Bauer
Jet Grouting
Advantages of the Jet Grouting Process

During the jet grouting process, the soil surrounding the drill string is eroded by a high energy fluid jet and mixed with a self hardening cement suspension. The main advantage of this process is that large solidified jet grout elements can be produced in the ground by a relatively small drill rod (borehole diameter approx. 15 cm). The applications are virtually unlimited.

Applications:
- Underpinning / Foundation support
- Gap closure
- Deep and high level sealing slabs
- Tunnel crown stabilisation
- Sealing and cut-off walls
- High level of safety as jet grouting is carried out prior to any excavation (e.g. sealing slabs and underpinning)
- Load-bearing capability as result of compressive strength
- Application in restricted site and limited headroom conditions
- Virtually unlimited drilling depths and complicated geometrical shapes possible
- Underpinning by jet grouting enables excavations adjacent to the building line
- Low-vibration process
**Process Description**

### Construction Sequence

1. **Drill jet grouting drill string into the ground**
2. **Switch to jetting**
3. **High pressure jetting**

**Step 1:**
A string of jet grouting rods is drilled into the ground to the required depth by a rotary drilling rig. The lower end of the drill string is fitted with a nozzle holder and a laterally mounted jet grouting nozzle.

**Step 2:**
A jetting fluid (water and/or binder suspension depending on the type of jet grouting process) is pumped through the jet grouting nozzle at high pressure (400 - 600 bar). This produces a high-energy “cutting jet” which erodes the soil from its natural position and mixes it with the binder suspension. The diameter of the column (up to 5 m) is determined by the density and type of soil as well as the jet grouting parameters.

**Step 3:**
By rotating and simultaneously retracting the jet grouting drill string, the cutting jet describes a tightly-spaced helix in the soil, resulting in a column-shaped space filled with binder suspension and soil. The binder causes this mixture to set and solidify, as a result of which load-bearing jet grouting columns are formed.
Different jet grouting methods

Depending on the prevailing soil conditions, different jet grouting methods are employed.

<table>
<thead>
<tr>
<th>BAUER definition</th>
<th>Definition in accordance with EN 12716:2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Binder cutting. In granular soils for small to medium column diameters</td>
</tr>
<tr>
<td>BL</td>
<td>Binder cutting with air shrouding. In granular soils for medium to large column diameters</td>
</tr>
<tr>
<td>WB</td>
<td>Water cutting and filling the soil with binder. In cohesive soils for small to medium column diameters</td>
</tr>
<tr>
<td>WLB</td>
<td>Water cutting with air shrouding and filling the soil with binder. In cohesive soils for medium to large column diameters</td>
</tr>
</tbody>
</table>

Jet Grouting Process B

- Air shroud 5 - 6 bar
- Cement suspension, high pressure 100 - 600 bar

Jet Grouting Process BL

- Air shroud 5 - 6 bar
- Cement suspension, low pressure 3 - 10 bar
- Water, high pressure 100 - 600 bar

Jet Grouting Process WB

Jet Grouting Process WLB
Process Description

Site Installation

**Procedure Process B and BL**
The B and BL processes are primarily used in non-cohesive soils.
In the BL process, air shrouding increases the range of the grout jet.

**Procedure Process WB and WLB**
The WB and WLB processes are primarily used in cohesive soils. In both processes, the soil structure is eroded by the high pressure water jet and subsequently mixed with the binder suspension.
**Jet Grouting Parameters**

The essential parameters which are responsible for the result are:
- High pressure pump 100 – 600 bar
- Number of nozzles 1 – 2
- Nozzle diameter 2 – 7 mm
- Drill string rate of extraction 1 – 12 min/m
- Air shrouding 4 – 12 bar
- Drill rod speed of rotation 2 – 15 rpm
- Binder suspension W/B ratio 0.5 – 1.5
- Injection rate 100 – 400 l/min
- Injection pressure 3 – 10 bar

**Materials**

In general, jet grouting requires only water and binder suspension (generally in the form of cement). Selection of the appropriate binding agent is determined by the following requirements:
- Strength
- Impermeability
- Erosion resistance
- Workability

**Forms of Jet Grouting Elements**

Depending on the rotation and movement of the drill rods, different geometric forms of jet grouting elements can be created, such as:
- Circular columns
- Half columns
- Segmental columns
- Panels

**Limits of Application**

The erosion capability of the cutting jet renders the jet grouting process suitable for use in virtually all types of soil. The process is, however, not suitable for hard soil and soft rock formations in which stabilization is not generally required and would also not be economical.

