

Block 185: Slurry Diaphragm Wall Construction in Austin, TX

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ABSTRACT

Standing at 589 ft tall, Block 185 will be the newest addition to Austin's ever growing skyline and the fourth tallest tower in the city. Located in the developing waterfront district, the project site is situated just 250' north of the Colorado River and is bounded on the west by one of its major tributaries, Shoal Creek. To accommodate the six-story below grade parking garage, a slurry diaphragm wall system was selected for support of excavation. This design-build method of SOE was selected to meet the myriad of challenges at this site, which included excavation extending some 45 ft below the groundwater table through highly variable geologic stratifications from loose sands to weak shales to highly competent limestone. The construction and engineering challenges, solutions, and lessons learned on this project will be explored and discussed in this paper.

INTRODUCTION

Block 185 is located at the northwest corner of the intersection of Cesar Chavez Street and Nueces Street in downtown Austin, TX. This is the final parcel of what was formerly the Green Water Treatment Plant (GWTP), which was demolished in 2010 and split into 4 separate parcels as illustrated in Figure 1.

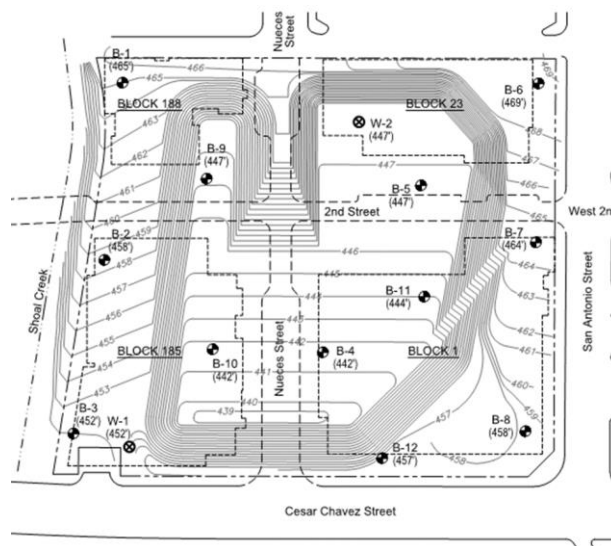


Figure 1. Green Water Treatment Plant redevelopment plan

The project site is located just 250' north of the Colorado river and bounded on the south by Cesar Chavez street, a highly traveled 4-lane surface street and one of the main arteries into downtown Austin off State Highway Loop 1 (MoPac Expressway). To the north the site is bounded by 2nd Street, which includes a single span, deep foundation supported suspension bridge over Shoal Creek that was constructed in 2015 as part of the GWTP redevelopment plan. To the west the site is bounded by Shoal Creek, which is the largest of Austin's north urban watersheds with a total length of 11 miles and feeding approximately 8,000 acres of runoff to the Colorado River.

