

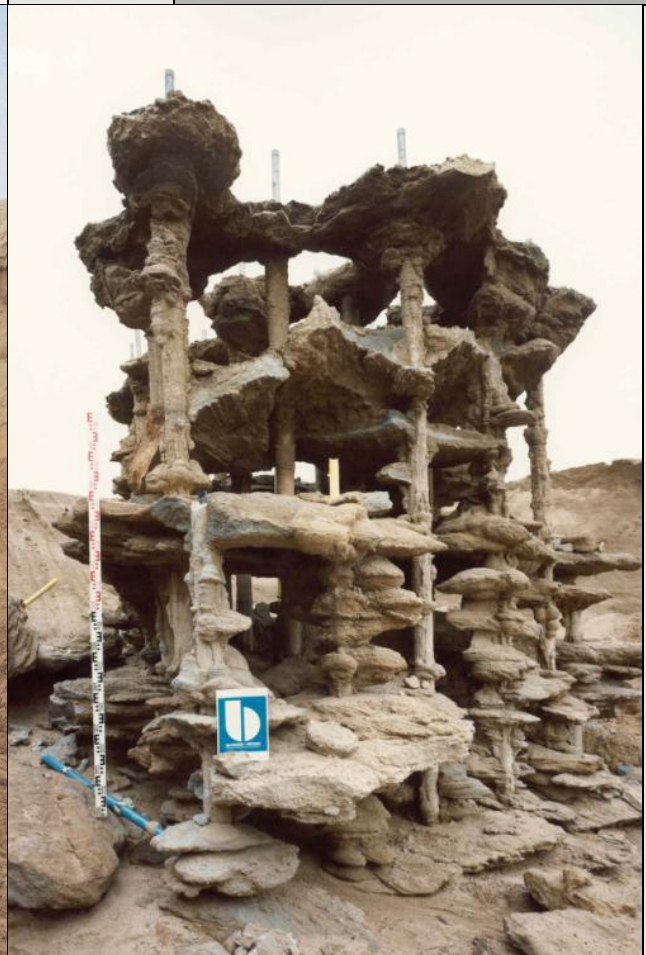
JET GROUTING



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Introduction

Grouting of soil bodies for strength improvement and/or sealing is a standard method in geotechnical engineering.

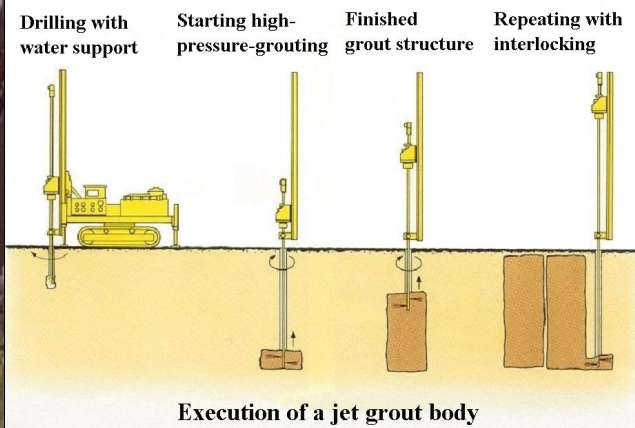
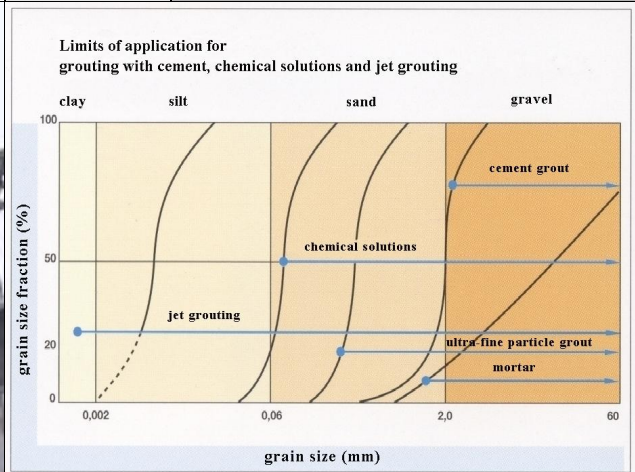
Low pressure injection grouting with solid particle suspensions, chemical solutions or artificial epoxy resins has been in use for some time. It is restricted to soils with certain void ratios and pore sizes. Conventional low pressure grouting uses pressures up to 20 bar to inject grout into the naturally existing pores and voids of a soil. Apart from displacing air or water in pores and voids with grout, the structure and fabric of the soil remains unchanged. The resulting grout body in the ground is an undefined random structure. Conventionally, fine grained soils can only be grouted with chemical solutions or artificial resins, which increasingly raises environmental concerns.

