

JET GROUTING

Hayward Baker's jet grouting systems offer a unique degree of design flexibility for a broad range of applications.



Above: Excavation support begins for construction of Atlantic City, NJ's expressway extension.

Right: SuperJet struts support the tunnel alignment between the existing Penrose Canal and an established residential area.



Jet grouting is a Ground Modification system used to create in situ, cemented formations of soil called soilcrete. Jet grouting is an alternative to traditional grouting systems, deep slurry trenching, proprietary underpinning systems, micropiling, or the use of compressed air or freezing in tunneling.

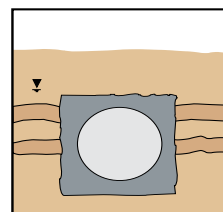
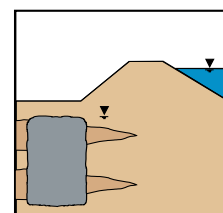
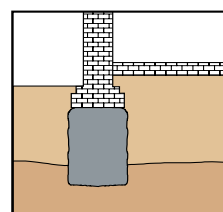
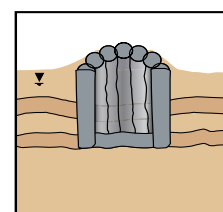
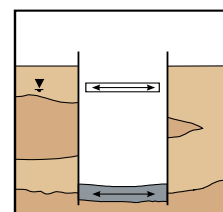
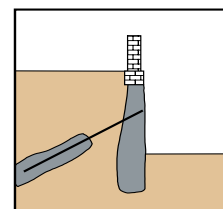
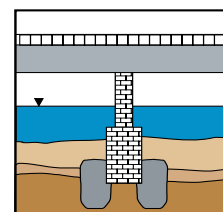
Applications of the jet grouting system fall into three broad categories:

- ◆ Underpinning and/or excavation support
- ◆ Temporary or permanent stabilization of soft and/or liquefiable soils
- ◆ Groundwater or pollution control

The ability to construct soilcrete in confined spaces and around subsurface obstructions such as utilities, provides a unique degree of design flexibility. Indeed, in any situation requiring control of groundwater or excavation of unstable soil (water-bearing or otherwise) jet grouting should be considered.

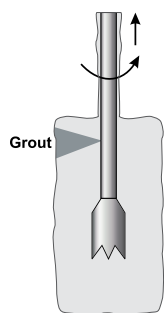
Usually, jet grouting can be accomplished without disrupting normal facility operations. Jet grouting is not only one of the safest methods of construction available but in many cases the process is so fast that construction schedule savings are realized.

The recent development of small containerized, highly mobile support equipment has enabled starting work on the first day of setup, greatly reducing mobilization and demobilization costs. This ability will enable many projects previously considered too small to absorb these costs to become usable.



Jet Grouting Systems and Applications . . .

There are three traditional jet grouting systems. Selection of the most appropriate system is generally a function of the in situ soil, the application, and the physical characteristics of soilcrete required for that application. However, any system can be used for almost any application providing that the right design and operating procedures are used.

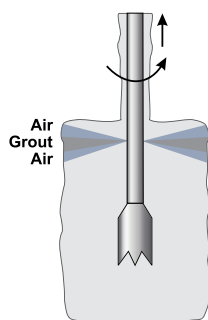


Single Fluid Jet Grouting (Soilcrete S)

Grout slurry is pumped through the rod and exits the horizontal nozzle(s) in the monitor with a high velocity [approximately 650 ft/sec (200m/sec)]. This energy causes the erosion of the ground and the placement and mixing of grout slurry in the soil. In gravelly soils, soilcrete column diameters of 2 to 4 ft (0.6-1.2m) can be achieved. In loose, silty and sandy soils, larger diameters are possible. Single fluid jet grouting is generally less effective in cohesive soils.

