MANAGING SOE CONSTRUCTION RISK THROUGH DESIGN-BUILD SYSTEMS

Rob Jameson, VP Construction Engineering, Malcolm Drilling Company, San Francisco, CA, 1.415.901.4400, rjameson@malcolmdrilling.com

ABSTRACT

The demand for commercial and residential construction has continued to evolve across the United States over the last decade. Our markets demand larger, deeper and inherently more complex structures, located within increasingly constrained urban locations and with challenging geotechnical conditions. As project demands incrementally escalate, specialty contractors are continuously challenged to extend their state of practice. Development in the size and capabilities of construction equipment, tooling, techniques, monitoring and verification systems over the last decade has consistently allowed contractors to build larger and deeper. For support of excavation (SOE), in addition to scale, selection of the most appropriate system has been a key to success in the most challenging ground conditions. This selection process is based on sound engineering and construction practice, and also prior experience, both positive and negative. Ultimately many Owners have chosen to manage their risk of SOE construction through design-build contracts, which allows specialty constructors to optimize the balance of cost, schedule, scope and associated risk based on their local expertise. Successful implementation of a design-build methodology begins long before a contractor is selected, with identification of key project requirements and risk factors during the feasibility studies and design development phases. In these early stages of the project development, advice and budgets are frequently solicited from Specialty Contractors. The Owner, Construction Manager and Consulting Team will filter this input from multiple sources to provide their specific recommendations, develop construction documents and select the appropriate form of contracting. Only in the final stages, after award of a Design-Build Subcontract, can the successful specialty contractor directly influence risk management approach on the project. A case study is presented from Block 9 in San Francisco's Transbay District. This project demonstrates the incremental identification, assignment and mitigation of construction risk through the planning and design build process for SOE on the deepest planned excavation in San Francisco.

INTRODUCTION

The mature urban development market in United States results in high demand for complex Support of Excavation (SOE) schemes on constrained sites. The Design-Build approach can be applied to increasingly difficult SOE challenges, combining regional specialty subcontractor knowledge and experience in order to optimize solutions for cost and schedule. The most successful applications will involve early engagement of shoring subcontractors within the project teams, during feasibility and design development stages, in order to identify key scope and risk issues, and their potential solutions. Throughout the project development, it is important to reasonably assign responsibility for construction risks amongst the project stakeholders who are best able to control them.

This paper presents a case history for San Francisco's Block 9, a well-planned and successfully executed design-build SOE project in San Francisco's Transbay Redevelopment area. Throughout the 4 year period from the Developers initial proposal to the Redevelopment agency, through completion of excavation down to subgrade, the project team developed a series of increasingly refined SOE schemes, with corresponding scope definition and cost and schedule estimates. This program relied on early identification of key challenges and risks for the project, and evolved through multiple phases of proposals as first the Construction Manager (CM) and then Specialty Shoring Subcontractor were engaged for the project. The scheme, cost and schedule refinements continued throughout construction in order to accommodate unanticipated conditions and events as they unfolded.

The project is presented from the perspective of the Design-Build Shoring Subcontractor and highlights key issues and program features that identified and mitigated construction risk throughout the process.

