Shoring of Long Beach Main Pump Station utilizing Ground Improvement Methods, Long Beach, CA

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ABSTRACT

Condon-Johnson & Associates, Inc. (CJA) with the assistance of design consultant, Brierley Associates, designed and installed a water tight shoring system utilizing several ground improvement techniques jointly. Prior to the installation of the shoring system, a test program consisting of the installation and testing of 7 jet grout columns; 1 soil mix panel; 7 soil anchors and 3 tie downs was performed to verify design assumptions. State-of-the-art quality control measures were employed throughout the project.

The shoring system consisted of:

- Deep Soil Mixing (DSM) wall utilizing triple axis tooling to install overlapping columns along the perimeter of the proposed excavation to a treatment depth of 54 feet.
- Installation of steel piles in DSM to provide rigidity to the wall.
- Installation of a jet grout bottom seal, installed from surface to a depth of 58 feet below existing grade.
- Installation of 153 soil anchors, 1-1/4” diameter and 47’-6” length, to tie the jet grout bottom seal to the native soil below to resist hydrostatic uplift, installed from existing grade to a depth of 91 feet.
- Installation of walers and pipe struts for internal bracing
- Installation and stressing of 117 tie downs, 1” diameter and 16 ft length, to tie the pump station mat slab to the jet grout bottom seal, installed from inside the excavated pit.

Subsurface conditions at the site consist of uncontrolled fill materials to a depth of 20 feet comprised of sandy silt and clayey sand. The native soils underlying the fill generally consist of soft and compressible lean clay and silt with varying amounts of sands to a depth ranging from approximately 44 to 54 feet below ground surface, which in turn are underlain by dense to very dense silty sand. The groundwater elevation at the site is approximately 8 feet below ground surface.

This paper covers the design aspects, construction, and quality control measures undertaken by the geotechnical contractor, with supporting figures.

Keywords: soil mixing, jet grouting, soil anchors, tie downs

INTRODUCTION

The owner, County Sanitation District No. 2 of Los Angeles County, designed upgrades to their existing Long Beach Main Pumping Plant Facility. The upgrades consist of a new pump station that includes a reinforced concrete below-grade wet well and dry well, a two-story operations building, two 78-inch diameter pipe inlets, two 42-inch diameter discharge pipelines connecting the existing manifold, two pipe junction structures, two insert-type junction structures, and electrical transformers. This paper focuses on

the excavation shoring for the new pump station. The original shoring design concept for the pump station excavation illustrated on the contract plans consisted of pressed in sheet piles, a jet grouted bottom seal with soil anchors, 2 levels of internal bracing, and tie-down anchors to resist hydraulic uplift forces on the buried pump station.

A RFI was submitted requesting the District consider the use of alternates to pressed in sheet piles while maintaining the vibration-free, watertight shoring requirements. By addendum, the District allowed the use of alternates. Once CJA had won the job with General Contractor Steve P. Rados, Inc., CJA retained Brierley Associates to design a DSM perimeter wall with one level of internal bracing to shore the excavation as a value engineered option.

SITE GEOLOGY

The mud rotary borings and CPTs showed relatively consistent soil conditions across the site:

- Existing grade to approximate depth of 5 foot: sandy fill (SW-SM)
- Approximate depths of 5 – 13 feet: silt (ML or MH), with clay lenses, approx. 5 blow count
- Approximate depths of 13 – 34 feet: clay (CL or CH), approx. 3 blow count
- Approximate depths of 34 – 46 feet: silt (ML or MH), approx. 25-30 blow count
- Approximate depths of 46 – 55 feet: sand and silty sand (SP – SM), approx. 38 blow count
- Approximate depth of 55 feet and below: sand (SP), approx. 45-60 blow count