Soilcrete S Applications

- ◆ Cutoff walls in porous soil
- ◆ Soil consolidation for tunnel roof
- ◆ Bottom bracing for deep trenches in soft soil
- ◆ Anchorages
- ◆ Sealing applications

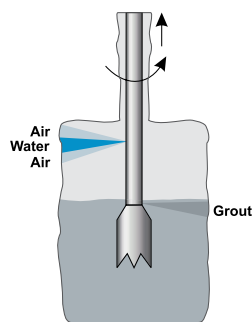


Double Fluid Jet Grouting (Soilcrete D)

A two-phase internal rod system is employed for the separate supply of grout slurry and air down to different, concentric nozzles. Grout slurry is used for eroding and mixing with the soil. The air shrouds the grout slurry jet and increases erosion efficiency. Soilcrete column diameters of more than 3 ft (1.0m), in medium to dense soils, and more than 6 ft (1.8m) in loose soils, may be achieved. The double fluid system is more effective in cohesive soils than the single fluid system.

Soilcrete D Applications

- ◆ Soil stabilization
- ◆ Some underpinning applications
- ◆ Panel cutoff walls
- ◆ Bottom bracing for deep trenches in soft soil

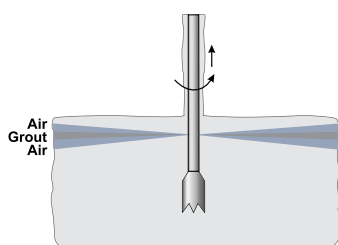


Triple Fluid Jet Grouting (Soilcrete T)

Grout slurry, air and water are pumped through different lines to the monitor. High velocity coaxial air and water form the erosion medium. Grout slurry emerges at a lower velocity from separate nozzle(s) below the erosion jet. This somewhat separates the erosion process from the grouting process and yields a higher quality soilcrete. Soilcrete columns with diameters ranging from 3 ft (0.9m) to more than 5 ft (1.5m) can be achieved. Triple fluid jet grouting is the most effective system for cohesive soils.

Soilcrete T Applications

- ◆ Underpinning and excavation support
- ◆ Horizontal slab/ground water control
- ◆ Panel cutoff walls
- ◆ Sealing applications
- ◆ Most fine grained soil stabilization



