Sample Chapter

Special Deep Foundation - Compendium Methods and Equipment

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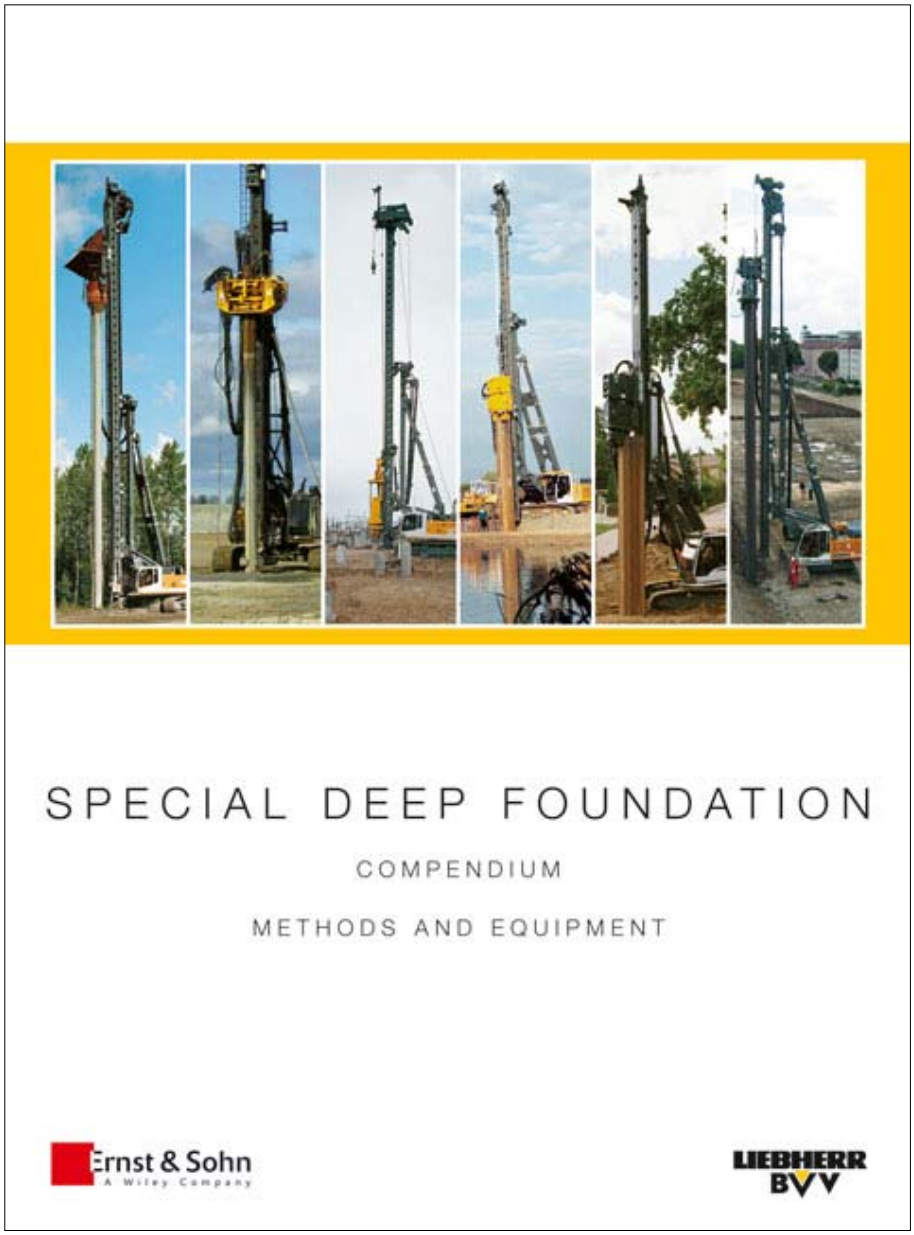

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Which method and which equipment