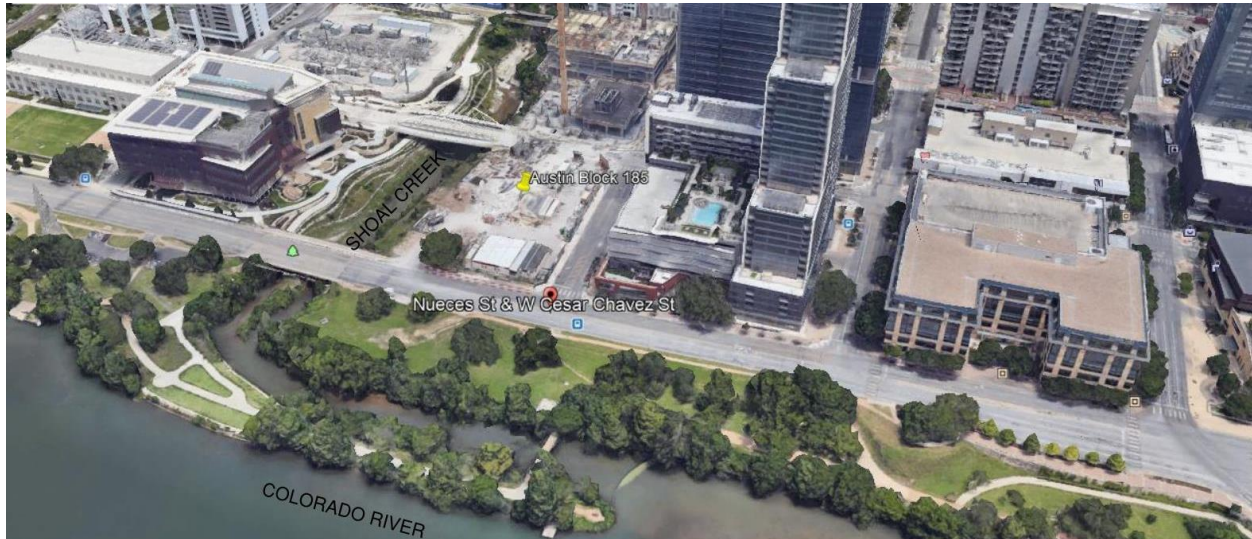


Figure 2. Overview of the project site

The planned development for the project site included an architecturally unique 37-story office tower with 6 levels of below grade parking. At a total height of 589 feet the development will be the 4th tallest building in Austin and the tallest office tower in Texas outside of Dallas or Houston. Prior to beginning construction, the development had already been leased in its entirety to Google, who is currently leasing multiple floors in a tower just one block to the northeast.

EXISTING SITE AND SUBSURFACE CONDITIONS

During the demolition of the GWTP the existing 20' – 30' of below grade basement structures were backfilled and compacted. The existing grade at the project site sloped from approximately elevation 466 at the north (2nd Street) to approximately elevation 452 at the south (Cesar Chavez Street). This significant grade change occurred over approximately 275 linear feet.

The native subsurface soils varied widely from north to south, with more cohesive and competent soil and rock disappearing moving south towards the Colorado River as illustrated in Table 1 and Figure 3.

Table 1. Subsurface Soil Stratums

Layer	Description	Depths (North Extent)	Depths (South Extent)
Fill	Sandy Lean Clays (CL) and Clayey Sands (SC)	0' to 20'	0' to 20'
In Situ Soils	Sandy Lean Clays (CL), Fact Clays (CH), Poorly Graded Sands (SP), Silty Sands (SM)	20' to 30'	10' to 50'
Buda Limestone	Light gray to gray, variable weathering, some fresh and very intact, up to 7,000 PSI	20' to 45'	N/A – Not Present
Del Rio Shale	Dark gray to gray, clayey shale, low strength (< 750 PSI)	35' to 70'	50' to 70'

