



Jet Grouting (Soilcrete®)

An efficient and versatile method
for soil treatment



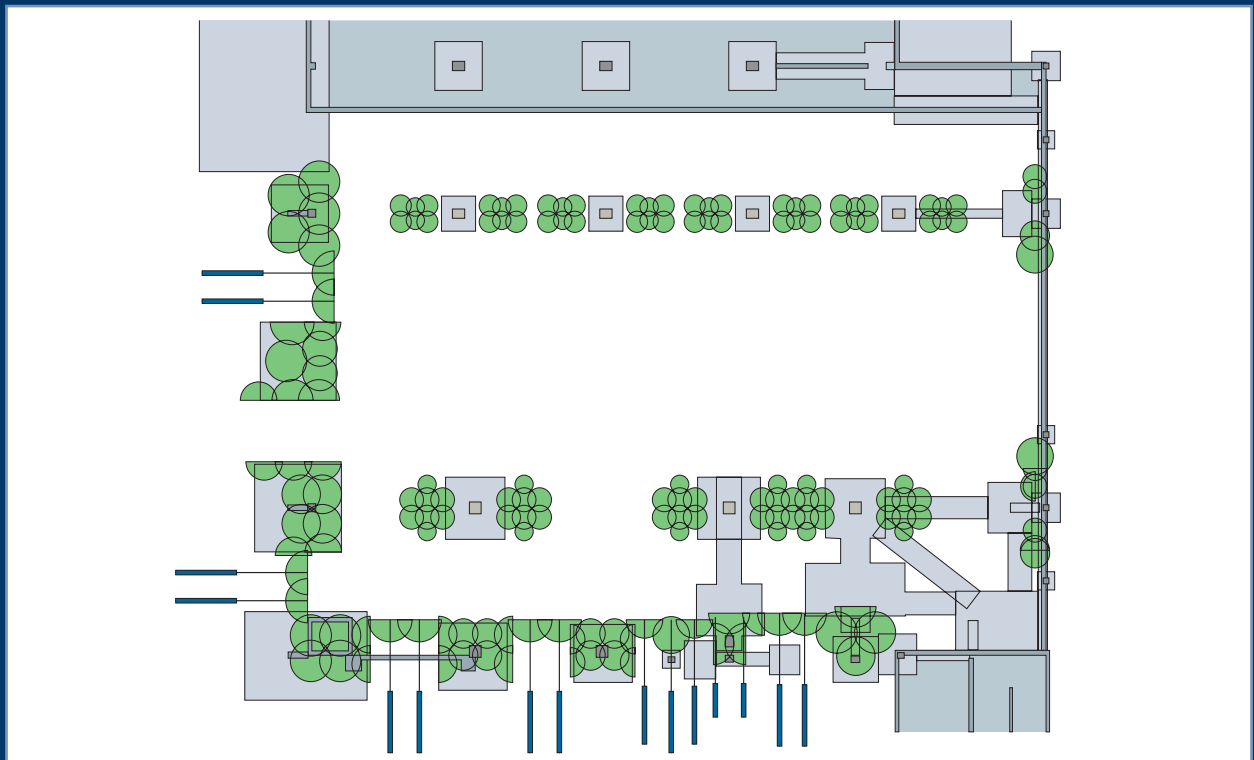
Soilcrete® – history

With the acquisition of a licence in 1979 for the jet grouting process and the introduction in Germany under the trademark "Soilcrete®", Keller entered into a new field of soil stabilisation.

