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

Small scale underpinning works were the beginnings of an unusual way of jet grouting. To reach today’s state of the art, additional development was necessary.

- The process was modified to suit different types of soils.
- The application was developed step by step to provide solutions to a variety of problems.
- Equipment was developed and improved.
- The Soilcrete®-technique has been enhanced constantly.

This brochure reports on the state of the Soilcrete®-technique today.
The name “Soilcrete” derives from the concept “soil” to “concrete” a form of soil with a concrete consistence, a description that characterizes the type of soil stabilization.

Soilcrete® – Jet Grouting Process

The jet grouting process “Soilcrete®” is recognized as a cement soil stabilization. With the aid of high pressure cutting jets of water or cement suspension having a nozzle exit velocity ≥100 m/sec eventually air-shrouded the soil around the borehole is eroded.

The eroded soil is rearranged and mixed with the cement suspension. The soil-cement mix is partly flushed out to the top of the borehole through the annular space between the jet grouting rods and the borehole. Different geometrical configurations of Soilcrete®-elements can be produced.

The erosion distance of the jet varies according to the soil type to be treated, the kind of Soilcrete®-process and the jetting fluid being used, and may reach up to 3.5 meter. This technique is regulated by European Standard EN 12716.

Applications
In contrast with the conventional ground stabilisation methods Soilcrete® may be used for stabilization and sealing of all kind of soil ranging from loose sediments to clay. This applies also for non homogeneous soil formations and changing soil layers, including organic material. Soft rock formations have also been treated by Keller – for example sandstone with weak grain texture.
The Soilcrete®-properties
Soilcrete® acts in the ground according to the specification either as a stabilization or as a sealing structure. A combination of both properties is increasingly required. The compressive strength of Soilcrete® ranges from 2 to 25 N/mm² and is determined by the cement content and the remaining portion of the soil in the Soilcrete® mass. The sealing effect of Soilcrete® against water ingress is achieved by selecting a suitable grout suspension and if necessary by the addition of bentonite. The type and quantity of the injected grout material as well as the kind and volume of the remaining soil particles in the Soilcrete® mass guiding the sealing properties.

Compressive strenght of Soilcrete®

<table>
<thead>
<tr>
<th>Grain size [mm Ø]</th>
<th>Silt</th>
<th>Sand</th>
<th>Gravel</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.002</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>0.06</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>1.0</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2.0</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>6.0</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>10.0</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Type of soil | Compressive strength [N/mm²] |
-------------|-----------------------------|
Silt         | ≤ 5                         |
Sand         | ≤ 10                        |
Gravel       | < 25                        |

Depending on the nature of soils, Soilcrete®, cut-offs are able to reduce the coefficient of permeability by several decimal powers. High quality requirements in respect of the degree of sealing effect necessitate extensive production efforts. For many applications both the strengthening and sealing characteristics of the Soilcrete®, elements are used. The selected suspensions need to be composited accordingly.
Soilcrete® is produced in three different ways. The method to be used is determined according to the prevailing soil conditions, the geometrical form and the required quality of the Soilcrete®-elements.

**Soilcrete®-S**
(Single direct process) operates with a grout jet of min. 100 m/sec exit velocity for simultaneous cutting and mixing of the soil without an air schroud. The S process is used for small to medium sized jet grout columns.

**Soilcrete®-D**
(Double direct process) operates with a grout jet of min. 100 m/sec exit velocity for simultaneous cutting and mixing of the soil. To increase the erosion capability and the range of the grout jet, air shrouding by means of shaped air jet nozzle is used. The D process is mainly used for panel walls, underpinning and sealing slabs.

**Soilcrete®-T**
(Triple separation process) erodes the soil with an air shrouded water jet of min. 100 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 used for underpinning works, cut off walls and sealing slabs and is mainly used for the treatment of cohesive soils.
The basic geometrical form of Soilcrete® elements is created through movements of the drill rods:

- Pulling of the drill rods without rotation resulting in panels — if several jet nozzles are used multiple panels may be produced.
- Pulling and swivelling create segments.
- Pulling and rotating create complete columns.

Soilcrete® – basic forms
The Soilcrete® basic forms may be arranged and combined in any way to form each type of element.
Soilcrete®-site installations consist of storage containers, silos and a compact mixing and pumping unit. Several high pressure hose connections and control cable lines connect the pumping unit with the Soilcrete® drilling rig at the installation point. The mast length of the rig varies from 2.0 m in cellars or shaft sand up to 35.0 m in open areas. The bore points are normally located in small trenches equipped with sludge pumps. From there the excess material, water-cement-soil mixture is pumped to setting ponds or tanks.