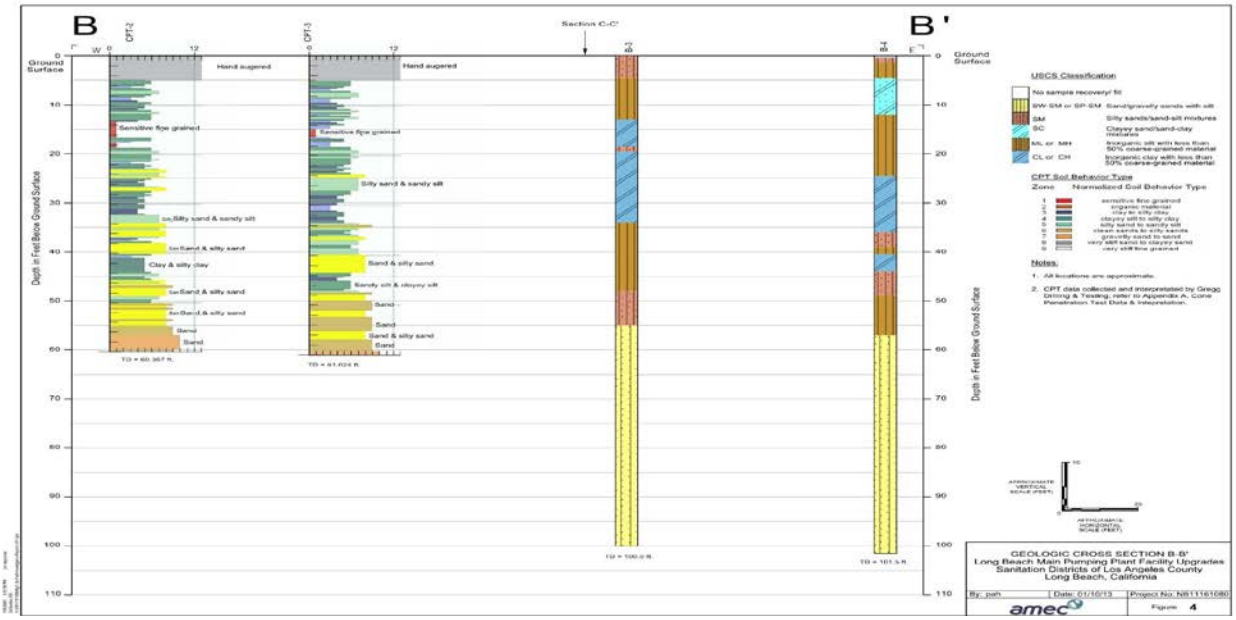

Figure 1: Cross Section illustrating typical soil profile

DESIGN

Brierley Associates provided a design tailored to CJA's specifications. The earth pressure for shoring design was provided in AMEC's geotechnical report. A design ground water table elevation of +2 was specified in the contract documents.

The DSM wall was reinforced with soldier piles. The design utilized a minimum soil mix unconfined compressive strength (UCS) of 50 psi. At full depth, the DSM wall was supported by one level of internal bracing.

The shoring system relied on lateral support provided by a jet grout plug at the base of the excavation and a single waler level. The specified minimum unconfined compressive strength (UCS) of the jet grout was 250 psi.

The excavation, bracing installation and bracing removal sequence was as follows:

1. Excavation to an approximate depth of 8 feet below existing grade (to elevation -0.5) and installation of internal bracing at elevation +1.5
2. Excavation to subgrade (elevation -34.5)
3. Construction of improvements and backfill to elevation -8.5 (16 feet below grade) at which point internal bracing was removed

The cantilever conditions (prior to bracing installation and after bracing removal) were analyzed using Teng's simplified method. The full depth (braced) condition was analyzed assuming a Fixed Earth Support condition.

Risa 3D was utilized for the bracing analysis and design. The bracing design has six wale members, four short diagonal struts, four long diagonal struts and one crosslot strut. All the struts were preloaded by jacking to 50% of their design loads.

The soil anchors were designed to withstand the hydrostatic uplift forces acting on the base of the jet grout plug at full depth excavation.

