (API) standard procedures. The concrete level was measured by soundings using weighted tapes after every three trucks discharged (one truck for secondary panels) to monitor concrete volume.

For the west side of the project, where tiebacks encroached on the railroad easement, the first three tiebacks and ten percent remaining tiebacks were performance tested and all other tiebacks were proof tested. For all other sides of the excavation a minimum of the first two tiebacks and two percent remaining tiebacks were performance tested and all other tiebacks proof tested. All tiebacks were required to be de-tensioned during the Facility 610 build-out, so future construction around the excavation would not encounter a locked-off tieback.

CONSTRUCTION

Mobilization and Site Utilization

Logistics was a primary challenge for the construction of this project due to multiple concurrent activities to meet the project schedule. In addition to the diaphragm wall construction on this project, Malcolm also installed 290 each 3 ft and 4 ft diameter auger cast piles, 233 each 4 ft diameter cased drilled shafts and 526 each 1 ft diameter tie down anchors. For 3 shallower structure excavations (up to 26ft in depth), Malcolm installed a Brierley Associates designed, temporary CSM shoring wall which was supported by 1 level of internal bracing. Over 50 dewatering wells were installed by Malcolm to manage and treat the groundwater at the various excavations.

The site configuration including access/egress, installation sequence, and support equipment layout was carefully planned prior to mobilization. The general site configuration is shown below in Fig. 9. Onsite daily meetings included all drilling superintendents and subcontractors to plan the next day's activities, and a unique coordination map was created each day to reflect the new work areas. This level of coordination was required to manage the large site and ensure that spoils were efficiently off-hauled and ready-mix concrete made on time deliveries to drilling locations. At the peak, 80 trucks of spoil were being loaded out while 80 trucks of concrete were being delivered to the jobsite daily.

