TECHNOLOGY

Jet Grouting

TREVI

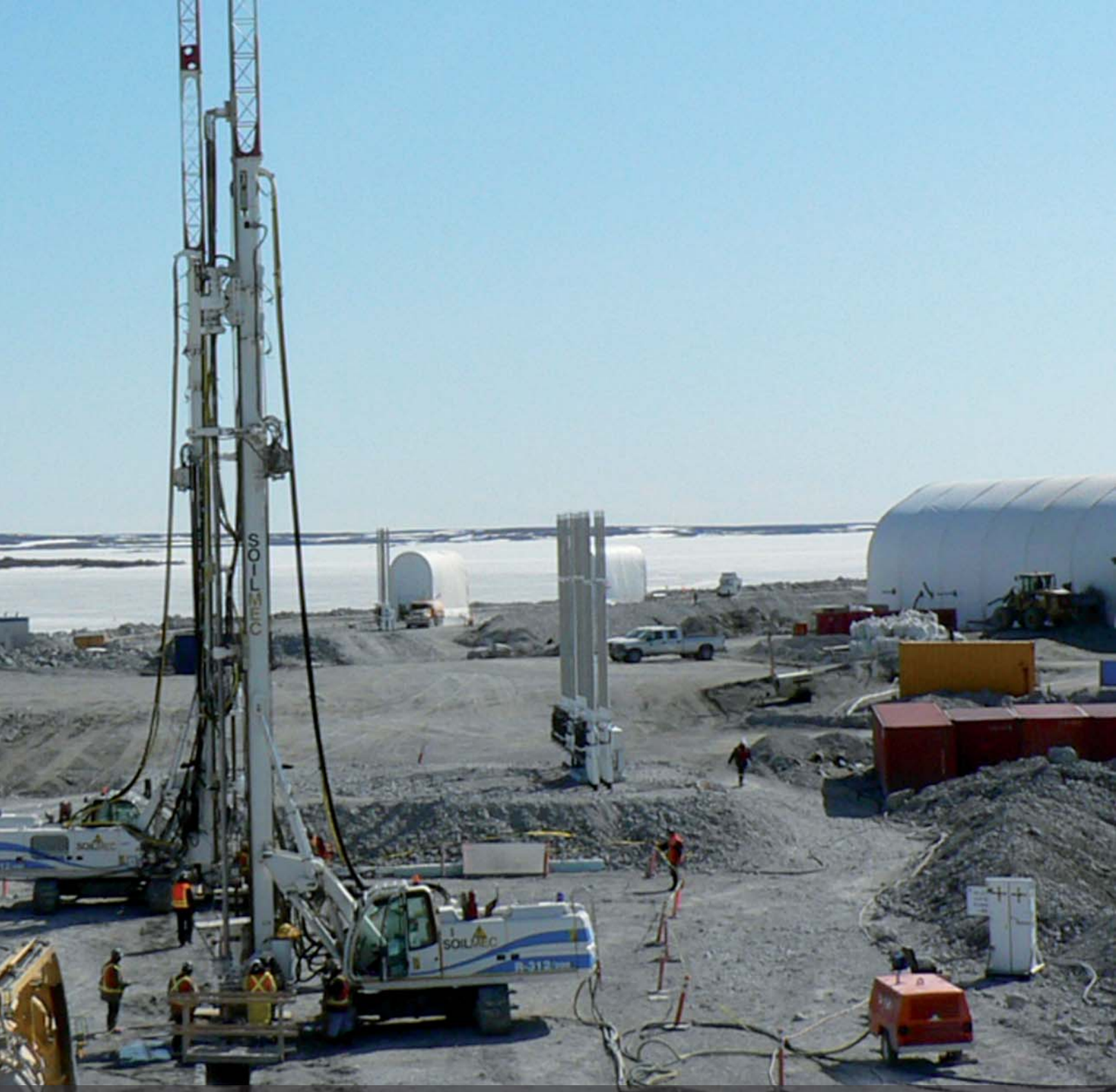
Jet grouting improves soil mechanical and permeability properties by using high-speed jets of water/cement mixtures injection treatment.

