Deep Foundations

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OPA Runner Up: The Route 1&9T/New Road

Support of Excavation for Microtunneling Shafts

Rammed Aggregate Pier Load Tests

Refurbishment of a Piled Building

FEATURE ARTICLE

The Route 1&9T/New Road: An Outstanding Project Runner Up

Final roadway

The Route 1&9T/New Road project is a three-part program to relieve the notoriously congested Route 1&9 (Tonelle Avenue) in the heart of the industrial sector of Jersey City, New Jersey. Contract 1 consisted of constructing a new road over a 1 mi (1.6 km) long stretch of unimproved land serving as part of the parking lot to a large postal facility. To get to grade, modular gravity retaining walls were specified on either side of the 54 ft (16.5 m) wide roadway corridor. While the proposed wall heights ranged from only 2–8 ft (0.6–2.4 m), the soils present on-site were not even suitable for a shallow embankment. The underlying soils were mixed fills and organic peat, underlain by soft clay and silt to depths of up to 75 ft (23 m).

The proposed solution presented in the project plans certainly would have worked on paper; however, Menard, having had poor experiences with rigid inclusion installation and load transfer platform (LTP) compaction at or just above the groundwater table, recognized the potential difficulties, delays and rework that would likely be required during construction of what was shown on the contract plans. As such, it proposed a value-engineered solution that resulted in a vast improvement in the constructability, performance and overall cost of the system. However, the benefits of this solution were not appreciated by the owner and the solution was met with high levels of scrutiny, perhaps because it differed from what was shown on the contract plans. The level of testing required of the solution was far greater than what was required of the design shown on the contract plans. Such rigorous and unwarranted confirmation of a value-engineered solution consumed time, money and resources that could be better used elsewhere. Instead, these designs should be compared to the design in the original contract plans based on technical merit and expected long-term behavior. This article walks through the design and construction process for the value-engineered solution and highlights the many challenges experienced by the contractor to get final approval of the work performed. Though the COVID-19 Pandemic was an unanticipated complication, the perceived distrust of the contractor's proposals and work was a barrier to progress that the authors hope will not exist in the future.

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Value-Engineered Solution

The project plans depicted 12 in (305 mm) diameter driven timber piles on 6 ft (1.8 m) centers overlain with a 3 ft (0.9 m) thick, geotextile-reinforced granular LTP. The specifications were open such that a contractor-designed column supported embankment could be proposed. The bottom of the plan LTP elevation (-2.0 ft [-0.6 m]) was below the groundwater table and into the organic soils. Dewatering such a large area and proper placement and compaction of the granular LTP over the organics would have been extremely problematic. To simplify construction, the team proposed a contractor-designed solution consisting of a shallow soil-mixed LTP working from elevations ranging between +0 and +3 ft (+0 and +0.9 m) supported with rigid inclusions installed using displacement equipment. The shallow soil mixing (SSM), which varied from 3–10 ft (0.9–3 m) thick, provided a stable working platform for the rig and acted as the LTP for the rigid inclusions in the final configuration. The rigid inclusions were drilled through the cured soil mixed platform and bonded to it by nature of the column grout bonding to the cemented soil platform.

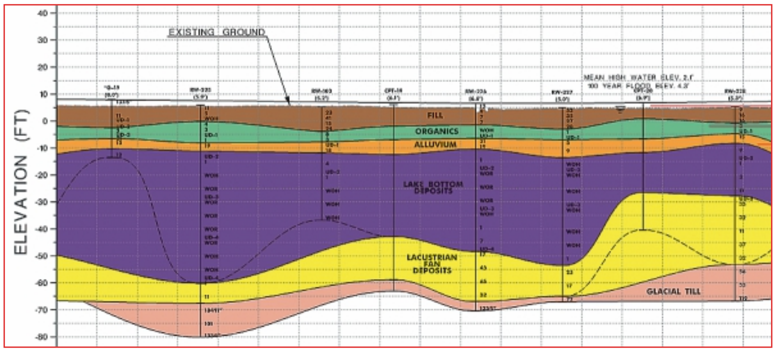
The soil profile consisted of a highly compressible organic layer (water contents up to 400%) and compressible lake bottom deposits. In areas, the compressible soils were up to 50 ft (15 m) thick and the depth to dense sand and glacial till varied significantly from the existing ground surface. Rigid inclusions, installed from the top of the SSM layer, ranged in length from 20–78 ft (6–24 m). Rigid inclusion spacing was optimized due to significant variation in wall geometry and soil conditions along the 1 mi (1.6 km) long project area. The center-to-center spacing of the 12.5 in (0.3 mm) diameter rigid inclusions ranged from 7.5–10.0 ft (2.3–3 m) for an area replacement ratio of about 1-2%. The complex design involved finite element models at multiple locations along the length of the roadway. Comprehensive analyses were performed during design that included checks for bearing capacity, vertical settlement, lateral spread and global stability.