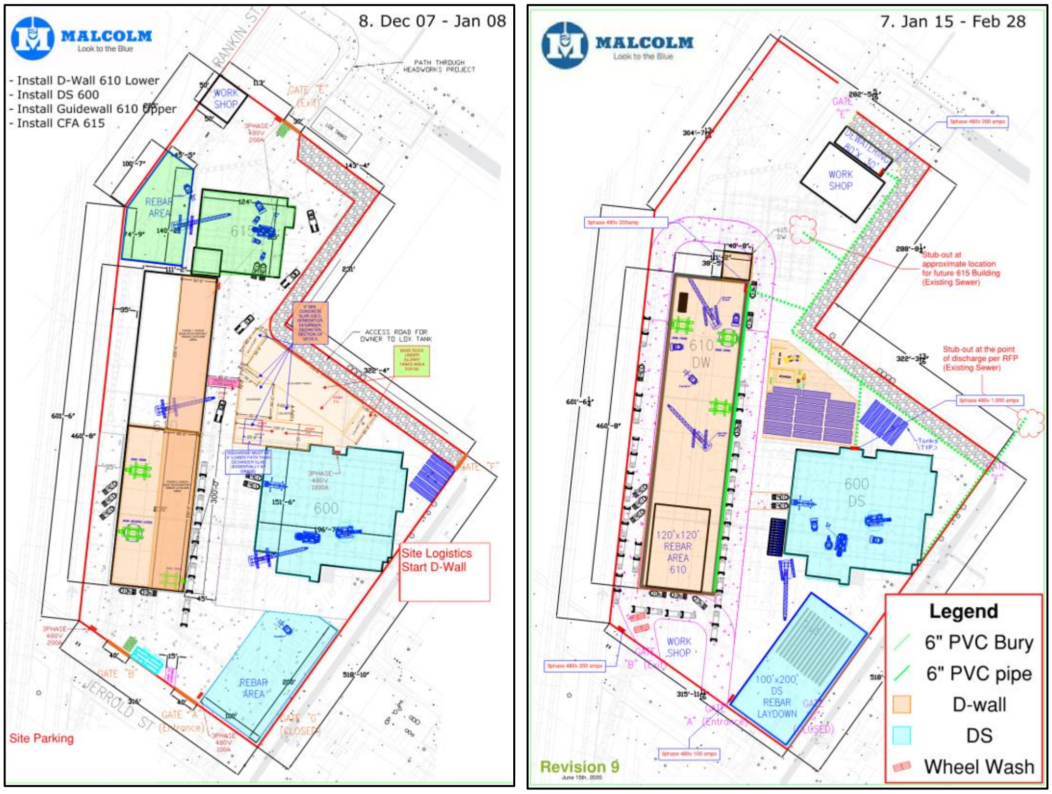

Fig. 9. Malcolm Logistics Plans to manage work flow

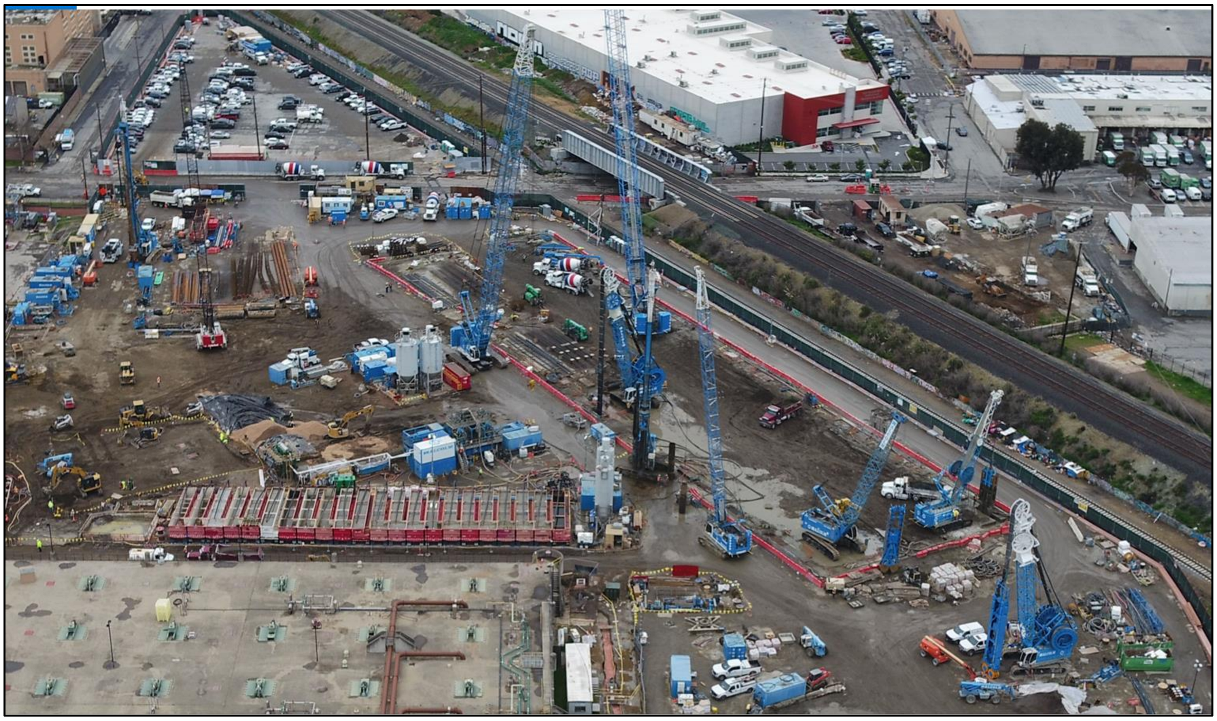

Fig. 10. Photo of actual site construction during D-Wall installation

The equipment used to install the diaphragm wall included a Bauer BC40 Hydro cutter mounted on a Bauer MC96 crane, one hydraulic grab mounted on a MC64 crane, one mechanical grab mounted on Liebherr HS 885, one 300T class support crane, one 150T class support crane, a Bauer BE550 Desander unit, a centrifuge, and (22) 21,000-gallon open top mixing tanks (see Fig. 10 above).

Diaphragm Wall Construction

Temporary reinforced concrete guide walls were constructed along the alignment of the diaphragm wall to be utilized as a guide for the excavation equipment and the setting of the rebar cages. The guide walls consisted of two parallel reinforced concrete beams that were 1 to 2 ft wide by 3 to 4 ft deep. Extremely high levels of accuracy and quality control for the guide wall construction are critical as they are used to maintain diaphragm wall panel verticality, location, and rebar cage elevation control. The top of the guide wall was also used for the installation of hard survey control points for the diaphragm wall construction.