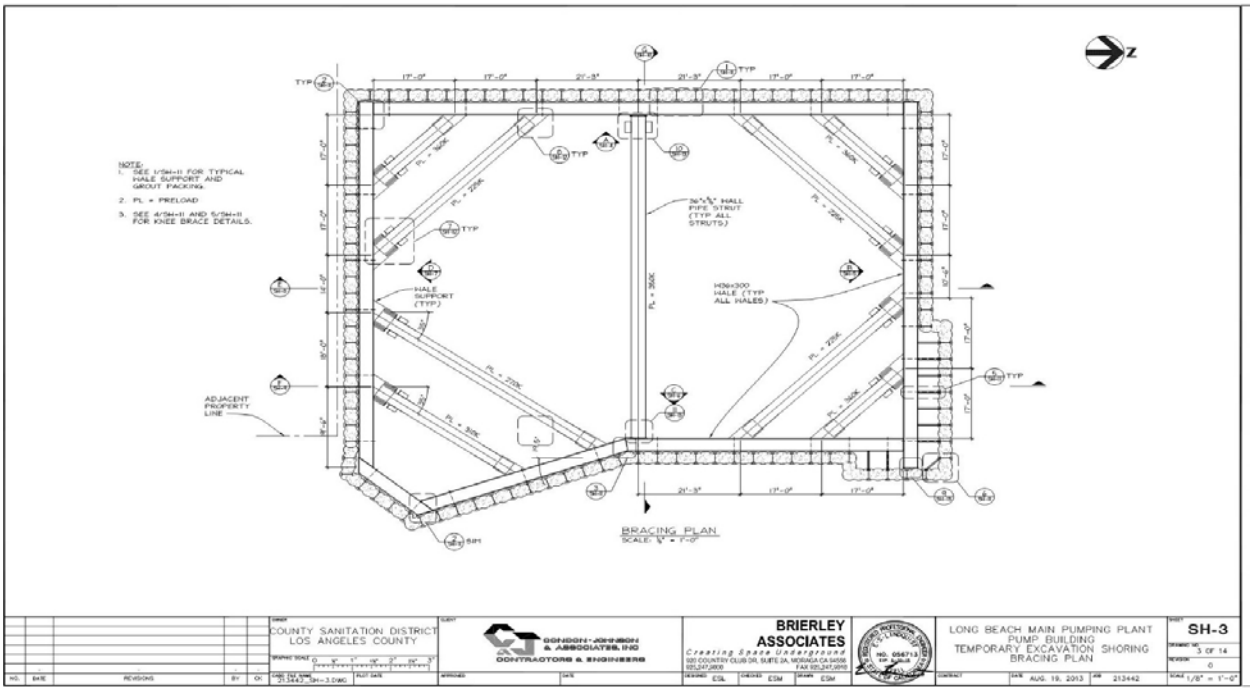

Figure 2: DSM Wall and Internal Bracing Layout

PREPRODUCTION TEST SECTION

Soil Mixing

Prior to the start of production soil mixing, one (1) non-production panel was installed. The test panel permitted the grout mix and soil mixing parameters to be calibrated based on experience in similar ground conditions.

Jet Grouting

Two (2) jet grout mixes were utilized in the Jet Grout Test Section Program (TSP) to select the final jet grout mix utilized in production. Five (5) test jet grout columns utilized a certain specific gravity (SG) and pull rate and two (2) other test jet grout columns utilized another SG and pull rate. CJA cored the interstice of the columns to confirm geometry as well as to retrieve samples for UCS and permeability testing. The specifications had a requirement of 75% recovery and for each 4-foot core segment and total average recovery of 85%. As noted above, the design jet grout UCS was 250 psi at 56 days.

SOILCRETE CORE LOG

Core ID:	LBMPP - CB01	Core Date:	1/9/14
		Jet Grout Date:	12/23/13
Surface Elevation:	7	Jet Grout Age (Days):	17
Location Details:	Jet Grout Test Section	Cored By:	CJA
		Logged By:	BPH

Run No.	From Depth Feet	From Depth Meters	From Elev.	From Start Time	To Depth Feet	To Depth Meters	To Elev.	To Finish Time	Elaps'd Time	Run Length	Recovered Lgth (ft)	Recovered %
5	54.6	16.6	-47.6	14:08	57.5	17.5	-50.5	14:16	0:08	2.9	2.5	86%

Coring Notes:

Core Hole Summary

From Depth	40
To Depth	57.5
Total Core Len	17.5
Total Len Recovered	14.95
Total Percent Recovered	85.4%

Figure 3: Test Section Core Log and Core Photograph

The test program results allowed the selection of the SG and pull rate to achieve adequate treatment in the clayey material.

Soil Anchors/Tie Downs

Two (2) soil anchors and two (2) tie downs were installed in one of the jet grout test section, two (2) soil anchors and one (1) tie down were installed in the other jet grout test section, and three (3) soil anchors were installed in native soil. The soil anchors and tie downs installed in the jet grout columns were installed with 15.5 feet of embedment into the jet grout columns. The soil anchors installed in native soil, were drilled to a depth of 90 feet below ground surface with a 30-foot bond zone. Load testing to determine the ultimate grout to ground bond was performed; however, in all cases the grout to ground bond exceeded the allowable

(80% GUTs) bar stress. Therefore, the ultimate grout to ground bond was not determined, but the testing proved that the grout to ground bond exceeded the design requirements. Based on the test results, a value engineered option was proposed to the owner to reduce the quantity of tie downs. The owner accepted the value engineering proposal and the number of tied downs was reduced from 198 to 117.