Quality Control

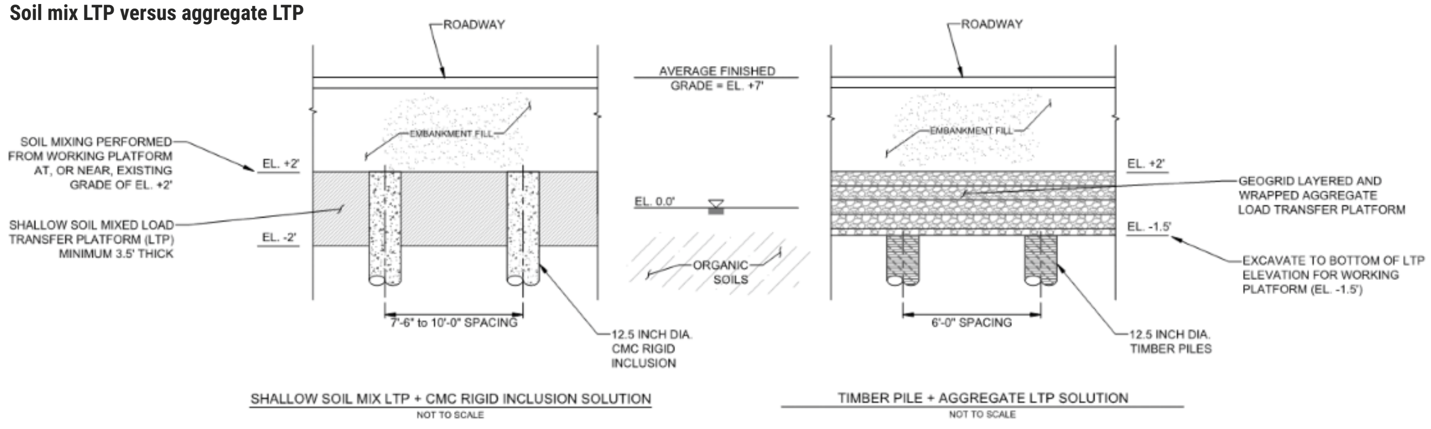
The design initially determined a conservative value for the compressive strength of the soil mix at 89 Psi (0.6 MPa). The Federal Highway Administration (FHWA) allows up to 10% of samples to fall below the target strength. Wet grab samples were taken with an excavator bucket every 75 cu yd (57 m3), which is at least three times the frequency recommended by the FHWA. Due to the large number of samples that would need to be collected, cured and tested, special-purpose modular on-site facilities were set up to allow for moisture content control, sample curing and strength testing.

Over nine months, the team collected more than 700 bulk samples, resulting in approximately 6,600 cylinders cast and tested. Of those samples, the median compressive strength after 28 days was 164 Psi (1.1 MPa) with a first quartile value of 110 Psi (0.75 MPa). Overall, 92% of the tested cells had a compressive strength above the initial 89 Psi (0.6 MPa) target value, meeting FHWA criteria. Cells that did not obtain this value were reanalyzed and often remixed. Of the 8% not meeting strength, remedial measures were taken to accommodate this by reducing the design's rigid inclusions spacing. Due to team (contractor and client reviewers) oversight, 2% of the panels sampled remained with strengths less than 89 Psi (0.6 MPa). For these two specific cases, additional calculations using plane strain Plaxis models were submitted showing that an unconfined compres-

Generalized soil profile along roadway



Soil mix LTP versus aggregate LTP



Testing lab

sive strength of 40 Psi (0.3 MPa) was adequate. However, the client still would not accept a strength lower than 89 Psi (0.6 MPa), despite the additional modelling.