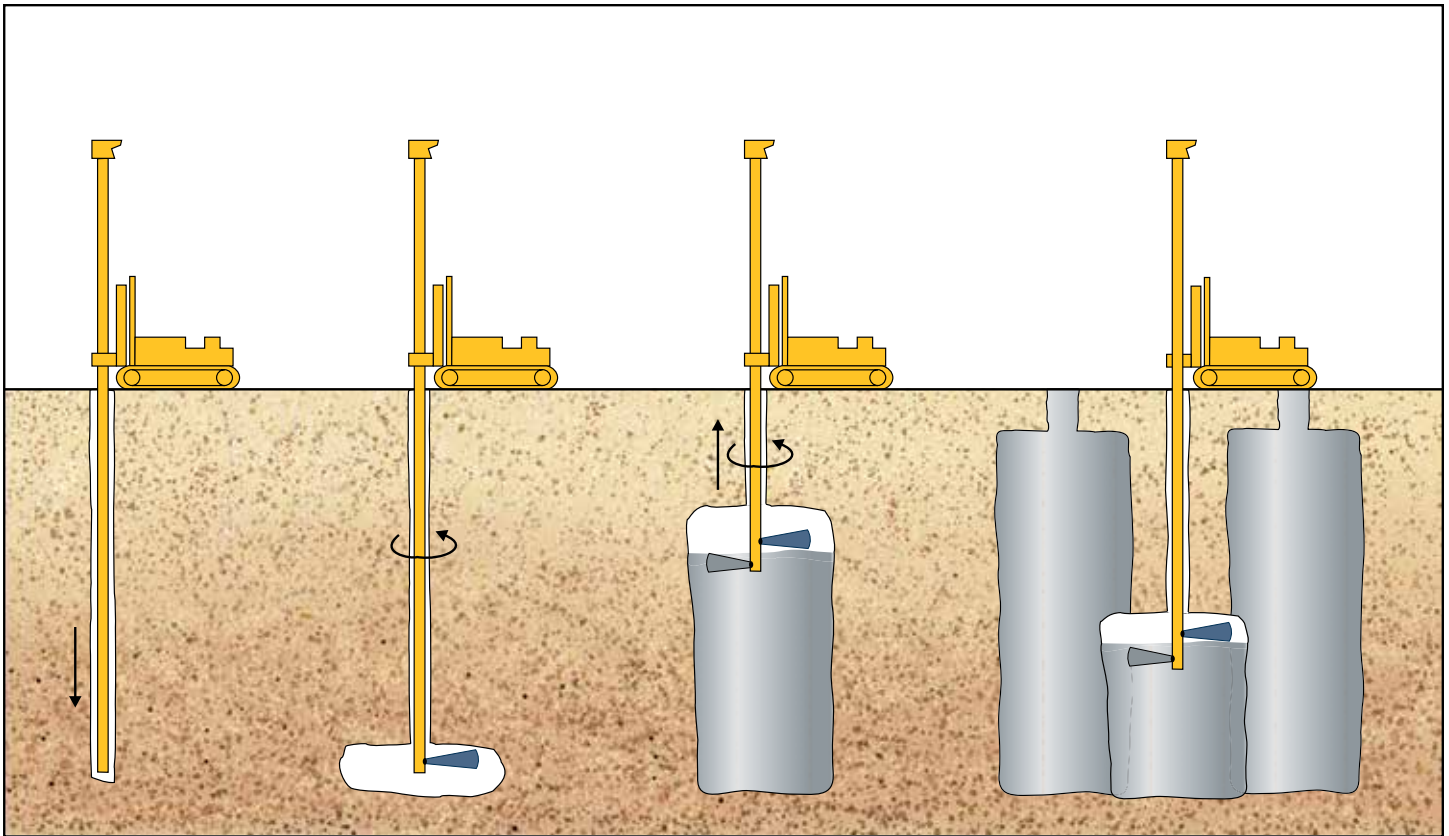
SuperJet Grouting

Grout slurry, air and drilling fluid are pumped through separate chambers in the drill string. Upon reaching the design drill depth, jet grouting is initiated with high velocity, coaxial air and grout slurry to erode and mix with the soil, while the pumping of drilling fluid is ceased. This system uses opposing nozzles and a highly sophisticated jetting monitor specifically designed for focus of the injection media. Using very slow rotation and lift, soilcrete column diameters of 10 to 16 ft (3-5m) can be achieved. This is the most effective system for mass stabilization application or where surgical treatment is necessary.

SuperJet Applications

- ◆ Horizontal slab/ground water control
- ◆ Stabilization of liquefiable strata
- ◆ Panel cutoff walls
- ◆ Structural supports across excavation walls
- ◆ Stabilization of soft soil for microtunneling

The experience of the specialty contractor in selecting the optimum Jet Grouting system and operating procedures is critical to the success of each project.



Jet Grouting Procedures

Predrilling or foundation coring may be necessary to access the treatment zone. The borehole is typically 6 inches (150mm) in diameter, and is stabilized by using grout or a drilling mud during the procedure. Since jet grouting is a bottom-up procedure, erosion is initiated at the design depth with high velocity injection of cutting and replacement fluids. This continues with consistent, uniform rotation and lifting to create column geometry, while expelling eroded spoil out of the top of the borehole. Designed integration of adjacent columns creates a soilcrete mass. Since jet grouting equipment operates from above foundation grade, and soilcrete is constructed in a designed sequence, structural integrity is maintained and safety considerations are simplified. Jet grouting equipment is specially designed to be highly maneuverable and capable of low-headroom interior work as well as restricted-access exterior work.

Jet Grouting Geotechnical and Structural Considerations

Jet grouting is effective across the widest range of soil types of any grouting system, including silts and some clays. Because it is an erosion based system, soil erodibility plays a major role in predicting geometry, quality and production. Cohesionless soils are typically more erodible than cohesive soils, as shown at right. Since the geometry and physical properties of the soilcrete are engineered, the degree of improvement is readily and accurately predictable.