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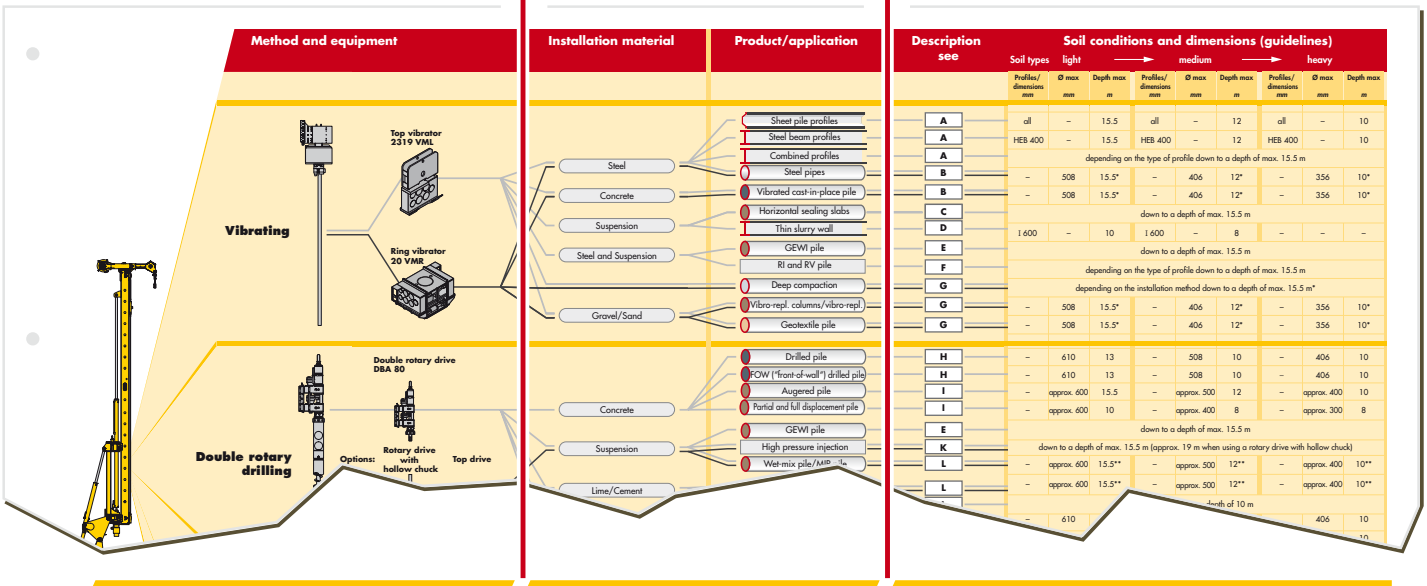
Foundation soil guidelines, dimensions, depths (recommended) 3

under which foundation soil conditions, to which dimensions and to what depth



Method and equipment 3

is which method using which equipment suitable (required)

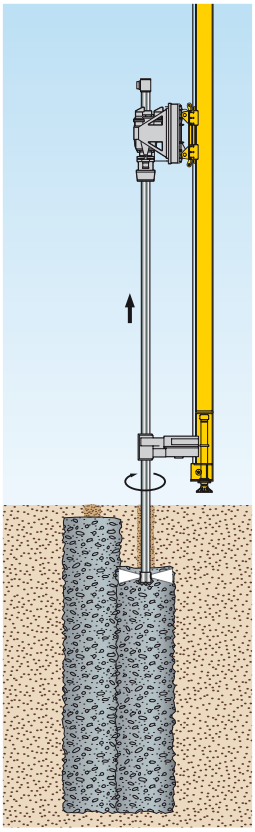
Installation material Product/ application 2

for what product using which installation material

Foundation soil guidelines, dimensions, depths (recommended) 1

For which dimensions, to what depth and under which foundation soil conditions,

High-pressure injection (jet grouting, high-pressure soil stabilisation/ cementation, jetting)



High-pressure injection (jet grouting, high-pressure soil stabilisation/cementation, jetting)

1 General

The term **"high-pressure injection"** or **"jet grouting"** is used in deep foundation industry and foundation engineering to describe a method in which the present soil is mixed with a binding agent (usually a cement suspension) under high pressure. In the process, the ground structure is completely destroyed. This results in a stabilised structure made up of ground material and binding agent. Depending on the soil composition, the mixing process takes place with low to almost complete displacement of the ground which was originally present.

This method is also referred to as **soil cementation** or **soil stabilisation** as part of the high-pressure injection method, and this term is more accurate, as this process, unlike the conventional injection methods in deep foundation engineering, does not consist of filling the present pores and cavities in the subsoil with an injected material. In Austria, this process is known under the abbreviation HDBV, which stands for the German name for **high-pressure soil cementation** ("Hochdruckbodenvermörtelung").