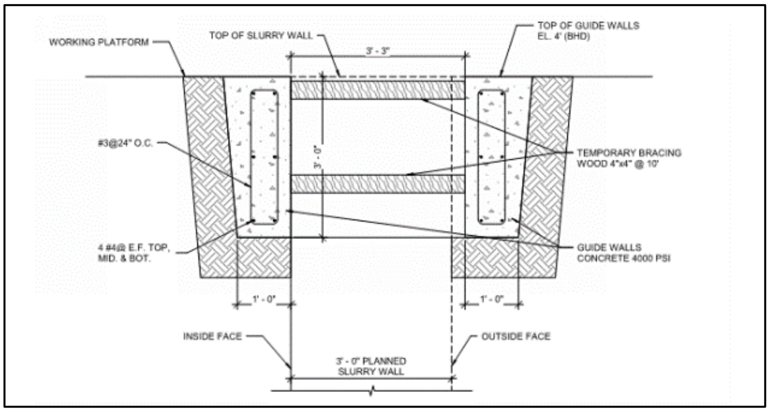

Fig. 11. Guide Wall Construction

The BC40 Hydro cutter is an extremely powerful, versatile, and proven machine with a 41 ft guide frame equipped with steering flaps and real time verticality monitoring to control the plumbness of the excavation. At the bottom of the large, rigid steel frame are two cutting wheels that can swapped out to match the precise width of the required diaphragm wall design and cutting teeth that can be changed to accommodate the type of soil or rock being excavated.

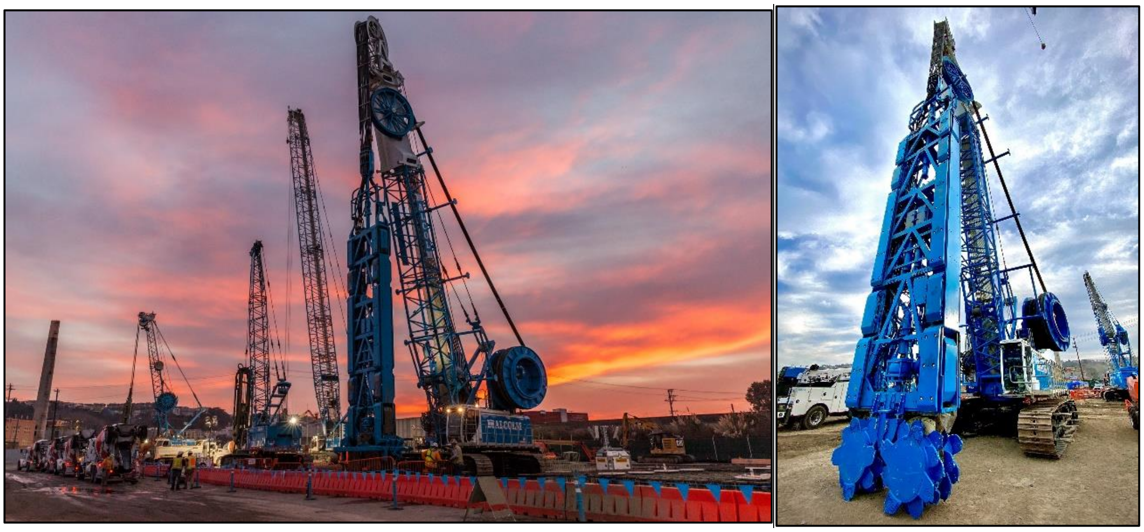

Fig. 12. BC40 Hydro cutter mounted on MC96 crane.

