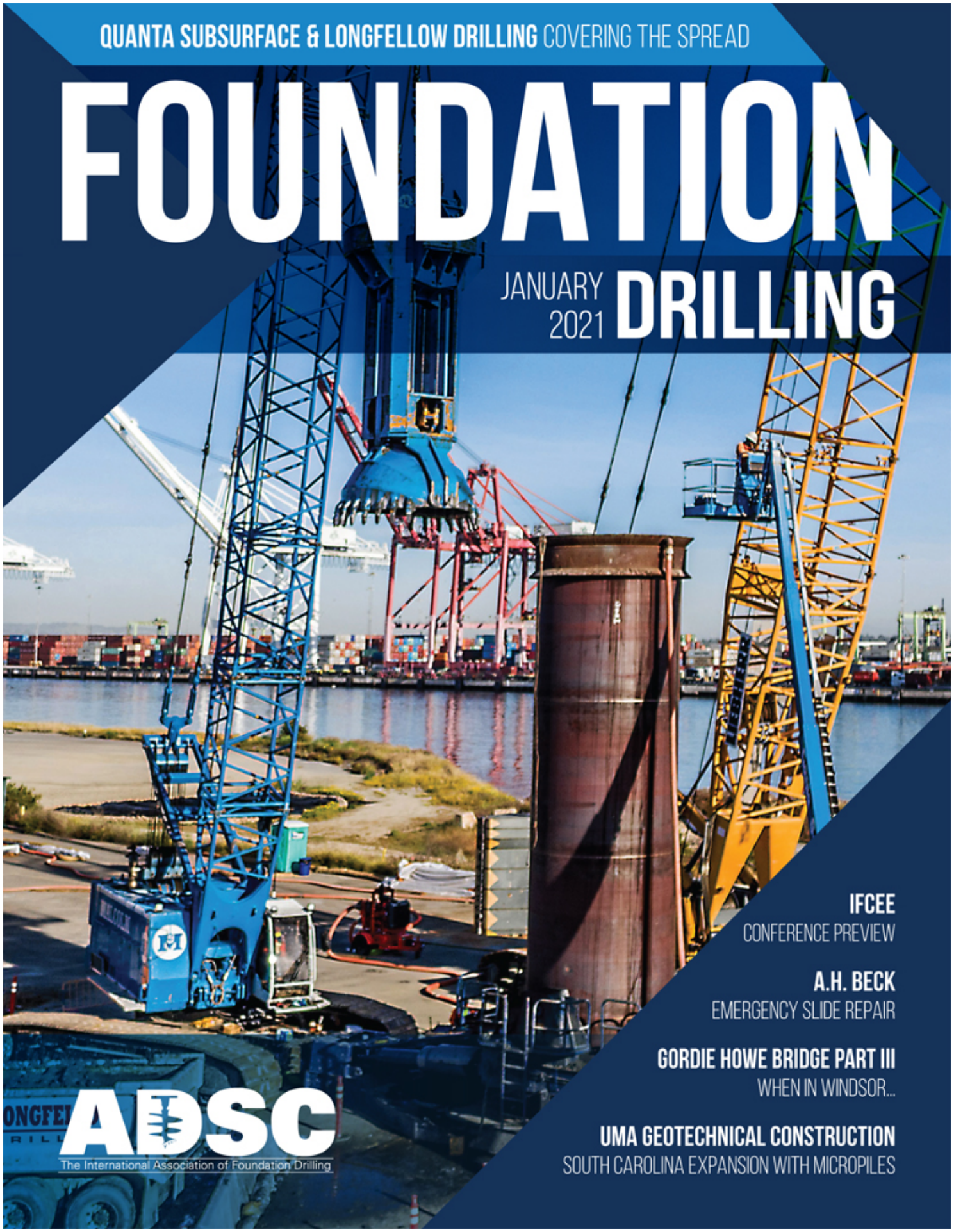
QUANTA SUBSURFACE & LONGFELLOW DRILLING COVERING THE SPREAD
FOUNDATION
JANUARY 2021
DRILLING
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CONFERENCE PREVIEW
A.H. BECK
EMERGENCY SLIDE REPAIR
GORDIE HOWE BRIDGE PART III
WHEN IN WINDSOR...
UMA GEOTECHNICAL CONSTRUCTION
SOUTH CAROLINA EXPANSION WITH MICROPILES
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FEATURE STORY: GORDIE HOWE BRIDGE PART 3

GORDIE HOWE BRIDGE PART III WHEN IN WINDSOR

BY PEGGY HAGERTY DUFFY, P.E., D.GE., ADSC TECHNICAL DIRECTOR

Windsor, Ontario, is a former outpost on the edge of the province. It is the home of Sandwich, the oldest continually inhabited settlement in Canada west of Montreal, and was the starting place for the War of 1812 between the British and the United States. Windsor began as the land of several First Nations, including tribes of the Huron and Algonquin, and transitioned into an agricultural community when French settlers arrived in the 1700s. A critical hub on the Underground Railroad in the mid-1800s, the area around Windsor is thought to have received as many as 100,000 enslaved people fleeing the U.S.

Situated at the southern tip of Ontario, surrounded by the Great Lakes, and tucked

Situated at the southern tip of Ontario, surrounded by the Great Lakes, and tucked in between U.S. states, Windsor developed into an industrial hub in the 1800s.

Local settlers and traders ventured into salt mining and manufacturing, among other businesses. The manufacturing moved into the automotive industry in the 20th century, making the most of the proximity to the U.S. auto manufacturing region and capitalizing on the many transportation routes available through the Great Lakes–St. Lawrence Seaway System. Windsor earned the nickname "Automotive Capitol of Canada" through smart development and leverage of a deep local workforce.

