JET GROUTING GAINS

PAUL TARRICONE

After a sluggish start in the early 1980s, jet grouting is making inroads in the U.S.

In December 1986, CIVIL ENGINEERING published an article on jet grouting in the U.S. The European import was scarcely known in this country at that time, and the article claimed that the stabilization technology was being adopted only at a "snail's pace." Two years later, another article took note of the growing number of projects in the U.S. and declared that the pace of jet grouting had quickened. Now, eight years after that original article, the use—or pace, if you will—of jet grouting has accelerated once again.

Donald Bruce, technical director and vice president of Nicholson Construction Co., Bridgeville, Pa., places the overall yearly market for jet-grouting services in the U.S. at $10 million–$20 million. As many as 30 jet-grouting projects are completed each year in the U.S., according to industry estimates, and Odenton, Md.–based contractor Hayward Baker alone has completed close to 60 jet-grouting jobs in the U.S. since 1987. "The jet-grouting market is still a growth market," says Hayward Baker vice president Joseph Welsh. "It hasn't matured yet."

Over the past few years, jet grouting has been used in a number of diverse applications: for excavation support, as a ground-water barrier, as a bottom-sealing technique to prevent pollutants from entering excavations, to combat scour beneath bridges, to stabilize slopes beneath gabion retaining walls and even to underpin the Olympic luge foundations in Lake Placid, N.Y.

But the most common use of jet grouting in the U.S. is to underpin existing foundations in commercial and industrial settings, says Welsh, who predicts that jet grouting will eventually replace the pit method as the underpinning technique of choice, due to its cost-effectiveness and faster, safer application. "For [traditional] underpinning, you have to physically make a pit and get men under the foundation. You could have a faulty foundation, which could collapse, or you could have soil run into the pit. With jet grouting you don't have to get people under the foundation."

During jet grouting, a water and/or cement grout is pressure-injected into the ground through rotating jetting pipes under extremely high pressures (generally 4,000–6,000 psi), creating an intimate mix of the grout and native soil. Jet grouting can strengthen soft soils or create load-bearing structural members. Drills can now form "soilcrete" elements in just about any shape—"pie-shaped, cylinders, half-cylinders," says Welsh—and in horizontal, vertical or interlocked rows.

The evolution of jet grouting is reflected in a number of recent projects completed in the U.S. Here are eight noteworthy applications.

BUILDING A BATHTUB

An emerging market for jet grouting is in its use as a horizontal bottom-sealing technique for ground-water control. Hayward Baker, which now does about 20% of its jet grouting for water control, completed the first project of this kind in North America, according to Welsh, at a Jacksonville, Fla. powerplant. Engineers on the 1992 project were Black & Veatch, Overland Park, Kan., and Ogden Environmental and Energy Services, Knoxville, Tenn.

The project involved the construction of a subsurface coal unloading and storage facility (measuring 173 ft by 53 ft) for a cogeneration plant. Located adjacent to a processing plant, the cogeneration facility would burn coal to produce electricity and supply steam to the plant. However, contaminated ground water posed a serious problem for the planned excavation.

The solution was to build a pit, measuring 8,200 sq ft by 30 ft deep, within the excavation to prevent infiltration of contaminated ground water. A cement-bentonite sheet-pile cutoff wall and a horizontal soilcrete floor were built, fully enclosing the site and creating what Welsh describes as an impermeable, structurally sound "bathtub" (see figure).

The cement-bentonite slurry wall was constructed in panels to a depth of 46 ft, and interlocking steel sheet piling was set to a depth of 40 ft, prior to the initial set of the slurry. The horizontal seepage barrier (or bathtub bottom) was constructed by triple-rod jet grouting across the entire pit base, at a depth of 53 ft. To resist the uplift and horizontal forces of the ground water, 140 anchors were uniformly spaced to tie down the bottom slab. The soilcrete mat was extended along the edge of the pit to connect with the sheet piling.

Though the bathtub was designed for a maximum inflow of 100 gpm, postconstruction inflow measured less than 5 gpm.

FIGHTING SCOUR

In another application believed to be the first of its kind, Hayward Baker constructed 1,300 cu ft of soilcrete columns below river level to protect a bridge abutment from scour. The 1993 project was conducted in the Salt River Canyon for Arizona DOT.