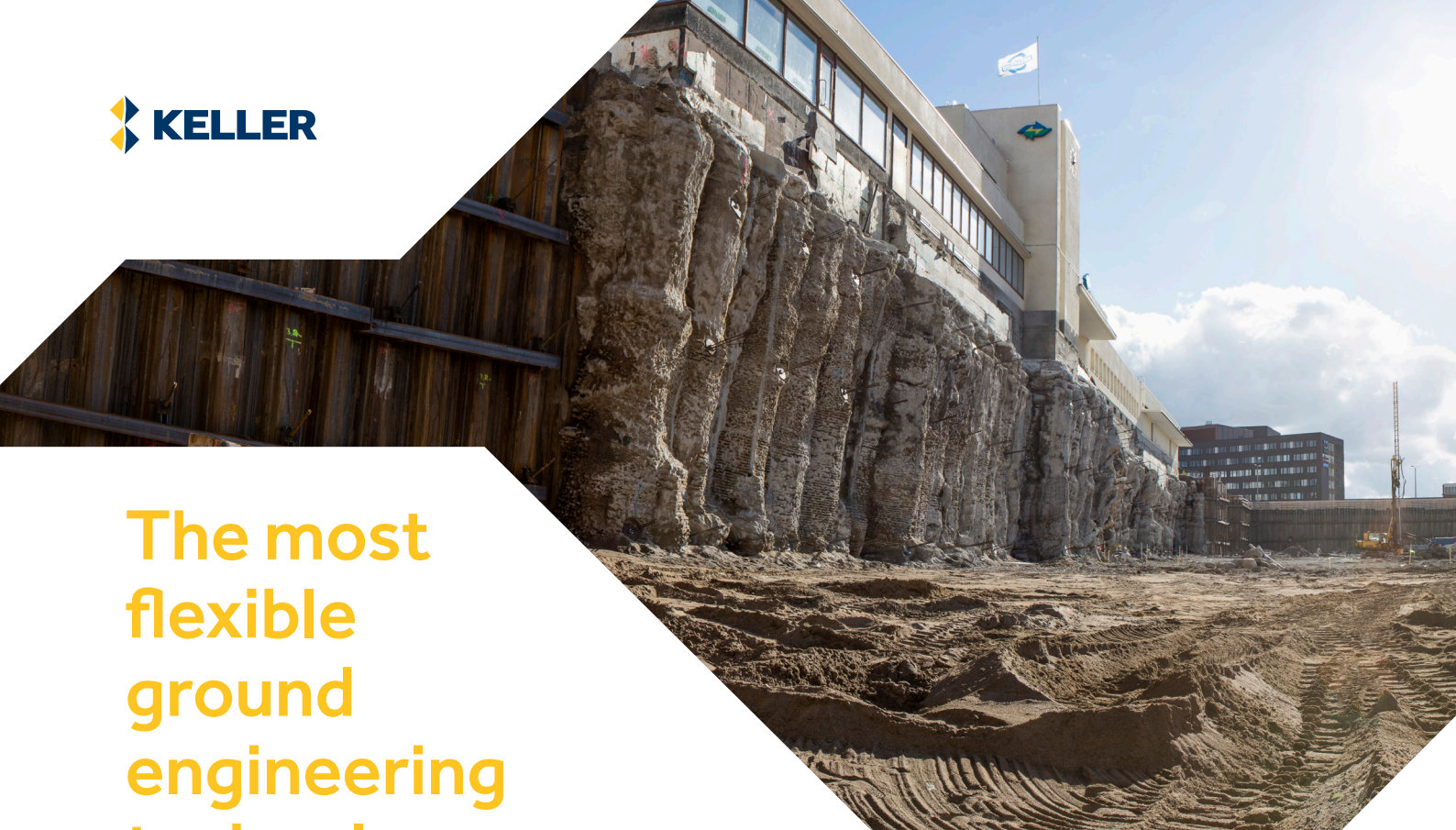
Soilcrete® – Construction sequence

Small scale underpinning works were the beginnings of an unusual method of soil treatment. To reach today's state of the art technique, constant development was necessary.

- The soilcrete® process was modified to suit different types of soils.
- The range of applications was extended to provide solutions to a variety of problems.
- Equipment was developed and improved.



Rehabilitation, modification and extension of an existing foundation



The most flexible ground engineering technology

Soilcrete® (Jet grouting) is one of the most efficient and flexible soil treatment methods to create structures for load bearing and sealing in geotechnics. Keller pioneered this technology and introduced it to the German market in 1979 and uses it all over the world today. Thanks to continuous research and innovation as well as investment in our equipment, we are market and technology leaders and can deliver solutions for almost all applications in a wide range of soil conditions from loose sediments to stiff clay.