Throughout its existence, Windsor has been characterized by adaptability to change and resourcefulness. These traits have kept the city alive and relevant moving into the 21st century. The stereotypical Canadian humility and reserve are on full display in this working community, where things get done and obstacles are minimized rather than dramatized.

It follows that the drilling contractor constructing the Canadian foundations for the Gordie Howe International Bridge, GFL Environmental, of Vaughn, Ontario, would perform as one does in Windsor. How was the project? "It was fine." Did you run into any problems? "Not really." Did you find it difficult working in man baskets 7 meters above the ground in mid-winter with 40 km/hour winds whipping around? "It wasn't too bad. Seen worse." No doubt GFL will be entered in the annals of Windsor history as yet another example of big strides being made with little fanfare.

SANDWICHED IN

In the early 20th century, as automotive manufacturing began to take off in Detroit, Michigan, the Great Lakes—St. Lawrence Seaway was a critical transportation network for automotive delivery and for support industries. But overland transportation modes from the various bodies of water were lacking. In the 1920s, Joseph Bower decided to build a bridge to cross the Detroit River, thus providing a direct path for automobiles and automobile parts to travel across the U.S.–Canadian border from Windsor to Detroit. The city of Windsor was fertile ground for the birth and development of numerous manufacturing businesses supporting automotive production in Detroit and the surrounding area. In addition, a new

bridge would make it easier to transport completed vehicles from Detroit to sell in Canada.

The Ambassador Bridge, as the project was called, was billed as a great opportunity for the people of Windsor, particularly for those in the tight-knit community of Sandwich, where the Canadian side of the bridge would be located. The bridge would bring traffic right through the center of Sandwich, requiring demolition of some existing structures but bringing the promise of new opportunities for businesses in the area. Unfortunately, fate wasn't in the meeting when the plan was hatched. The bridge opened in 1929, right at the start of the Great Depression. Actual traffic volumes initially were fractions of those projected. Goods didn't flow across the bridge, they trickled. For the people of Windsor, particularly in Sandwich, the Ambassador Bridge was a big investment in space with no immediate payoff.

As North America dug out of an economic sinkhole, the automotive business began to take off. By the 1960s, vehicles, as well as parts, were being produced in Canada, and the value of the Ambassador Bridge was in full view. But a change in ownership of the bridge led to monopoly issues, and manufacturing growth soon outstripped the capability of the bridge to handle the traffic demand. A new bridge was needed.

The people of Sandwich have long memories, and they weren't interested in another bridge laying waste to more of their historic community. They petitioned

long and hard to bridge officials to find a route that would avoid Sandwich. According to Mark Butler, of the Windsor-Detroit Bridge Authority (WDBA), the requirements of the Canadian Environmental Assessment Act (CEAA) weren't the only reasons the WDBA made such strong efforts to maintain the integrity of the Sandwich community.

"Sandwich has suffered a lot of losses in the past, and we wanted to honor their very vocal requests to preserve and enhance their neighborhood."

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ALL
CRANE RENTAL

Project officials made a commitment to make every effort to find an alignment outside Sandwich and instead provide development incentives through proximity to the new bridge access. This new bridge would see at least a portion of 25% of all commerce flowing across the U.S.– Canada border. The local citizenry was happy with the apparent environmental sensitivity, at least as happy as a community can be when a large construction project will create at least some disruption. Alas, this was just the first hurdle in the quest to site and construct a new bridge.

HIDDEN DANGERS

Determination of the bridge alignment and placement of the Canadian Port of Entry (POE) included many more evaluations and complications than avoiding Sandwich. Planning began in 2001, with hundreds of studies needed to identify all of the conditions present in order to make the best decision possible.

Like the Detroit side of the river, Windsor has a history of salt mining. The salts were deposited when the area was part of a warm inland sea during the Silurian geologic period. Great coral reefs surrounded the area, blocking flow of freshwater into the zone. Sea water gradually evaporated, leaving heavy salt deposits.

Windsor Salt is the largest producer of salt in Canada. Brine wells typically are used, which are deep wells that circulate brine down into salt deposits and bring up salt from the dissolved bulb that forms at the bottom. Traditional room and pillar mines also have been excavated in the past, and mine records (in any industry) are notoriously incomplete. Currently two mine locations exist in western Windsor, both within the potential alignment of the new bridge and the Canadian POE. Fears about possible subsidence and loss of bridge foundation support stemmed from a large subsidence event that occurred in the 1950s at the Prospect Street mine in which a large warehouse building sank into the ground. The two mine locations – the Prospect Street site and the Morton Drive location to the south – hemmed in the potential alignment area, making it difficult to site the bridge and approaches without getting close to the salt operations. Thus, extensive geotechnical explorations were necessary to make sure that the exact foundation locations were not in close proximity to subsurface voids that could compromise

support or present the risk of future subsidence.

A more well-defined subsurface hazard exists throughout the Windsor-Detroit region in the form of artesian conditions in the rock below the deep glacial till deposits. The geotechnical exploration activities confirmed that about 30 feet of old fill were located over 60 feet of sands and gravels. A hardpan of lightly cemented glacial till, 3 to 4 meters thick, is located at the bottom of these deposits and acts as a confining layer over the hard limestone below. The result is a head of 5 to 7 meters (15 to 20 feet) in the rock layers in the region. In addition, the limestone is very hard and not easily excavated. To compound these conditions, organic debris in the rock produces hydrogen sulfide gas, a highly toxic gas that requires special precautions. (In fact, a resort with “hot springs,” a byproduct of these conditions, formerly was located in the area). All of these concerns would be required to be considered when siting and designing the bridge and associated features.