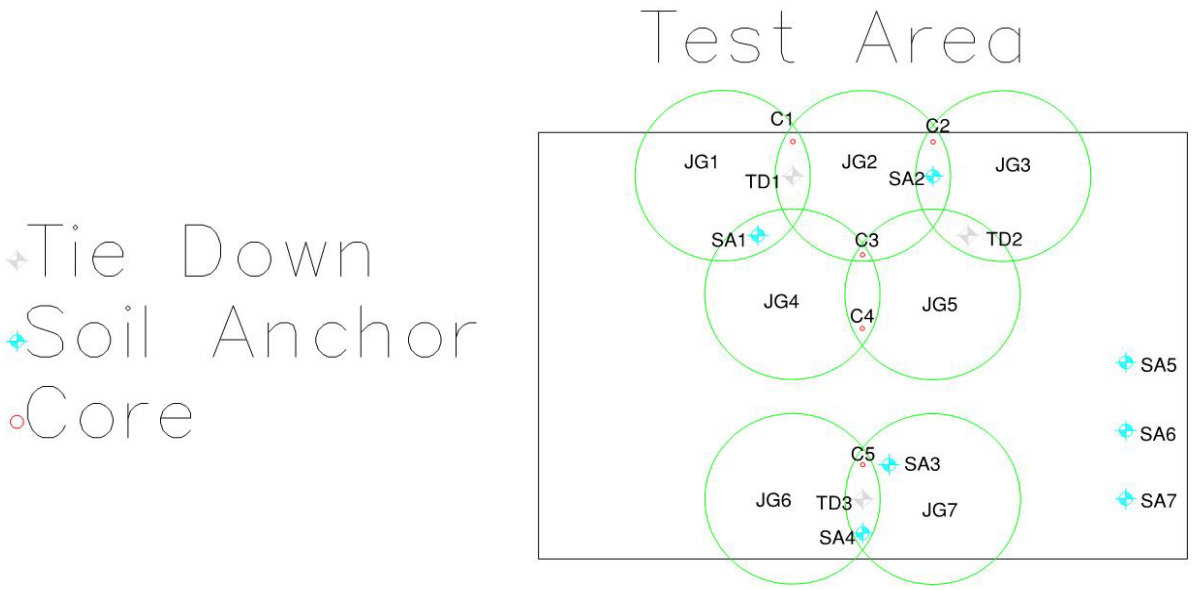

Figure 4: Test Section Program Layout

PRODUCTION WORK

Soil Mixing

One hundred eleven (111) DSM panels were installed with a 24-Meter ABI rig from approximately elevation +7 to elevation -46.5 for a total depth of 53.5 feet. The 24M ABI was outfitted with a specialized soil mixing data acquisition program. Prior to mixing, a continuous trench was excavated to collect soil-cement spoil generated during the mixing process. The cement dosage was based on achieving the 50 psi UCS design requirement. The specific gravity was confirmed via daily flow meter and mud balance testing.

Figure 5: Soil Mixing Rig and Tool with Pre-Excavated Trench

Beams were inserted into the still fluid soil mix material with a 17-Meter ABI rig.