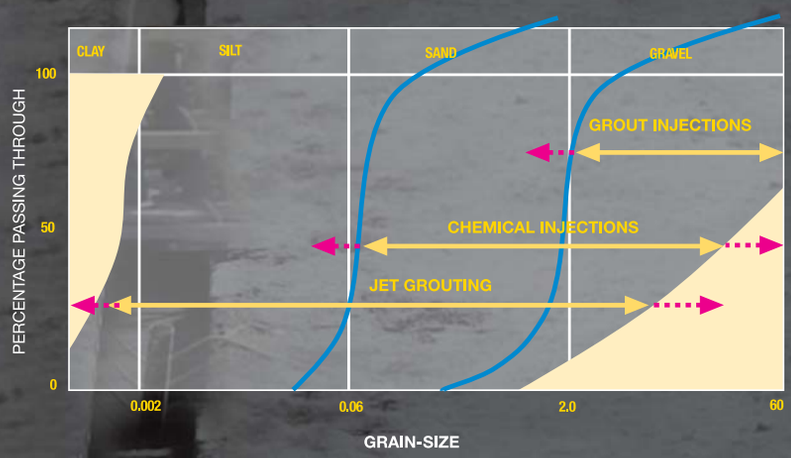
Jet grouting can be advantageoudly in the following conditions:

- **difficult logistic conditions**
- **confined spaces**
- **presence of obstacles to cross**
- **high-depth treatment with crossing of voids**

Suitable soils

The jet grouting technique allows to improve a wide range of soil types. As it is based on soil erosion, soil erodibility is crucial to the final result.
The more consistent the soil to be treated, the smaller the column diameter. Therefore, larger columns can be obtained in loose soft soils and smaller ones in cohesive soils.





No value for money

Profitable

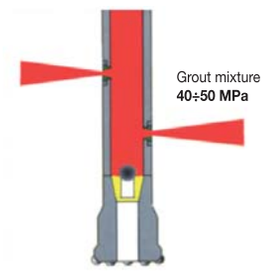
Technology

Consolidated elements – *usually columns* – are constructed using small-diameter drilling (*100 to 140 mm)*, by means of light and easy to handle rigs.
Moreover this technology allows to realize consolidated soil elements and overcome underground obstacles *(foundations, blocks, etc.)*.
Jet grouting is usually performed down to depths of 20-30 m. However, special projects reaching 100 m-depth have also been realized.

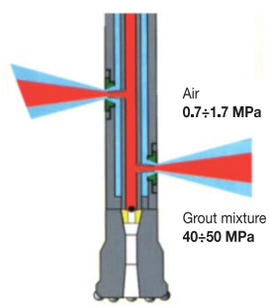
All jet grouting techniques envisage a preliminary phase of drilling, followed by extraction and rotation at preset values, and simultaneous pumping of the fluids at high pressure.

Depending on the number of fluids used, the European standard EN 12716 has identified three main techniques:

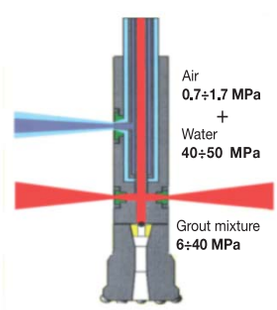
- **Monofluid (TREVIJET T1):** a water/cement mixture is injected to break up and simultaneously mix the soil in-situ. Diameters usually range from 0.4 to 1 m.
- **Bifluid (TREVIJET T1/S):** a combination of water/cement mix and air is injected to break up and simultaneously mix the soil in-situ. Diameters usually range from 0.8 to 2.5 m.
- **Triple fluid (TREVIJET T2):** a combined water/air jet is used to break up and partially remove the soil in-situ, whereas soil mixing is ensured by a lower water/cement injection.