During construction of the Salt River Canyon Bridge, heavy rains pushed the river's water more than 30 ft above normal levels, surrounding the new bridge abutment. Most canyon walls beneath the bridge are sheer vertical rock faces, but an area immediately adjacent to the new abutment—thought to be

AS PART OF THE ONGOING BOSTON CENTRAL ARTERY PROJECT, JET GROUTING IN CLAY HELPED SHORE UP A PREVIOUSLY INSTALLED EXCAVATION SUPPORT SYSTEM ADJACENT TO LOGAN INTERNATIONAL AIRPORT. JET-GROUTED COLUMNS AVERAGED ABOUT 5 FT IN DIAMETER WITH COMPRESSIVE STRENGTH OF 300 PSI.

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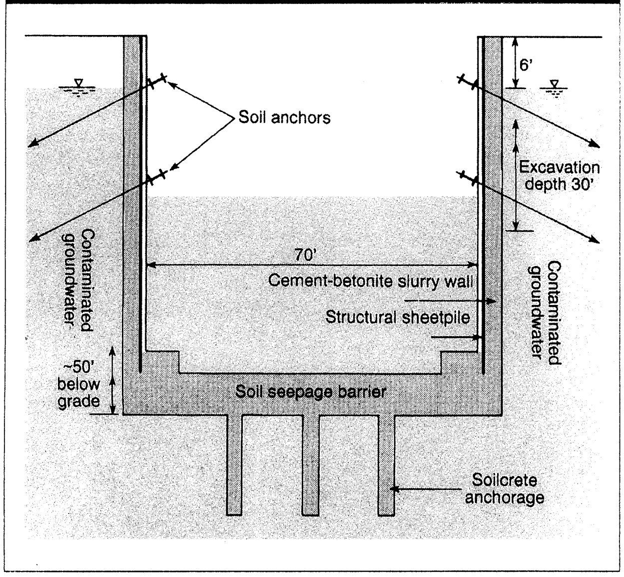
AN IMPERMEABLE 'BATHTUB'



AT A JACKSONVILLE, FLA. POWERPLANT EXCAVATION, JET GROUTING WAS USED AS A HORIZONTAL BOTTOM-SEALING TECHNIQUE FOR GROUND-WATER CONTROL. A CEMENT-BENTONITE SHEET-PILE CUTOFF WALL AND A HORIZONTAL SOILCRETE FLOOR WERE BUILT, ENCLOSING THE SITE AND CREATING A STRUCTURALLY SOUND BATHTUB.

a solid portion of canyon wall—was scoured out, leaving a 20 ft wide gouge in the rock. The gouge threatened the stability of the new bridge and washed away the only access road to recreational areas along the river's edge. The gap became visible when the river waters receded.

Rehabilitation required placing a retaining wall between the rock faces, on both sides, to protect the new bridge abutment. A mass of soilcrete was jet-grouted below the normal river level, filling the gap and acting as an arched retaining wall, stabilizing the scour zone. After the jet grouting, a concrete retaining wall was founded on top of the soilcrete to fill the gap above water level. The washed-out access road was also restored.

JET GROUTING IN CLAY

Two recent jobs undertaken by joint venture Nicholson Construction Co.–Rodio, Inc., Bridgeville, underscore the progression of jet grouting. "Until the last 12 months or so, the jet grouting conducted in the U.S. was done in sands and gravels and predominantly for structural underpinning," says Nicholson's Bruce. "These two projects have a double novelty: The jet grouting was done in clays, and the purpose was ground treatment for tunneling."

The first job is part of the ongoing Boston Central Artery project, in which jet grouting helped shore up a previously installed excavation support system adjacent to Logan International Airport. Bridgeville-based joint venture Nicholson–SMW Seiko received a contract for 400,000 sq ft of anchored shoring wall up to 82 ft deep and approximately 3,000 ft long, secured by more than 3,400 high capacity, prestressed anchors.

During excavation, however, unacceptably large lateral wall movements occurred. Partial backfilling of the excavation stabilized the situation, but investigation revealed that the clays in this area were of unexpected depth and weakness. To improve the engineering properties of the clay at the base of the excavation, Nicholson-Rodio created grouted soil buttresses against each wall, mostly through the soil-mixed–wall (SMW) method. But since limited access made it impossible to install these buttresses right up to the existing SMW wall, jet grouting was done to fill this 9 ft wide gap. Similar space restraints on the large SMW drilling rig meant some of the buttresses had to be formed entirely from jet-grouted soil.