Jet Grouting

Jet Grouting or High Pressure Grouting can be employed in all soils from clays to coarse gravels irrespective of grain size distribution, void ratio or pore sizes. Jet grouting uses a high pressure jet (approx. 400 bar) to cut the natural soil in order to mix and partially replace it with the grout. This creates a "soilcrete" body whose strength and/or permeability characteristics are independent of the original soil fabric.

1 Grout body produced by jet grouting (Soilcrete Columns)

2 Grout body produced by low pressure conventional grouting (Injection Grouting)



To construct a jet grouted column, a small diameter bore is drilled with the jet rods and drill bit down to the design depth. Drilling gear and drill fluid are chosen to be appropriate for the soil type. To increase the diameter of the jet grouted column and to optimise usage of cement and efficiency in dense, cohesive or very compact soils, pre-cutting with high pressure water may be employed during the initial drilling.

As soon as the design depth has been reached, the rods and drill bit are slowly withdrawn from the soil. During the withdrawal, grout is injected at high pressure (approx. 400 bar) into the soil from jet nozzles which are situated horizontally just above the bottom of the drill bit. The speed of particles in the jet is approx. 200m/s. Because the drill rods and drill bit are kept rotating during withdrawal and jetting, a homogenous cylindrical body is produced consisting of a mix of injected grout and displaced soil.

Form and size of the jet grout body can be influenced by varying jet pressure, withdrawal rate and rotation of the jetting gear.

Some of the soil-grout mixture overflows through the drill hole onto the ground surface. This spoil is collected and removed.

All materials used in the jet grouting process – water, cement, occasionally bentonite and the soil -- are natural inert materials which have no negative impact on groundwater and environment.

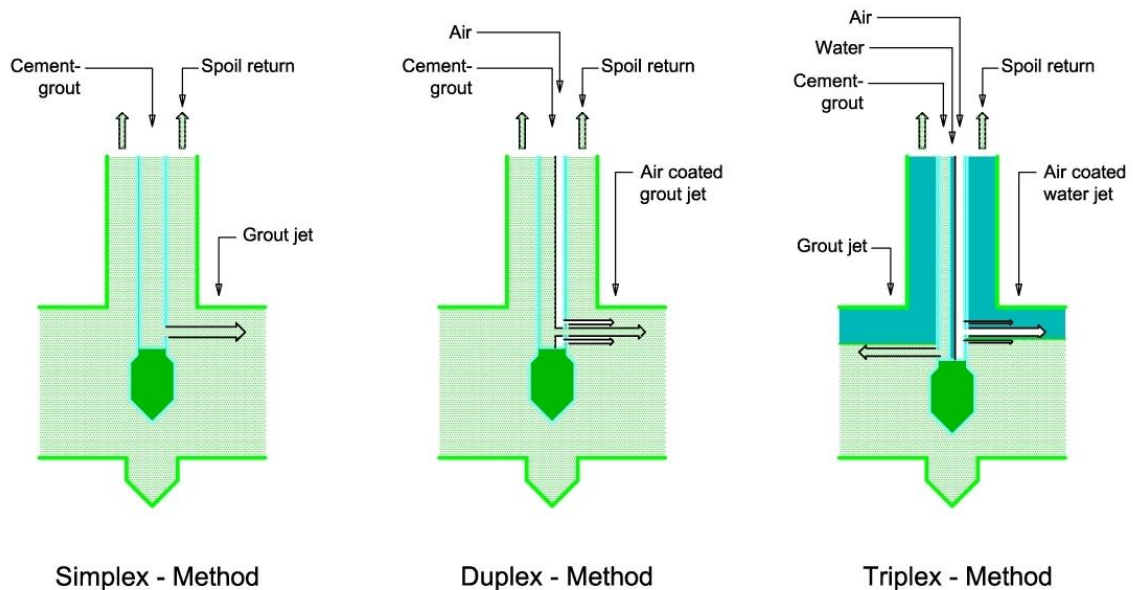
Jet grouted columns can be executed as vertical columns or in any inclination.

1 high pressure jet

2 limits of application for grouting methods

3 schematic execution of a jet grout body

Jet Grouting Methods



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Jet Grouting Methods

Bilfinger Spezialtiefbau GmbH uses three different methods for jet grouting:

Simplex-Method

Cement grout is injected into the soil with high pressure (approx. 400 bar) at the drill head (monitor). The jet cuts the soil and mixes it thoroughly with the grout. The Simplex-method is appropriate for shallow depths and horizontal jet grouting.

Duplex-Method

Using special rods with double inner conduit (Duplex string) compressed air is introduced into the grout jet at its exit point. This adds energy and enables the Duplex-method to reach much greater depths and achieve larger diameters than the Simplex-method.