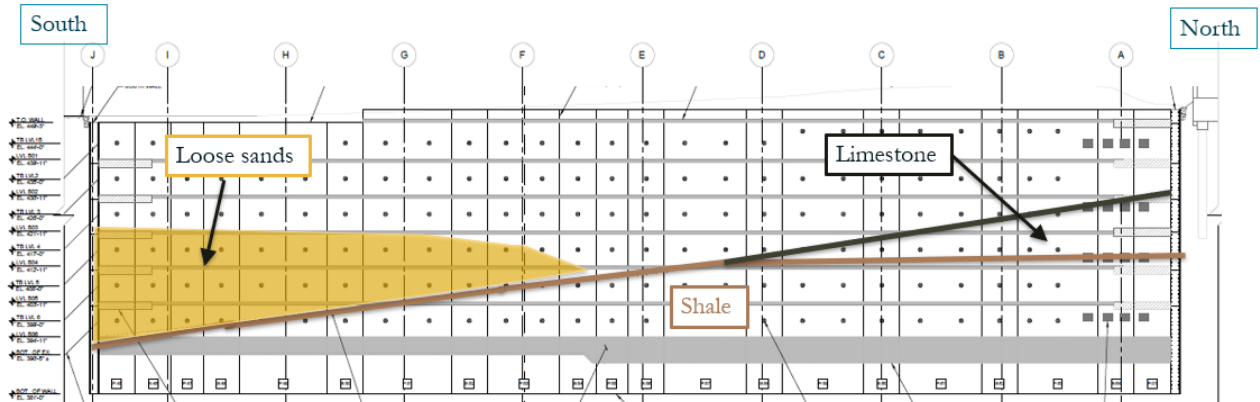


Figure 3. Typical soil profile north to south

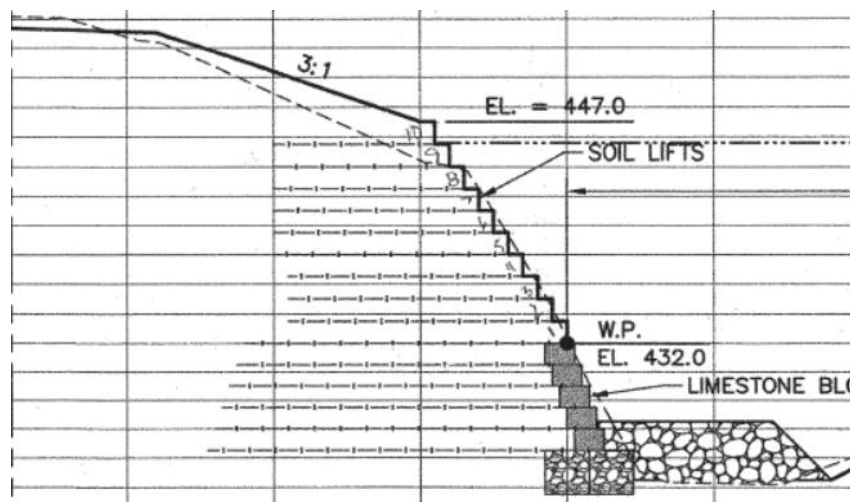


Figure 4. Shoal Creek MSE Wall

Additionally, as part of the GWTP decommissioning and deconstruction the banks of Shoal Creek were improved with the construction of a large mechanically stabilized earth (MSE) wall as shown in Figure 4, which was only 10' to 15' west of the project property line.

DESIGN AND CONSTRUCTION CONSIDERATIONS

Malcolm Drilling, Inc. (MDCI) engaged GEI Consultants, Inc. (GEI) for the design of approximately 950 linear feet of support of excavation for the project. A slurry diaphragm wall system was selected as the optimal design-build solution for the project to account for the myriad construction challenges including the excavation depth below groundwater, the variable subsurface soils conditions, and the overall cost and schedule benefits.

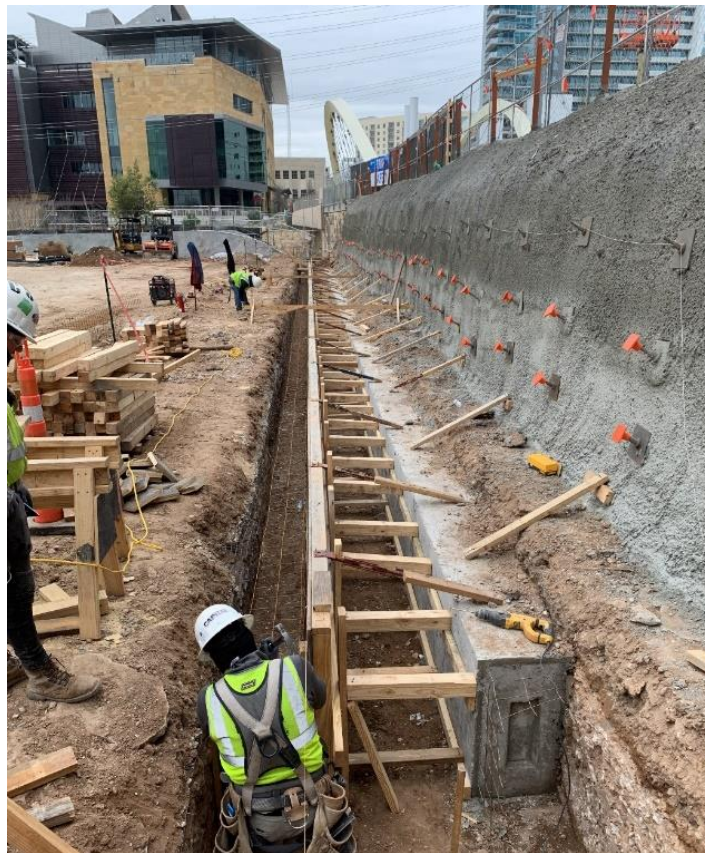


Figure 5. Soil nail wall and guide wall construction

Initial Support of Excavation

In order to prepare the site for diaphragm wall construction the site first needed to be leveled. Temporary soil nail and shotcrete walls were installed along the northern portion of the site and extending approximately half way down the east (along Nueces Street) and west (along Shoal Creek) walls. The soil nail walls were used to maintain the existing roadways, sidewalks, and embankments while allowing the site to be brought down to a level working pad elevation. MDCI partnered with Dallas-based contractor Oscar Orduno, Inc. for the installation of the soil nail and shotcrete walls.

Once the soil nail walls were complete and the site was leveled, construction of the temporary concrete guide walls began concurrent with the mobilization of the slurry diaphragm wall gear, as shown in Figure 5.

Groundwater

The design of the support of excavation system was greatly influenced by the depth the excavation was extending below groundwater. Firstly, because the excavation was extending some 40 feet below the groundwater through non-cohesive and high transmissivity soils a cut-off wall shoring system was required. Secondly, that depth below groundwater meant that the water pressure was a huge driver of the overall loading and design of the shoring system. In the temporary condition the wall had to be designed to account for 40 feet of water pressure, roughly equivalent to 50 kips per lineal foot of wall. In the permanent condition, the wall was required to be designed to resist the 100-year flood elevation, which was 15' higher for a total of 55 feet of water pressure. Figure 6 shows an overlay of the water pressure diagram through a cross-section on the west wall.