Experienced staff, modern equipment, strict quality control and vast design experience are the basis for leading-edge performance in challenging conditions. With Soilcrete®, Keller offers innovative ways for tunnel support, foundations for new and existing structures, the restoration of historic buildings and lateral support. It also includes the impermeable underpinning of walls and bottom seals against groundwater ingress in excavations.

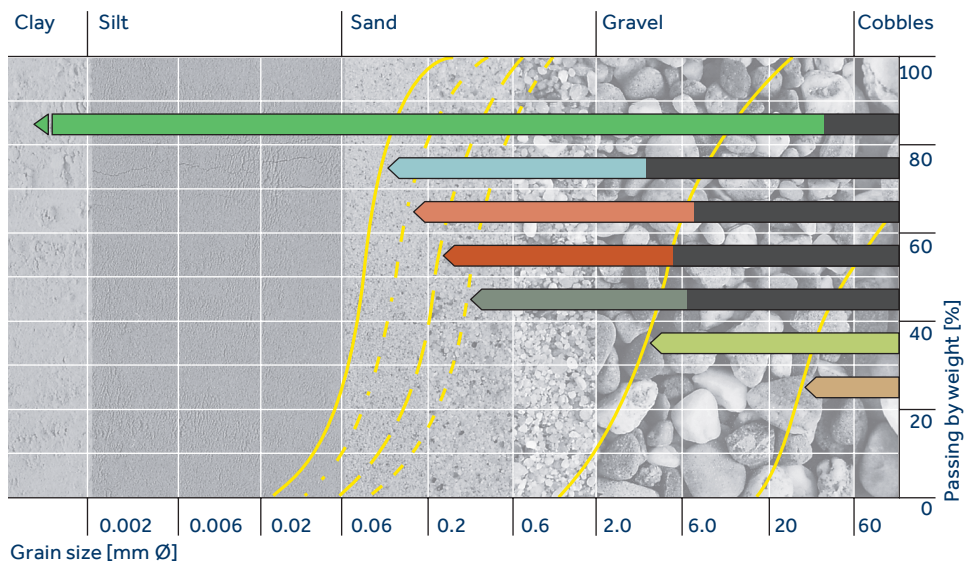
Application limits for grouting techniques

- █ Soilcrete® – Jet grouting
- █ Synthetic solutions
- █ Sodium silicate solutions [lv]
- █ Silicate Gel [hv]
- █ Ultra fine cement
- █ Cement suspension
- █ Mortar

lv = low viscous
hv = high viscous

◁ economical

▬ uneconomical

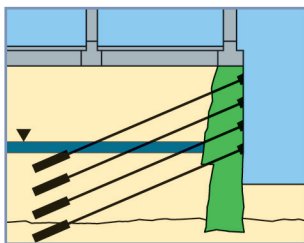




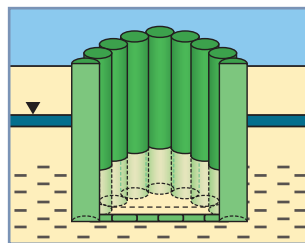
Applications

Soilcrete® is the method of choice for a large range of applications.

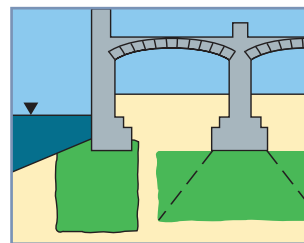
Stabilisation	Sealing
Underpinning	Cut-off walls and panels
Starter blocks and receiving blocks for tunnels	Bottom seals
Tunnel roof and floor stabilisation	Vaulted slabs
Foundation enhancement and extension	Sealing membranes
Foundation modification	Dam core sealing
Lateral support including shafts	Soldier pile wall infill
Deep foundations	Sealing of joints and gaps between structures