All told, nearly 1,500 jet-grouted columns measuring more than 47,000 lineal ft have been installed using the two-fluid method. The columns averaged about 5 ft in diameter with a compressive strength of 300 psi.

A second Nicholson-Rodio application of jet grouting for soft-ground tunneling is the Islais Creek project in San Francisco (News, CE October 1994). During tests conducted earlier this year, jet-grouted columns were constructed in an effort to strengthen Bay mud prior to the excavation of two sewer tunnels. A pilot test conducted in March resulted in six two-fluid columns measuring more than 6 ft in diameter and six single-fluid columns more than 2.5 ft in diameter. The test results were "extremely positive," according to Rodio's Mario Mauro, with average column strength exceeding 120 psi. Construction of 600 vertical columns followed for the longer, 500 ft Davidson Avenue tunnel, and tunnel excavation was slated to begin as CIVIL ENGINEERING went to press. Jet grouting for the second, shorter tunnel was to begin soon after press time.

IMPROVING CAISSON CAPACITY

Construction of the new Boston Garden and its underground multilevel parking garage was able to continue after jet grouting in clay improved caisson bearing capacity. To support the high foundation loads of this combined facility and allow for the faster top-down construction method, high-capacity drilled-shaft foundations were designed to carry interior structure loads. The drilled shafts mainly derive support in the dense glacial till and underlying bedrock formation below the site.

However, during construction of one caisson, workers encountered a 3 ft thick layer of silty clay embedded within the glacial-till bearing soils about 85 ft below ground level. (The completed caisson extends nearly 100 ft deep with the last 19 ft embedded in rock.) The affected foundation shaft was designed to support the arena, garage and adjacent railway platform loads with a design load of 1,821 kips. Engineers determined that the factor of safety for the bearing capacity of the completed caisson was "marginal" because of the clay layer.

The project team explored several options to provide additional load-carrying capacity at that location. Compaction grouting couldn't be done due to the large number of drill holes required. Drilled minipiles were ruled out because of the difficulty in transferring structure loads to new foundation elements. Engineers eventually selected jet grouting since the larger-diameter soilcrete elements would require fewer drill holes than standard grouting, and because the process would strengthen the soils without creating the need for load transfer.

Fonditek International, a Boston-based specialty foundation contractor, used a single-fluid system to improve the soil in place, significantly reducing the amount of spoils brought to the surface compared with the triple-fluid system.

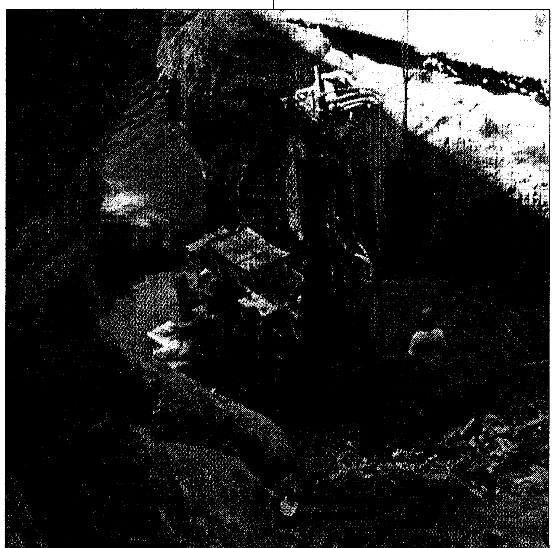
Although underground utilities, foundation grade beams, overhead structural steel beams and railway platforms hindered the jet-grouting operation, the use of flexible drilling equipment and an injection pressure of more than 8,000 psi created nine jet-grouted columns, at varying inclinations, to a depth of 90 ft. The silty clay layer and glacial bearing soils were improved along 80% of the caisson circumferential surface, increasing the area for friction bearing. The design engineer approved the results and allowed arena construction to continue.

UNDERPINNING HISTORIC STRUCTURES

Yet another jet-grouting project in the Boston area involves the underpinning of historic structures in the Boston National Historical Park in Charlestown, Mass. A number of structures in the park, constructed on shallow foundations bearing on man-made fill materials, have settled over the years, resulting in cracks and distorted foundations and walls.