Shallower concerns came in the form of past activities in this busy area of western Windsor. The riverfront land had been used as docks and loading points for boats of all sizes for hundreds of years. There were no comprehensive records of all the various enterprises that had existed at the potential locations for the Windsor side of the bridge In addition, Mark Butler stated that an amusement park once was located in the study zone, and a small community had been built in the area in the past when a factory had been planned to be built in western Windsor. The amusement part was torn down, and the residential community has diminished over the years, leaving behind unknown quantities of old foundations, outbuildings, and other remnants. Although such debris wouldn’t constitute hurdles that couldn’t be overcome, the potential for extra costs and additional time drilling through debris had to be considered when determining a final alignment.

The subsurface questions were compounded by significant complications presented by environmental considerations. The Butler garter snake and the Eastern foxsnake both were identified in the study zone, and project officials were committed to determining an alignment that would allow an optimum opportunity to protect these endangered species. In addition, a number of sensitive plants were located throughout the area, and new stormwater runoff patterns created by the proposed bridge and POE features could have harmed fish populations and other

aquatic life if not designed properly.

A DECISION IS MADE

After several years of geotechnical evaluation and thousands of hours of careful consideration of environmental impact, the WDBA team chose an alignment. The Windsor side of the bridge would be sited just south of the Prospect Street salt mine at the location of an aggregate storage facility, with the POE to the east. “Where we decided to build,” said Butler, “the ground is perfectly safe.”

Stormwater would be controlled in part through the Broadway Drain project, an enhancement of an existing drainage feature that added snake hibernacula (underground chambers for winter hibernation), which are expected to become the winter home for hundreds(!) of hibernating snakes. Plants were relocated very carefully to other habitat areas, and 4.3 kilometers (2.7 miles) of snake fence were installed to keep snakes from getting into the construction zone and being killed. Tree stumps and other features also were placed strategically along the Broadway Drain to create fish habitats, and a jetty was constructed to extend into the Detroit River to minimize erosion where the Drain discharges into the river.

BUILDING A BRIDGE

Once plans were in place to keep the snakes and fish happy, the business of building bridge foundations could get started. WBNA entered into an agreement with Bridging North America (BNA) to build the bridge, and BNA went looking for foundation contractors who could construct the large drilled shafts needed to resist the loads generated by the longest main span of any cable-stayed bridge in North America.

The professionals at GFL were well known as experts at installing large diameter drilled shafts into the glacial till and hard rock in the project area. GFL Vice President of Major Projects Ron Vermey said that representatives of WDBA and BNA had begun talking with GFL in late 2018, evaluating methods and schedules and discussing budgets. Project officials knew GFL had the expertise to execute the project, and GFL expressed a desire to contribute to this important regional endeavor. ADSC Contractor Member Malcolm Drilling, of San Francisco, California, had been brought into discussions about constructing foundations in

similar conditions on the U.S. side of the river. So, it was settled – Malcolm would handle fluctuating river levels and tight quarters on the U.S. side, and GFL would try not to run into river debris and avoid squashing snakes on the Canadian side. May the best ADSC contractor win. Not that it was a competition. Not that anyone would be eyeballing the other's progress across the river or comparing progress. As everyone in the construction business knows, contractors never are competitive, right? Right.


AMHERST

"Malcolm would handle fluctuating river levels and tight quarters on the U.S. side, and GFL would try not to run into river debris and avoid squashing snakes on the Canadian side."

UNDER PRESSURE

Malcolm set up shop in Detroit, and GFL got to work in Windsor. (For more details on the Detroit side of the project, see the November/December issue of Foundation Drilling). The first question GFL had to answer was how it would drill the shafts. Drilling through debris and sand and gravel layers next to the river required skill, but resisting pressures caused by artesian conditions while removing very hard rock was not just another day at the jobsite. Nineteen 3-meter diameter shafts were proposed to be advanced about 27.5 meters (90 feet) through overburden and 4.5 to 6 meters (14.75 to 19.7 feet) into hard limestone. GFL Project Manager Mike Hatch stated that GFL decided the conservative route was the most prudent course of action. They would advance permanent casing to top of rock instead of trying to use temporary casing and removing it during concrete placement.

To resist artesian pressures, casing would extend 7 meters above grade and would be filled with water. This setup would be in place from the start of drilling through concrete placement. Hatch indicated that the combination of water and permanent casing meant that slurry was not necessary, and the team could avoid potential pitfalls with casing extraction during concrete placement. "We knew it would take longer," he said, "but the decrease in risk was worth it."

To provide the most efficient conditions for working 7 meters above grade, GFL personnel came up with a system of movable catwalks that could be attached to the top of the casing. Vermey said this system gave workers access beyond the confines of man baskets and provided a safe environment in which to work. The catwalk elements could be reconfigured as work progressed and tasks required. "That's not to say it wasn't cold working up there in the winter," laughed Vermey. "Some guys were working up in the air for full days during the worst of the winter.

But it helped with efficiency and mobility, which helped with safety."

Plan in hand, GFL geared up to start work in late spring of 2019. They assembled an experienced in-house team led by Brad Burrows, a 20-year GFL veteran with expertise in installing large diameter deep shafts. Burrows brought with him Tim Peyton and Patrick Gourly, drillers who could be aggressive in removing very hard rock and who also could exercise delicate control when working in the complicated subsurface. The GFL crew knew that round-the-clock work would be necessary for at least part of the job, but this seasoned group of foundation professionals was up for the task.

A TEST

GFL's proposed process would be tested with construction of the Canadian-side test shaft, which took place in June of 2019. Some debris was encountered in the near-surface soils, but the team was able to vibrate the casing to the top of rock while maintaining adequate head above grade. A Bauer BG55 drill rig was used to advance the hole and to install the rock socket. Rock was removed by pilot-drilling smaller diameter holes within the shaft diameter.

In general, the test shaft was completed with no significant problems. The size of the reinforcing steel cage caused some complications when it deflected during lifting, damaging some of the strain gauges installed for testing. But ADSC Associate Member Loadtest, of Gainesville, Florida, was able to work with GFL to

Associate Member Loadtest, of Gainesville, Florida, was able to work with GFL to modify the instrumentation so that accurate test results could be obtained.