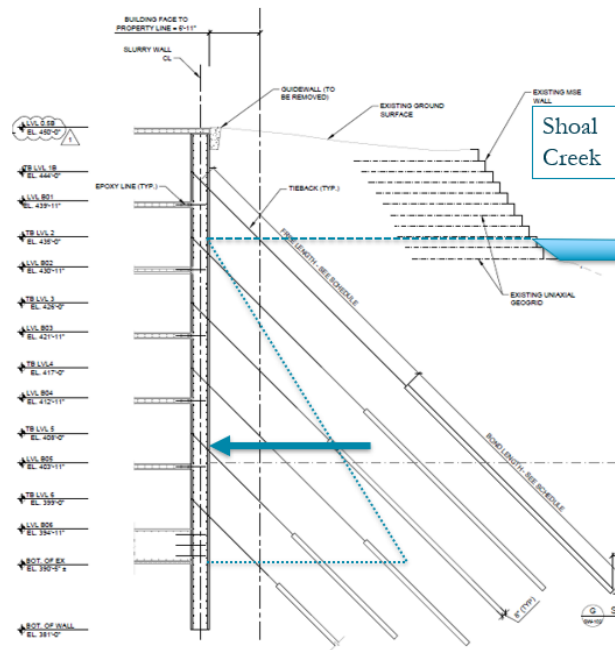


Figure 6. Water pressure diagram.

Diaphragm Wall

The slurry diaphragm wall system was chosen to provide a full groundwater cut-off system and to accommodate the high water pressure loading as well as the highly variable subsurface soils, which included very competent, intact, and high strength limestone.

The diaphragm wall was 800mm thick and extended approximately 8' to 10' below the bottom of excavation into the Del Rio Shale formation for total panel lengths of approximately 72' on average. In the temporary condition the diaphragm wall was laterally supported by (6) rows of tieback anchors. In the permanent condition the diaphragm wall is laterally supported by the interior floors slabs and the tieback anchors are detensioned. This is one key advantage of a

slurry diaphragm wall system – that it serves as both the temporary and permanent support of excavation and eliminates the need to construct a supplemental permanent basement wall in front of a temporary shoring wall.

Tiebacks

In the temporary condition the wall is supported with temporary tieback anchors with bond lengths extending into the Buda Limestone and Del Rio Shale formations. The tiebacks were temporary strand anchors ranging from four to seven strands with bond lengths between 15 and 40 feet to accommodate design loads of 110 kips to 245 kips.

Following the installation of the permanent floor slabs the tiebacks were sequentially detensioned and the floor slabs became the permanent lateral support for the slurry diaphragm wall.

MDCI partnered with Dallas-based contractor Oscar Orduno, Inc. for the installation of the tiebacks on this project.

Corner Bracing

In the northwest corner of the project the slurry diaphragm wall extended to within a few feet of the abutment of the West 2nd Street Bridge, which was constructed in 2015 as part of the GWTP redevelopment plan. The bridge is a 160-foot single span canted parabolic arch bridge constructed on deep foundations. When the bridge was originally constructed, a tangent pile wall was constructed on the Block 185 side of the abutment serve as shoring for the anticipated future below grade development at the Block 185 site. However, at the time that future development was only anticipated to extend 3 levels below grade; or about 40’ higher than the actual tip of the slurry diaphragm wall for Block 185.

Due to the presence of the tangent pile wall and abutment drilled shafts tiebacks could not be used in the NW corner. 4 levels of internal corner bracing were used to replace the tiebacks in this corner. Additionally, the slurry diaphragm wall design had to accommodate some 350 kips of lateral loading from the abutment drilled shafts.