Triplex-Method

The Triplex-method uses a high pressure water jet with compressed air to cut the soil. Cement grout is introduced into the soil and mixed with it through a separate jet nozzle situated just below the jet nozzle for the water (Triplex string with triple inner conduit rods). The Triplex-method is an appropriate method for underpinning, especially in cohesive soils.

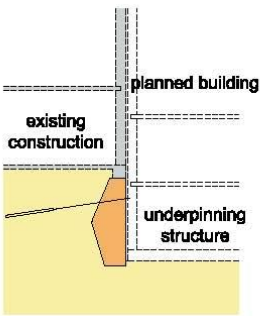
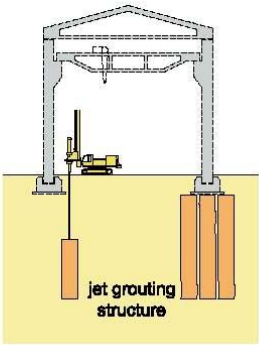
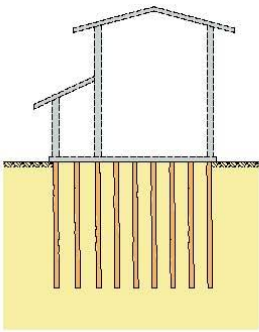
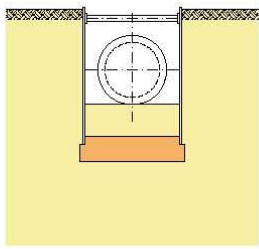
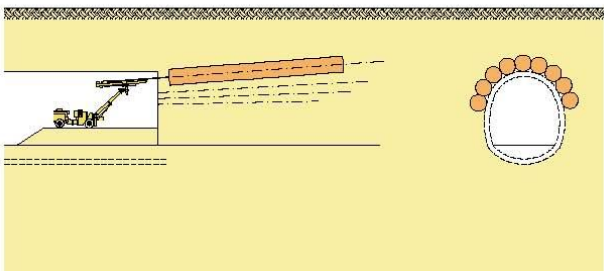
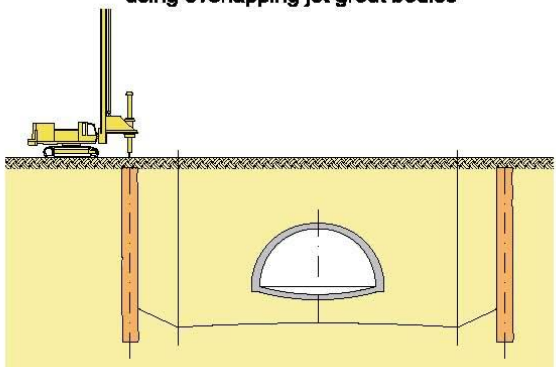
Dimensions

Different geometric forms and dimensions of the soilcrete body can be produced with jet grouting:

- without rotation of the rods during withdrawal and jetting, cut-off walls of various thickness can be produced;
- with partial rotation, segments of a cylinder can be produced (bow-tie);
- with full rotation, a cylindrical body is produced; diameter of the cylinder can be changed by varying withdrawal rate and/or jet pressure.

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Jet Grouting Methods

	<p>Underpinning of existing buildings</p> 	<p>Foundation improvement in case of increased loads</p> 	<p>Soil improvement underneath existing buildings</p> 	<p>Sealing slab in excavation pit</p> 
1	<p>Horizontal canopy for tunneling</p> 	<p>Vertical impervious barrier wall using overlapping jet grout bodies</p> 		

Jet Grouting Parameters

Jet grouting parameters which are chosen for a given project depend on the required characteristics of the finished product, the geotechnical characteristics of the soil and the chosen jetting method.

Principle jet grouting parameters are:

- withdrawal rate of the jet string
- rotation speed of the jet string
- flow rate of the grout
- jet pressure
- jet volume
- number and diameter of jet nozzles
- volume and pressure of compressed air
- mix design of the grout

Applications of Jet Grouting

- underpinning of existing structures
- downward extension of foundations in the case of settlements or increased load
- soil improvement, even underneath existing structures
- vertical impervious barriers
- impermeable base for excavations
- bracing and stiffening of excavations underneath their base
- connection of sealing walls to existing structures and/or services and utilities
- walls for cylindrical or polygonal excavations
- horizontal screens and canopies for tunnelling
- soil stabilisation between neighbouring excavations or foundation works
- impervious connection of individual piles in pile walls

1 Applications of Jet Grouting



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Quality Control

Requirements for quality control are listed in:

- European Standard EN 12716, Execution of Special Geotechnical Works, Jet Grouting
- Accreditation of Bilfinger Spezialtiefbau GmbH for Jet Grouting by the German Institute for Civil Engineering (Zulassungsbescheid Düsenstrahlverfahren Bilfinger Berger (HDI) des Deutschen Instituts für Bautechnik)

European Standard EN 12716 defines in chapter 4 which information must be determined prior to design or execution activities:

- detailed description of the ground profile and its geotechnical properties within the intended extent of treatment;
- hydrogeological conditions;
- boundary conditions such as adjacent structures, buried structures and services, overhead power lines and other work restrictions, access;
- environmental requirements, in particular disposal of spoil;
- acceptable deformation of structures to be underpinned or of adjacent structures.

1 removal of overbreak

2 anchored underpinning of an existing building next to an excavation

3 underpinning of pillars next to an excavation



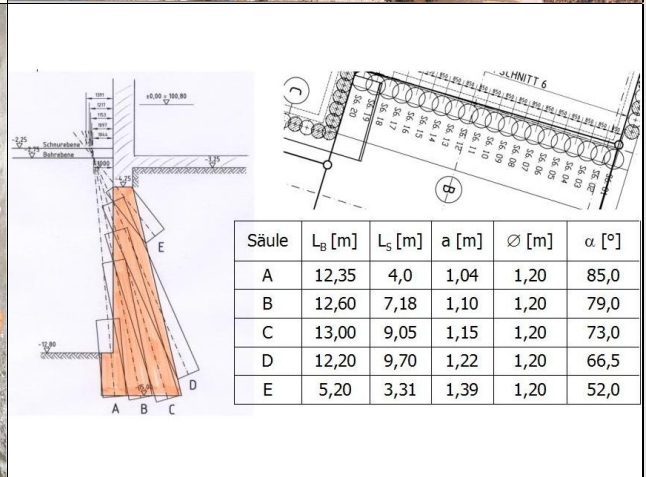
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Verification and Trial Columns

In comparable soil conditions, the same jet grouting parameters produce the same dimensions and properties of the jet grouted structure. If comparable experience on the same jet grouting system in similar ground conditions is not available, appropriate preliminary field tests are performed. These take the form of verification or trial columns. The number of necessary verification columns depends mainly on the variability of expected soil conditions.

Verification columns are executed with a chosen set of jet grouting parameters, which must be recorded during the execution. The verification columns serve to demonstrate that with this set of jet grouting parameters all design requirements (diameter of column, strength etc) are achieved.

Column diameters are usually checked after production of the verification column by

- excavation and physical inspection of the column; problems can be restricted space, groundwater
- inclined control bores into the column from which the position of the encountered grout can be calculated; problems can be deviations of the control bores.

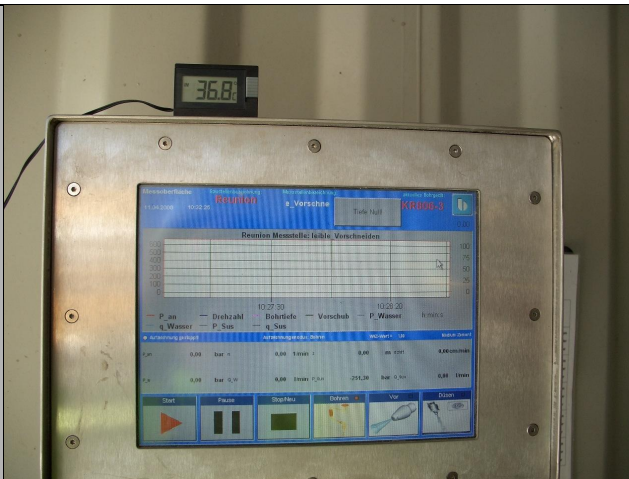
Bilfinger Spezialtiefbau GmbH has developed a new method for the control of column diameters which uses hydrophones. Hydrophone Measurement avoids the above mentioned problems and can be executed during the production of the columns. It thus saves time otherwise required before columns can be excavated, and avoids safety issues associated with excavation and visual inspection.

1 jet grouting works for an impermeable excavation base

2 soil improvement using jet grouting

3 jet grouting in confined space

4 column drawing for underpinning works



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Quality Controls during and after Production

- delivery control of cement type
- density and viscosity of fresh grout
- density of spoil return
- continuous and automatic recording of jet grouting parameters with regard to time and depth
- testing for unconfined compressive strength (UCS) of samples and cores
- monitoring of movements on adjacent structures during foundation or underpinning works

1 recording jet grouting parameters

2 Hydrophone measurement

3 monitoring of movements on adjacent structures

4 testing for unconfined compressive strength