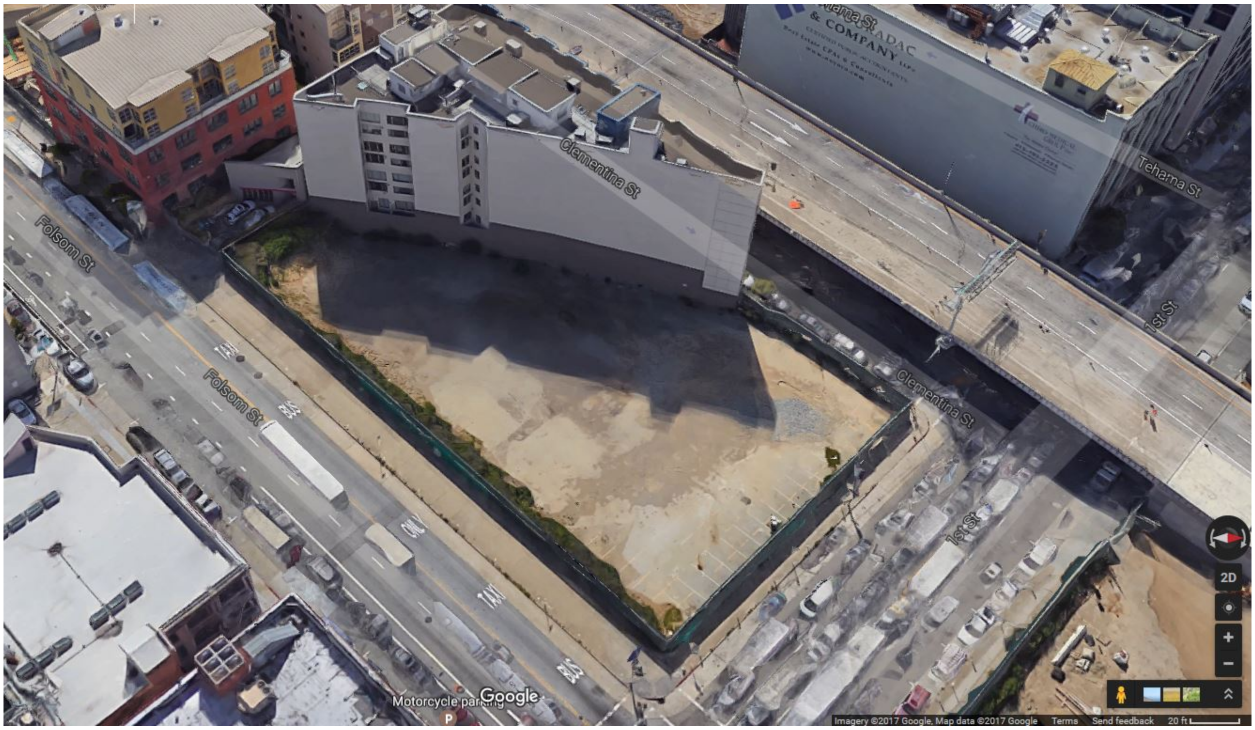

Figure 1: Aerial View of Site and Surrounding Conditions

PROJECT DETAILS

Block 9 is residential high rise development located at 1st & Folsom Street within San Francisco's Transbay Redevelopment Area. The irregular shaped lot is approximately 275 FT by 150 FT, constrained within the footprint of a now demolished freeway ramp structure. The northwest wall follows the curved property line of 19 Clementina Street, a mid-rise apartment building. The north wall abuts the State DOT right of way for an active freeway ramp which is supported on drilled shafts. Existing city streets, Folsom and 1st, run along the south and east perimeter respectively. The Transbay Block 8 redevelopment site is located across 1st street, to the east of the site. The complete Block 9 site will be excavated for a 6 level parking garage, extending from 63 to 77 FT below existing sidewalk grades. A 440 FT tower is proposed to rise on the center of the site, with podium structures extending to property lines on all sides.

The site is located on the north slope of San Francisco's Rincon Hill and the perimeter grades from Elev. 47 (SFCD) at southwest corner on Folsom street down to Elev. 36 (SFCD) in the northeast corner at 1st and Clementina Streets. A geotechnical section from southwest to northeast across this site is shown as Figure 2. The upper 10 to 15 FT of fill and dune sand are underlain by a thin layer of clayey and silty marsh deposits. The predominant ground within the excavation is the Colma Formation, a dense to very dense sandy soil with variable silt and clay components. In the southwest corner, base of the Colma is almost 30 FT above subgrade, and the interface between Colma Formation and the underlying interbedded sands and clays slopes down to the northeast at an average slope of 1 in 5. The bedrock, comprising sandstone and sheared shale of the Franciscan Melange Complex, is encountered 15 to 20 FT above subgrade in the southwest corner and will be excavated to reach subgrade over the western third of the site. The rock surface drops steeply and is over 80 FT below excavation grade on the 1st Street eastern perimeter. A layer of dense to hard interlayered sand and clay is observed in between the Colma and Bedrock. Design groundwater table was set at Elev. +10, however after several years of drought, the groundwater elevation observed during investigation borings was at approximately Elev. 0.