> ***"ADSC Associate Member Loadtest, of Gainesville, Florida, was able to work with GFL to modify the instrumentation so that accurate test results could be obtained."***

Justin Beaveridge, Tower Foundation Engineer for BNA, also stated that some lessons were learned during installation of the test shaft that were useful when completing the production shafts. GFL and the construction team implemented several changes to their procedures to help mitigate the artesian water flow outside the casing, such as minimizing vibration in the rock, thorough removal of overburden obstructions, and grinding smooth the casing during installation to ensure a tight seal. These insights were helpful as GFL moved forward to provide optimal results during production shaft construction. After load testing produced satisfactory results, the test shaft was converted into the foundation for the tower crane.

COMPLICATIONS

Between the time that GFL successfully finished test shaft construction and started production shafts, BNA was at work on the site, overseeing wick drain installation for areas to receive large fill deposits and excavating for miscellaneous support structures. Their excavations encountered heavy debris and an unexpected situation. Not only were railroad ties, cribbing, and concrete debris found, but metal rails and old tiebacks were discovered. Project officials determined that the debris presented more than tough drilling conditions, and they decided to try once again to wade through reams of records of historical activity in the area to understand the conditions better. It was an effort that paid off. Sanborn maps from the 1950s showed the location of a gantry crane running right through the area of the new south tower foundations. Also, the site at one time had been an old shipyard, and the seawall formerly was farther inland than where it presently exists. The tiebacks encountered had been installed to retain the old seawall, and disturbance of those elements potentially could have made the subgrade at the work site unstable.

BNA developed a plan to remove most of the steel rails from the old crane line and

to retain the old seawall with members extending at a 35-degree angle from the river so they would not cross the drilled shaft locations. GFL moved to the north foundations, while BNA went about the task of “clearing” the subsurface so that work could continue unimpeded in the south foundations zone.

Brad Burrows was quick to point out that removal of the crane rails and tiebacks didn't mean that no real debris was found in the production shafts. "We ran into a lot of timber piles from the old dock structures," he said. "Some of those piles were 30 to 40 feet long." He said that a former shipping lane had been backfilled in part of the construction area, and the fill included pieces of concrete slabs, cribbing and old tiebacks. (In true understated Canadian fashion, he said this debris was just "annoying.") According to Beaveridge, the city's history of rum running during Prohibition in the U.S. often was on display in the miscellaneous debris that was brought up during construction. "The harbormaster said that as recently as 10 years ago they still were bringing up Model Ts full of rum that had been lost during illegal trips across the river."

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Drilling also encountered boulders down in the glacial till at depths of 12 to 15 meters (40 to 50 feet) below grade in some locations. These naturally-deposited obstructions presented additional "annoying" complications for advancing the casing through the subgrade.

THE GRIND

At the heart of GFL's approach was careful progress through complicated conditions. This tactic paid off, as each shaft was advanced to the top of rock while water was added to balance pressures in the hole, allowing spoils to be removed without creating voids outside the casing. Care continued to be observed as rock was removed from the sockets, the bottoms of the shafts were cleaned, and steel and concrete were placed.

But care takes time. Each welded connection took 3 skilled welders 4 to 6 hours to complete. Rock sockets required 1 to 2 weeks to excavate, due to the very hard rock involved. GFL worked 15- to 16-hour days during much of the project, and rock coring was conducted around the clock when it was ongoing. Cleaning of the

shaft bottoms took 12+ hours for every hole.

Although winter weather was “mild” by area standards, with an average temperature of 3°C (37°F) and the biggest snowstorm dumping “only” 12 inches on the city, wind proved to be a significant issue. With so much of the work taking place on the catwalk system and in man baskets, crews were bound by safety constraints for such settings. Wind speeds higher than 45 km/hr (25 mph) triggered stoppage of work above the ground, which limited progress overall. Burrows estimated approximately 17 days of drilling were lost during the year-long project due to high winds, but the crew busied themselves with other tasks during the down time.

Safety was front and center in general during the work, with stringent guidelines from BNA for the project reinforced by very strict internal safety standards at GFL. Spotters assigned to every piece of equipment and strictly delineated work zones to prevent personnel from entering dangerous areas (e.g. swing radii) were just a couple of the many policies designed to make sure everyone walked off the jobsite in one piece.

PUTTING IT ALL TOGETHER

The enormous reinforcing steel cages for the shafts required pick plans designed by project engineers, and special sensors were installed to make sure the cages did not move appreciably once concrete placement began. Cage placement was complicated by the fact that an inner cage was designed to sit inside the main cage in the upper portion of the shafts.

Project officials initially stipulated that the cages should be maintained at a specific temperature prior to placement in the holes, but that policy later was changed to dictate that the shaft water only was required to be maintained at a minimum temperature of 5°C (41°F). Glycol heaters often were placed in the shafts prior to concrete placement to ensure suitable temperature conditions.

BNA was responsible for providing concrete for the shafts, and GFL had the job of placing it in the completed holes. Risks associated with the artesian conditions were overcome by observing strict tremie placement procedures. Placement didn’t begin until at least four concrete trucks had arrived at the site, and the tremie head

begin until at least four concrete trucks had arrived at the site, and the tremie head was embedded 3 meters in the concrete at all times. A thermal control plan was

devised for the shaft concrete prior to the start of construction and was adhered to strictly throughout foundation construction. Mass concrete specifications included thermal differential limitations. Mix design formulation had been careful and thorough to account for all of the contributing variables, including the size and installation method of the foundation members. “Surprisingly,” said Beaveridge, “we had more complications when the weather was hot than when it was cold.”