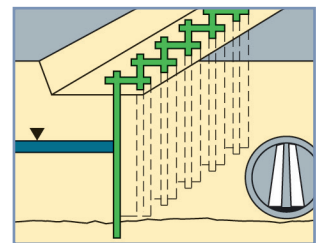
Underpinning



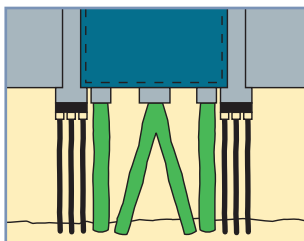
Shaft support



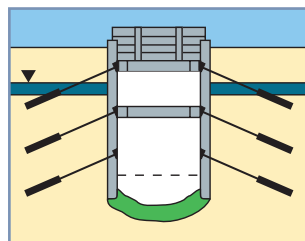
Foundation enhancement and extension



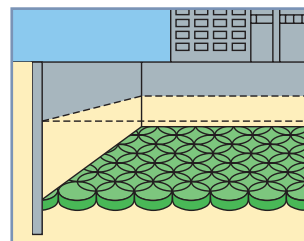
Panel and cut-off walls



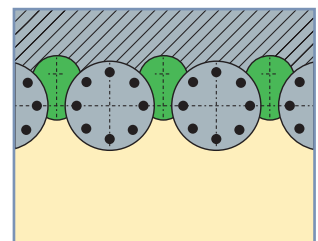
Deep foundations



Vault slabs



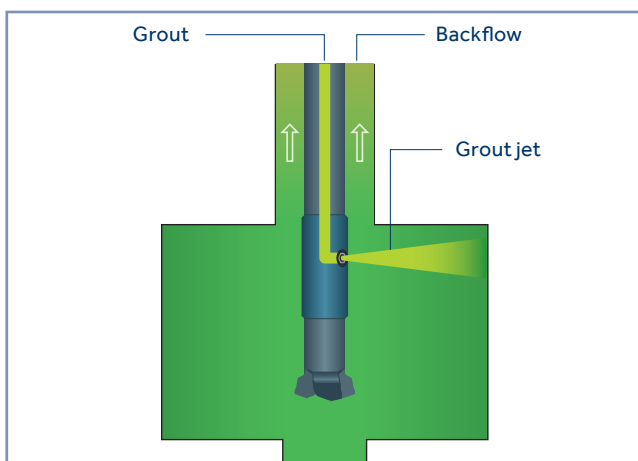
Bottom seals



Soldier pile wall infill

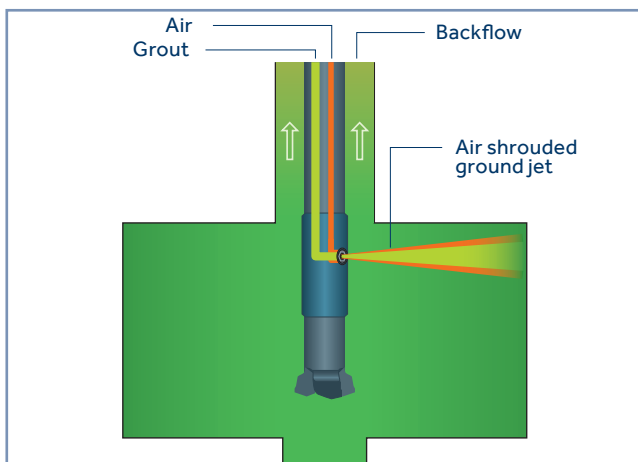
Soilcrete® process variations

Soilcrete® is produced in three different ways. The method used is determined according to the prevailing soil conditions, the geometrical form and the required quality of the Soilcrete® elements.



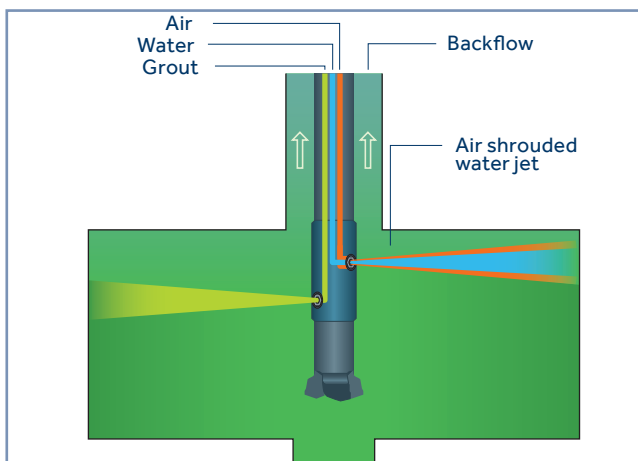
Soilcrete® - S

The single direct process operates with a grout jet of up to 200 m/sec exit velocity for simultaneous cutting and mixing of the soil without an air shroud. The S process is used for small to medium sized jet grout columns.