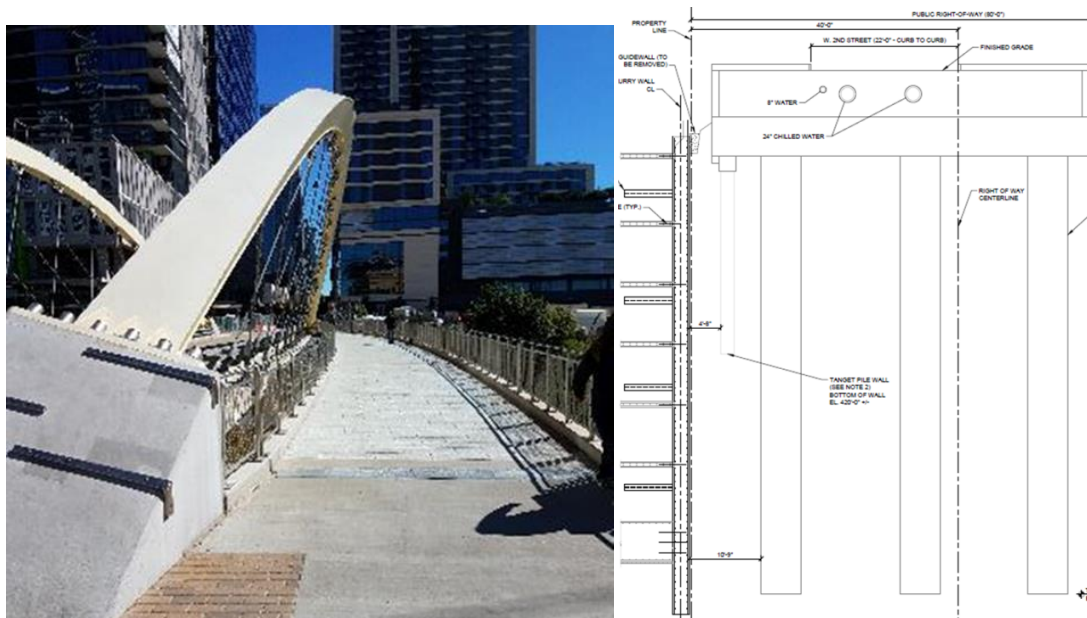


Figure 7. Existing 2nd Street Bridge at northwest corner

Lateral Earth Analyses

The diaphragm wall was analyzed for two separate conditions, the temporary condition where the wall was fully supported by tiebacks, internal braces, and external wales and the permanent condition where the wall is fully-supported by the basement floor slabs.

In the temporary condition, the loading was analyzed using WALLAP where the wall is analyzed as a beam-on-elastic foundation (Figure 8). The soil and struts are treated as elastic or elastic-perfectly plastic springs, there is an initial spring with displacement equal to zero (at-rest conditions). As the model is run movement causes forces within the springs to increase or decrease until limiting values are reached (K_a and K_p).

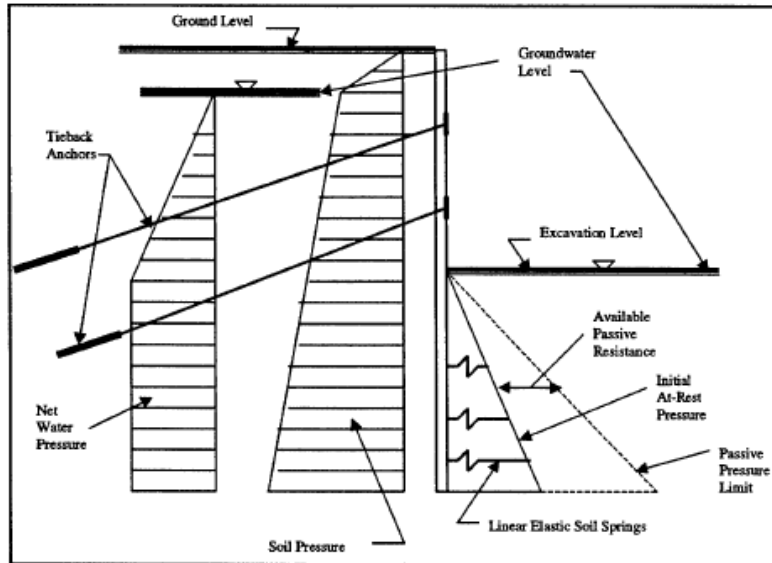


Figure 8. Simplified beam-on-elastic foundation model (USACE)

In the permanent condition the wall was analyzed using typical Equivalent Fluid Pressures using At-Rest conditions (Figure 9). This method used pressures that were generally recommended in the site geotechnical report.

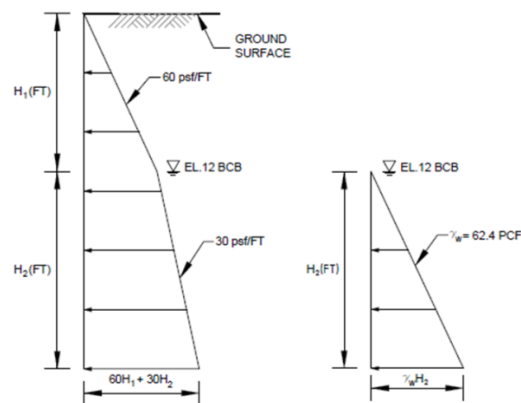


Figure 9. Example of typical equivalent fluid pressures.

CONSTRUCTION

Mobilization and Site Utilization

Logistics was primary challenge for the construction of this project due to a limited site footprint. The site configuration including access/egress, installation sequence, and support equipment layout was carefully planned prior to mobilization.