FINISHING UP

GFL completed drilled shaft construction in March of 2020, (the same month Malcolm finished). Although the same careful diligence was in evidence from the start of the project to the end, the confidence level for the entire team certainly increased as work progressed. “Everyone was nervous at first because there were so many things that could go wrong,” said Mike Hatch, “but by the end, it was old hat.”

Fortunately for GFL, their work ended right about the time COVID-19 was disrupting the world. No significant delays or supply-chain issues were experienced before shaft construction was complete.

For Ron Vermey, the project was challenging but welcome. “This was right up our alley,” he said. “We are the largest foundation specialty contractor in Canada, and we had a hand-picked team to do the job.”

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SO…..WHO WON?

Many non-professionals in the Detroit–Windsor community have been certain in their assessment of who “won” this foundation challenge. Many have tried to point to completion dates or start dates as proof of a victor, and a number of ordinary citizens have been certain of the status of work that frankly was too far behind construction barriers for the average bear to see or assess. Patriotism in this

region curiously seems to extend beyond hockey to infrastructure foundations. There are worse things to brag about.

"We were very happy with GFL and the work they did, and we are proud that the Canadian shafts really shine in the overall foundation operation for the bridge. Ours are even the prettiest."

Surprisingly, none of the Malcolm or GFL personnel interviewed seemed eager to tout the accomplishments of their team over their cross-border "rivals." "We had different scopes of work," or "We seemed to be moving along at about the same pace," were common refrains. However, one individual was willing to commit. Justin Beaveridge, of BNA, grinned and indicated his pride in the work of BNA's subcontractor on the Canadian side, GFL. "We were very happy with GFL and the work they did, and we are proud that the Canadian shafts really shine in the overall foundation operation for the bridge. Ours are even the prettiest." Perhaps he who is willing to state his opinion gets the last word.

COVERING THE SPREAD: DESIGNING FOR LATERAL SPREAD IN DEEP, LIQUEFIABLE SOILS

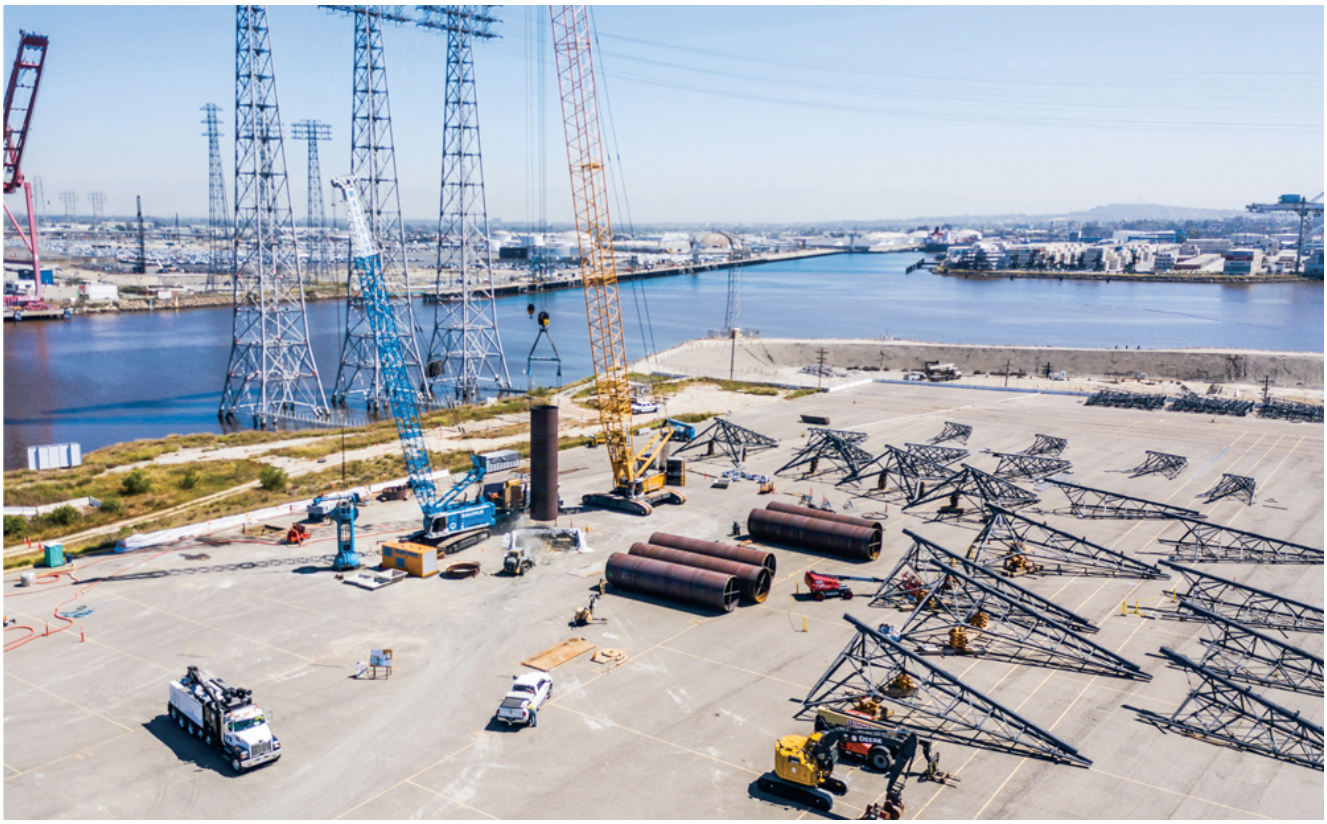
BY DYLAN B. WELSH, LONGFELLOW DRILLING AND J.T. MCGINNIS, P.E., QUANTA SUBSURFACE

AERIAL VIEW OF COMPLETED GRADE- AND TIE-BEAM SYSTEM

Accommodating seismic impacts in foundation design is nothing out of the ordinary. However, when the design is for a stakeholder-critical electric

transmission structure – situated on the banks of a major shipping channel in one of the most seismically active areas of the country – the challenges begin to multiply.