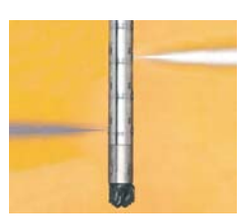
Trevijet T1
Monofluid

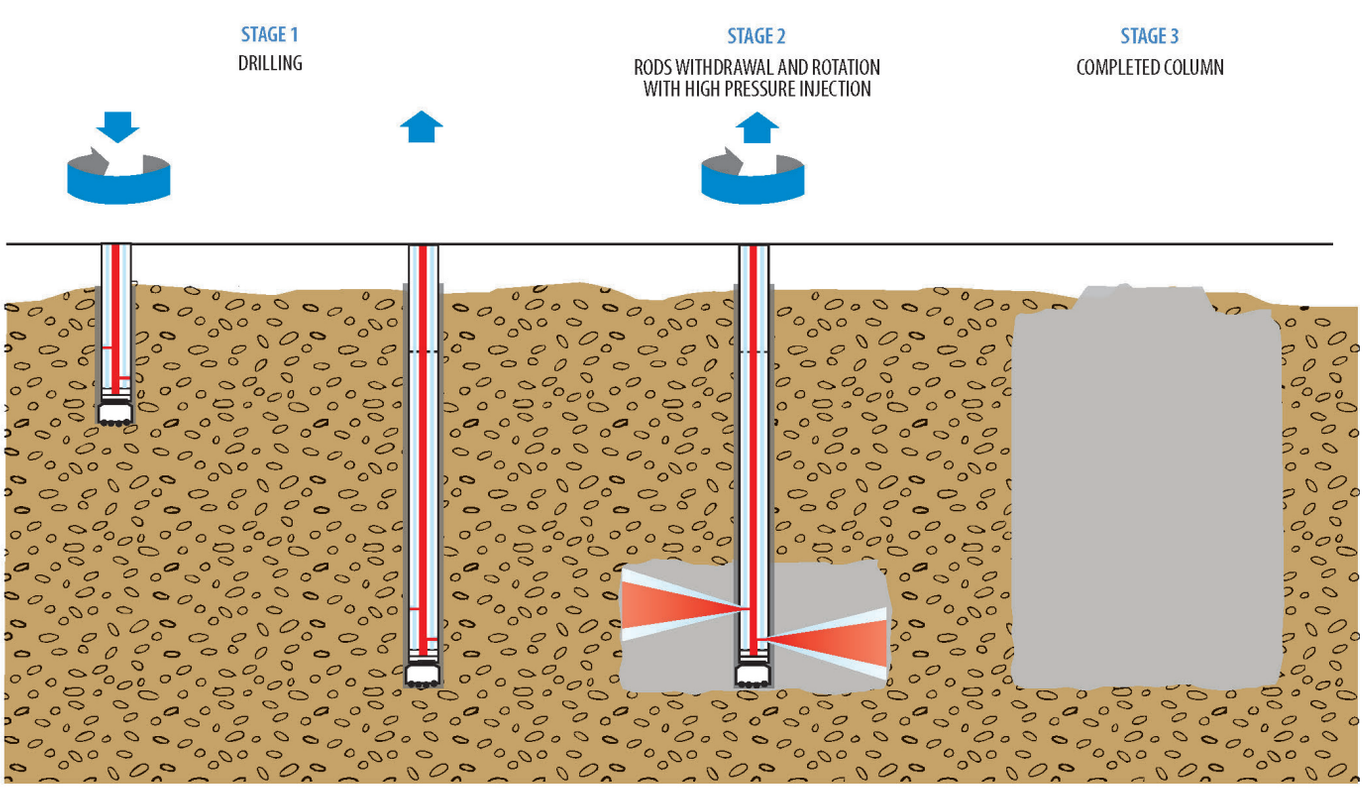


Trevijet T1/S
Bifluid



Trevijet T2
Triple fluid





Before starting to work, the position of each drilling point *(distance between the centres and from the reference points)* must be determined and staked out on the ground, or marked by means of a satellite positioning system.

The **treatment parameters** are chosen only after conducting preliminary field tests.

In case of very cohesive soils, the **pre-cutting** technique may be used. It consists in a pre-treatment with water under pressure which is conducted during extraction or drilling.

The grout must be **injected** immediately after drilling, by extracting and rotating the string at pre-set and constant raising and rotation speeds while pumping the cement mixture at high pressure.

The injection mixtures generally consist of water and cement; additives and bentonite can be added to stabilize them.