Soilcrete® - D

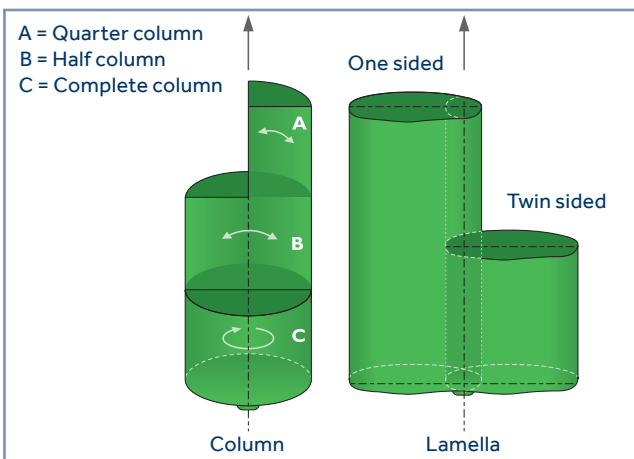
The double direct process operates with a grout jet of up to 200 m/sec exit velocity for simultaneous cutting and mixing of the soil. To increase the erosion efficiency and the range of the grout jet, an air shroud by means of a ring-shaped air nozzle is used. The D process is used for medium sized to very large jet grout columns.



Soilcrete® - T

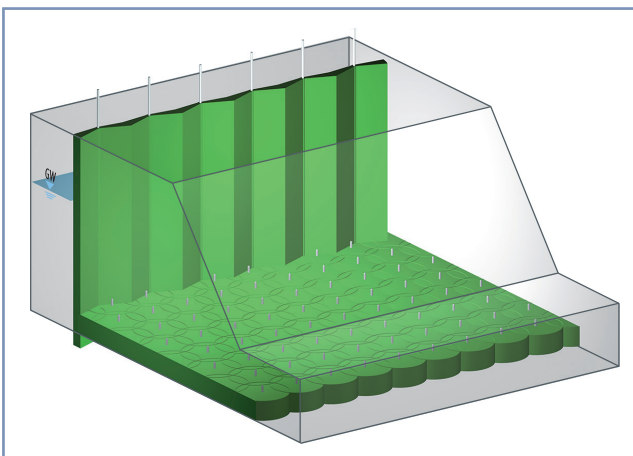
The triple separation process erodes the soil with an air shrouded water jet of up to 200 m/sec exit velocity. Grout is injected simultaneously through an additional nozzle located below the water jet nozzle. The grout pump pressure ranges above 15 bar. A variation of this process operates without air shrouding of the water jet. The T process is mainly used for the treatment of cohesive soils.

Soilcrete® construction forms

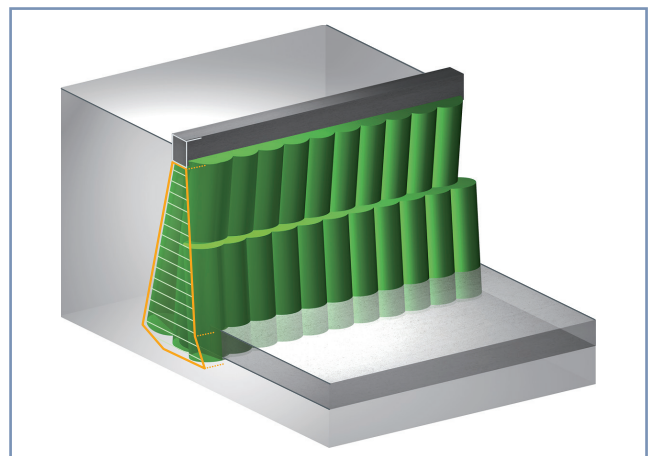


The basic geometrical form of Soilcrete® elements is created through movements of the drill rods:

- Pulling, rotating and creating complete columns.
- Pulling, swivelling and creating segments and half columns.
- Pulling without rotation resulting in lamellas – if several jet nozzles are used multiple lamellas may be produced.



