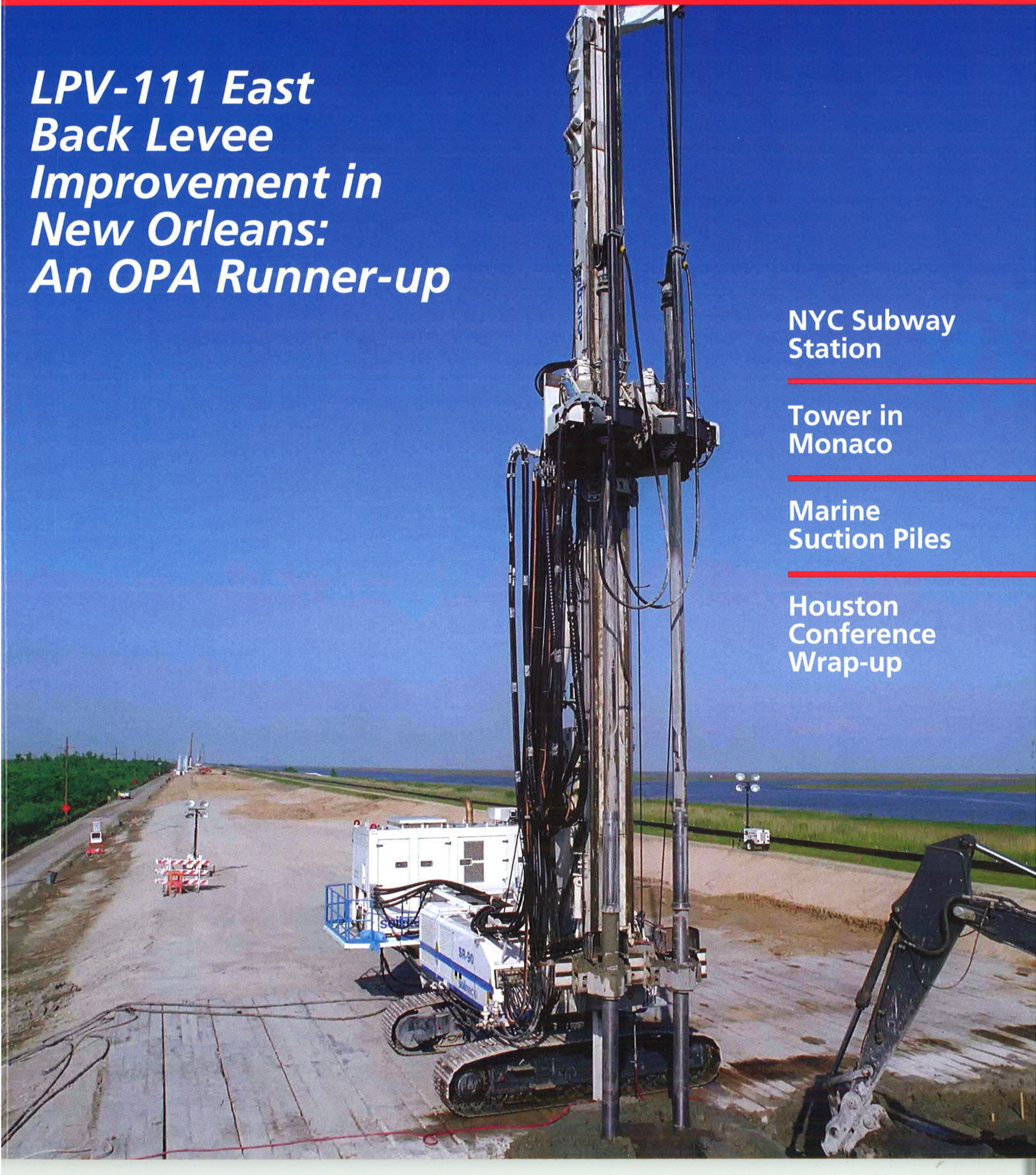
THE MAGAZINE OF THE DEEP FOUNDATIONS INSTITUTE JAN/FEB 2013