The equipment used to install the slurry diaphragm wall included a Bauer BC40 Hydromill Cutter mounted on a Bauer MC96 crane, one hydraulic clam shell grab mounted on a Liebherr HS8100 crane, a 200T class support crane, a Bauer BE550 Desander, a centrifuge, and (8) 21,000-gallon open top mixing tanks.

The general site configuration is shown below in Figure 10. The rebar cage fabrication area was re-located multiple times as needed during the installation process.

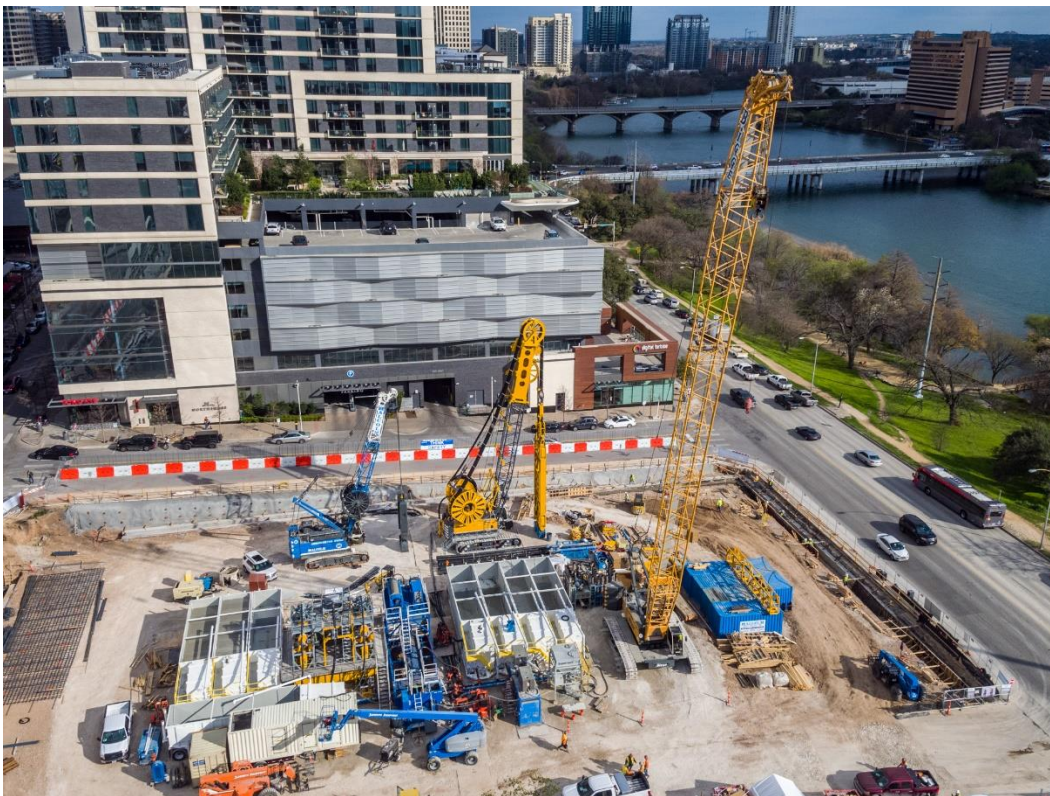


Figure 10. Site configuration for Diaphragm Wall Construction.

Diaphragm Wall Construction

Temporary reinforced concrete guide walls were constructed along the alignment of the slurry 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' wide by 3' to 4' 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 tops of the guide walls were used for the installation of hard survey control points for the diaphragm wall construction as well.



Figure 11. Guide wall construction.

Excavation of the diaphragm wall panels was accomplished using a Bauer BC40 Hydromill mounted on a Bauer MC96 crane and with a Liebherr HSG 5-18 hydraulic grab mounted on a Liebherr HS 8100 Crane.

The BC40 Hydromill is an extremely powerful, versatile, and proven machine with a 41-foot 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 that type of soil or rock being excavated.



Figure 12. BC40 Hydromill mounted on MC96 crane.

The Liebherr HSG 5-18 hydraulic grab is a very powerful, heavy duty machine specifically designed for slurry wall construction with a 21-foot long guide frame equipped with steering flaps to control verticality of the excavation. At the bottom of the rigid frame are two cutting jaws again matched to the precise width of the required diaphragm wall design and equipped with changeable teeth to accommodate the type of soil or rock being excavated. A hydraulic grab or other piece of equipment is required to start the excavation of each panel down to a minimum depth of 10' to 12'. The BC40 hydromill has to be submerged in water or slurry down to this depth and below its pumps and gearboxes before it can be operated.



Figure 13. Liebherr HSG 5-18 mounted on Liebherr HS8100 crane.