The mixture standard composition is the following *(for 1 m^3)*:

- cement (kg) 500 ÷ 1100
- water (l) 650 ÷ 800
- bentonite or fluidifying agents (kg) 0 ÷ 14

If required by the project, a **reinforcement** tube or H-beam can be installed through the mixed soil, at the end of the treatment. Sometimes re-drilling is necessary to place the reinforcement element.

During treatment, any excess fluid is evacuated to the surface *(commonly named drain)*. Although it may seem a waste of material, the lack of it could actually indicate an ineffective treatment.

Innovation

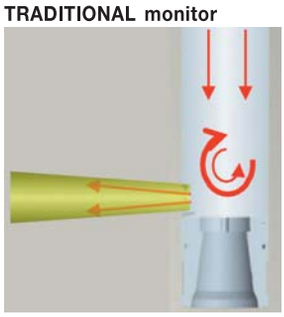
ETJ (Enhanced Trevijet)

TREVI has recently designed and patented a new high-efficiency monitor *(ETJ = Enhanced Trevi Jet)*. The ETJ system includes a cutting-edge monitor and standard jobsite equipment for jet grouting (mixing systems, pumps, drilling rigs, jetting rods).The monitor is fitted with two curvilinear conduits that reduce head losses caused by any sudden variation of the fluid direction *(from axial in the rods to radial through the nozzles).*
In this way, the jet is extremely consistent and allows to significantly improve jet grouting efficiency, and to obtain column diameters larger than the ones realized using standard methods.

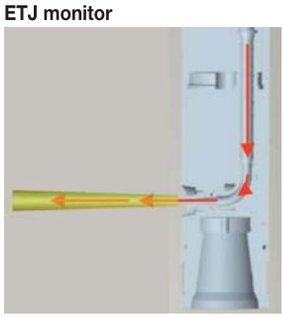
The ETJ system can be used for both monofluid and bifluid treatments.

Increased efficiency		
Monofluid	**Diameter variation**	***25-50%***
Monofluid	**Treated volume**	***60-100%***
Bifluid	**Diameter variation**	***15-20%***
Bifluid	**Treated volume**	***25-40%***