Panel wall with sealing slab



Underpinning elements

The beauty of excellence



Soilcrete® – Process description

Soilcrete® (Jet grouting) is a soil treatment and improvement method. The soil around a borehole is eroded by high speed cutting jets of cementitious grout or water. Soilcrete® is executed in three process variations, depending on the soil conditions and the project specifications: Single direct process with one or more grout jets; double direct process with one or more air shrouded grout jets; triple process with one or more air shrouded water jets and concurrent grout jets.

The eroded soil becomes the aggregate in suspension and is mixed with the cementitious grout (and water in the triplex process). Excess soil-cement-water mix is released through the annular space between jet grouting rods and borehole. The soil erosion and replacement process is constantly controlled and monitored electronically and in real time through DAQ systems. Soilcrete® elements are created in various geometrical forms through movement of the drill rods and can be combined and extended in a variety of ways.

The Soilcrete® – Properties

The unconfined compressive strength (UCS) of Soilcrete® is determined by the cement content, the remaining portion of the soil in the Soilcrete® mass and its properties. The sealing effect of Soilcrete® against water ingress is achieved by elimination of the pore volume in the soil as it is replaced by the grout material. The homogeneity achieved in the treatment process governs the degree of permeability reduction.

Depending on the nature of soils, the injected materials and the achieved homogeneity, Soilcrete® cut-offs are able to reduce the coefficient of permeability by several orders of magnitude. High demands in respect of the degree of sealing can be achieved by the selection of appropriate materials and working parameters together with a strict regime of quality controls. In many applications Soilcrete® elements are used both for structural support and for sealing purpose.

Technical highlights

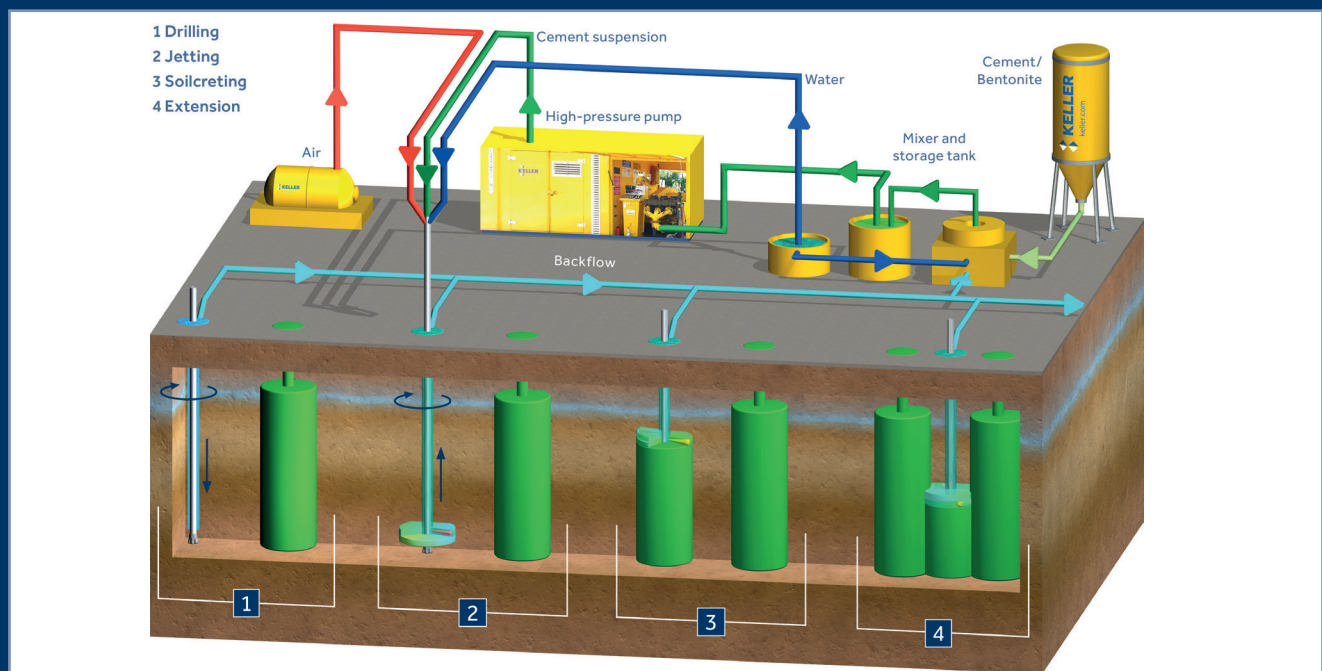
- High speed cutting jets of grout or water and air with exit velocity > 200 m/sec
- Erosion range of jets up to several metres
- Applicable for subsoils from organic peat and clay up to coarse gravel
- Characteristic unconfined compressive strength up to 20 N/mm²
- Drilling depths exceeding 50 m
- Variable geometrical forms of Soilcrete® elements can be produced
- Execution according to European Standard EN 12716