The “Bauer Jet Grouting Process” can be used in non-cohesive or cohesive soils and also in slightly organic soils and fill materials.
Applications

Underpinning

Sealing slabs

Sealing slabs

Foundation support
Equipment for Jet Grouting
The universal Bauer BG base carriers can be converted for most of the established specialist foundation construction techniques. Attaching the required jet grouting equipment is also easy.

Numerous jet grouting projects around the world have already been completed with different BGs. Three examples of BG jet grouting configurations are illustrated below.

Bauer rigs can be preset for a grouting pressure of 420 bar (standard) or optionally 560 bar.

<table>
<thead>
<tr>
<th></th>
<th>BG 15 H</th>
<th>BG 24 H</th>
<th>BG 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rod diameter</td>
<td>89 – 133 mm</td>
<td>89 – 133 mm</td>
<td>89 – 133 mm</td>
</tr>
<tr>
<td>Jetting depth</td>
<td>ca. 29.9 m</td>
<td>ca. 35.3 m</td>
<td>ca. 35.5 m</td>
</tr>
<tr>
<td>Overall height</td>
<td>39.24 m</td>
<td>45.2 m</td>
<td>45.4 m</td>
</tr>
<tr>
<td>Max. power output</td>
<td>230 kW</td>
<td>354 kW</td>
<td>403 kW</td>
</tr>
<tr>
<td>Weight</td>
<td>56.1 t</td>
<td>80 t</td>
<td>107 t</td>
</tr>
<tr>
<td>Mast inclination</td>
<td>± 5°</td>
<td>± 5°</td>
<td>± 5°</td>
</tr>
<tr>
<td>Rotary drive</td>
<td>KDK 10 S</td>
<td>KDK 10 S</td>
<td>KDK 10 S</td>
</tr>
</tbody>
</table>

1 dependent on level of jet nozzle holder
KLEMM Bohrtechnik GmbH, a subsidiary of BAUER Maschinen GmbH, is a leader in the development and manufacture of hydraulic drill rigs and accessories for all types of drilling jobs for anchoring, overburden, injections and micropiles. The compact Klemm drill rigs can be used for a wide range of jet grouting applications.

### Klemm Rigs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>3.8 m</td>
<td>6.3 m</td>
<td>8.8 m</td>
<td>15.3 m</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>0.75 – 1.2 m</td>
<td>1.8 m – 2.4 m</td>
<td>2.3 m</td>
<td>2.5 – 3.3 m</td>
</tr>
<tr>
<td><strong>Overall height with drill mast</strong></td>
<td>6.1 m</td>
<td>12.9 m</td>
<td>20 m</td>
<td>27.3 m</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>5.0 t</td>
<td>12.0 t</td>
<td>13.3 t</td>
<td>27.5 t</td>
</tr>
<tr>
<td><strong>Power output</strong></td>
<td>45 kw</td>
<td>115 kW</td>
<td>129 kW</td>
<td>173 kW</td>
</tr>
<tr>
<td><strong>Rod diameter</strong></td>
<td>89 mm</td>
<td>89 – 133 mm</td>
<td>89 – 133 mm</td>
<td>89 – 133 mm</td>
</tr>
<tr>
<td><strong>Rod inclination with drill mast</strong></td>
<td>-2.5/+10°</td>
<td>-2.5/+10°</td>
<td>-2.5/+10°</td>
<td>-3/+5°</td>
</tr>
<tr>
<td><strong>Jetting depth single pass max.</strong></td>
<td>5.5 m</td>
<td>12.5 m</td>
<td>16.5 m</td>
<td>24 m</td>
</tr>
<tr>
<td><strong>Rotary drive, recommended</strong></td>
<td>KH9SK</td>
<td>KH9SK/KH14SK</td>
<td>KH12SK/KH14SK</td>
<td>KH12SK/KH14SK</td>
</tr>
</tbody>
</table>