Among the buildings being rehabilitated are the U.S.S. Constitution Museum and its electrical substation. Fonditek completed the substation's jet-grouted underpinning in March and is set to begin work on the museum annex.

Due to decades of uncontrolled water infiltration into the loose man-made fill materials below one corner of the 138-year-old substation, the building had experienced more than 8 in. of differential settlement. Single-fluid jet grouting filled voids in the fill under the foundation and improved the fill quality. The single-fluid method was used because ground movement during construction is "negligible" and potential damage to the foundation is minimal.



IN AN APPLICATION BELIEVED TO BE THE FIRST OF ITS KIND IN THE U.S., 1,300 CU FT OF SOILCRETE COLUMNS WERE CONSTRUCTED BELOW RIVER LEVEL TO PROTECT A BRIDGE ABUTMENT FROM SCOUR IN ARIZONA'S SALT RIVER CANYON.

Specifications required a minimum of 2.5 ft diameter columns with 500 psi compressive strength at 28 days, and preconstruction test samples averaged 1,000 psi. Three rows of jet-grouted columns (78 columns total) at inclinations of 10, 25 and 55 deg. from vertical were installed below 60 ft of the foundation wall to the natural bearing soils 15 ft deep. Construction monitoring indicated no structure movement due to the jet-grouting operation.

WORKING AROUND UTILITIES

When Geo-Con, Monroeville, Pa., undertook jet grouting this past summer at an Occidental Chemical Co. waste site in Niagara Falls, N.Y., one goal was to keep water-intake utility lines in service throughout the project.

The project involved the construction of a steel sheet-pile/soil-bentonite cutoff barrier wall to separate the contaminated plant area from the Niagara River (CE October 1994). However, at two locations, water pipes connected to several neighboring businesses bisect the barrier wall.

As a result, the barrier wall at these locations was constructed by jet grouting between and around the pipes. Because shot-rock fill on the site was too porous for this technique, contractor Herbert F. Darling, Williamsville, N.Y., first excavated the shot rock around the pipes and backfilled with sand and gravel, which are compatible with jet grouting.

According to Geo-Con project manager Mike Carey, three rows of overlapping jet-grouted columns were then constructed around and under the 48 in. diameter water-intake pipes.

Another jet-grouting project around existing utilities is set to begin next spring in Tampa, Fla. Specialty contractor Earth Tech, Tampa, will use a single-fluid jet-grouting system to create a continuously grouted cutoff wall adjacent to an existing 400 ft long steel sheet-pile bulkhead along Tampa Bay.

The existing bulkhead has been compromised by corrosion and there are a number of 1–2 in. holes in the sheet pile. Before constructing the cutoff wall, Earth Tech will repair the holes by welding patches on the seaward side.

Previously, concrete and flowable fill were placed in the void areas in the hope of repairing the bulkhead, but these efforts proved unsuccessful. "We proposed jet grouting due to the confined available working areas and the proximity to existing water lines, electrical conduits and tiebacks along the existing wall," says Earth Tech principal engineer Arthur Baker.

After completing a test section, Earth Tech will construct jet-grouted columns with a minimum diameter of 24 in. and an overlap of one-eighth of the column diameter to form a continuous 400 ft wall. Roughly 200 columns will be installed on approximately 4 ft centers in a triangular pattern to create the overlap effect and a total diameter of 3 ft.

LOOKING AHEAD

What will the next step in the maturation process bring? While Walsh envisions "a continuing trend toward technically difficult jobs in urban environments," he also says that some of the early problems with jet grouting may be repeated. "One reason why jet grouting didn't catch on in the early 1980s was because contractors tried to adapt equipment from other grouting applications," says Welsh. "As jet grouting gains acceptance, more contractors will procure equipment from mainly European suppliers, and, with the high capital expenditure required, will try to use their systems in all installations."

Nicholson's Bruce adds that jet grouting "had problems in the early 1980s because it was often wrongly prescribed, [and the columns were] badly constructed and inadequately verified. This was mainly because the original contractors tried to push jet grouting for commercial reasons and with minimal experience."

Still, the sophistication of the equipment and the automation of the process itself is likely to win converts. Welsh describes the computerization of jet grouting, with printouts updating the consistency of the grout mix. And Bruce mentions an automatic recording system called Paper Jet, which monitors all grouting parameters. But he is quick to point out that jet grouting is a "great technology but not a panacea. It's just another arrow in your quiver."