Internationally, the English terms **"jet grouting"** or **"jetting"** are the standard terms for high-pressure soil stabilisation.

There are also various company-specific names for this process. The most accurately descriptive of these names is **"Soilcrete"**. The application of this method is governed by DIN EN 12716 under the name **jet grouting**.

2 Production, applications

2.1 Production method

The following stages are involved in producing a stabilised ground structure using the jet grouting method:

- Using the rotary drilling method with water jetting, a special drilling rod is installed. This rod is guided by a crawler drilling rig with a drilling mast or by a crawler crane with a leader.
- The jetting process starts once the final depth has been reached. Under pumping pressures of up to 600 bar, a cement suspension is pumped in through the drilling rod. The cement suspension then emerges as a jet spray at the nozzles which are situated at the bottom end of the drilling rod.

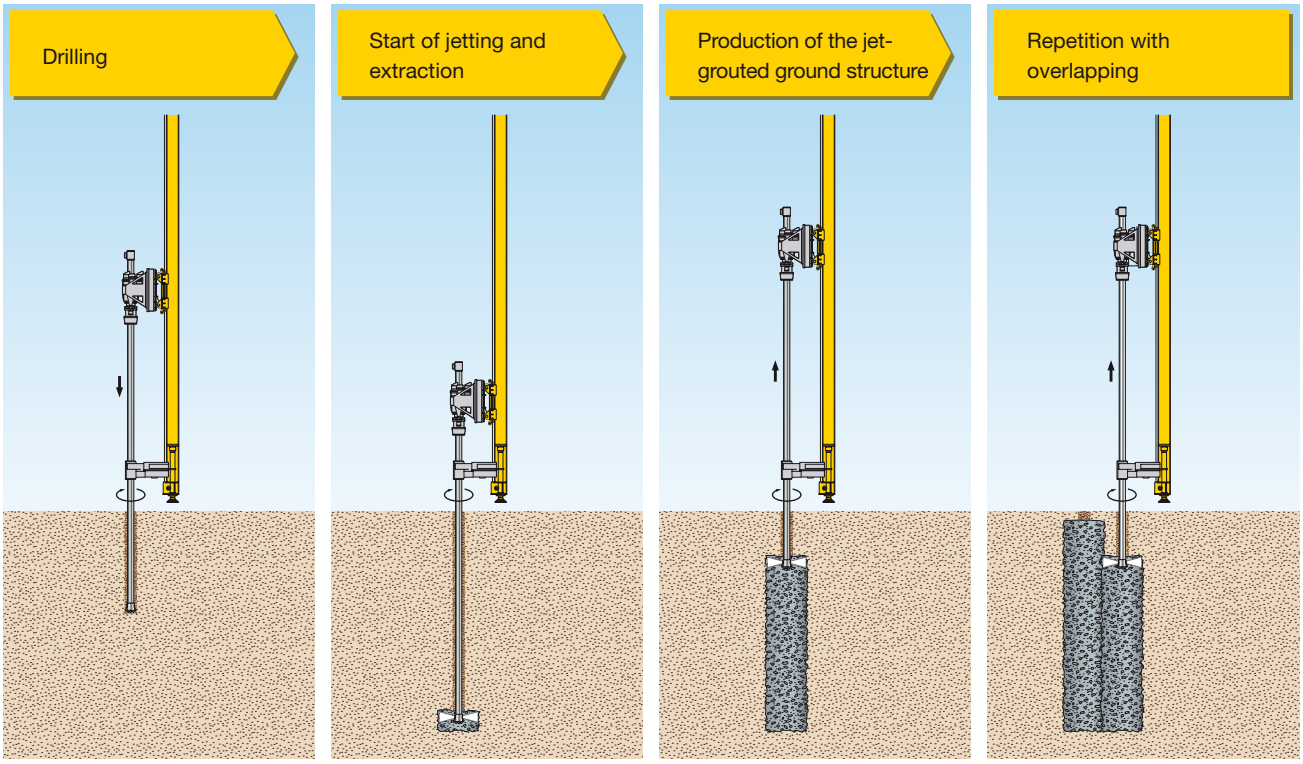
Nozzle holder

High-pressure injection (jet grouting, high-pressure soil stabilisation/cementation, jetting)