1 Drilling
Drill rods equipped with jet nozzle holder and drill bit are used to drill the jet grouting hole down to the required depth. Normally the jet grout mixture is used as drill flushing to stabilize the borehole during the drilling operation. In masonry and concrete, special drilling bits are used.

2 Jetting
The dissolution of the grain texture with a powerful fluid jet starts at the lower end of the Soilcrete®-element. The excess water soil cement mixture is removed to the surface through the annular space between drill rod and bore-hole wall. The pre-selected production parameters are constantly monitored.

3 Grouting
For all Soilcrete®-variations cement suspension is injected under pressure simultaneously with the erosion of the soil. The turbulences caused by the jetting technique results in the uniform mixing of the grout with the soil within the treatment zone. Until the grout in the Soilcrete®-elements starts setting hydrostatic pressure in the borehole is kept by backfilling grout into the hole from time to time.
**Process monitoring**

Up to 12 different parameters for the construction of Soilcrete®-elements may be recorded and used by the engineer-in-charge of supervision and control.

**4 Extension**

Soilcrete®-elements of each form may be constructed fresh on fresh as well as fresh against firm and combined and connected in a variety of ways. The working sequence follows the technical requirements and the conditions of the structure to be treated.

Optical and manual checking as well as controls and tests according to the requirements laid down in the European standard EN 12716 ensure quality workmanship.
Soilcrete® for stabilisation

Underpinning work for adjacent construction pits is one of the main tasks of soil stabilisation – followed by foundation modifications and restoration. Soilcrete® opens new ways for tunnel constructions in loose soils.

**Underpinning**
Underpinning by means of low deformation gravity walls sometimes also used as a ground water sea-page barrier, may be safely constructed even from confined working areas.

**Tunnel protection**
Soilcrete®-tunnel protection is mainly constructed in loose soils below or close to endangered structures, sometimes with the aim of reducing the groundwater ingress into the tunnel excavation.

**Foundation restoration**
Historical buildings may be endangered in the event of settlements occurring. Soilcrete® provides a safe foundation with the maximum structural protection.

**Soilcrete® – Horizontal**
Horizontal Soilcrete®-columns protect tunnel drives in loose soil formations. They are constructed from working faces and are horizontal or slightly inclined.

**Foundation modification**
Changes in utilisation or modifications of buildings often require an enlargement or alteration of the foundation. Soilcrete® is an economical and flexible solution for this task.

**Shaft supports**
Shafts with intersecting Soilcrete®-columns are constructed if a vibration free installation is required and/or the shafts enter into groundwater bearing strata.

**Deep foundation**
Soilcrete® is used for new foundations which require special care in view of nearby existing structures such as historical buildings and other shock-sensitive constructions.

**Earth-pressure relief**
Structures exposed to earth pressures, such as historical walls, abutments, avalanche galleries, steep slopes protections or quay walls may be relieved by the addition of or connection to a statically calculated backup Soilcrete® body.
Soilcrete® for sealing

Building pit walls constructed of deformation and ground water resistant Soilcrete®, underpinning elements, combined with low permeable Soilcrete®-slabs enables the execution of deep building pits without the need for large scale ground water lowering. Environmental safe mineral binder materials are used for Soilcrete®.

<table>
<thead>
<tr>
<th>Panel walls</th>
<th>Vault slabs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilcrete®-panel walls to cut off ground water are used below roads and buildings, for crossing pipelines and to subdivide building pits into different excavation sections. According to the sealing requirements single or multiple panels may be constructed.</td>
<td>For small building pits and shafts with reduced width Soilcrete®-slabs are used as prevention against the water uplift pressure, reducing the required depth of slabs normally required to resist the hydrostatic uplift.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Column walls</th>
<th>Sealing cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the event of higher mechanical strain by shearforce, danger of undermining or of a high impermeability requirements, cut off walls of intersecting Soilcrete®-columns may be constructed.</td>
<td>The Soilcrete®-cover protects the groundwater below buildings against affects from construction activities and old toxic waste de-posits.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dam sealing</th>
<th>Joint sealing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilcrete® may be used to repair dam cores or enlarge cut-off walls in or below dams.</td>
<td>For sealing of joints between piles, sheet piles or other construction parts in the ground the Soilcrete®-wing-jet is applied.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sealing slabs</th>
<th>Groundwater exits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soilcrete®-sealing slabs are constructed by means of overlapping columns within an uplift proof depth. The sealing slabs may be connected to any kind of vertical sealing systems.</td>
<td>Sealing walls are often used as temporary ground water barriers. The reinstatement of the permeability may be reached using the Soilcrete®-process to wash out the binder material from predetermined sections.</td>
</tr>
</tbody>
</table>