The northern slope of Rincon Hill was developed with mixed residential and industrial use early in the Gold Rush era of San Francisco. After extensive damage in the 1906 Great Earthquake, this area was levelled and re-built. The Block 9 site was within the direct pathway into downtown from the Oakland-San Francisco Bay Bridge and was a key transportation corridor initially for rail and bus lines, and later an elevated freeway. Structural damage in the 1989 Loma Prieta earthquake, along with social pressure to remove the waterfront Embarcadero Freeway resulted in demolition of the elevated structure and the land area was assigned for redevelopment as the Transbay District. Eleven pile supported freeway footings were removed to grade, and then abandoned in the site footprint.

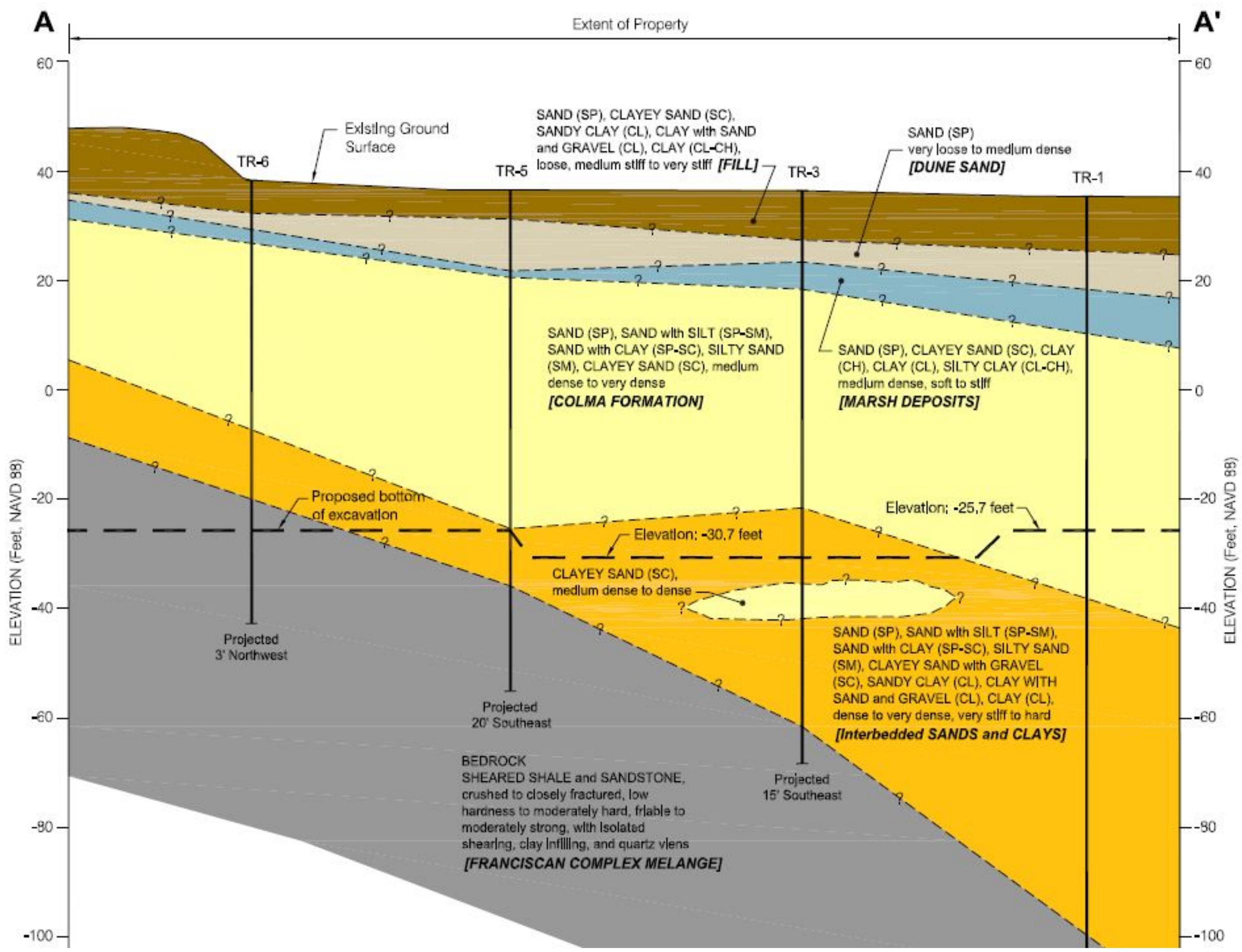

Figure 2: Geotechnical section from SW to NE across site (Langan Treadwell Rollo)