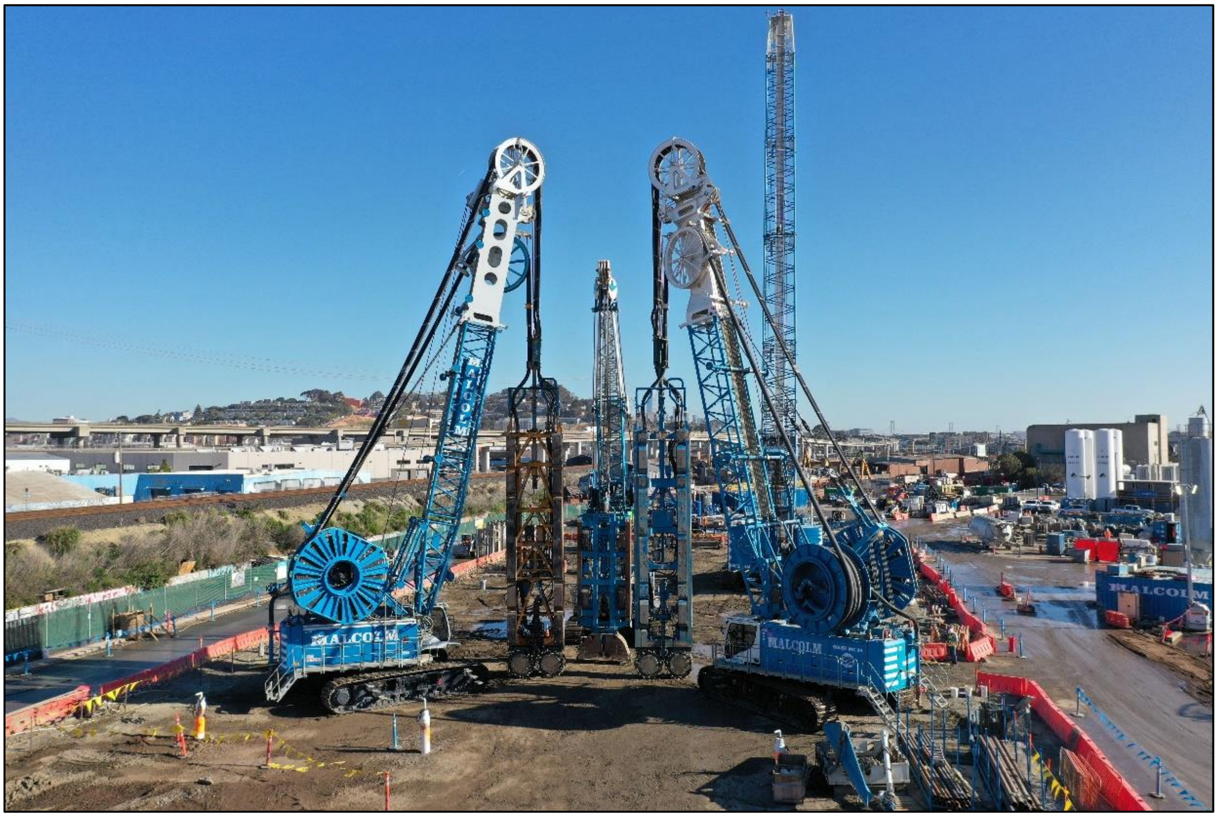

Fig. 13. Two Hydro cutters and One Hydraulic grab

Quality control of the panel excavation is critical for the water tightness of the diaphragm wall system. Prior to concrete and rebar placement, the panel excavation is again independently checked via a KODEN drilling monitor, which uses ultrasonic waves to measure a precise profile of the panel excavation to confirm it meets dimensional tolerances.

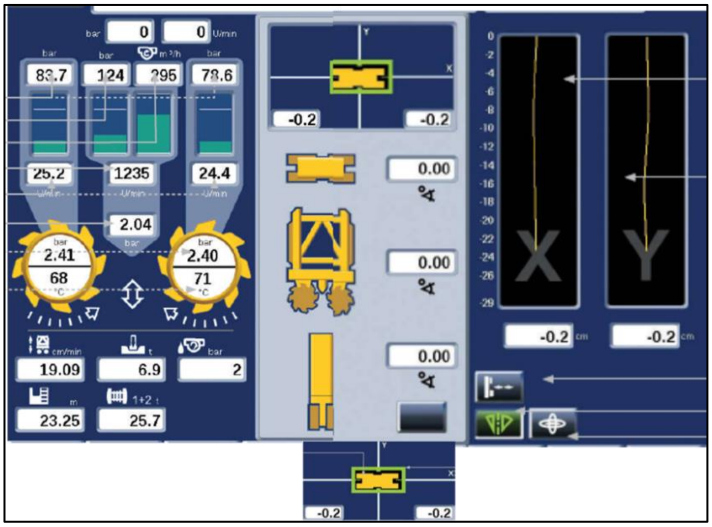

Fig. 14. Real-time monitoring by B-Tronics of panel excavation

Panel reinforcing cages were assembled horizontally on the ground at the project site and later uplifted to a vertical position for installation. Bracing embeds with shear studs, and tieback blockout pipe sleeves, were all installed in the rebar cage prior to lifting and installation. Right angle corner panel cages were assembled, lifted, and installed monolithically as well. All of the cages were lifted with the single 300 ton support crane and brought to the panel for installation, with the heaviest cage weighing approximately 20 tons.

Fig. 15. Rebar cage installation in tandem with slurry wall excavation.

Placement of the 5,000 psi design strength concrete was achieved via tailgate placement into gravity tremies. Each primary panel pour was approximately 400 CY and required the use of three simultaneous tremies. Each secondary panel pour was approximately 160 CY and required the use of two simultaneous tremies. In total approximately 25,000 CY of structural concrete were placed for the slurry diaphragm wall.