DEEP FOUNDATIONS



LPV-111 East Back Levee Improvement in New Orleans: An OPA Runner-up

NYC Subway Station

Tower in Monaco

Marine Suction Piles

Houston Conference Wrap-up

COVER STORY

New Orleans Levee Improvement Project: An OPA Runner-up

The LPV-111 East Back Levee Improvement Project lies along the Gulf Intracoastal Waterway (GIWW) in Orleans Parish of New Orleans, La., and is an essential component of the New Orleans Hurricane Protection System. The Hurricane Protection Office of the U.S. Army Corps of Engineers (USACE) attributed failure of the New Orleans East levees system to overtopping, erosion and subsequent breaching of LPV-111 along the GIWW, as well as other sections of flood protection during Hurricane Katrina in 2005. The existing levee suffered extensive damages from Hurricane Katrina, such that the USACE elected to provide earth stabilization and to rebuild the levee sections. Due to the adverse geotechnical properties of the foundation soils, the Corps deemed ground improvement necessary to stabilize the new levee and to limit its footprint. Wet Deep Mixing Method (DMM) was selected as the most suitable technology for this task.

Challenges

Design: This reach specifically protects East New Orleans and the Bayou Savage National Wildlife Refuge, the largest urban wildlife refuge in the U.S. and home to several threatened or endangered species of birds as well as many reptiles, amphibians and small mammals.

The Corps chose DMM due to the sensitivity of the protected marshlands and because the method limits the footprint of the raised levees. The increase in the load bearing capacity of the treated soil significantly decreases the footprint necessary to attain the required height increase. This limitation required the new levee to have steep slopes, drastically increasing the surcharge on foundation soils characterized by overall poor geotechnical properties (soft clays and peats). The design also considered the increased horizontal stresses on the levees due to the extreme storm surges during a hurricane.

The design of the 1.6 m diameter (5.25 ft) DMM elements called for overlapping them to form a double auger element that formed buttresses perpendicular to the levee alignment. The contractor installed the buttresses at a maximum on center spacing of 4.7 m (15.5 ft). One additional double auger DMM element was midway between consecutive buttresses at the centerline of the levee to further help prevent settlement (Figure 1).

The design called for more than 17,000 elements to complete the project. Most elements were formed by using double auger rigs. Each auger was 1.6 m (63 in) in diameter and had an overlap of 0.30 m (12 in). Some areas of the site had limited access and the contractor used single auger rigs win these areas.

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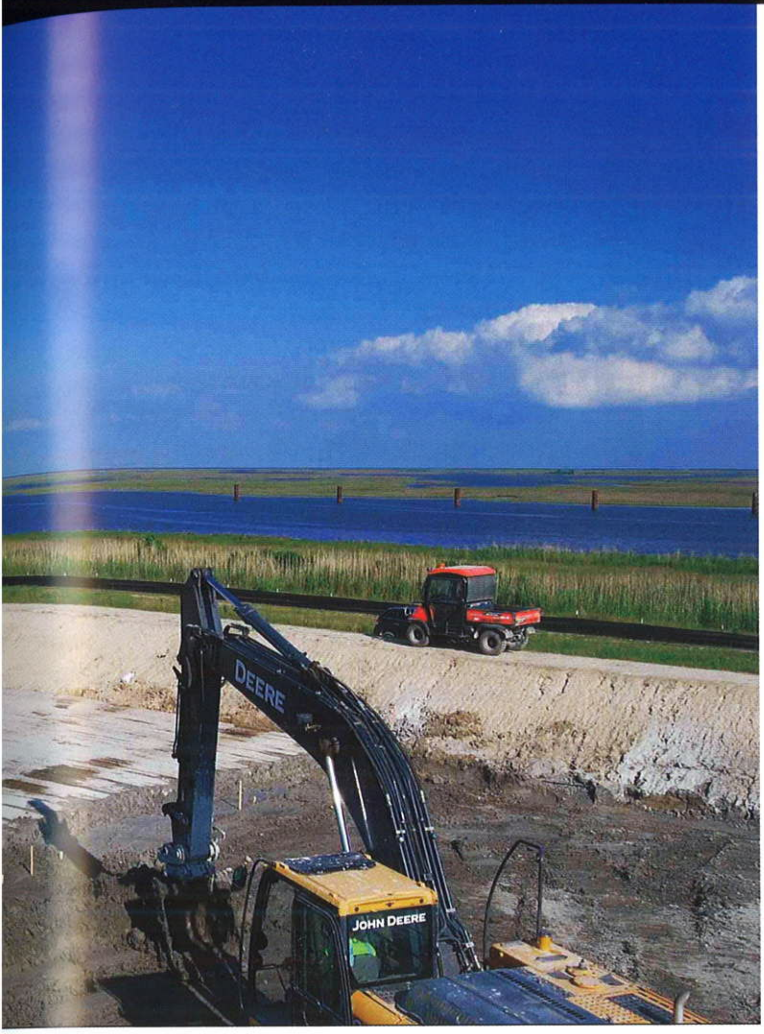