TRADITIONAL monitor



ETJ monitor

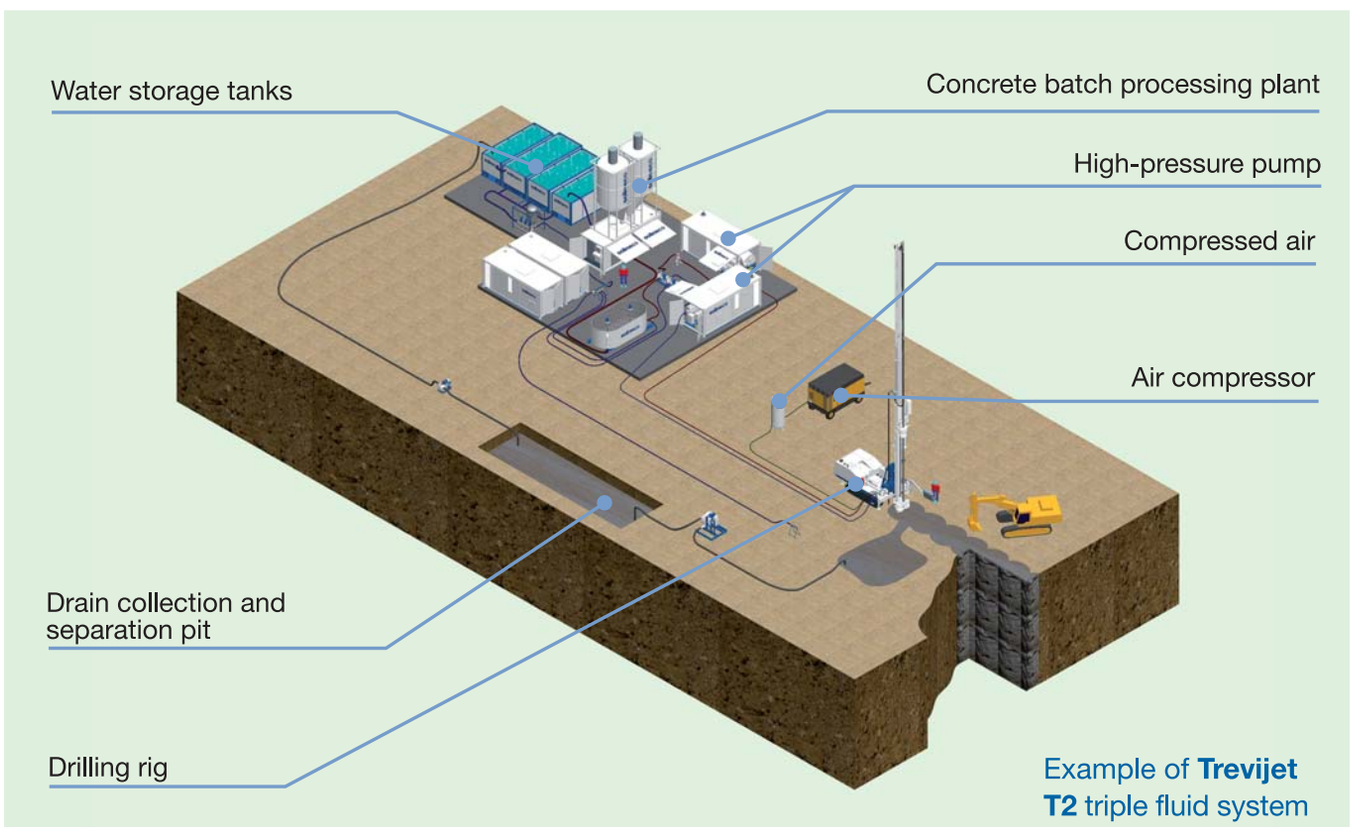


Logistics

The equipment needed for jet grouting are the following: drilling rigs, concrete batch processing plants, high pressure pumps, compressors. The type and number of equipment depend on the technique used.

Installed power ranges from min. 600 HP *(monofluid)* to max roughly 1000 HP *(triple fluid)*.

Method	Installed power
TREVIJET T1	**HP** *600 ÷ 700*
TREVIJET T1/S	**HP** *700 ÷ 800*
TREVIJET T2	**HP** *850 ÷ 1000*



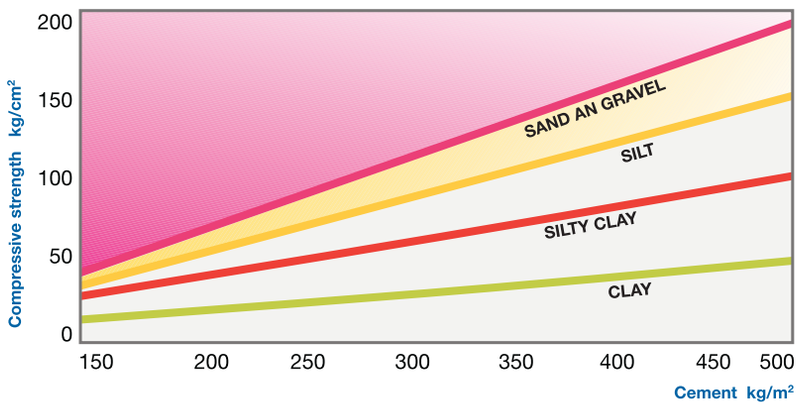
Example of **Trevijet T2** triple fluid system

Properties of consolidated soils

The physical and mechanical properties of consolidated soils mainly depend on the type and composition of the soil itself, as well as on the cement quantity which remains in the ground. Unconfined compressive strength values of 6÷15 MPa can be obtained in coarse alluvial soil, whereas strength is considerably reduced in the presence of cohesive lithotypes.

Average soil permeability values range from 10^{-6} to 10^{-7} m/sec.

Strength depending on lithology and cement quantity



The physical-mechanical characteristics of the treated soils depend mainly on the nature and composition of the soil itself, and on the quantity of cement remaining in the soil. In the chart here, is shown the strength of various type of treated soils as a function of the quantity of cement actually incorporated in the final product. In the chart it is evident as values of unconfined compressive strength (UCS) of 6 to 15 MPa can be achieved in coarse alluvial soils, whereas in cohesive lithologies the strength is sensibly lower.