PROJECT TEAM AND DESIGN DEVELOPMENT

The Block 9 project falls within the Transbay Redevelopment area. The Transbay Authority issued a request for development proposals in Fall 2012. The successful development team, Essex Property Trust / Avant Housing were awarded the site in February 2013. Following 2 years of project development, the land purchase was finalized in February 2015 and start of construction followed approximately 1 year later, after completion of design development and permitting.

Due to unusual depth of excavation and complexity of site, developers and their preferred general contractors solicited input for SOE feasibility and budgets from specialty contractors at the outset of the project. Initial contacts were made during Developer RFP period, and continued through GC/CM selection in 2014 and final selection of specialty subcontractor in spring 2015. Malcolm were awarded the project in April 2015, based on a best value selection process from the GC/CM. Groundbreaking was approximately 1 year later in spring 2016.

The SOE market in San Francisco is mature, with numerous deep excavations for high rise projects in the Transbay area having been constructed within the last 10 years. This local expertise results in both high quality initial evaluation and recommendations by the Owner’s consultants, and similarly educated responses from the proposing SOE contractors. The majority of technical challenges encountered on the project were identified in the early RFP’s for budget proposals, including:

- Abandoned footings and deep foundations from demolished freeway structures
- Encroachment limitations for tieback anchors below adjacent structures and freeway
- Groundwater table up to 40 FT above excavation subgrade
- Support and protection of adjacent structures, facilities and utilities, particularly the apartment building on shallow foundations along northwest wall alignment
- Sloping site topography with top of bedrock encountered 20 FT above subgrade in southwest corner and dipping 100 FT across the site footprint.

Throughout the conceptual development and budget phases, multiple specialty contractors provided cost and schedule estimates, but critically, also highlighted the capabilities and limitations for cost effective state-of-practice construction. Input from these specialty contractors was employed to evaluate feasibility of many excavation configurations, enabling the Ownership group to select an optimal configuration. These budgeting exercises evaluated:

- Various depths, ranging from 4 to 7 levels with final design based on 6 sub-surface floors.
- Comparison of direct underpinning support to adjacent structures compared to stiff, impermeable SOE walls designed for surcharge loading along face of structure.
- Comparison for internal bracing or tieback anchors in response to potential to easement limitations from adjacent property owners around site perimeter.

Throughout the 30 month period of design development, the invited Specialty Contractors provided feasibility, budget and scope refinement recommendations to the Construction Manager, and on occasion directly to the Geotechnical Engineer. The Specialty Contractors highlighted areas of technical concern through both the narrative and qualifications presented in their proposals. These issues could then be scrutinized for cross-comparison and bid-levelling between the proposers. The risk management objectives for the Speciality Contractors were to establish realistic client expectations for scope, pricing and schedule which would address project challenges within their control and and allow them to offer a competitive proposal for final selection.

RFP REQUIREMENTS AND SELECTED SOLUTIONS

The final round of proposals for SOE Subcontractor selection were issued in the Spring of 2015. Through the design development process, excavation geometry and constraints were refined including the notable adjustment to set-back permanent structure by 3 FT from Northwest property line. This allowed construction of a stiff shoring system along the face of the adjacent apartment building, instead of direct underpinning. Plans of the historic freeway structures over the site, with details on the abandoned in-situ foundations were included in the SOE RFP. The final Geotechnical report advised that either soil mix retaining and cut-off walls could be employed, or soldier piles and lagging in combination with dewatering. However, the Construction Manager scope requirements limited proposals to only the soil mix approach and precluded the use of tieback anchors below groundwater table. At the time of RFP, easement agreements were still under negotiation with the adjacent property owners and the State DOT, and a range of alternates were requested to accommodate the potential outcome scenarios. Critically for this project, the Geotechnical report included realistic estimates of ground deformation due to both shoring deformation and potential for dewatering induced settlement, compatible with the recommended SOE approaches.