Highly Erodible

Cobbly Soils

Gravelly Soils

Clean Sands

Loose Silty Sands

Peats and Organic Silts

Dense Silty Sands

Loose Clayey Sands

Low Plasticity Silts

Dense Clayey Sands

Low Plasticity Clays (soft)

High Plasticity Silts

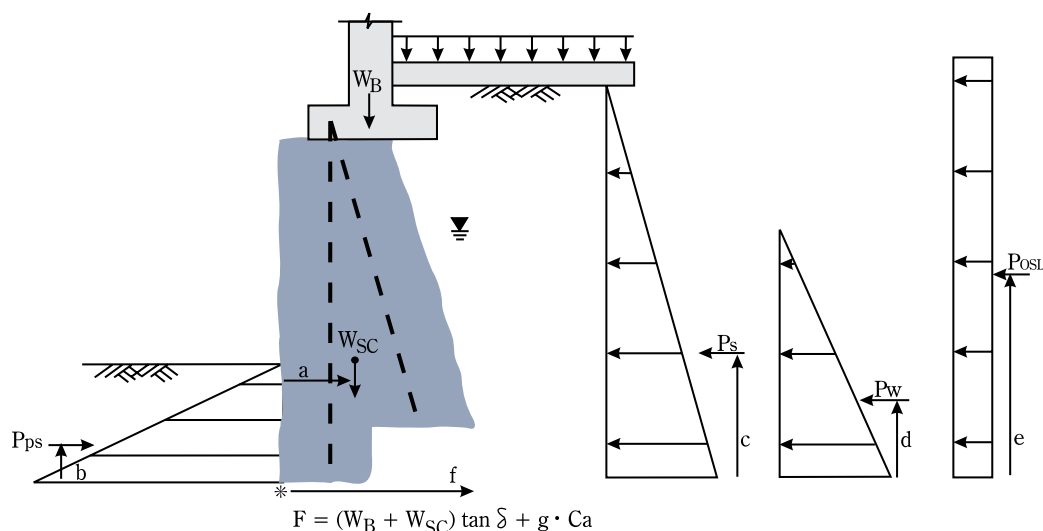
Low Plasticity Clays (stiff)

High Plasticity Clays

Difficult to Erode

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Geotechnical Construction

Jet Grouting Design and Quality Control ...



$$FS_{\text{overturning}}^* = \frac{(W_B + W_{SC})a + P_{ps} \cdot b}{(P_s \cdot c) + (P_w \cdot d) + (P_{osL} \cdot e)} \geq 1.5 \quad FS_{\text{sliding}} = \frac{P_{ps} + F}{P_s + P_w + P_{osL}} \geq 1.5$$

Jet grouting systems can be designed to mix the soil with a grout slurry or nearly replace it with grout slurry. For underpinning and excavation support (with groundwater control), the design consists of developing continuous soilcrete masses with contiguous soilcrete columns, to resist overturning and sliding while maintaining the integrity of supported structures and nearby utilities.

The design engineer should assess the competency of the soils at the base of the soilcrete for bearing and settlement. Evaluation of internal stresses (shear and bending) in the soilcrete will provide guidance for required soilcrete strength. Soilcrete strength is a function of the in situ soils and strength variations are to be expected. A factor of 3.0 is therefore applied to the required soilcrete strength for an average allowable strength.

Soilcrete Design and Operating Parameters

Theoretically, treatment depth is unlimited, but jet grouting has rarely been performed to depths greater than 164 ft (50m). Treatment can also be pinpointed to a specific strata. The size of the soilcrete mass to be created is determined by the application. A variety of geometries are available as shown at right. The width or diameter of each panel or column is determined during the design stage. Accurate, detailed and frequent description of soil type, with reasonable assessment of strength or density allows this prediction to be made with confidence. If required, shear and/or tensile reinforcement can be incorporated into the soilcrete.

The operating parameters of air, water and/or grout slurry flow, and pressure, together with monitor rotation and withdrawal speed are selected (following detailed engineering assessment of soil conditions) and automatically controlled and monitored throughout construction. Reduced flow or increased withdrawal speed produces a smaller soilcrete geometry.

LEGEND

a,b,c,d,e	Moment arms
C_a	Base soil adhesion
δ	Base soil friction angle
f	Base width
F	Friction force
FS	Factor of safety
P_s	At-rest or active soil force
PosL	Surcharge force
P_{ps}	Passive force
P_w	Hydraulic force
W_B	Weight of structure footing load
W_{SC}	Weight of Soilcrete
W_{SL}	Surcharge load

SOILCRETE PLAN GEOMETRIES

	Full Column
	Half Column
	Partial Column
	Single Panel Wall
	Double Panel Wall
	Sheet Pile Sealing Systems

A properly designed structure should be analyzed by a professional engineer familiar with the site conditions and technologies applied.