The validation portion of the project started in late November 2009. Due to the length of the project, spanning over 5 mi (8 km), the contractor divided this phase into 5 areas specified along the levee to ensure proper parameters were in accordance with the geology. This measure also insured that the parameters selected for the DMM would produce acceptable results. The contractor originally intended that all 5 areas of the validation phase were to be completed before actual production started. However, to insure meeting the project schedule, the team initiated a production test when only two validation areas were complete. DMM parameters developed during the initial tests were set until the remainder of the validation areas could be completed. Once all validation and production test locations were complete, production began in full force. The design team scheduled the DMM work accordingly and simultaneously with earthwork. They used one additional DMM rig and mobilized two additional grout plants to make sure the completion date was met.

The contractor had to use a total of 1.3 million m^3 (1.7 million cu yds) of foundation soils on a 5.3 m (8.5 km) stretch in slightly over a one year schedule (January 2010 – March 2011). The levee embankment, 1.2 million m^3 (1.6 million cu yds), was constructed subsequent to the verification of the ground improvement quality. Both operations were performed simultaneously.

Logistics: The project required managing a large amount of equipment in a relatively tight and sensitive area: 8 DMM rigs, 8 complete mixing plants, earthwork equipment, cement trucks, clay trucks, concrete pump-trucks, cranes, piling rigs, work vehicles, etc. (Figure 2). The job had only one entrance and only one two-way haul road, for all the equipment, machinery, supplies, etc. There were occasions where the traffic was so congested that it took hours to move from one side to the other of the project (Figure 3).

At LPV-111, the contractor used two different technologies to treat over 1.3 million m^3 (1.7 million cu yds) of foundation soil: 1) Trevi Turbo Mix (TTM), single and double and 2) Contrivance Innovation Cement Mixing Columns (CI-CMC) (Figure 4). Both technologies are considered "wet systems;" the binder is injected in the form of liquid grout slurry through outlets positioned near the end of the hollow stems of the rigs. The workers injected the grout in advance of the stirring tool, which is properly configured to fine-cut the soil and to mix it with the grout to create a homogeneous mixture.

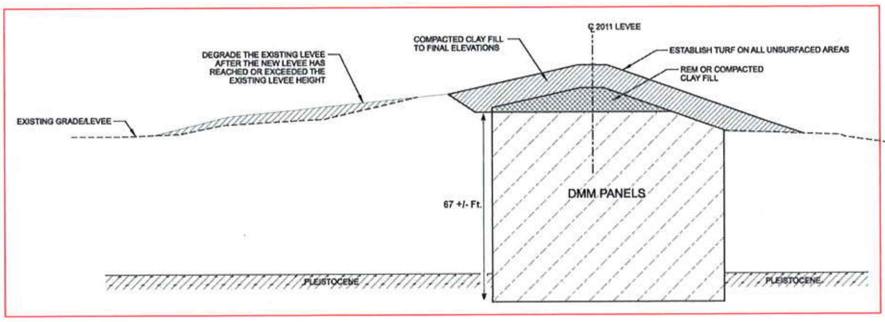

Figure 1. DMM elements (typical cross section)

Schedule: The schedule for the project was very aggressive; as the project had to be substantially completed by June 1, 2011. The original start date for the DMM was to have been November 9, 2009, and the DMM was to be completed by March 30, 2011. The project included 6 main phases:

1. Desk Study – researching previous DMM projects in the New Orleans area to analyze the results
2. Soil Investigation – determining the property of the soils to be treated and collecting samples for the bench test
3. Bench Test – combining the different soil samples with various binder ratios to determine the optimum mixing parameters
4. Validation Tests – conducting full field trials from the information from the bench tests
5. Production Test – using the information from the first two validation areas to install a large area of DMM
6. Production

Figure 2. Operations at LPV-111

Both the TMM and the CI-CMC employed multiple sets of blades or paddles located at the bottom end of the drilling rods to enhance the cutting and mixing effect of the rotation applied to the rod string. The combination of vertical penetration/withdrawal rates, rotational speed and tool configuration, along with the injection parameters and the properties of the grout, are fundamental for the success of the soil treatment. Extensive laboratory tests and field tests established the most suitable construction parameters, which included the most effective materials, and addressed the particular subsurface conditions.

The Bench Scale Test was preceded by a comprehensive soil investigation of the main underground features that provided material for soil testing and mixing. This was done in four distinct phases. Phases 1, 2 and 3 used soils from reaches 12B, 12A and 11B, respectively, progressing from west to east and then north along the project alignment. Engineers also conducted a smaller Phase 4 to supplement previous investigations of binder type.

Five field validation phases were, on the other hand, accomplished at different locations along the levee, while the production was progressing in previously validated areas, once the results of the lab tests performed on soils from specific sections of the levee became available.

Figure 3. Traffic congestion on the haul road

Supply and Delivery of Materials: The material used for the project consisted of binder and water. The binder consisted approximately of 25% type I/II Portland Cement and 75% slag cement.

The Bench Test determined these optimal proportions of the cement/slag. For the entire project, over 417,000 tonnes (460,000 tons) of binder was used.

The water used in the grout mix came from a potable (city) water line installed along the entire length of the project. This water amounted to over 454,000 m^3 (120 million gallons).

The project included 7 active batch plants, spaced at approximately 500 m (1,500 ft) intervals along the protected side of the levee. The contractor mostly used Soilmec equipment at each of the grout plant locations. The contractor's concern regarding plant placement was that, with increased pumping distance, there was a risk of compromising grout quality, especially considering the extreme high temperatures during the summer months in New Orleans. Each batch plant could store approximately 225 tonnes (250 tons) of binder. The cement tankers used to feed the silos had to share the site haul road with the trucks hauling clay and other site traffic, so extra binder capacity was needed to insure an adequate supply of binder.

Quality Control: Stringent contract requirements and a relatively new application for the ground improvement led to the implementation of a very thorough QC program (especially for the DMM) which, given the extent, pace and logistics of the project, resulted in a vast amount of controls, tests and records. QC results proved that the quality of the work was astonishing: ground improvement (over 30,000 DMM columns) of very soft clays and peats was completed with no remedial work necessary.

The specifications required that 3% of the elements be cored to verify the quality of the DMM. To accomplish this, the contractor used three Soilmec coring rigs with a PQ3 or Geobore coring system. The cored samples were typically retrieved once the columns had set for at least 26 days. Subsequently, on the 28th day after element installation, the crew trimmed the samples and performed Unconfined Compressive Strength (UCS) testing (Designed UCS is 100 psi = 700 kPa) (Figure 5).

The contractor performed over 500 corings by the end of the project, and each 1.5 m (5 ft) core run was accurately measured, logged and photographed. The crew also selected and tested over 5,000 cored specimens for UCS assessment. All the results were tracked, analyzed and combined with the other available data from the Bench Scale Test and Validation Test programs on a day-by-day basis to fine tune the production parameters and the QC/QA procedures, and to determine whether corrective actions should be taken.

Quality control of the batch plants was also crucial to verify that the grout supplied to the DMM rigs met the specifications. The contractor calibrated the mixing equipment using test weights periodically to insure proper proportioning. The engineers also performed tests on the fresh grout, including apparent viscosity, using a Marsh Funnel, and density, using a calibrated mud balance. Every day, they took cylinders of the fresh grout from each plant and checked for unconfined compressive strength.

All of the DMM rigs were equipped with a GPS system to facilitate the accurate layout of the elements. The rig GPS was validated at least once per shift by a hand-held GPS to verify element location. Additionally, the Soilmec drill rigs included the Data Mate System (DMS) installed to control, record and transmit installation para-meters and rig performance data. The DMS also controlled the drill rig to preset parameters for up to 4 different soil types and transmitted all the data by email when each element was complete so it could be reviewed for accuracy in near real time.