Quality control of the panel excavation is critical for the slurry diaphragm wall system. Vertical deviation of the excavation is monitored in real time in the cab of the excavation via the hydromill and the panel can be adjusted via the steerable flaps on the guide frame. 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 falls with acceptable tolerances.

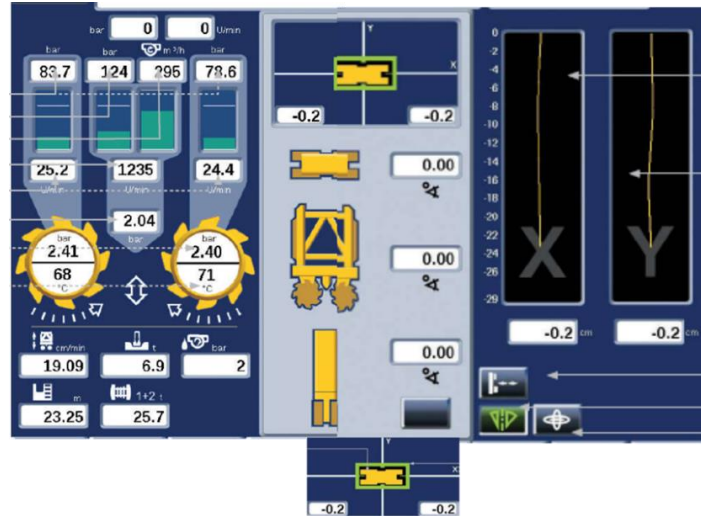


Figure 14. Real-time monitoring by B-Tronics of panel excavation.

Panel reinforcing cages were constructed horizontally on the ground at the project site and later uplifted to a vertical position for installation. Bracing embeds with shear studs, tieback blockout pipe sleeves, and slab shear keyways were all installed in the rebar cage prior to lifting and installation. Right angle corner panel cages were constructed, lifted, and installed monolithically as well. All of the cages were lifted with the single 200T support crane and brought to the panel for installation, with the heaviest cage weighing approximately 15 tons.

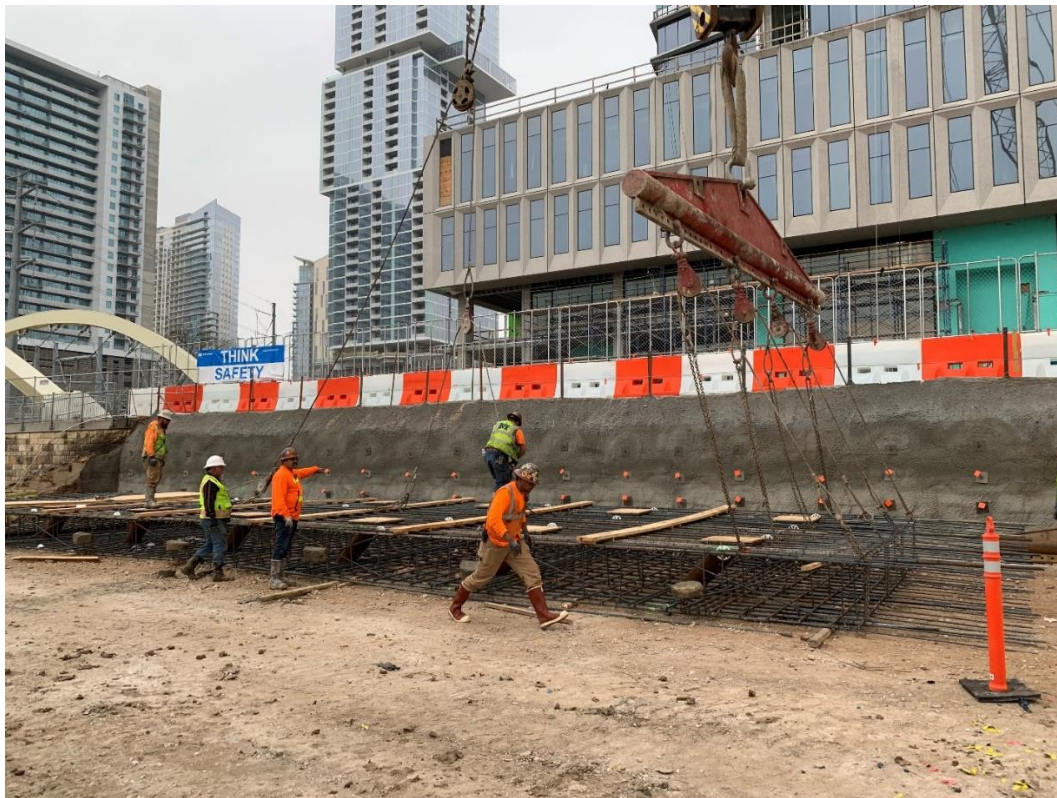


Figure 15. Primary panel rebar cage.