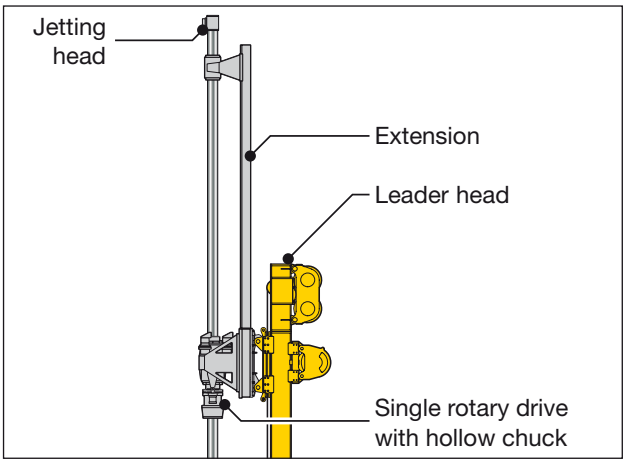
- The existing ground substance is mixed with the cement suspension while, at the same time, the drilling rod is extracted under rotation. In the process the ground structure is completely destroyed. Due to the rotation and upward movement of the drilling rod, a cylindrically cemented ground structure is produced in the effective range of the jet spray. The jetting process is performed up to the planned height. Together with the excess cement suspension, the dissolved ground material is fully or partially rinsed through the annular space of the borehole to the surface. There it must be collected and disposed of safely.

- Depending on the soil conditions present, the form and size of the cemented ground structure can be controlled by adjusting the pumping pressure, nozzle layout, rotational speed and extraction speed. The simultaneous rotation produces a reinforced ground column, while oscillating rotation of the drilling rod can be used to produce a reinforced structure in the shape of a fan or fin. The process can then be repeated, with the produced reinforced ground structures either positioned side-by-side or overlapping, in order to create any desired reinforcement structure in accordance with the requirements of any given application. The overlapping structures can be produced either "fresh on fresh" or "fresh on solid".

Production phases



Instead of the double rotary drive a single rotary drive with hollow chuck can be used. In addition, the rotary drive can be fitted with an extension guiding the top end of the drilling rod with the jetting head. Thus, drilling depths considerably greater than the leader length can be achieved.



2.2 Variations of the method

The following variations of the method are used:

- The **single method**:
  A high-pressure jet of cement suspension cuts the ground open and mixes it with the cement suspension. The jet of cement suspension serves two purposes here – to cut up and to cement the ground.

- The **double method with concrete suspension and air**:
  Using a double drilling rod, cement suspension and compressed air are injected separately via a special nozzle. The high-pressure jet of cement suspension which is used to cut and cement the ground is additionally sheathed in a ring of compressed air which is delivered through a ring nozzle. This increases the cutting force and therefore also the range of the jet of cement suspension. A secondary benefit is that the return part of the process, in which material is flushed back, is improved.

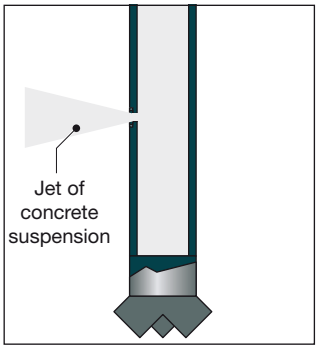
- The **double method with concrete suspension and water**:
  This method is a fundamentally different approach. The cutting work is performed with a high-pressure water jet instead of the cement suspension. Using a double drilling rod, two nozzles which are arranged apart from each other are used to deliver first water under high pressure and then subsequently a cement suspension under low pressure in the same step.

- The **triple method**:
  This method represents a progression of the previous method. Here, in order to increase its efficiency, the high-pressure water jet is sheathed in a ring of compressed air which is delivered via a ring nozzle. A triple drilling rod is used to do this.