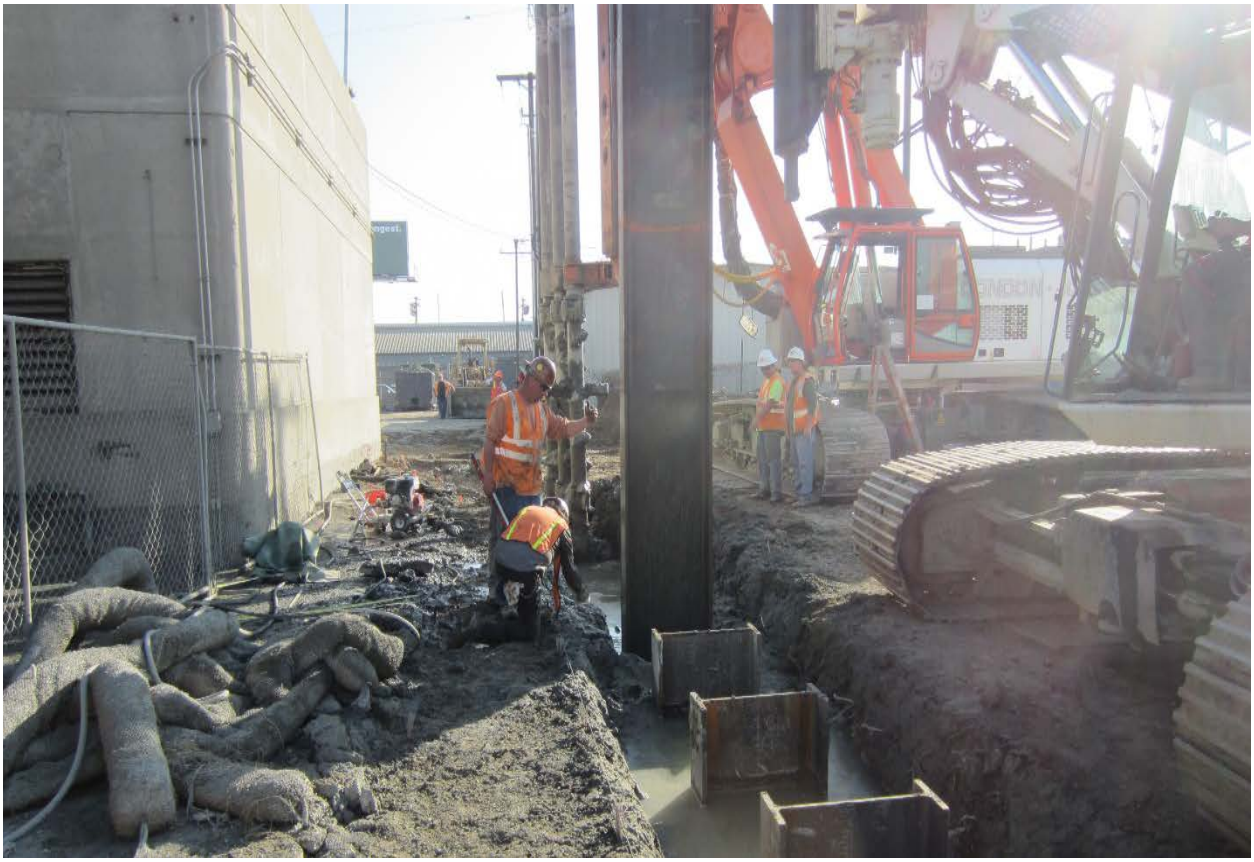

Figure 6: Steel Beam Installation

Jet Grouting

A hydraulic rotary Klemm 3012 drill rig outfitted with jet grout controls was utilized for production jet grouting. The drill head has special drive motors that allow for consistent slow RPM speed. The drill has electronic sensors which display the verticality of the drill mast in two directions to ensure column plumbness. The drill unit contains a rotary head coupled with automatic chucks mounted on a crowd winch system which runs along the mast.

The jet grout tooling consisted of CJA's 152 mm CJM jet grout system. This system utilizes drill rods which pass two fluids and air. One fluid is for the drilling and the second fluid is for high-pressure grouting. Air also passes through the drill rods and exits out of a large nozzle which surrounds the grout nozzles. The jet grout swivel is located at the top of the drill steel. The grout swivel connects the high pressure grout, drilling fluid and air hoses to the drill steel and directs the fluid into the appropriate annulus of the drill steel. Additionally, it allows the rotation of the drill steel separate from the hose connections. At the base of the drill steel the fluid exits through the jet grout monitor. The monitor transfers the flow of the grout into a highly concentrated stream perpendicular to the axis of the drill steel. The monitor also provides pathways that allow the air to "shroud" the stream of the high pressure grout. A high pressure triplex piston pump (Soilmec 7T600J) was used to pump the grout from the agitation tank to the drill through high pressure hoses.

Figure 7: Jet Grout Operation

Soil Anchors

The Klemm 3012 was utilized to drill and install the soil anchors. However, the drill steel was changed from the 152 mm jet grout rods to 6" diameter drill casing. The soil anchors were installed after the jet grout plug was installed. CJA attempted to drill to depth and install the soil anchors; however, the sands at depth, under a great amount of hydrostatic pressure, would flow into the drill steel, even with grout in the drill casing. To overcome this issue, cased drilling was extended into the jet grout plug, at which point the casing was broken and the soil anchor bar was installed within the casing, and drilling was then continued to depth. Once the specified tip elevation was reached, without shutting off the grout pump, the drill steel was reversed, leaving the drop off bit at the bottom of the hole. The soil anchor and drill bit remained in the drilled hole.

Tie Downs

The tie downs were installed with a Soilmec SM-14 hydraulic drill rig after the pit was excavated to subgrade (elevation -34.5). The tie downs were drilled, utilizing water as the drill medium, 10 feet into the jet grout bottom seal slab, with 6 feet sticking up for embedment into the mat slab. The General Contractor installed block-outs through the mat slab that the tie downs could be stressed after the mat slab was placed and cured. Post grout tubes were installed in case post grouting for additional capacity was necessary. Because the number of tie downs was reduced from 198 to 117, the design load increased. All the tie downs were successfully proof stressed to 133% of their design load, and none required post grouting.

QA/QC AND VERIFICATION

Batching

To ensure consistent mixing, the specific gravity of the mix was monitored via flow meters as well as mud balance to confirm the digital readings. Additionally, the grout mixing plant tracked the quantities (lbs) of water and cement used per batch, which were verified based on cement deliveries and cement remaining at the end of shift.

Soil Mixing
A customized data acquisition system in conjunction with a mass flow meter was used to monitor and record the soil mixing data during the mixing process.