Innovative Solutions

This project included many innovative solutions; contractual, technical and technological, in the design and construction to address the unique challenges, including time constraints.

- The USACE used the Early Contractor Involve-ment approach to expedite contractor selection and the project construction schedule. As part of this process, Treviicos was also actively involved in the final design and in con-sideration of constructability.
- There were extensive pre-construction desk, lab and field studies to explore ahead of time the possible technical solutions and avoid delays during production.
- The design team used an innovative technical approach in using large diameter (5.25 ft/1.6 m) DMM columns, as opposed to typical 3 ft (0.91 m) diameter columns. They chose this approach as the most efficient ground improvement solution to reduce the number of columns installed while ensuring the schedule was met.
- We used cutting-edge equipment and technologies to improve larger-than-usual volume of soil and monitor in real-time all the aspects of the operation, technical and mechanical. In particular, the Soilmec Drilling DMS allowed the computer controlled installation and the immediate QC of the constructed element through a data email that allowed the resolution of issues in a timely manner.
- DMM operations return material (Recycled Embankment Material), upon verification of its suitability for the designated purpose, was used to build the core of the new levee in lieu of the typical clay material, thus greatly reducing costs and time.

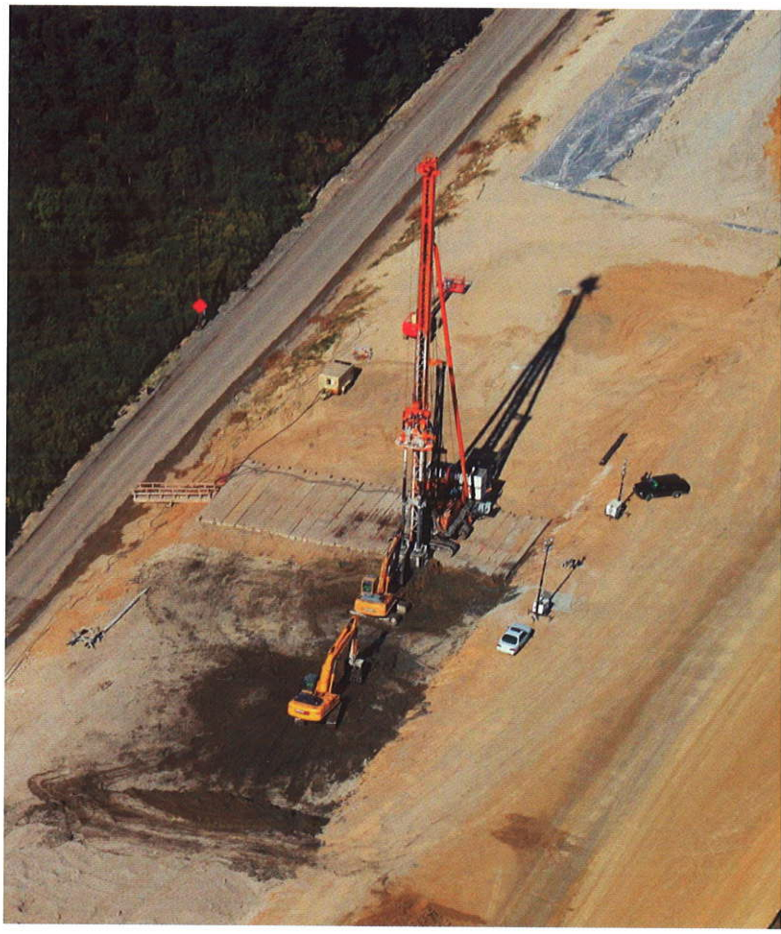

Figure 4. CI-CMC twin auger rig installing DMM

Conclusion

All the challenges of this unique project, substantially completed on schedule and under budget, were successfully overcome thanks to the variety of innovative solutions adopted by the owner and the contractors. The project, the largest deep soil mixing job ever accomplished outside of Japan, was completed ahead of schedule with no remedial work, and with an outstanding quality end-product delivered.