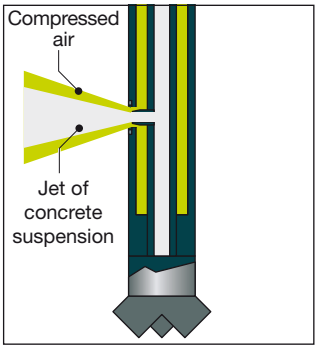
The choice of the most suitable method depends on the local geological conditions and the geometric objectives. Each of these methods has its own preferred fields of application, whereby an exact understanding of the construction objectives, the boundary conditions (ground) and the requirements (loads, required strength) is extremely important.

High-pressure injection (jet grouting, high-pressure soil stabilisation/cementation, jetting)

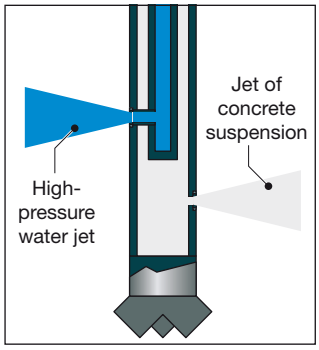
Single method



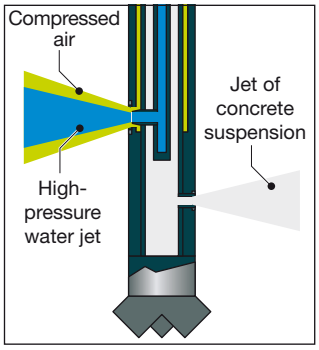
Double method with concrete suspension and air



Double method with concrete suspension and water



Triple method



2.3 Applications

Due to its manifold potential applications, this method has found widespread use since it was first introduced nearly thirty years ago.

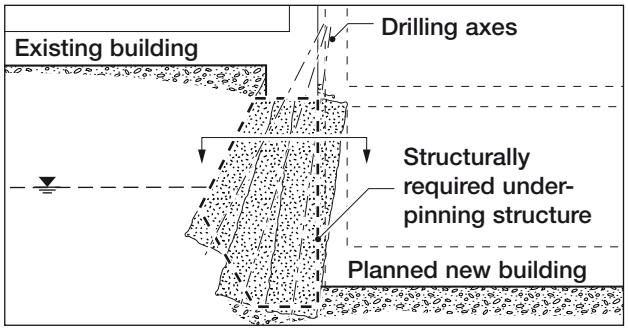
The process of soil cementation or soil stabilisation (high-pressure injection) has a broad range of potential applications. Thanks to the possibilities for combining different reinforced bodies in different ways, the method is used for the production of underpinnings, foundation pit walls, foundation reinforcements, new foundations, soil improvements, lowering of foundations, horizontal sealing slabs, vertical sealing walls, for closing of gaps and joints on lining walls (e.g. at pipe crossover points, between piles, on sheet-pile walls, as a means for closing gaps).

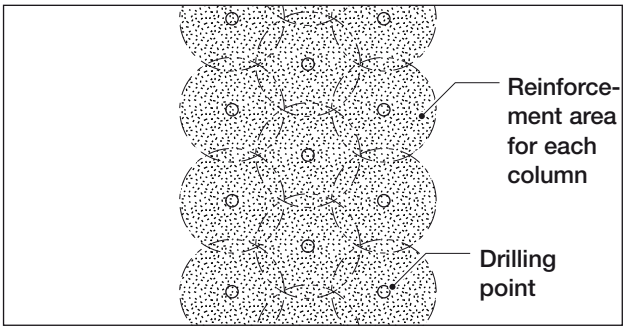
Multiple anchored underpinning wall

High-pressure injection (jet grouting, high-pressure soil stabilisation/cementation, jetting)

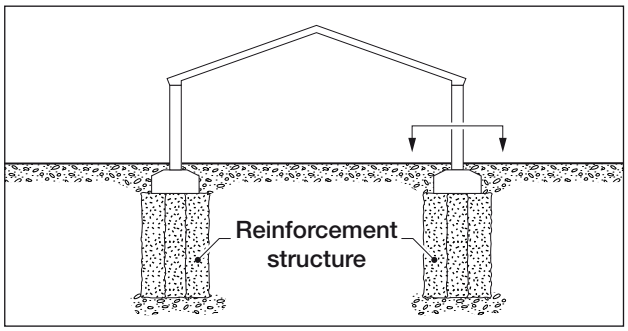
Examples (shown in cross-sectional and ground plan view)