Alternative Quality Control Attempt

Due to the large volume of sampling and testing, the contractor attempted to lessen the frequency of wet sampling and quantity of cylinders by proposing to develop in-situ strength correlations using cone penetration tests (CPT). The CPT also provided verification of the thickness of the LTP (not an original intent). The team initially proposed that the CPT would serve as a secondary measure of the soil mix strength to reduce the frequency of the bulk sampling. The correlation between measured tip resistance during the CPT and strength of the material was dependent on an empirical factor from testing in natural soils. Because the SSM is not a homogeneous soil and varied in composition based on the soils mixed and dosage of cement used, a good correlation of tested strength to the CPT results was not obtained. No changes were made to the frequency of testing since the secondary measure was unsuccessful. However, this exercise cast doubt on the strength of the soil mix in the eyes of the client, despite the highly satisfactory results from the cylinder breaks.

Field Conditions for Mixing

Permit issues and the pandemic delayed the start of work by several months. This ultimately led to the soil mixing operation being completed in adverse winter conditions. Soil mixing field trials began in June 2020, followed by full production in July of 2020. The soil mixing operation faced a myriad of issues, which included restrictions and precautions due to the pandemic, pockets of higher than anticipated peat content, and higher than expected tidal water elevations. The latter required adding cement beyond the values obtained from the lab bench scale testing, additional rigid inclusions and remixing in many cases. For all the panels mixed, about 35% were remixed, essentially doubling the cement content when high organic contents were present.

Soil mixing

When mixing was performed in winter conditions, the team used thermal integrity profiling (TIP) in the soil mix to continuously monitor its in-place curing temperature. TIP wires were installed with sensors on 6 in (152 mm) intervals to determine if the curing, and ultimately compressive strength, was compromised by the winter conditions. The results of the TIP monitoring showed that the in-situ temperature of the soil-mixed material did not fall below 50°F (10°C), despite ambient temperatures of less than 40°F (4°C) Therefore, the testing confirmed that the effectiveness of the curing process was not compromised by the winter conditions encountered during construction.

Rigid Inclusions

Following the soil mixing operation, rigid inclusion installation began in September 2020 and lasted until April 2021. Approximately 3,500 rigid inclusions were installed from atop the soil mixed LTP, or working platform surface in this instance, which varied in elevation based on the elevation of the bottom of the proposed retaining wall. The rigid inclusions were drilled through the shallow soil mix, organics, alluvium and lake bottom deposits before terminating mostly in the lacustrine fan deposits at depth. A computer-recorded log of the installation parameters was generated for each rigid inclusion and reviewed by on-site engineers. Occasionally if predetermined termination criteria were not achieved in the lacustrine fan deposits, indicating a slightly looser material, the rigid inclusions tipped into the glacial till layer.

Four single-element static load tests were spread out and performed during production to verify the geotechnical load carrying capacity of a single rigid inclusion. The load applied during testing was based on maximum stresses in the rigid inclusion observed during design, which included the use of 2D Plaxis axisymmetric and plane

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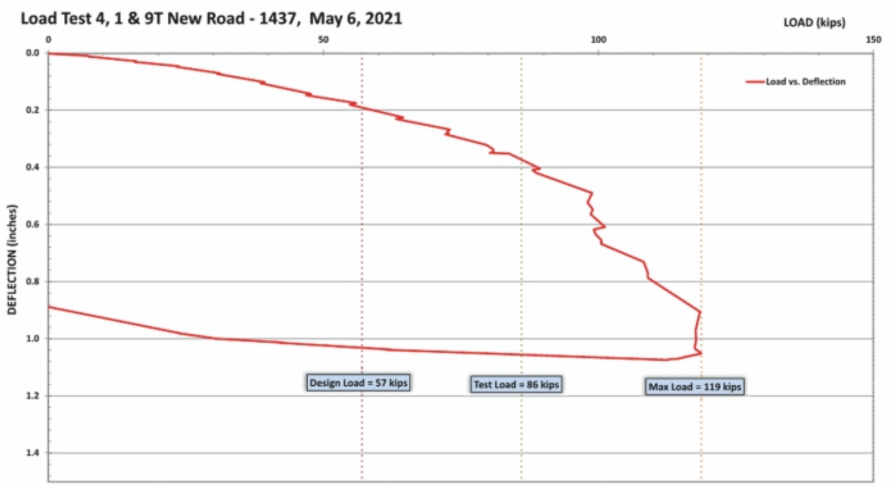