Quality controls

The jet grouting technology is intended to create underground consolidated elements and, as a result, it is often impossible to directly check the quality of the final product. However, quality control is crucial for some works.
Given the wide range of different soils in which jet grouting is carried out, it is always recommended to realize a test field in order to calibrate the operating parameters and obtain the expected results.

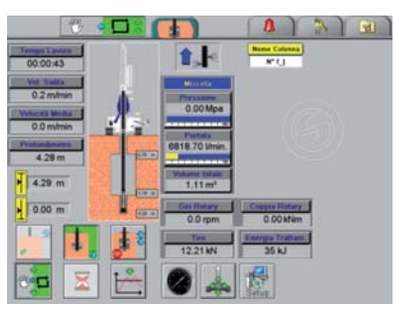
DMS (Drilling Mate System)

During the construction of columns in-situ, it is advisable to use an automatic device to record the parameters and use the ones defined in the test field. In this way, a document is created for each column, which describes the operating method.

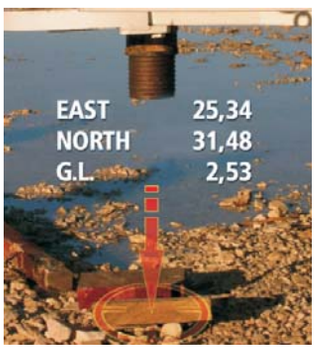
The DMS is a recording system that can be assembled on any drilling rig. It consists of an automatic device that records and checks the drilling and treatment parameters, ensuring high quality standards.
The operator can set the parameters by means of a touch screen.

The device can also be interfaced with a number of instruments and accessories to measure verticality and help the operator position the machine.

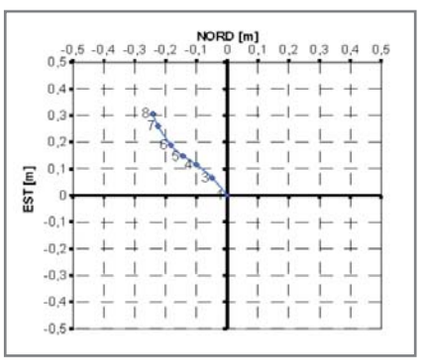
DMS display (SOILMEC)



DPS display



APS polar chart



DPS JET (Drilling Positioning System)

The DPS has been developed to control the position of monofluid and bifluid jet grouting columns. The device allows to make measurements within an area of +/- 60 degrees from the vertical.
This control is extremely important in the execution of bottom plugs and deep waterproofing shields. he DPS provides inclination and direction data, the standard deviation value of each of the abovementioned measurements, the deviations calculated in North-East and polar coordinates for each stop and the stop heights.

APS (Automatic Positioning System)

The APS is a GPS-guiding system capable of integrating in real time the topographic position coordinates and the drilling parameters for each equipment used in the jobsite.

When positioning the drilling rig, the operator is guided towards the drilling point by the indications on the display. Moreover the operator can check every function from a display installed onboard the drilling rig.

This device allows to improve quality control, by recording the precise initial and final height of each column, and saving the already treated points.