Soilcrete® – Construction Sequence

Soilcrete® site installations consist of silos for the cement or binder and other grout components, automatic mixers, agitator tanks and high pressure pumps. Certified high pressure hoses connect the drill rig at the borehole with the pump.

The mast length of the rig varies from less than 2.0 m for limited headroom and up to 35.0 m in

open areas. The boreholes are normally located in small trenches, from where the spoil return is removed with sludge pumps. From there the excess spoil is pumped to decantation ponds, tanks or skids. If suitable, additional plant and equipment for the recycling and volume reduction of the spoil is used.



Drilling

Bore rods equipped with a monitor (jet nozzle holder) and drill bits are used for drilling to the required depth.

Jetting

Eroding the soil with the cutting grout/water jets starts at the lower end of the borehole. Excess water-soil-cement mix is released to the surface. Constant monitoring of all relevant parameters is guaranteed through DAQ-systems.

Grouting

Simultaneously to the erosion of the soil, cement suspension is injected either in the form of the cutting jet itself or through separate outlets in the monitor or drill bit. Turbulence caused by the jetting process results in the required uniform mixing of the components forming the Soilcrete® element.

Extension

Soilcrete® elements of various shapes can be constructed fresh on fresh or fresh against firm and combined or connected in a variety of ways.

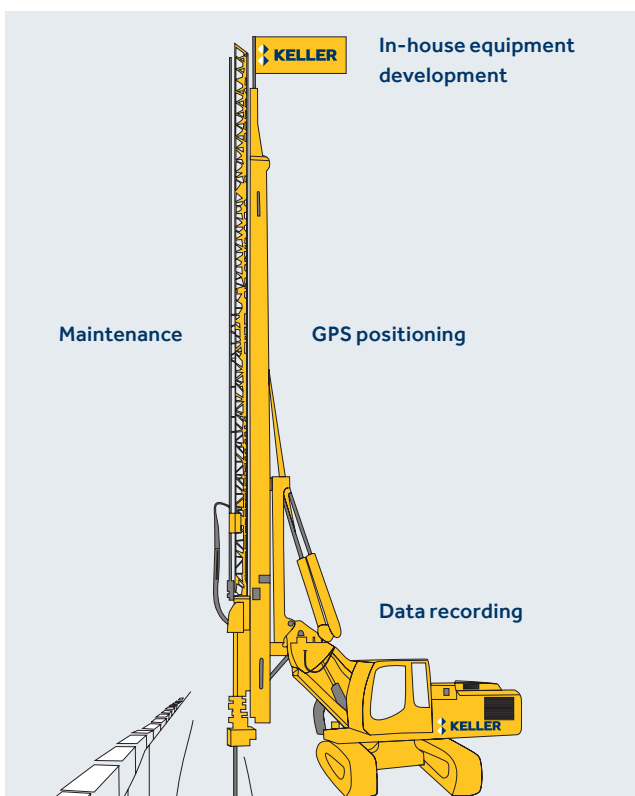
Soilcrete® quality control

Efficiency, reliability and quality through process automation and process control.