Quality Assurance

Quality assurance and quality control are critical components of a successful jet grouting program, ensuring that subsurface soils are consistent with design assumptions and that design parameters are met or exceeded throughout the project.

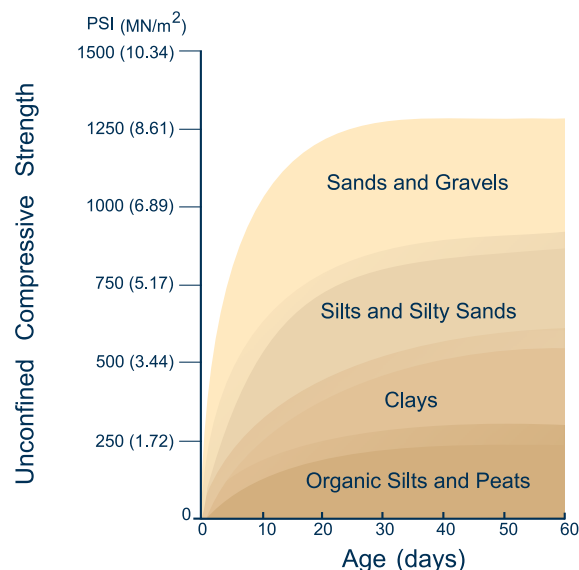
Quality assurance begins with a test section to verify the design geometry of the soilcrete and the quality and strength characteristics of the soilcrete product.

Retrieved wet-grab and core samples are laboratory tested to confirm that satisfactory unconfined compressive strengths are achieved. The pre-production quality assurance measures form the basis for quality control during production grouting. Computerized data collection of all jet grouting parameters is available along with continuous real-time observation.

Quality Control

In addition to the quality control inspection items for soilcrete element construction, additional project-specific quality control measures such as structural monitoring or permeability testing may be required.

Controlled jet grouting must create a spoil material during the erosion process. The volume of spoil can be predicted from the injected volumes and is typically in the range of 40 to 60 percent of the soilcrete volume. The spoil retains a significant cement content, and gains strength over time. Within 12 hours it can typically be handled as a firm to stiff clay and is frequently used as a construction fill.



Soilcrete strengths are variable and difficult to predict, particularly in layered soils. This chart represents an estimate of average results expected.



Typically, soilcrete cores are greater than 3 inches in diameter and recovery is greater than 75 percent with specialized coring equipment.

QUALITY CONTROL INSPECTION ITEMS

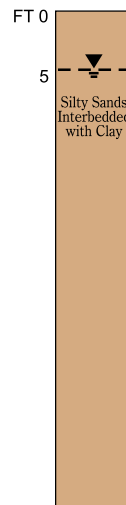
Drilling	Location, angle, depth, methods to maintain repeatability
Batching	Preparation of grout slurry for consistency in material content and physical and chemical properties
Jetting	Checking of drill parameters (lift, speed, rotation rate) and injection parameters (pressure and flow of all components)
Documentation	Accurate documentation for each element constructed. Construction times and correlation to any sampling performed
Sampling and Testing	Retrieval of representative samples for external testing

Case Histories . . .



Nimitz Relief Sewer Honolulu, Hawaii

As a value-engineered and less disruptive alternative to open cut construction, jet grouting was selected to provide a homogenized tunnel horizon and minimize post-construction settlement for the installation of a 54-inch (1.4m) relief sewer through soft, lagoonal deposits. Two rows of interconnected, 4-ft (1.2m) diameter soilcrete columns were installed to bedrock over a 2,800 lf (850 linear meter) stretch of tunnel alignment to prepare an encapsulated tunnel horizon for micro-tunneling. In addition to providing a fully stabilized tunneling face, the soilcrete mass ensured that post-construction settlement of the sewer would be eliminated.