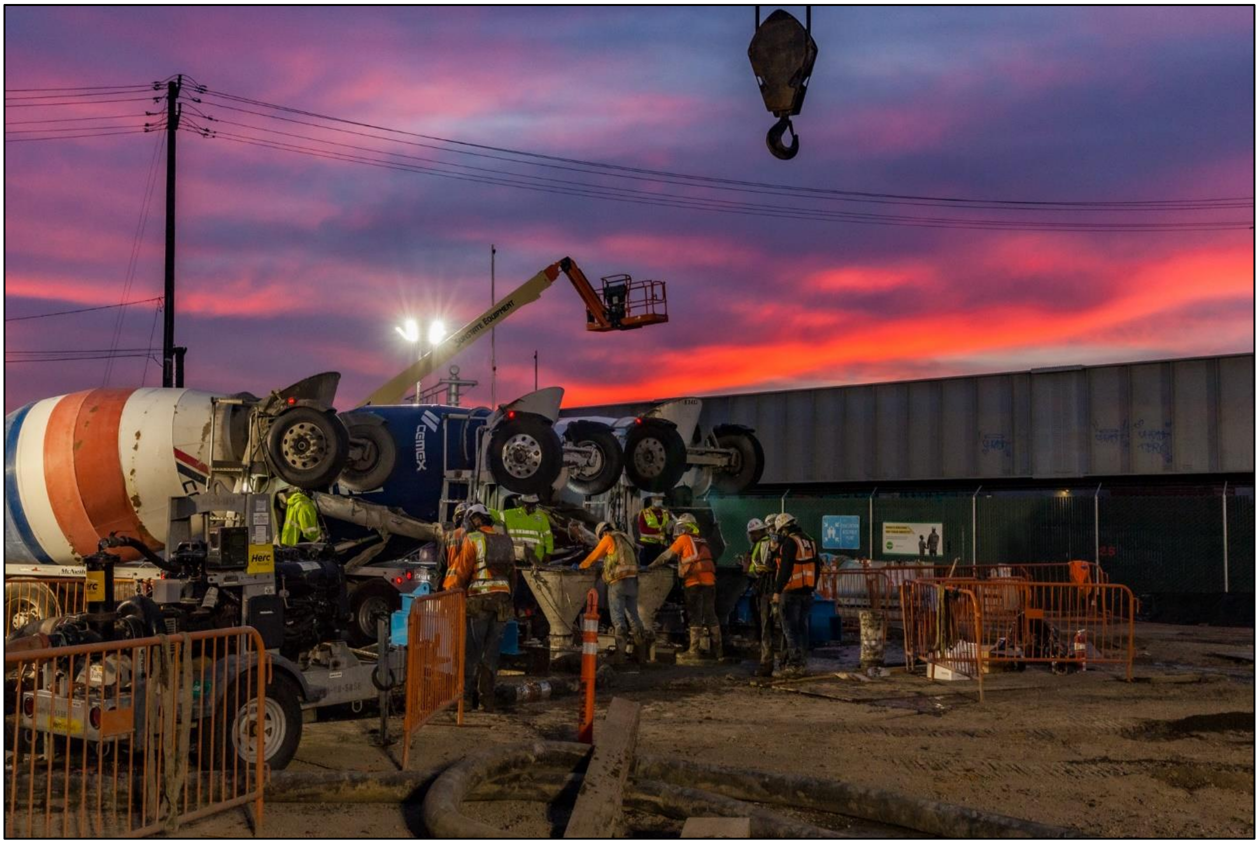

Fig. 16. Primary Panel concrete placement with simultaneous excavation in background.

Quality control of the concrete mix design is a critical factor for the slurry diaphragm wall system. An extensive pre-production trial batch program was implemented prior to mobilization for this project to develop a mix with local suppliers that met the required design strengths and workability parameters. During construction, continuous testing of the delivered concrete for flow, flow retention, and segregation following the EFFC-DFI Guide for Tremie Concrete was implemented prior to the concrete going in the ground.

CONCLUSIONS

The early involvement of a core trade subcontractor proves successful to the design and construction of mega infrastructures that are complex and require intensive coordination between owner, CMGC, Design Team and contractors to overcome the many challenges a project like this presents.

In 2018 and 2019, Malcolm spent many hours traveling to, and attending, in-person meetings with the Design Team and the CMGC, which were indeed necessary, but now with online meetings so commonplace, this collaboration process only became more efficient as the project progressed.