Placement of the 5,000 PSI design strength concrete is achieved via tailgate placement into gravity tremies. Each primary panel pour was approximately 180 CY and required the use of three simultaneous tremies. Each secondary panel pour was approximately 75 CY and required the use of two simultaneous tremies. In total approximately 6,800 CY of structural concrete were placed for the slurry diaphragm wall.

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 slump, spread, flowability, slump retention, and segregation was implemented prior to the concrete going in the ground.

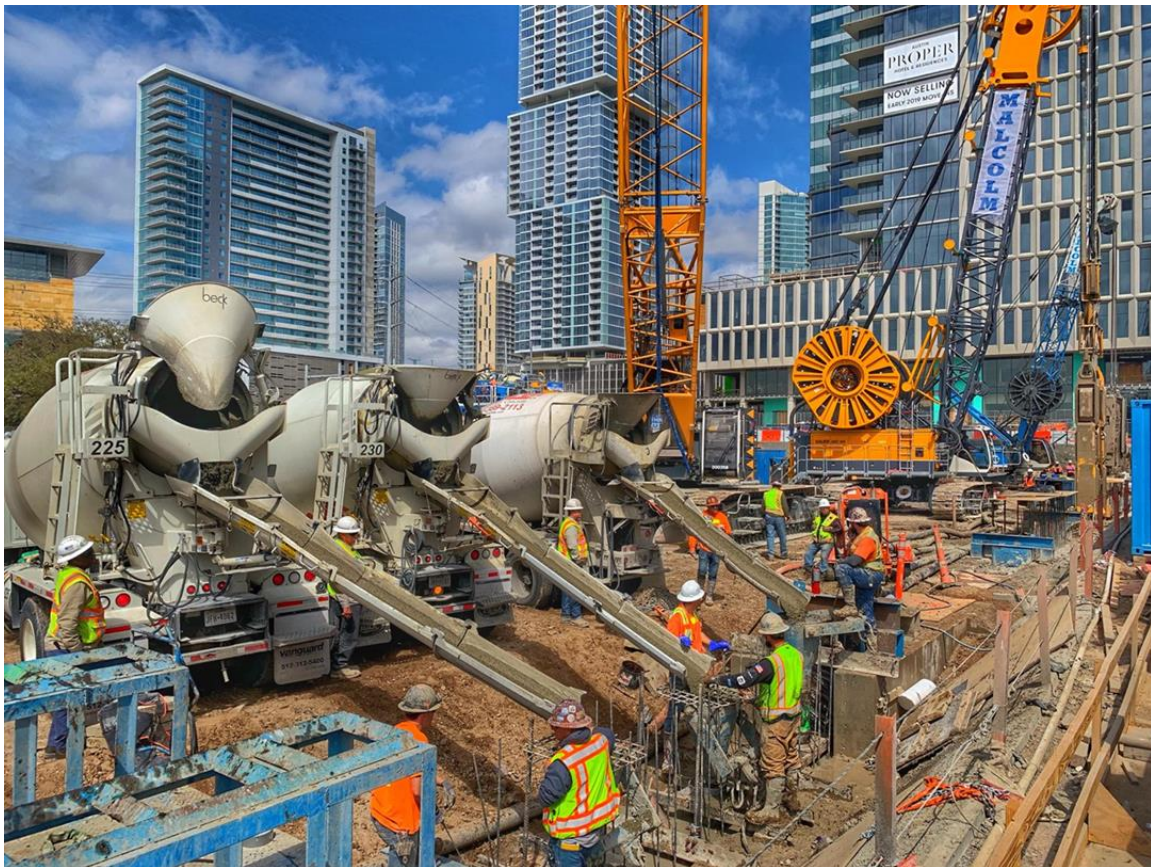


Figure 16. Primary Panel concrete placement with simultaneous excavation in background.

CONCLUSIONS

As Austin continues to grow and expand the need for and economic feasibility of deeper excavations will continue to introduce construction challenges that are new to this market as well as to the Dallas and Houston metropolitan areas.

The Block 185 project required an innovative design-build approach that had to address a myriad of site constraints and difficult geotechnical conditions in addition to an aggressive

project schedule and a very competitive bid environment. The slurry diaphragm wall was able to provide a full water cut-off system that could penetrate the Buda Limestone formation and serve as both the temporary and permanent basement wall, eliminating the need for a supplemental permanent basement wall. Additionally, the stiffness and rigidity of the system was well-suited to handle the high surcharge loads from adjacent structures and improvements with limited deflections or disruptions in a tight urban area.



Figure 17. Aerial view of the completed diaphragm wall and excavation.

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