Kraft Foods Dover, Delaware

For construction of a 20-ft (6m) deep railcar unloading pit within an existing building, jet grouting performed three functions: excavation support, underpinning, and groundwater control. To meet project performance objectives, a 'bathtub' configuration was constructed via a perimeter wall of 20-ft (6m) deep, interconnected soilcrete columns enclosing a 6-ft (1.8m) thick soilcrete base. The perimeter columns provided excavation support while those at the corners of the pit also underpinned the existing adjacent footings. The jet grouting program successfully prevented building movement and vertical and horizontal groundwater infiltration.

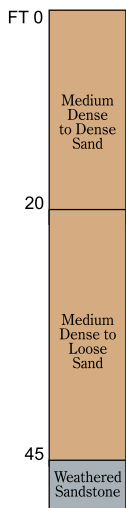


Transmission Towers Dallas, Texas

Four, 180-ft (55m) tall transmission tower structures were moving laterally on the compression leg. This was due to insufficient diameter and embedment length of the drilled shaft foundations. To improve the factor of safety against failure at ultimate loads, jet grouting was used to stabilize the compression leg foundation of each tower down to a competent bearing strata. Prior to production, a test column was constructed to establish effective column diameter, forming the basis for the design. An average of 12, 4-ft diameter (1.2m) soilcrete columns were constructed at each tower to hard limestone.

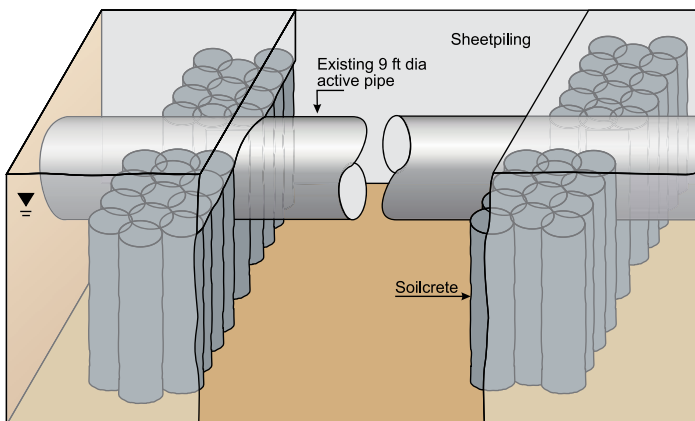


When owners and contractors need a fast, technically-effective solution to a tough geotechnical problem, Jet Grouting gets the job done.



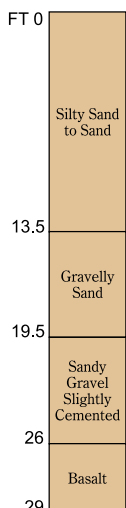
General Hospital Center at Passaic Passaic, New Jersey

Concerned that a conventional pit underpinning method would result in excessive settlement of the existing, five-story structure, the general contractor elected to use a jet grouting alternative for construction of a new, three-story hospital addition. For the addition, the site was pre-excavated to the top of the existing foundation. Column footings and foundation walls were then underpinned to a competent bearing strata by 3.5-ft diameter (1.1m), contiguous soilcrete columns. The continuous soilcrete wall thus formed also provided support for subsequent deep excavation of the prevailing clean sands. Existing building settlements were negligible.