The design and construction of a lattice tower, designated M0-T2X (T2X), on the Cerritos Channel Relocation Project (CCR) was uniquely challenged in a number of ways, the most significant of which was designing for lateral spread displacement that could ultimately lead to the structure's failure following an earthquake. In the end, the project team designed and constructed a drilled shaft foundation system featuring a unique, heavy-duty grade-and tie-beam system to meet the demands of the extreme structure loading and difficult geotechnical conditions.



M0-T2X STRUCTURE SITE

PROJECT DETAILS

The CCR involved replacing existing electric transmission towers that were nearly a century old within the Port of Long Beach in Southern California. Replacement structures included four tubular steel poles and two lattice steel towers located on each side of the Cerritos Channel. The purpose of the project is to raise the

electric transmission and telecommunication lines to accommodate taller, larger-capacity cargo ships entering the Channel. Foundation design was challenging across the board, but no structure faced the breadth of these challenges quite like the T2X tower located on the south bank of the Channel.

T2X is a four-legged lattice steel tower with a height of approximately 387 feet and a leg span of 60 feet square. The structure was heavily loaded; each tower leg foundation was required to support design compression, uplift, and shear loads of approximately 6770 kips, 3840 kips, and 580 kips, respectively, following incorporation of required factors of safety. A maximum displacement (vertical and lateral) of 1 inch was permitted under static loading conditions, with a requirement that the new structure not collapse and maintain its ability to carry normal working design loads after a design earthquake. In addition, the following conditions reported to exist in the area required consideration: highly corrosive and potentially contaminated undocumented fill soils, environmental sensitivities, and known and unknown underground utilities.

Based on project-specific subsurface data obtained prior to construction, and following over a year of technical review by the owner and a third-party entity, the contractor's geotechnical engineering firm established that the design liquefaction depth at T2X was 86 feet. Seismically induced lateral displacement was estimated to be greater than 72 inches (i.e. > 6 feet) as a result of the structure's proximity to the adjacent Channel. The result of this evaluation was that design of the foundation system would be required to resist and/or accommodate more than 6 feet of ground movement in the form of sliding towards the Channel due to seismically induced liquefaction of the underlying soils.

SITE HISTORY + GEOLOGY

The history of development within the Port had a major impact on both design and construction of T2X's foundation system. Up until 1897 when the Port was developed, the project site was a tidal mudflat and the structure location was underwater. In the early 20th century, the area was reclaimed by dredging the Cerritos Channel and filling adjacent areas to create what is now part of Terminal Island (Figure 1).

In 1936, oil was discovered within the harbor and erection of supporting infrastructure continued through the 1950's. Oil extraction from the deep strata under the site led to one of the most accelerated cases of land subsidence on record. By 1958, the impacted area was about 20 square miles with a depression of up to 29 feet at the epicenter, which was very near T2X's future location (Figure 2). In the 1960's, the subsidence was halted by injection of water into the deep strata layers from which oil was extracted.

Regarding area geology, the Port of Long Beach lies within the coastal area of the Los Angeles Basin, which generally consists of a large, low-lying alluvial floodplain. The area development over the past century has resulted in soft/loose Holocene deposits being capped with a relatively thick layer of undocumented fill material that is generally characterized as highly corrosive with isolated areas of high contamination. Groundwater was generally coincident with the Channel, which had a water level of about 10 to 15 feet below the ground surface at the T2X location.

The project area is also seismically active with several notable earthquakes occurring within and adjacent to the Basin. The largest historical earthquake within the Basin was the 1933 Long Beach earthquake with a reported magnitude of 6.4. The epicenter of the more recent 1994 Northridge earthquake, with a reported magnitude of 6.7, was located just 35 miles from the project site.

FIGURE 1: T2X STRUCTURE LOCATION ON THE PORT OF LONG BEACH (GOOGLEEARTH 2020)