The following information was displayed in the cab for the operator to monitor:

- Date/Time
- Depth (feet)
- Tool Rotation Speed (RPM)
- Grout Pressure (psi)
- Grout injection/Flow Rate (gallons/min)
- Verticality

During production mixing, one (1) wet grab sample, consisting of six (6), 3" x 6" cylinders were cast daily to be UCS tested to confirm the 50 psi requirement.

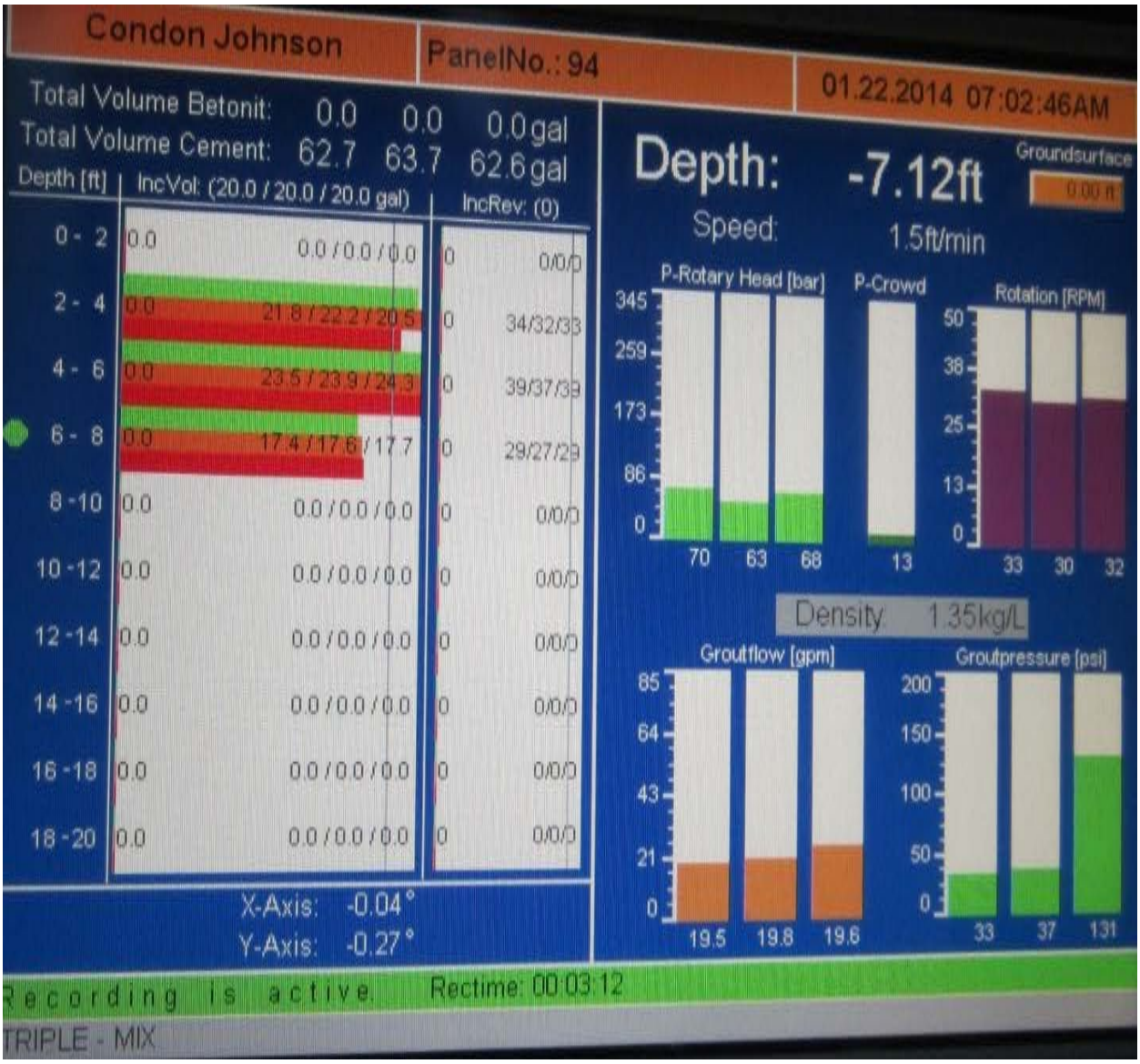

Figure 8: Soil Mix Operator Interface

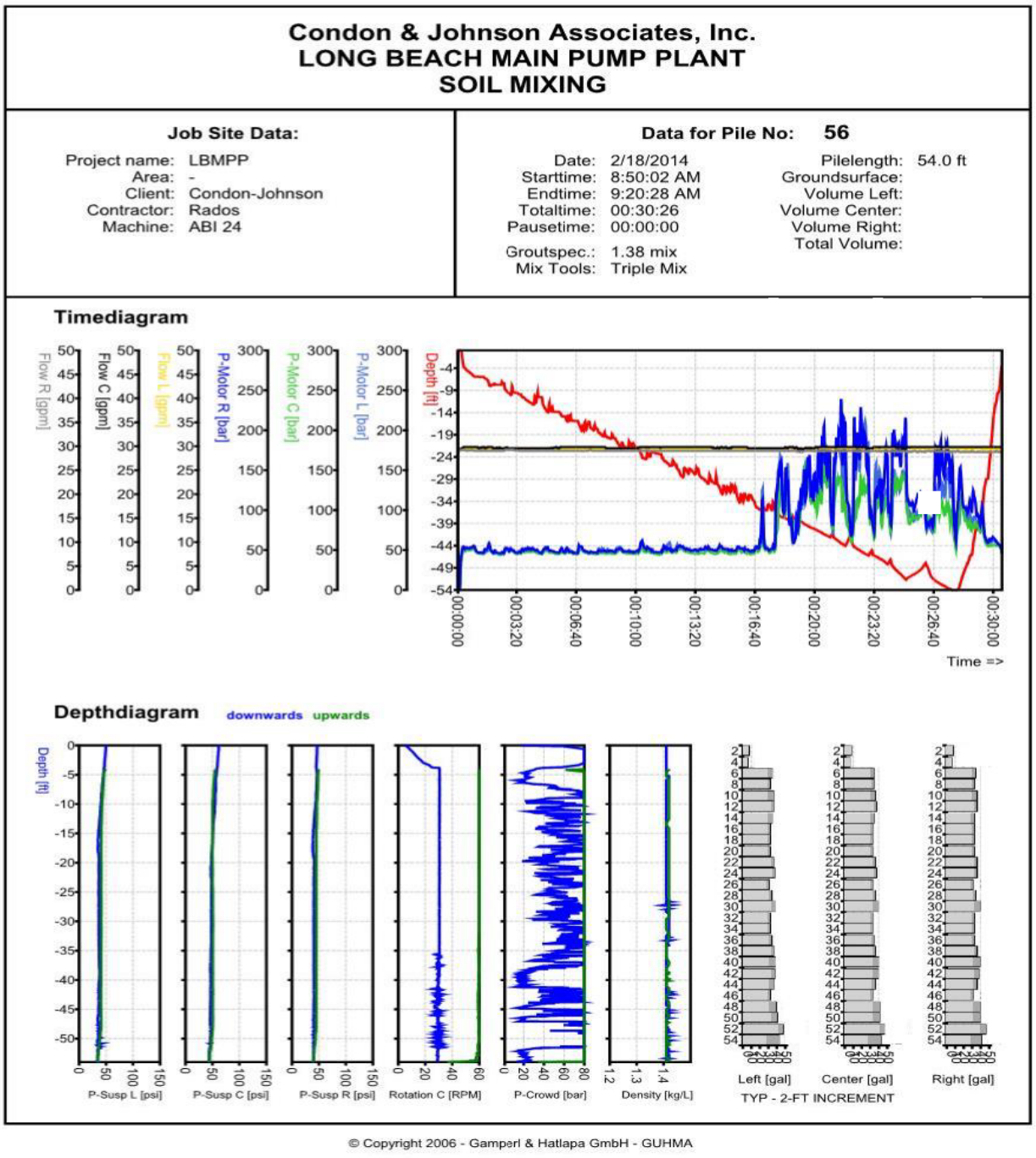

Figure 9: Soil Mix Log

Jet Grouting

A Bauer B-Tronic jet grout data acquisition system was used to monitor and record the jet grouting data. Real-time flow meter and grout pressures sensors data were visible to the operator in the drill cab during installation. Each jet grout column was recorded and an electronic report was provided with each element. The reports included: Date/Time, Element ID No., Depth (feet), Rate of Penetration/Extraction (feet/minute), Drill rod RPM, Grout Pressure (psi), Air Pressure (psi), and Grout Flow Rate (gallons/min).