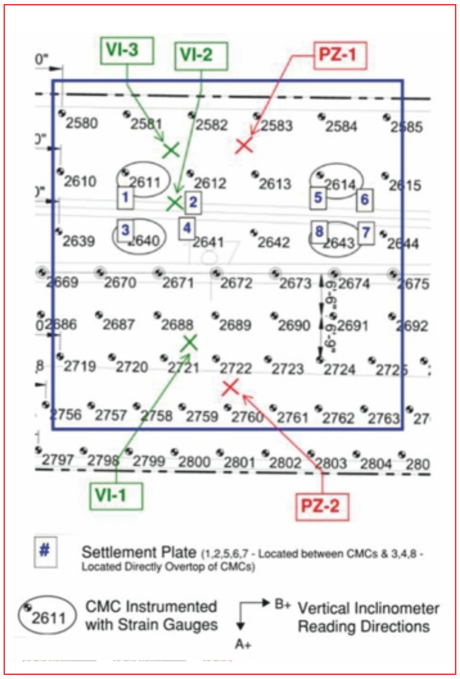
Maximum deflection recorded during single-element load test

Controlled modulus columns drill rig

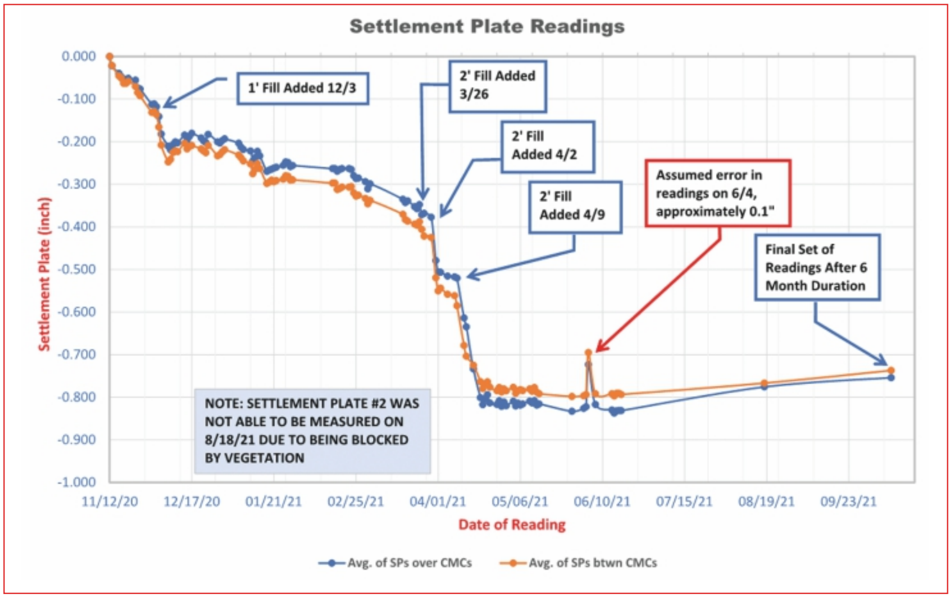
strain modeling. Deflection was measured at the top of the column and load at depth was analyzed using strategically placed strain gauges at various depths along the length of the column. Each of the four rigid inclusion compression tests performed well at the 57 kip (254 kN) design load, the 86 kip (383 kN) test load and beyond. The observed maximum deflection at the design and test loads was between 0.2–0.4 in (5–10 mm) for each test indicating ideal end bearing conditions for the elements.

Full-Scale Load Tests

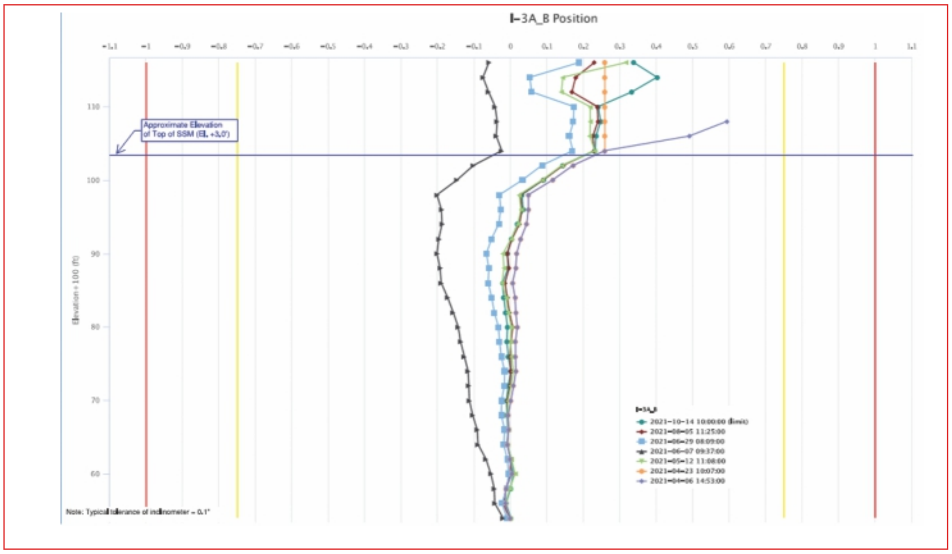
In addition to the single-element static load tests, a fully instrumented area load test covering 43 rigid inclusions was also performed. The purpose of the area load test was to verify performance of the entire ground improvement system including the efficiency of load transfer through the interaction of the LTP with the rigid inclusion. Fill above the rigid inclusions was built up incrementally to a maximum height of twice the final fill height with hold periods at various levels to match the anticipated construction sequence across the rest of the roadway.