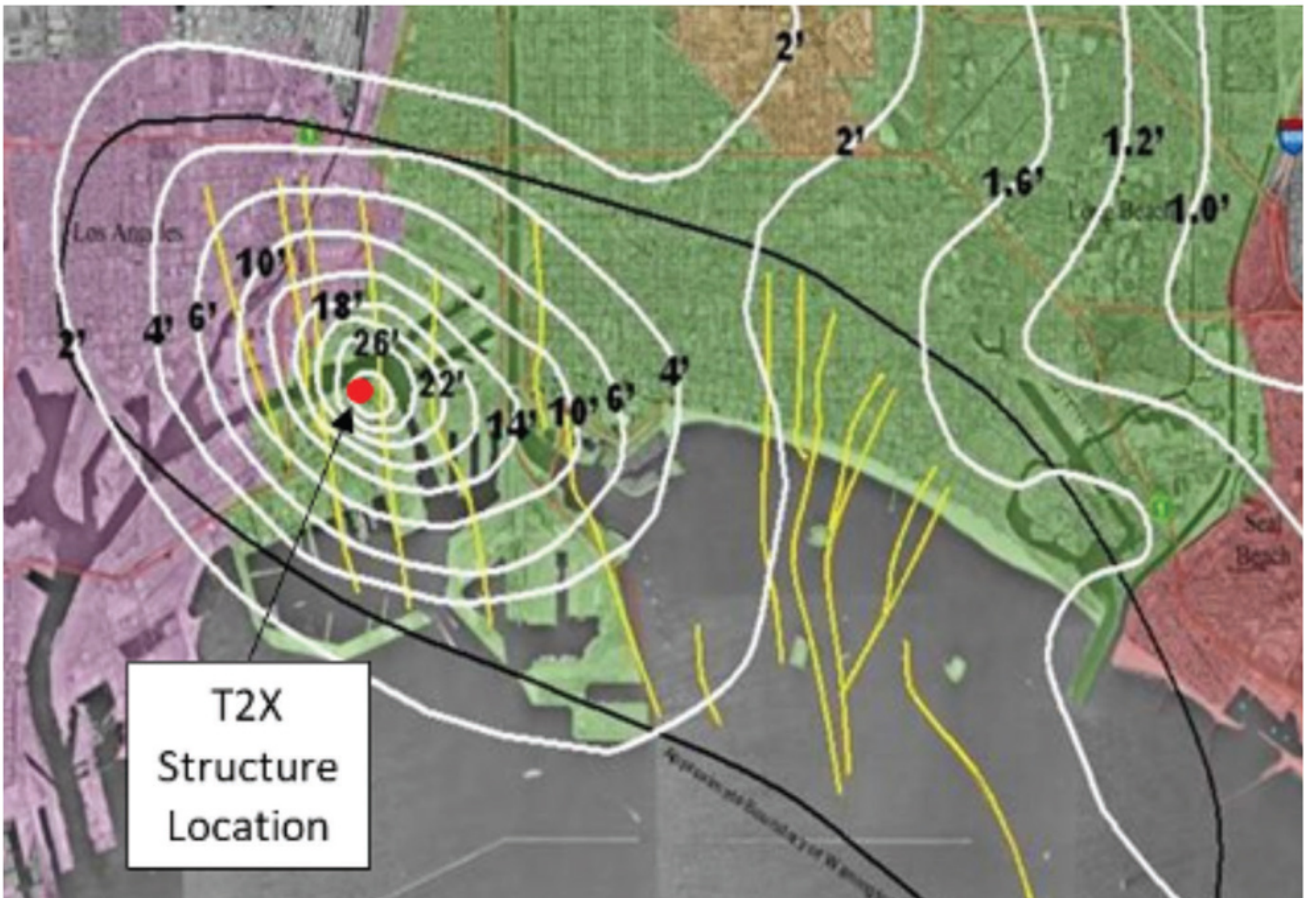


FIGURE 2: ISOMETRIC MAP OF GROUND SUBSIDENCE WITHIN THE PORT OF LONG BEACH

DESIGN ALTERNATIVE

A host of design and construction challenges were contemplated and addressed during a design process that continually evolved and ultimately spanned from Fall 2018 to early 2020. The original design approach, consisting of partially cased cast-in-place concrete drilled shafts, was based on information available at the time of bid that indicated underlying dense sands of the Gaspur Formation would exist at a depth of about 70 feet, and that lateral spread magnitudes at the T2X location would be on the order of 1.5 feet. Construction associated with the original design included installation of permanent steel casing using vibratory methods through softer, liquefiable material to the dense sand layer beneath. The steel casing would be installed to a depth of about 70 feet and traditional drilling methods using slurry were to be implemented to extend the drilled shaft to the planned tip depth. The inclusion of permanent steel casing in the original design was primarily for excavation stability during shaft construction.

A subsequent geotechnical investigation, executed by contractor Longfellow Drilling, revealed that liquefiable soils extended deeper than originally anticipated. In general, the subsurface conditions consisted of up to 34 feet of undocumented fill underlain by estuarine/marine deposits to a depth of about 95 feet where dense granular soil of the Gaspur Formation was encountered. Design recommendations based on the updated geotechnical data resulted in a potential lateral spread displacement estimate of greater than 6 feet; this represented an increase of approximately 400% over the contractor’s original design assumptions.

It became apparent that the existing foundation approach was not feasible. The updated magnitude of lateral spread required that permanent steel casing extend to the shaft tip elevation and approximately 20 feet into the underlying dense Gaspur Formation. Permanent casing was no longer incorporated into the design for construction purposes only; it was now required for both design and construction reasons. Vibratory advancement of permanent casing through approximately 90 feet of liquefiable materials and up to 20 feet into the dense granular bearing layer presented a number of risks and led the team to reevaluate

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SPHERICAL GRAB EXCAVATION

SPHERICAL GRAB EXCAVATION

The project's Foundation Engineer, Quanta Subsurface, collaborated with project foundation contractors, Longfellow Drilling and Malcolm Drilling, throughout the design process. This included iterative soil-structure analyses and working to establish the optimal foundation size based on design requirements, material and equipment availability, and cost. The final design included fully cased, large-diameter drilled shafts at each tower leg connected by a combination grade- and tie-beam system. Full size grade beams would be constructed perpendicular to the Channel slope, and tie beams parallel to the Channel face. The grade- and tie-beam system was specifically designed to address the liquefaction induced lateral spread in a four-legged structure. The final design was not developed to resist all lateral movement; instead it would result in uniform lateral displacement, enabling the structure to maintain normal working design loads after a design earthquake.