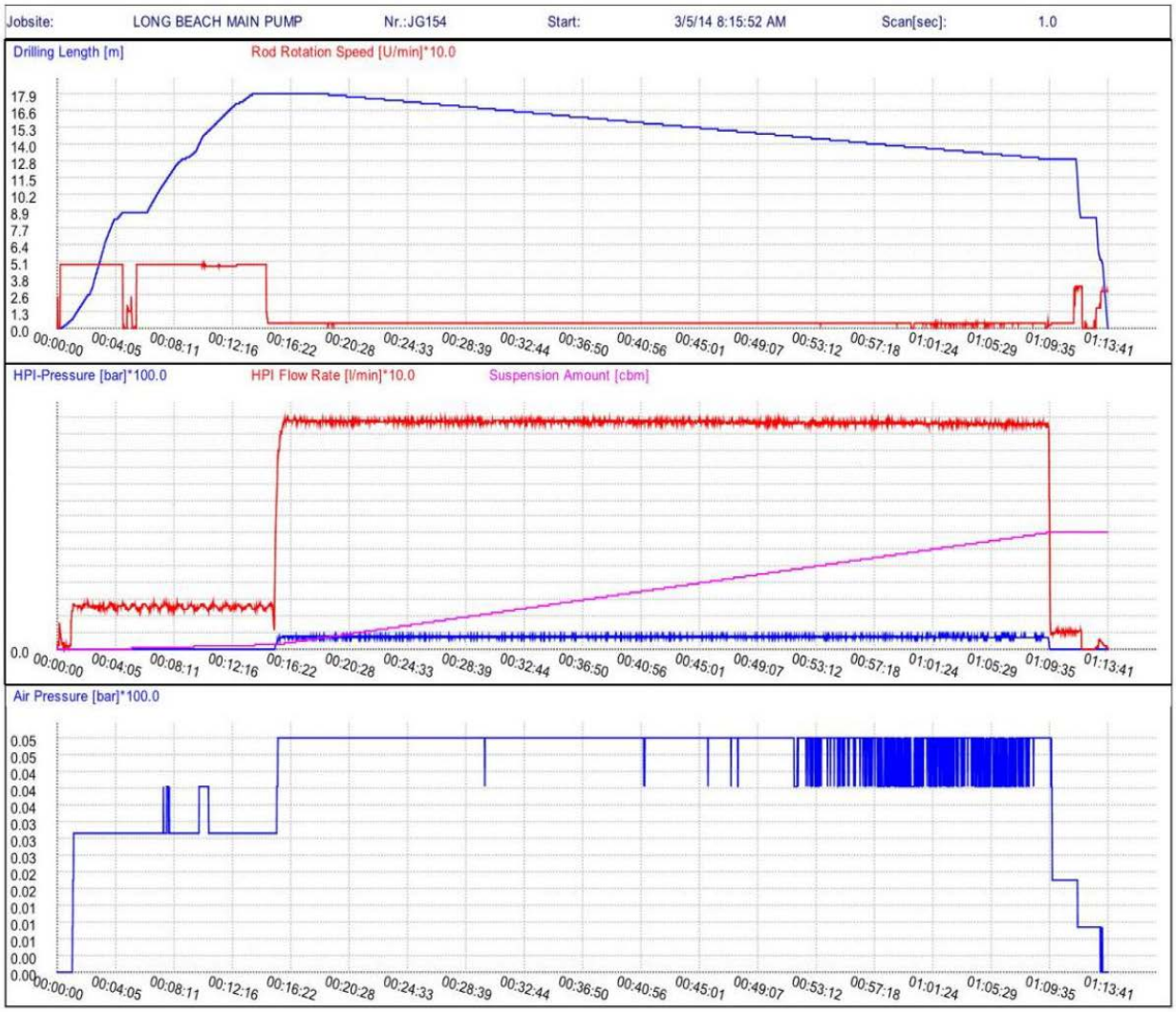

Figure 10: Jet Grout Log

On a daily basis during production grouting, six (6) wet grab samples, at column mid depth, were taken in 3" x 6" cylinders to be UCS tested.

One set of the wet grab samples showed low UCS breaks at 28 days. In response, the column was cored and the retrieved sample was UCS tested. The UCS of the core sampled was 696 psi at 33 days confirming that the as-installed column was acceptable.

Additionally, CPT testing was performed to confirm the jet grout geometry, treatment depths, and insitu strength during jet grout production work.

CONCLUSION

The pit was successfully excavated; and was essentially watertight. There was one slightly damp spot in the bottom seal plug and a small leak at one of the soil mix panel joints. Total water intrusion into the excavation was well below the permitted inflow.

Figure 11: Excavated Pit

For a view of the fully excavated pit during the tie down installation, you may search for Long Beach Main Pump Station on YouTube or directly at: https://www.youtube.com/watch?v=1lxH8NN31pc

REFERENCES

Geotechnical Investigation Report, Long Beach Main Pumping Plant Facility Upgrades, County Sanitation Districts of Los Angeles County, Long Beach, California, Prepared by AMEC, Irvine CA, January 28, 2013, Project No. NB11161080