1 Dimensions during operation
2 The rod diameter can be changed to suite requirements
Jet Grouting Drill Rods
Bauer and Klemm both provide different diameter drill rods for all three jet grouting systems. Depending on the application, drill rods are either equipped with screw or plug couplings.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>1-Phase</th>
<th>2-Phase</th>
<th>3-Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>88.9 mm</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>114.3 mm</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High Pressure Jetting Pump
The MP7 high pressure jetting pump has been specially tailored for the requirements of Bauer jet grouting plant.

<table>
<thead>
<tr>
<th></th>
<th>MP7-MP7ST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. flow rate</td>
<td>550 l/min</td>
</tr>
<tr>
<td>Max. power output</td>
<td>600 kW</td>
</tr>
<tr>
<td>Weight</td>
<td>14 – 15 t</td>
</tr>
<tr>
<td>Common operating pressure approx.</td>
<td>450 bar</td>
</tr>
</tbody>
</table>

Mixing Plant
Our branch company MAT supplies compact injection plant units for colloidal mixing and injection of suspensions for a range of different applications. The SCC and SCA range of mixing plants covers all project sizes.

<table>
<thead>
<tr>
<th></th>
<th>SCA-20K</th>
<th>SCA-30K</th>
<th>SCA-40K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixing capacity</td>
<td>20 m³/h</td>
<td>30 m³/h</td>
<td>40 m³/h</td>
</tr>
<tr>
<td>Total power input</td>
<td>43 kW</td>
<td>43 kW</td>
<td>63 kW</td>
</tr>
<tr>
<td>Weight</td>
<td>2.8 t</td>
<td>2.9 t</td>
<td>4.7 t</td>
</tr>
<tr>
<td>Mixer volume</td>
<td>1000 dm³</td>
<td>1500 dm³</td>
<td>2500 dm³</td>
</tr>
</tbody>
</table>

Grout Pump (Eccentric Screw Pump)
MAT’s eccentric screw pumps are ideally suited for the injection of cement suspension in the 2- and 3-phase processes with water jetting (WB or WLB).

<table>
<thead>
<tr>
<th></th>
<th>EP-12-400</th>
<th>EP-12-600</th>
<th>EP-14-400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery rate</td>
<td>400 dm³/min</td>
<td>600 dm³/min</td>
<td>400 dm³/min</td>
</tr>
<tr>
<td>Delivery pressure, max.</td>
<td>12 bar</td>
<td>12 bar</td>
<td>12 bar</td>
</tr>
<tr>
<td>Power input</td>
<td>18.5 kW</td>
<td>30 kW</td>
<td>30 kW</td>
</tr>
<tr>
<td>Weight</td>
<td>0.91 t</td>
<td>1.4 t</td>
<td>1.78 t</td>
</tr>
</tbody>
</table>
**Backflow Pump**
The backflow of excess water-soil-mixture resulting from the jet grouting process can be removed by MAT’s robust hose pump.

<table>
<thead>
<tr>
<th></th>
<th>HP – 30</th>
<th>HP – 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery rate</td>
<td>30 m³/h</td>
<td>50 m³/h</td>
</tr>
<tr>
<td>Delivery pressure</td>
<td>8 bar</td>
<td>8 bar</td>
</tr>
<tr>
<td>Weight</td>
<td>1 t</td>
<td>1.8 t</td>
</tr>
<tr>
<td>Power input</td>
<td>18.5 kW</td>
<td>30 kW</td>
</tr>
<tr>
<td>Grain size, max.</td>
<td>24 mm</td>
<td>32 mm</td>
</tr>
</tbody>
</table>

**Desanding Plants**
The BE range of compact desanding plants facilitates the efficient separation of the backflow into its constituent parts, making partial recycling of cement suspension possible.