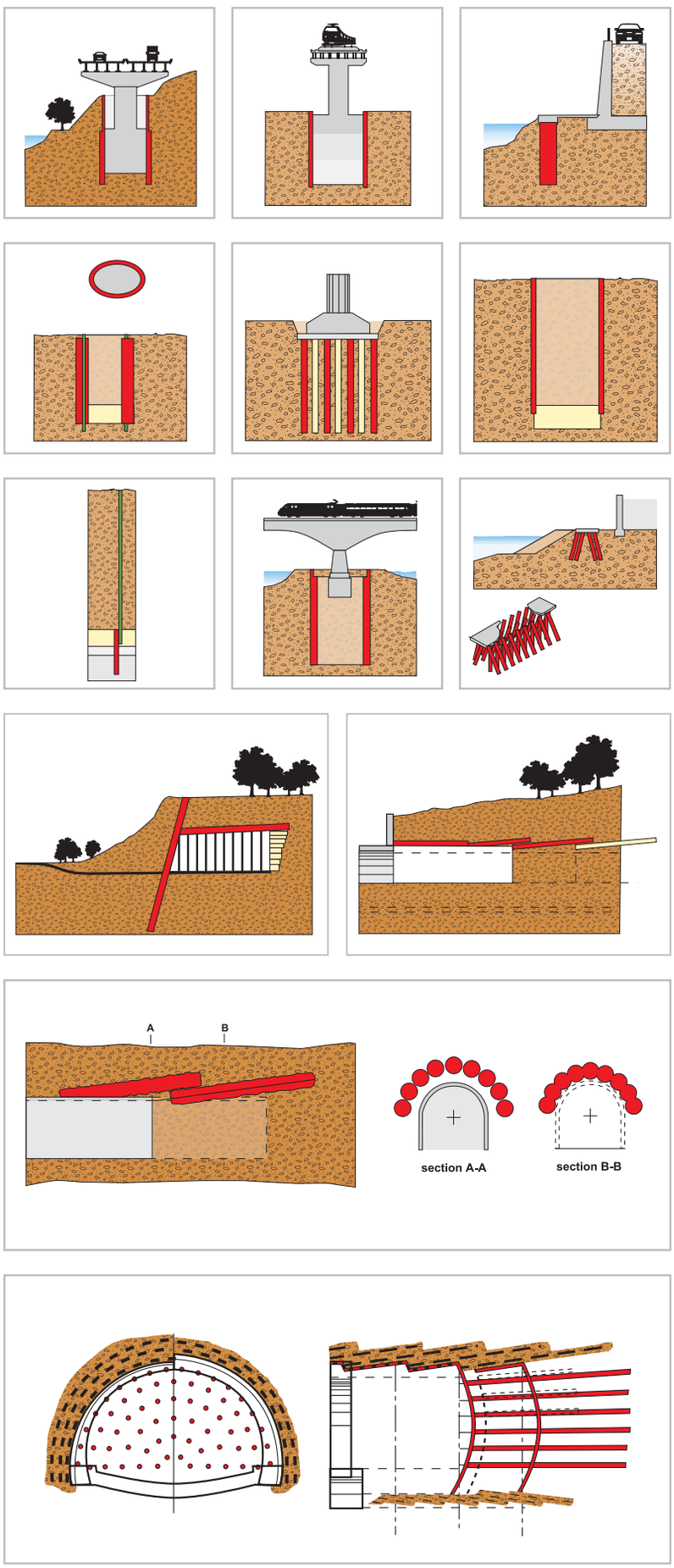
3D rendering of jet grouting columns - STANS Tunnel (Austria)

Applications

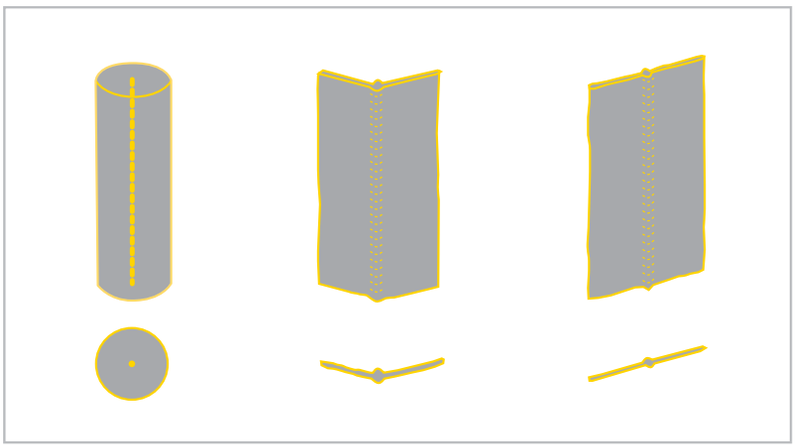
The jet grouting technique is suitable for a number of applications, when other techniques cannot be used.