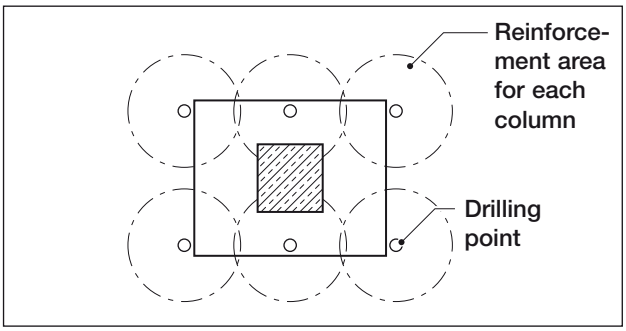
Underpinnings (reinforcement structure made of overlapping columns)



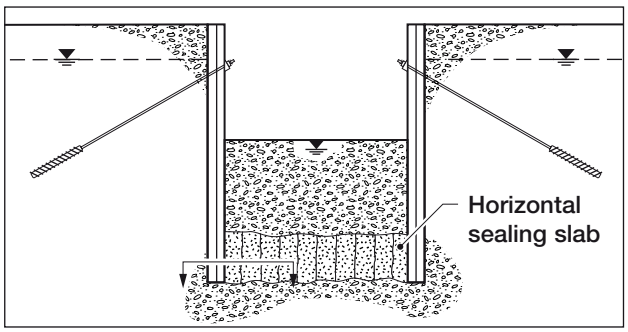


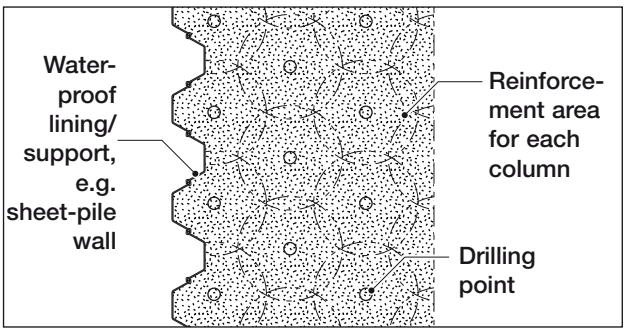
Foundation reinforcements, lowering of foundations



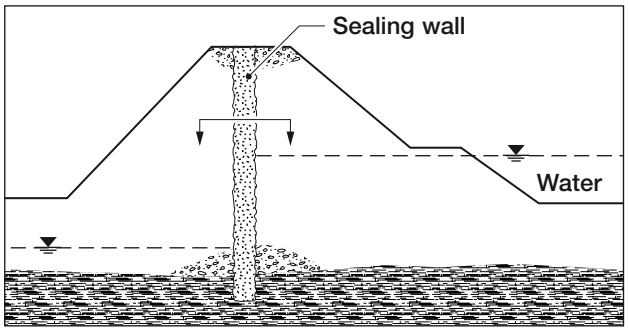


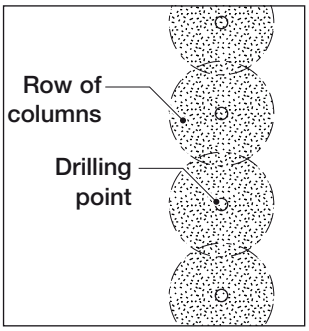
Horizontal sealing slab (ground segments made of individual elements)

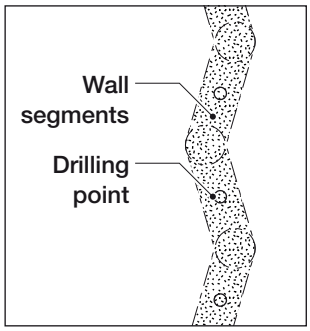




Sealing wall (row of columns or wall segments)