The procurement program included initial submittals, followed by review interviews, then final updated proposals. Subcontractors were permitted to note qualifications or exceptions to the RFP requirements, for consideration by the CM and Owner during their final selection of best overall value proposer. Malcolm's proposed SOE system addressed known project conditions and challenges as described in the follows paragraphs:

ABANDONED FOOTINGS FROM EXISTING FREEWAY: For footings and piles in direct conflict with the shoring wall alignment, employ surface shoring to expose and demolish the pile caps, then drill out the underlying piles using a high-powered rotary top drive rig. Pile caps and footings within the site perimeter would be removed during mass excavation.

GROUNDWATER CONTROL: Construct low permeability site perimeter wall, with minimum toe length of 17 FT below soil subgrade, or keyed at least 3 FT into bedrock. Per RFP, no penetrations for tieback anchors were proposed below the observed groundwater elevation.

SLOPING BEDROCK INTERFACE: Cutter Soil Mix (CSM) walls were the preferred technical, cost and schedule solution for shoring construction. However due to concern over the ability of CSM to penetrate the rock encountered on western portion of the site, Malcolm's shoring scheme proposed a combination of CSM and secant drilled piling. The soldier pile spacing was selected to allow either method of wall construction, and thereby optimize potential for the faster and cheaper CSM method subject to its ability to advance in the rock.

CONTROL GROUND DEFORMATION: The planned depth of excavation ranged from 63 to 77 FT below adjacent sidewalks. Based on standard empirical methods, lateral deformation and adjacent settlements were estimated for this exceptional height of retention systems. In order to minimize ground deformation, the SOE walls were designed as stiff structural elements with very heavy steel beam reinforcement. The lateral support was planned with up to 4 rows of post-tensioned anchors and two levels of internal pre-loaded bracing elements. Design accommodated at-rest active earth pressures adjacent to existing structures, resulting in tightly spaced rows of anchors on the northwest wall below the 19 Clementina structure, with wider vertical spans on the other walls to resist active design loads.

EASEMENTS: The preferred SOE support schemes included tieback anchors. In order to employ tiebacks around the full perimeter, temporary easement agreements would be required with the 6 adjacent property owners and agencies. A menu of different bracing configurations was developed to allow for the contingency that easements could not be obtained from any of these individual parties.

COST & SCHEDULE: The preferred solution for SOE was a reinforced CSM wall with tieback anchors. However in order to accommodate uncertainties and risk over rock penetration, easements and groundwater control, the selected scheme allowed for interchange with more robust drilled secant piling and internal bracing elements along partial lengths of the shoring wall alignment, with corresponding schedule adjustments quantified in the proposal.