Area load test layout plan



Additional fill and settlement plate readings after planned finished grade achieved



Deflection during the area load test was measured with eight settlement plates placed both between and directly above the rigid inclusions to observe differential settlement across the spacing. Four controlled modulus columns were instrumented with strain gauges, similar to the single-element tests, to measure load along the length of the rigid inclusions. Three vertical inclinometers were installed to measure lateral deflections across the width and along the length of the roadway for comparison with movements expected from the design. Two vibrating wire piezometers were placed to measure increases in pore water pressure; excessive buildup of pore water pressure would indicate the added stress from the placed fill reaches the soil beneath the LTP instead of being transferred into the rigid inclusions.

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Under twice the final embankment height, the settlement plates showed total settlement between 0.6–0.9 in (15–23 mm) within the tested area, which met the project performance criteria of 1 in (25 mm) post-construction settlement. Additionally, the observed settlement above and between rigid inclusion locations was generally consistent, indicating that the LTP was performing uniformly. There was minimal fluctuation in pore pressure measured within the piezometers, which meant that the majority of the stress from the fill was entering the rigid inclusions and not the soil. Further, the strain gauge data confirmed the anticipated load curves within the rigid inclusions, with the maximum load being just below the bottom of the soil-mixed LTP. The inclinometer readings remained generally below 0.1 in (2.5 mm) for the duration of the area load test.

Despite the results of the compressive strength breaks surpassing industry standards — and a successfully completed, fully instrumented area load test — the client had trouble giving final acceptance, due primarily, in the authors' opinion, to different expectations about what was to be shown by the secondary CPT correlation attempts. The client was also concerned about the heterogeneity of the SSM and feared that inclusions of soil or extraneous material in the mixed fill would reduce the overall strength of the SSM. The client embarked on some independent testing of the SSM in place, which involved trying to core, which proved unsuccessful because inclusions in the SSM made it difficult to obtain a good core sample. This trial created further doubt. The contractor's opinion remained that with average strengths of the SSM nearing 200 Psi (1.4 MPa), the LTP did not have to be uniform, and soil or other inclusions would not impact the final performance (as demonstrated in the full-scale test). To show this, the contractor carefully excavated bulk samples of the SSM and tested them. The results showed overall good strength above the 89 Psi (0.6 MPa) threshold. Yet, final approval from the client remained elusive.

Added Full Scale Tests

The client requested 10 additional areas for full-scale load testing and settlement monitoring at various points along the roadway to confirm performance requirements were achieved. The areas for monitoring were selected based on sampled soil-mixed cells with the lowest compressive strength results. To obtain a higher degree of certainty, additional fill was placed to heights resulting in 1.3–1.5 times the proposed final fill height. Each of these area tests showed total and differential settlement values within project performance specifications.

Conclusion

The project, as constructed, cost about $10 million less than the contract plan design and was proven to have excellent final performance. The rigorous additional testing program added one or two orders of magnitude more statistical reliability to the predicted final performance of the system. It should be noted that no full-scale load testing was required for the contract plan design, despite the fact that the likelihood of getting a well-constructed LTP below the groundwater table was low.

The double standard given to the value-engineered solution designed and installed by the contractor because it differed from the design in the original project plans complicated and extended the project but could have been avoided. The team, collectively, could have better communicated expectations for testing and behavior, and held routine meetings concurrent with construction. The pandemic increased the miscommunication, as the entire team was working remotely and unable to have meetings and discussions in person, which would have aided in the understanding of this complex and multi-phase construction. Additionally, the pandemic hampered the ability to meet on-site and gain a contemporaneous and common understanding of what the design build team was doing. In the end, bringing the construction out of the water, regardless of all the other distractions, made it much more constructible and resulted in a very high-performing and economical final result.

Acknowledgment

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