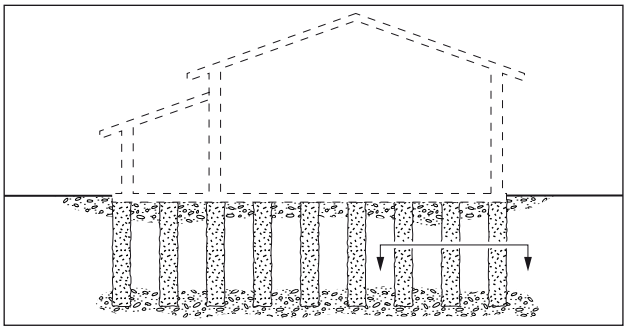


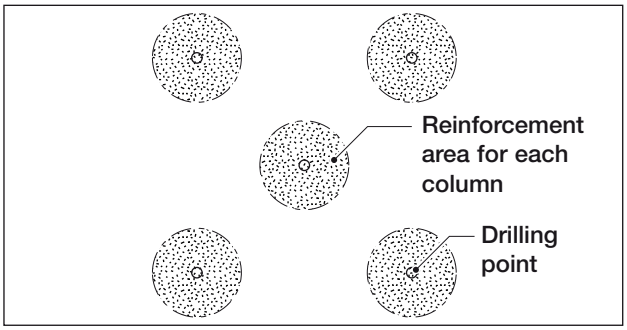




High-pressure injection (jet grouting, high-pressure soil stabilisation/cementation, jetting)

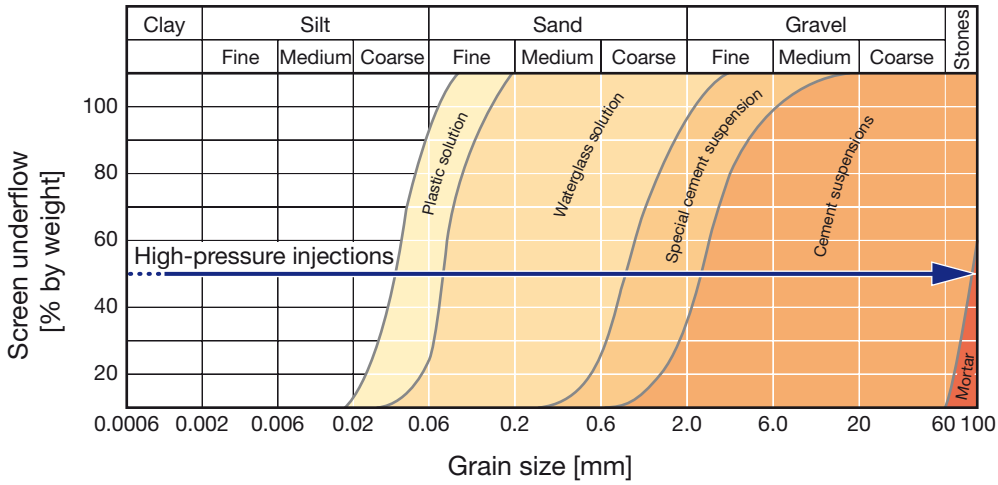
Soil improvements (dissolved columns)





The jet grouting method is suitable for use both in coarse and fine-granulated types of ground. It is also possible to cut open light sandstone, for example in order to seal fissures or gaps. The restrictions placed on the potential applications of the different injection media of conventional ground reinforcement methods (ground injections) due to the granulation size of the ground are no longer applicable.

A comparison of injection methods



Even in soil types with varying stratification it is possible to achieve a target diameter for the reinforced ground column.

LRB piling and drilling equipment from LIEBHERR is particularly well suited and cost-effective in the case of applications where it is required to cement soil to considerable drilling depths. Installation depths of up to 30 m can be easily achieved using the LRB 255 carrier machine. The LRB 125 carrier machine with an effective length of 15.00 m is particularly suitable for the production of a deep horizontal sealing slab.

3 Characteristics, special features

In comparison to other special deep foundation methods like drilled piles or impacted piles, the method of cementing the soil with the jet grouting method offers many technical advantages in terms of the process. The high degree of geometric flexibility allows the process to be optimally adapted to the given conditions, while the ability to produce variable structural forms allows the process to be matched to the particular construction task.

Damage to the existing structure of the building is prevented thanks to the low levels of vibration and movement generated by this production method.

The process enables effective installation of a reinforcement structure even underneath existing buildings.