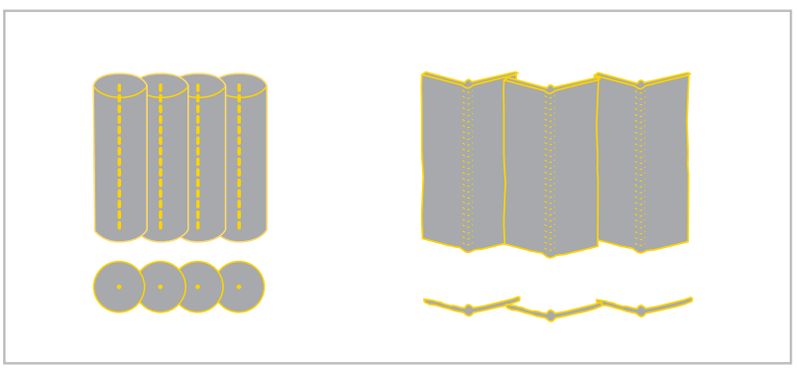
In particular, the following applications can be mentioned:

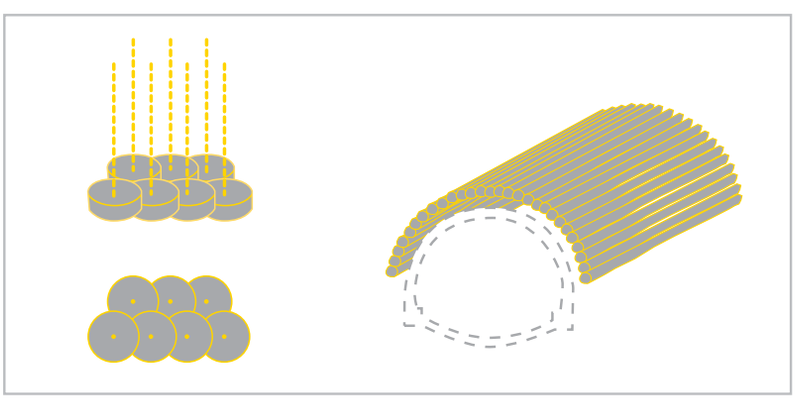
- **Consolidation of existing foundations**
- **Reduction in subsidence for new structures**
- **Retaining walls for excavation protection**
- **Waterproof curtain walls** *(horizontal and vertical)*
- **Preliminary consolidation** works (from the interior or exterior) for tunnelling.



Shapes







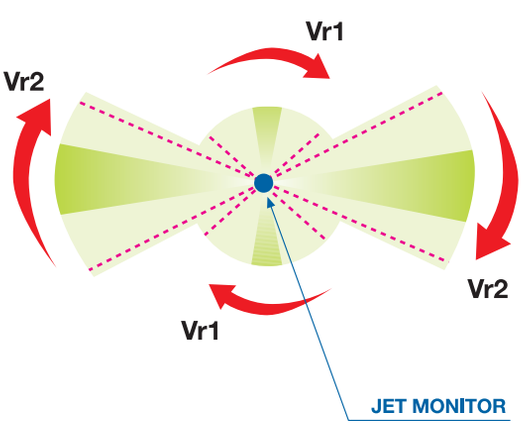
The common shapes of jet grouting treatments are cylindrical columns that are obtained by keeping constant rotating and raising speeds, or thin layers, which are constructed at a constant raising speed, without rotating the string.

Other shapes can also be obtained by modifying the rotation speed, to realize cylindrical sectors.

EJG (Elliptical Jet Grouting)

TREVI has patented an innovative technique which allows to realize pseudo-elliptical columns.
This geometry is obtained by modifying the rotation speed in a planned way. It allows to maximize the use of jet grouting columns when the treatment is aimed at constructing a curtain wall, thus ensuring significant time and material savings.

Operating principle for the construction of elliptical columns
The rotation speed varies from V1 to V2 to create variable radius sectors.



Vr2 < Vr1

World leader in ground engineering, Trevi has been working for more than 50 years throughout the world, strengthening its ability to provide solutions to any ground engineering issues.
Trevi works in the field of special foundation, soil consolidation, dam remedial works, tunnel construction and consolidation, marine works, rehabilitation and cleanup of contaminated sites and construction of underground automatic multi-storey car parks.
Trevi is committed to continuous innovation and search for solutions to complex problems of civil engineering worldwide.
Experimenting cutting-edge technologies, entrepreneurship and investing in research and human resources are the strengths of a company based in more than 30 countries.

TREVI
a TREVIGroup company

www.trevispa.com