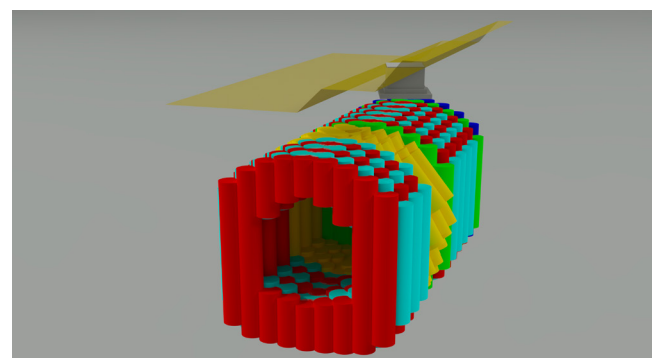
Cost and time efficiency without compromising on quality is our hallmark. We understand that our customers have committed themselves to their clients and stakeholders. As we lay the foundation of projects, we take our responsibilities very seriously and will deliver to meet our clients' expectations and requirements.

Keller's Quality Process Management (QPM) connects our engineering, support and maintenance departments directly with our staff and equipment on site. While our rigs are working, sensors are recording key production parameters such as depth, pressure, flow rates,

lift speed, rotation speed and other relevant data electronically and in real time to ensure process quality and report them back to our offices. Our engineers and support functions monitor this data to make decisions on design adaptation, process changes or necessary maintenance. This advanced degree of process automation and control enables us to reduce the downtime of our equipment, react flexibly to unforeseen soil conditions and optimise the progress and efficiency of our work. The benefit for our customers - quality and safety resulting in a reliable performance.



M5 data recording



Visualisation

Visualisation

Soilcrete® projects are becoming more complex than ever before. To sustain our high quality levels, new ways to visualise the installed elements are required. Keller is pioneering the development of accurate 3D visualisation of Soilcrete® elements in high resolution. The precise GPS controlled location of our tools and an accurate deviation measurement of the boreholes are combined to do this.

Equipment

Keller has its own mechanical engineering department providing state of the art jet grouting equipment and tools. It allows Keller to design and manufacture rigs for a wide range of requirements. Rigs weighing from three tonnes to more than 40 tonnes are available. Each rig is equipped with an M5 data acquisition system. Where necessary, GPS systems, rod handlers, mast extensions, specialist drilling and jetting tools can be attached. Remote and on-site maintenance is carried out by a large team of specialised electricians and mechanics.

Diameter control

Apart from material strength and sealing effect, the determination of the element diameter in all soil layers treated is essential to meet the project requirements. Keller's Acoustic Column Inspector – ACI® was developed and patented to be able to perform diameter measurements and execution parameter optimisation in great depth and during the jetting process. Another feature of the ACI® is the ability to control and demonstrate the connection between jet grouting elements and existing structures like sheet piles, D-walls and other lateral support systems.

Sampling and testing

Part of most project specific requirements is a certain characteristic strength, often together with a permeability reduction (hydraulic conductivity). Different methods for obtaining samples to verify the column properties are applied, such as coring, fresh sampling with grabbing tools or liners, as well as from spoil return. Those samples are tested in certified laboratories for strength and also permeability, if required.

M5 data recording

The revised EN 12716 of 2018 will make digital and continuous real time data recording mandatory. Keller has been using an in-house developed data acquisition system (M5) for all Keller products including Soilcrete® for many years. All relevant execution parameters such as lift speed and rotation number of the drill string, pressures and flow rates of all fluids and air as well as torque, down force and more are recorded. It is the most important tool for verification of the as-built parameter setup for every single element.



Diameter control



Sampling and testing



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Victoria Station, London

At Victoria Station, London Underground's District and Circle lines meet the Victoria Line, creating one of London's busiest interchanges. New pedestrian tunnels and a new ticket hall were required to improve passenger flow. The tunnels were to be excavated below ground water level, in highly permeable soils. The aim of the scheme was to provide a 2m thick treated annulus around the proposed tunnels to allow safe excavation, and to mitigate movement of the overlying structures. A geometrically complex array of boreholes was designed to provide a jet grouted zone through which the new tunnels could be excavated. Overlapping jet grout columns ranging in diameter from 1.4m to 1.8m, were installed to depths up to 14m. The scheme won Ground Engineering Magazine's Editors Award, the coveted Fleming Award and the Construction News Infrastructure Innovation Award.