For this mega project, not only did Malcolm deploy nearly every type of drilling method in our arsenal, but we undertook many scopes that normally the General Contractor handles. In addition, Malcolm had to meet a local small business hiring goal for the project which essentially meant that any subcontractor

Malcolm wanted to hire had to be a local small business San Francisco company. Through community outreach meetings and partnering with local companies, Malcolm was successful at finding and managing multiple local San Francisco subcontractors for the following scopes of work: excavation, spoil off-haul/disposal, rebar cage fabrication, surveying, site security, and dust control.

Many valuable lessons were learned on this project and while they don't come around often, Malcolm and Brierley are well suited to take on the next challenging mega project in the future.

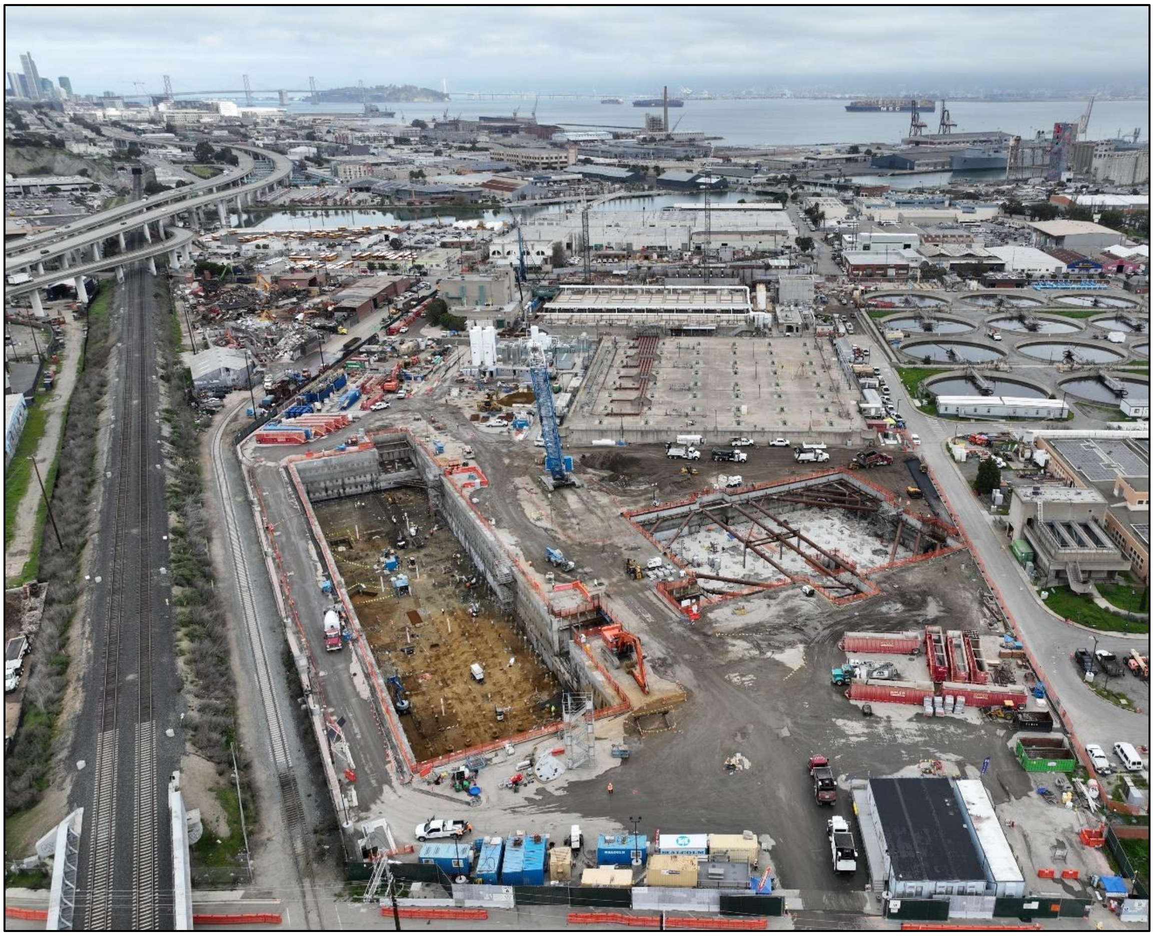

Fig. 17. Overview of project site with completed diaphragm wall excavation at Facility 610 (left) and internally braced CSM shoring wall at Facility 600 (right)

Acknowledgements

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