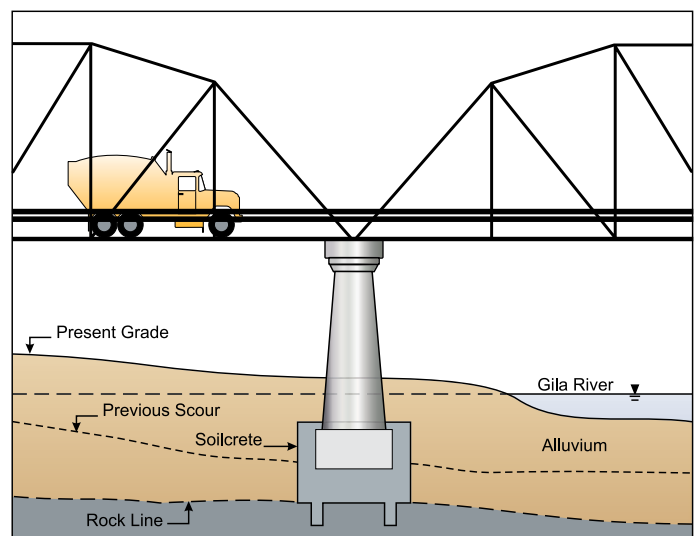
Virginia Key WWTP Virginia Key, Florida

Prior to incorporation of a storm surge pressure relief system into an existing outfall pipe, all three project requirements of underpinning, excavation support, and groundwater control were met by jet grouting. At each end of the excavation area, jet grouting was performed adjacent to and below the 8.5-ft (2.6m) diameter pipe down to limestone bedrock. Angled drilling and jet grouting beneath the pipe invert completed the encapsulation, thus forming a groundwater seepage barrier as well as excavation support and underpinning across the width of the excavation. Sheetpiles connected the sides of the excavation with the grouted zones. Safe operational integrity was maintained throughout the work.



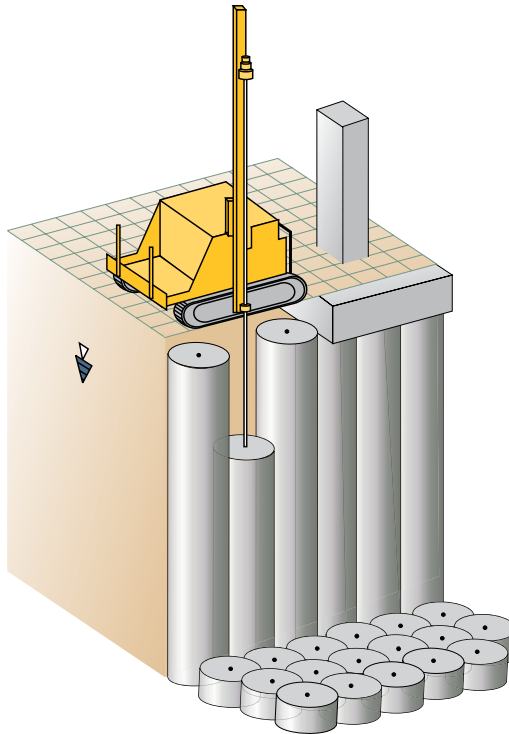
U.S. Highway 80 Bridge Maricopa County, Arizona

During heavy winter rains in the Arizona desert, the Gillespie Dam failed, sending water up to 150,000 cf (4,250m³) per second down the Gila River. Just 100 yds (92m) downstream, an old bridge for Highway 80 crosses the river. Flood waters were concentrated toward the eastern portion of the nine-span structure, scouring cavities beneath three easternmost piers and resulting in minor settlements and cracking. Jet grouting was recommended as the most economic method of underpinning and protecting the existing footings. Interconnected soilcrete columns were installed around the upstream portions of the pier and were either keyed into underlying basalt or taken to sufficient depths into underlying alluvium to underpin and protect the footings from future scour.



Advantages of Hayward Baker's Jet Grouting Systems

- ◆ *Nearly all soil types groutable*
- ◆ *Specific in situ replacement possible*
- ◆ *Designable strength and permeability*
- ◆ *Treatment to specific subsurface locations*
- ◆ *Only inert components*
- ◆ *No harmful vibrations*
- ◆ *Can be performed in limited working space*
- ◆ *Any cross-section of soilcrete possible*
- ◆ *Maintenance-free*
- ◆ *Safest method of underpinning construction*
- ◆ *Ability to work around buried active utilities*
- ◆ *Most effective method of direct underpinning of structures and utilities*
- ◆ *Much faster than alternative methods*



Why Should You Choose Hayward Baker's Jet Grouting?

As North America's largest geotechnical contractor, Hayward Baker has the resources to build your project. We manufacture much of our own equipment, ensuring the best performance and reliability in the industry.

From job start-up to installation of the last jet grout column, our attention to quality control ensures project specifications are achieved. Our network of offices and full-service equipment yards means fast mobilization and reduced start-up costs.

Hayward Baker is committed to providing the most economical solution that satisfies the technical requirements of each project.

Whether a situation is typical or unique, we have the experience and innovation to assist engineers, contractors and owners with identifying and implementing the best solution. For a variety of subsurface conditions, jet grouting may be the answer.

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