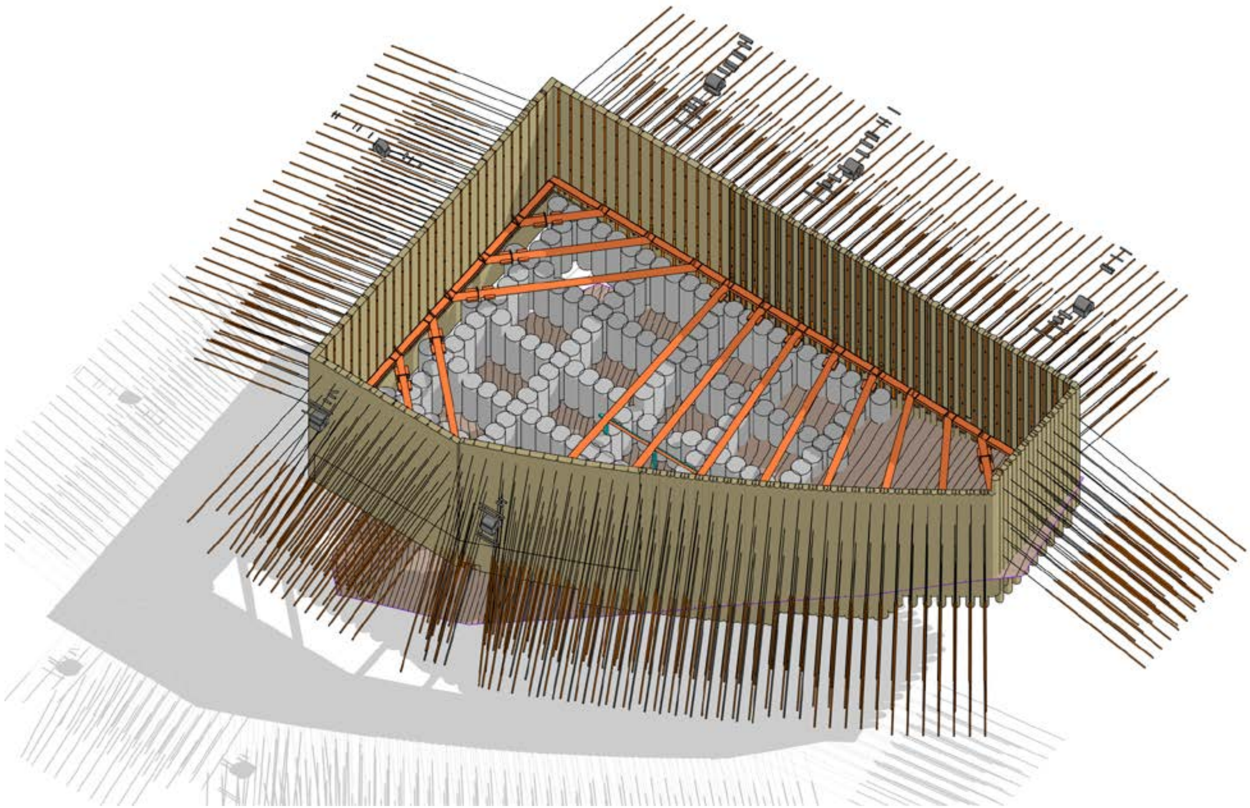

Figure 3: As-designed Support of Excavation Scheme

Key qualifications offered by the SOE Subcontractor were that the proposed scheme was anticipated to perform within boundaries of ground deformation identified in the geotechnical report based on sound construction practice. However the inherent risk that this magnitude of deformation may not be acceptable to, or could cause impacts to, adjacent properties and facilities remained with others. In addition, although the SOE contractor developed a work plan to address the known freeway footings, any impacts related to other unforeseen subsurface obstructions was excluded and would treated as a Contract Change. The Subcontractor proposal clearly identified any other technical exceptions or clarifications to RFP documents.

Through the negotiation period, the scheme was refined to optimize cost and schedule by installing 1 row of tieback anchors below groundwater level in place of the upper bracing level. This approach relied on center pockets on the soldier piles for ease of ground control during drilling, and for sealing after the anchor was installed and stressed. A full depth tieback solution was evaluated but rejected since the increased risk of installing anchors over 20 FT below groundwater table was consider by all parties to exceed the potential benefit of eliminating the lowest internal bracing level.

The overall SOE scheme was selected to manage known challenges and risks on the project. The SOE Subcontractor employed contractual mechanisms to limit their risk and exposure to factors within their direct control.

CONSTRUCTION

The shoring wall installation commenced in 2016, almost 4 years after the initial RFP to Developers was issued by the Redevelopment Agency. Overall, this time had allowed for careful evaluation of the project risks and requirements and development and contracting of an SOE scheme to meet the challenges. As always with Construction, several new challenges arose during the site operations, which were met and resolved to effectively complete the works.

Ultimately, the project owners executed temporary easement agreements with all the adjacent property owners, allowing the optimal tieback anchor solution to the employed around the full site perimeter. The most challenging was the State DOT where tiebacks were anticipated to advance and bond into ground in near proximity to drilled shaft foundations for the I-80 off-ram along the north side of the project. In order to obtain the temporary easement into the State DOT right-of-way, design had to account a no-encroachment zone directly around each shaft. A full-scale test was required to demonstrate the ability to maintain direction and tolerance on anchor alignment during drilling in order to maintain the no-encroachment zone, and to show that stressing of the anchor would not disturb ground directly adjacent to the existing drilled shafts. MDCI performed these tests during site preparation period, including down-hole alignment surveys using gyroscopic tools, under observation of the project Geotechnical Engineer and State DOT representatives. After anchors were installed and surveyed, inclinometers were laid out at pre-determined offsets from the bond zone and continuously monitored during loading. This study satisfied the State DOT that anchor load transfer would not impact the adjacent shafts, and the easement was granted.