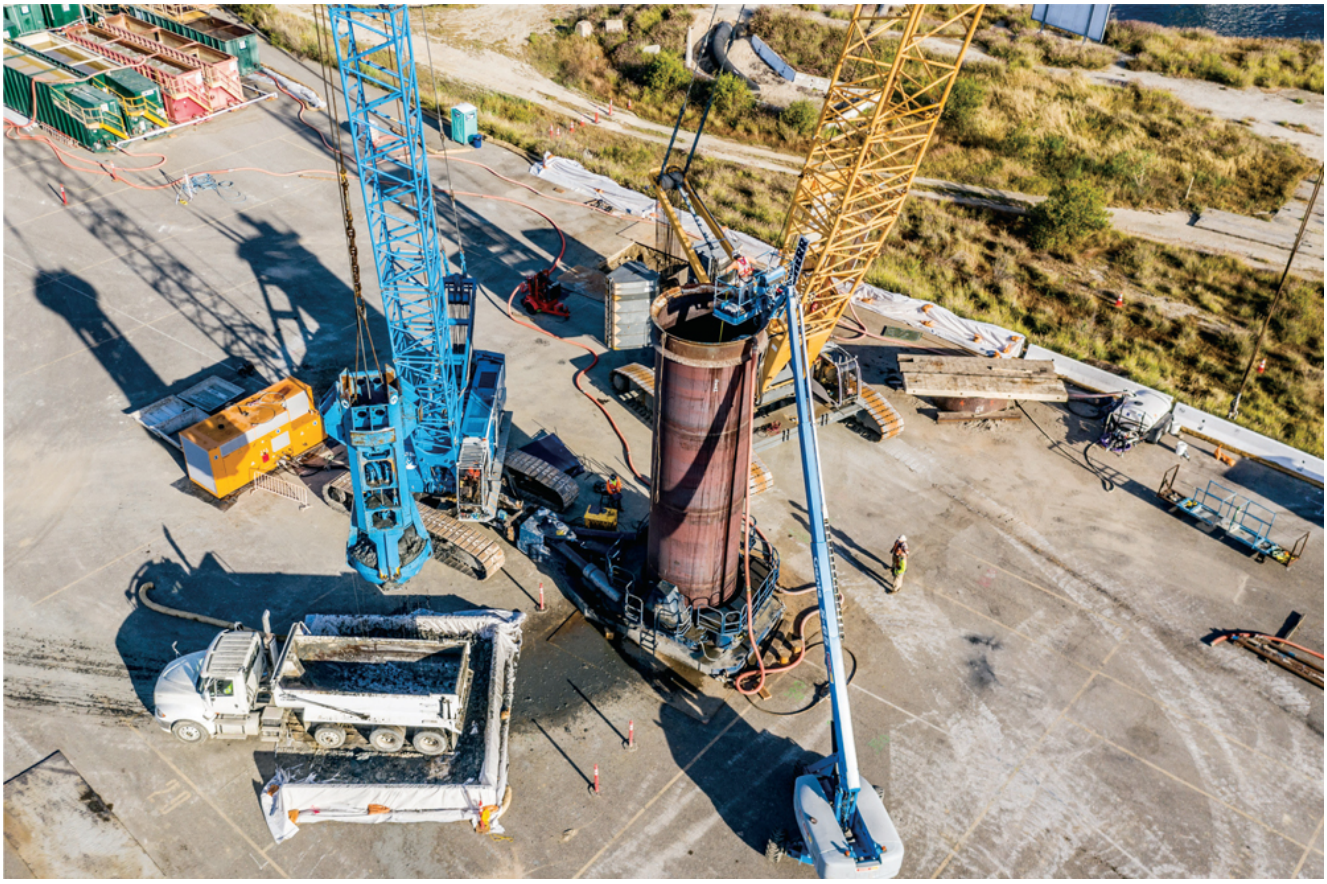
Other foundation systems and ground improvement methods were considered;

specifically, foundation systems that incorporated deep soil mixing. These were

considered in multiple combinations, including use in conjunction with drilled shafts to remove the need for full-length casing. Ultimately, deep soil mixing was deemed unfeasible due to potential environmental impacts, known and unknown underground utilities, the volume of required materials and the spoils generation, cost, and the lack of Port approval.

SHAFT CONSTRUCTION

The shafts were designed with an outside diameter of 9.84 feet (3 meters) and a minimum embedment depth of 115 feet below the ground surface. For both design and constructability reasons, designs incorporated permanent, 1.25-inch thick, full length steel casing. Casing was advanced in sections, requiring specialty welding with mag-particle testing, and a crane-suspended spherical grab was used to excavate overburden material. Upon completion and final cleanout, the 54,000-pound reinforcement cage was hoisted and set into position. Precise anchor bolt placement was critical to ensuring the foundations at each of the four tower legs aligned with the grade- and tie-beam system. Concrete placement was completed using a tremie pipe and concrete pump truck to the construction joint location. Post-construction QA/QC inspections were performed, as well as project-required Gamma-Gamma Logging to verify the integrity of the shaft.



EXCAVATION MATERIAL DISPOSAL

STUB ANGLE AND HEAVY SUPPORTS

Construction of the grade- and tie-beam system required mass excavation, setting the 16,500-pound anchor bolts, civil grade beam steel reinforcement place ment with anchor bolts in place, formwork and concrete placement. The anchor bolt tolerances, less than a fraction of an inch, were maintained by performing multiple survey checks to each bolt cluster to verify location from the center of the tower and in relation to each other. In addition to the lateral location of the anchor bolt cluster, a custom heavy-duty support system was fabricated to span the large grade beam excavations while ensuring the anchor bolts maintained design elevation tolerances. The concrete placement required for construction of the grade- and tie- beam system totaled approximately 500 cubic

yards and was performed monolithically. Concrete placement was completed using multiple concrete pump trucks to ensure precision placement pace and consistent concrete elevation throughout. This was crucial to prevent failure of the formwork system and to promote uniform concrete hydration.

PROJECT SUMMARY

ANCHOR BOLT CLUSTER (ABC) WITH STUB ANGLE ASSEMBLY

All foundation construction was successfully completed, and the upgraded infrastructure will continue to service the region with electricity while facilitating the Port's expanding operations through the end of this century. Although seismic and liquefaction concerns were primarily discussed, environmental protections, underground utilities and potentially contaminated soils presented additional hurdles that the team worked to successfully overcome. It should also be noted that construction began in early March of 2020 at the onset of Covid-19 shutdowns, creating a highly uncertain work environment and requiring further collaboration among team members to ensure employee safety and an overall successful project outcome. As a whole, project challenges were worked through collaboratively during the design phase and allowed construction to be smoothly and efficiently completed.

CAGE LIFT


project TEAM
LONGFELLOW DRILLING
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