The BE 100 - 60 is small, very compact units for small volumes of suspension. Cost-effective operation on small construction sites due to minimal installation time and low electricity power supply.

The Bauer BD 90 decanter can be used for removing fine solids up to silt fraction from a suspension. If required, the residual suspension can be separated into solids and water by the addition of a flocking agent.

<table>
<thead>
<tr>
<th></th>
<th>BE 100 – 60</th>
<th>BD 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery rate</td>
<td>100 m³/h</td>
<td>90 m³/h</td>
</tr>
<tr>
<td>Power input</td>
<td>24 kW</td>
<td>75 kW</td>
</tr>
<tr>
<td>Cut point (BE) or Grain size, max. (BD)</td>
<td>0.06 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Weight</td>
<td>2.8 t</td>
<td>12.5 t</td>
</tr>
</tbody>
</table>

**Bauer Pumps**
The Bauer BP 50 to BP 250 centrifugal pumps are used to feed the various Bauer desilter units. They can also be used for numerous other pumping operations. The pumps which are mounted inside a protective base frame are driven by an electric motor and V-belt. The entire unit can be controlled via an electric cabinet.

<table>
<thead>
<tr>
<th></th>
<th>BP 85</th>
<th>BP 125</th>
<th>BP 250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery rate</td>
<td>85 m³/h</td>
<td>125 m³/h</td>
<td>250 m³/h</td>
</tr>
<tr>
<td>Power input</td>
<td>18 kW</td>
<td>22 kW</td>
<td>55 kW</td>
</tr>
<tr>
<td>Weight</td>
<td>0.75 t</td>
<td>0.78 t</td>
<td>1.39 t</td>
</tr>
</tbody>
</table>
Quality Assurance in general

Quality assurance of jet grouting elements is divided into the following headings:
- Accurate setting out of jet grouting position – tape measure, inclinometer and optical levelling instrument
- Jet grouting production parameters – pressure, speed of rotation and flow rates are monitored throughout the entire work process by the B-Tronic (Bauer) or the MB S-4 (Klemm) electronic control system
- Element diameter – by taking core samples from test columns, rod level or measuring umbrella
- Strength – by way of core or backflow samples
- Impermeability – by laboratory testing
- Movement control – particularly for underpinning operations by way of optical or laser levelling instruments

Control of Production Parameters

(on monitor of rig operator)

**Bauer B-Tronic**

The B-Tronic electronic monitoring and control system can be fitted to all jet grouting plant. This data acquisition system monitors and controls both production parameters and all general equipment functions.

The following production parameters can be continuously acquired, visualized and stored:
- Depth
- Volume
- In-line suspension pressure
- Speed of rotation
- Flow rate
- Suspension scale
- Inclination in 2 directions

**Klemm MB S-4**

The jet grouting monitoring system MB S-4 is a programmable state-of-the-art recording and control system for daily use on construction sites. Similar to the B-Tronic, the MB S-4 continuously obtains specified production parameters (depth, speed of rotation, pressures etc.).
Before commencing jet grouting operations, it is essential to construct test columns, if comparable suitability tests are not available.

The average diameter of each test column must be determined and compared with the diameter specified in the design. Based on the results of this comparison, the production parameters may have to be adjusted accordingly.

Documentation

All production parameters are recorded and stored inside the drilling rig throughout the jet grouting process. A print-out of these data can be produced for every jet grouting element as a quality control document. The presentation can optionally be either time- or depth-dependent.

Test Columns

Before commencing jet grouting operations, it is essential to construct test columns, if comparable suitability tests are not available.

The average diameter of each test column must be determined and compared with the diameter specified in the design. Based on the results of this comparison, the production parameters may have to be adjusted accordingly.
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