UNANTICIPATED OBSTRUCTIONS: The shoring scheme was developed to accommodate the known abandoned freeway footings and piles. However, during the planned site clearance activity, numerous other earlier foundation elements were identified, in many cases underlying the abandoned freeway footings. These remnants from earlier land-use dated from pre-1906 earthquake and from levelling and reconstruction in the early 20th Century before the freeway construction. In the most challenging cases, some concrete structures were identified which straddled property lines redrawn in the 1950's around freeway alignments and which were partially buried below adjacent occupied structures. A comprehensive program for obstruction removal was developed and implemented, including trench shoring and sequential slot cutting, along with supplemental temporary pile and lagging shoring walls on the street perimeters.

INTERFACE WITH ADJACENT CONCURRENT DEVELOPMENT: When the project ultimately started in 2016, the excavation was advanced concurrent with a 40 FT deep soldier pile and lagging shoring system at Transbay Block 8, located on the opposite (east) side of 1st Street. Shoring schemes for both projects employed tieback anchors with maximum length of approximately 80 FT, which extending across the full street width from their respective property lines. Malcolm were the shoring subcontractor on both projects, and therefore was able to address and manage risk of damage to previously installed anchors on opposite sides of the street. A 3D BIM model was developed in order to identify potential conflicts. Minor layout adjustments allowed a nominal 30" minimum clearance between any interlaced anchors. For block 9, soldier piles had already been installed, adjustments were limited to 1 degree. For the adjacent Block 8 project, a total adjustment of up to 3 degrees was allowed for both beam installation and anchor alignment. Three walers were added to the interior face of Block 9 east wall in order to allow for load redistribution into adjacent piles in the event that existing pre-loaded anchors were hit and damaged during drilling on Block 8. In total, 100 interlaced anchors were constructed between the two projects, and by use of BIM to refine design, and careful field controls on layout and alignment, no anchors were compromised throughout this process.

ROCK PENETRATION: The contractor work plan allowed for a combination of secant piling and CSM methods to construct the perimeter wall. CSM is the preferred solution since there are fewer joints, lower unit cost and faster production. Based on initial evaluations of the rock profile, MDCI anticipated approximately half of alignment would be constructed using each method. During construction, MDCI employed pre-drilling using an auger in order to break-up and facilitate CSM penetration into the Franciscan bedrock formation. Through this construction program, CSM was successfully employed along over 90% of the site perimeter. The wall closure was completed with limited sections of secant piling in areas with the highest and hardest rock conditions.