TOTAL N	AVG UCS PSI	<100 N	%	STDEV PSI	COV	MEDIAN PSI
5029	292	66	1.31%	126	0.433	275

Figure 5. Summary of the statistical analysis on UCS for cored specimens

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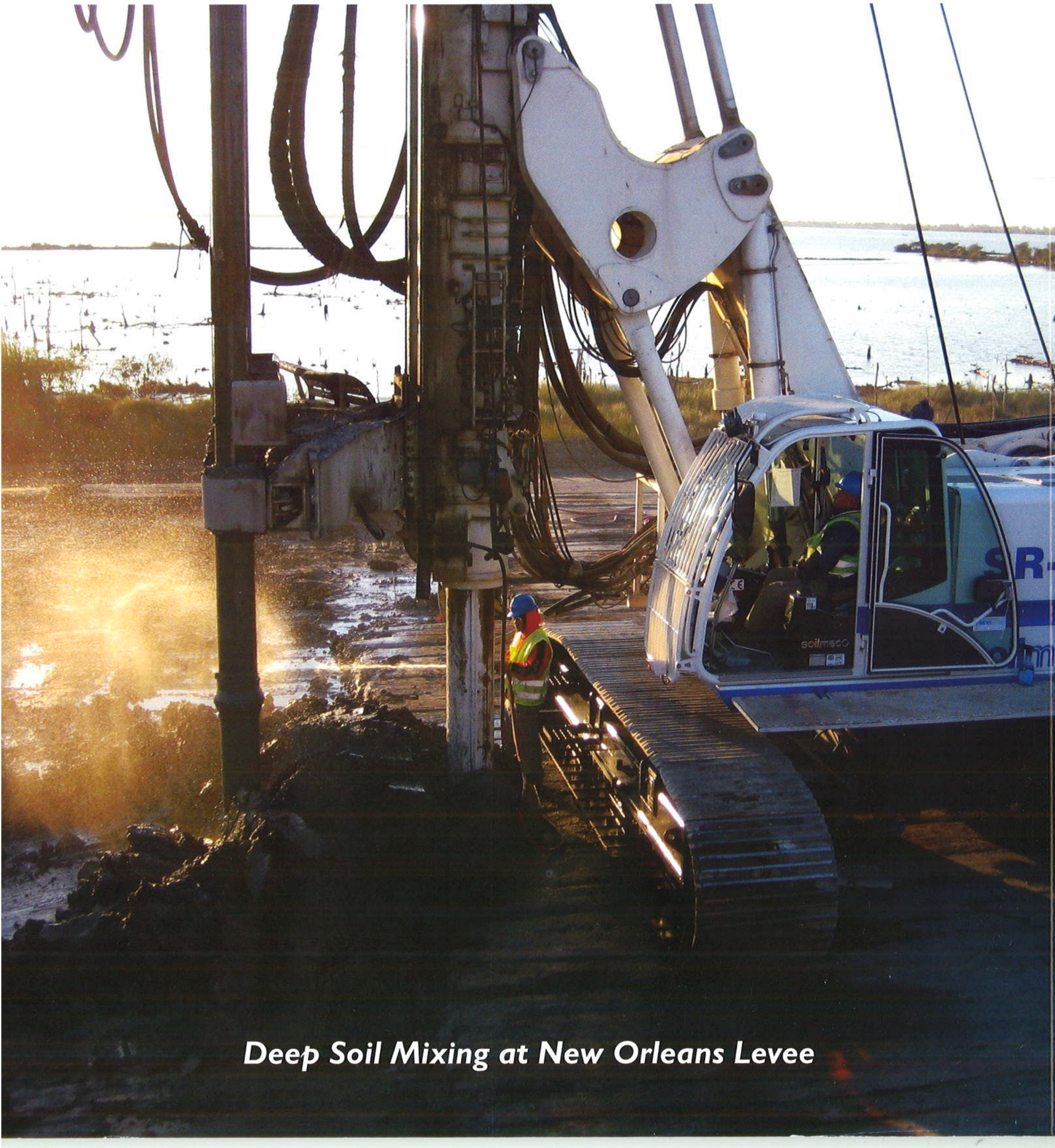

Deep Soil Mixing at New Orleans Levee