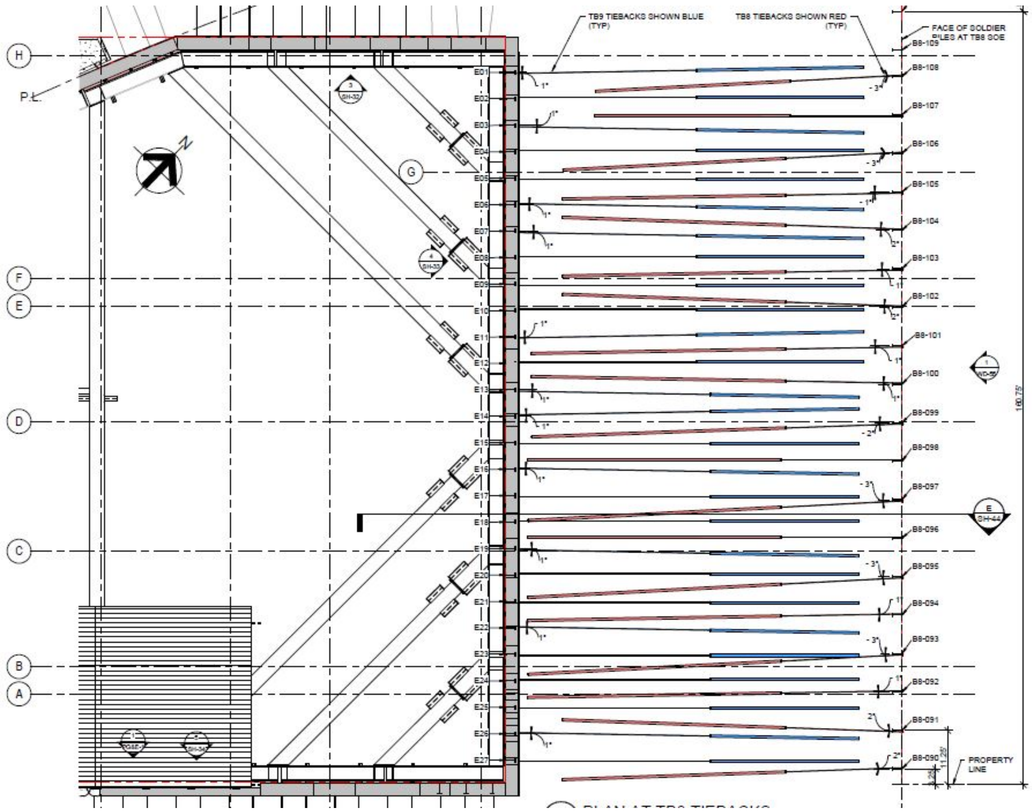

Figure 5: Plan view showing interlaced anchors below 1st Street

SYSTEM PERFORMANCE: The excavation for Block 9 was completed in early April 2017 and the system largely exceeded performance expectations. The geotechnical report had estimated deformation of 1 to 2", while in-wall inclinometers reported actual deformation of less than 0.75", consistent with optical survey of targets on the shoring and adjacent structures. The perimeter cut-off walls were effective in isolating drawdown of groundwater within the excavation relative to adjacent areas, and a limited lowering groundwater at the northeast corner was attributed to effects of a deep well system on the adjacent Block 8 site. The perimeter wall, bracing and anchor installation were performed within the timelines and budgets of the project. The main impact to schedule and cost was the removal of unforeseen obstructions beyond the existing freeway footings.

SUMMARY AND CONCLUSIONS

Complex SOE can be successfully implemented by combining a well-informed client team and experienced contractors employing design-build to select appropriate shoring systems, optimized for cost and schedule. The groundwork for success is laid by identifying key risk and scope issues, and their potential solutions, early in design development. These construction risks should be assigned to the project stakeholder best able to control them. Although the specialty subcontractor is not formally engaged until late in the design development, their experience can have a large influence on the selected pathway for the project. The subcontractor's budgetary proposals can identify and highlight construction risks within their scope for review and evaluation by the Owner, Construction Management and Design team. This allows critical risk issues to be mitigated by design modifications before permitting, or else clearly defined and assigned in the contract documents, and then managed by the selection of an appropriate temporary SOE plan. The subcontractors approach to critical risk concerns should be evaluated as part of the bid levelling and selection process. Shoring subcontractors should also retain the right to clarify risk assignment and limitations through the Subcontract language in the negotiation process. Once the SOE scheme is finalized, the Subcontractor is responsible to delivery their product in a cost effective and timely manner.

This case history of San Francisco's Block 9 presents the well planned and executed approach to SOE for an extremely challenging site. The project involved the deepest planned excavation in the Transbay District, addressed difficult soil, bedrock and groundwater conditions, known deep obstructions and provided tight deformation control for sensitive adjacent residential and freeway structures.

Figure 6: Excavation to Subgrade viewed from Northeast Corner

ACKNOWLEDGEMENTS

The author wishes to acknowledge the project team comprising of Essex Property Trust and TMG Partners, the Ownership Group, Architects SOM and Fougeron, Structural Engineers SOM and Structus, and Langan Treadwell Rollo, the Geotechnical Engineer. The CM/GC was Balfour Beatty. Subgrade works executed by Malcolm Drilling included SOE, Dewatering and Subgrade Ground Improvement, with SOE Design performed by Brierley Associates, and excavation by EBi, as a second tier subcontractor.