The strength which can be achieved depends on the type and quantity of binding agent components and the ground components remaining in the reinforcement bodies. As an order of magnitude, the following mono-axial compression strengths can be assumed (measured on test bodies):

Soil type	Mono-axial compression strength (breaking strength)
In silt and clay	up to 5 N/mm^2
In sand	up to 10 N/mm^2
In gravel	up to 20 N/mm^2

The range of the jet spray and therefore the achievable diameter of the reinforced ground column depend primarily on the prevailing type of ground, particularly on its density and its consistency. Given a suitable choice of method (see 2.2) and production parameters, the column diameters generally range from 0.6 m to 2.0 m, with maximum diameters of 3.0 m.

The materials used in this method – cement and water, plus possibly bentonite – are all natural products and hence environmentally friendly. This allows them to meet the increased requirements in terms of protection of the ground and groundwater.

The sealing effect is also influenced by the type and quantity of materials installed and the remaining ground components.

4 Application limits

The jet grouting method can be used in nearly all types of ground. The limits arise almost exclusively from the size (length, width, height) of the equipment used.

When using a rotary drive with hollow chuck depths can be achieved which exceed the leader length.

When obstructions are encountered in the ground, it is generally necessary to abort the drilling process and reinstall the drilling rod in a slightly offset position. Due to the small diameter of the drilling pipe, this risk is only a problem in the case of large obstacles.

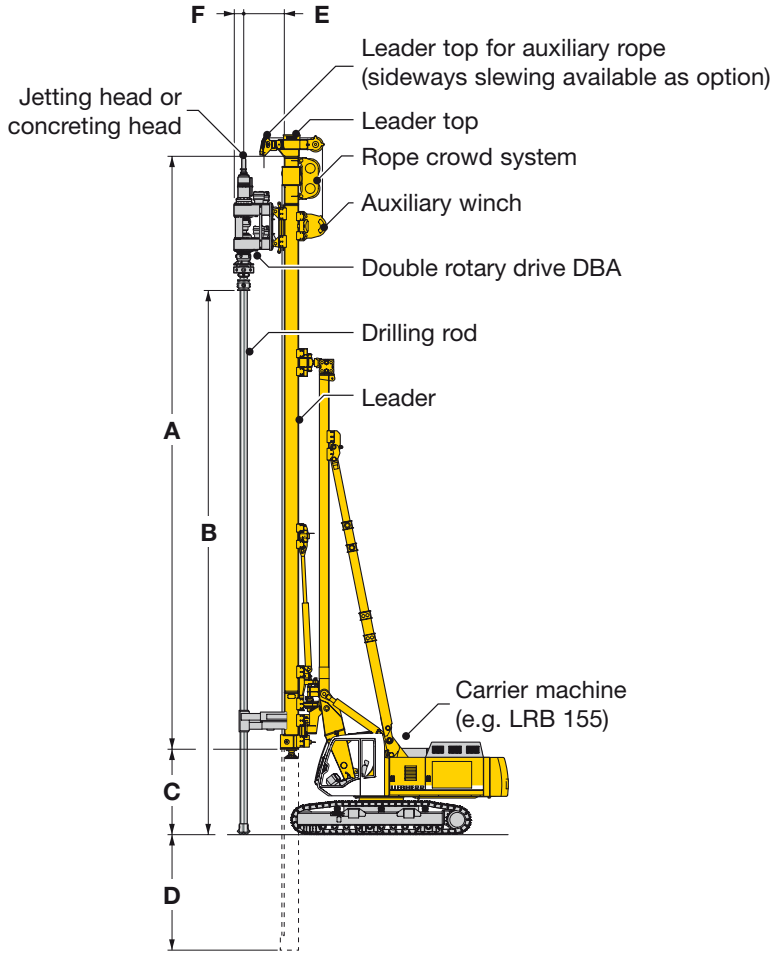
In ground with a high content of organic constituents, purely organic ground and extremely aggressive groundwater problems can arise in terms of the achievable quality of the cemented ground.

The excess cement suspension which emerges mixed with ground material from the mouth of the borehole can, depending on the soil type and method used, account for two to five times as much as the theoretically calculated volume of the reinforced ground structure which is produced. As the materials used are environmentally friendly, safe removal of this excess suspension is not a problem in terms of disposal, although it does often represent a logistical or cost problem.

5 Machine diagram with equipment

The drilling rod for the jet grouting method can be inserted using the carrier machines LRB 125, LRB 155 and LRB 255.

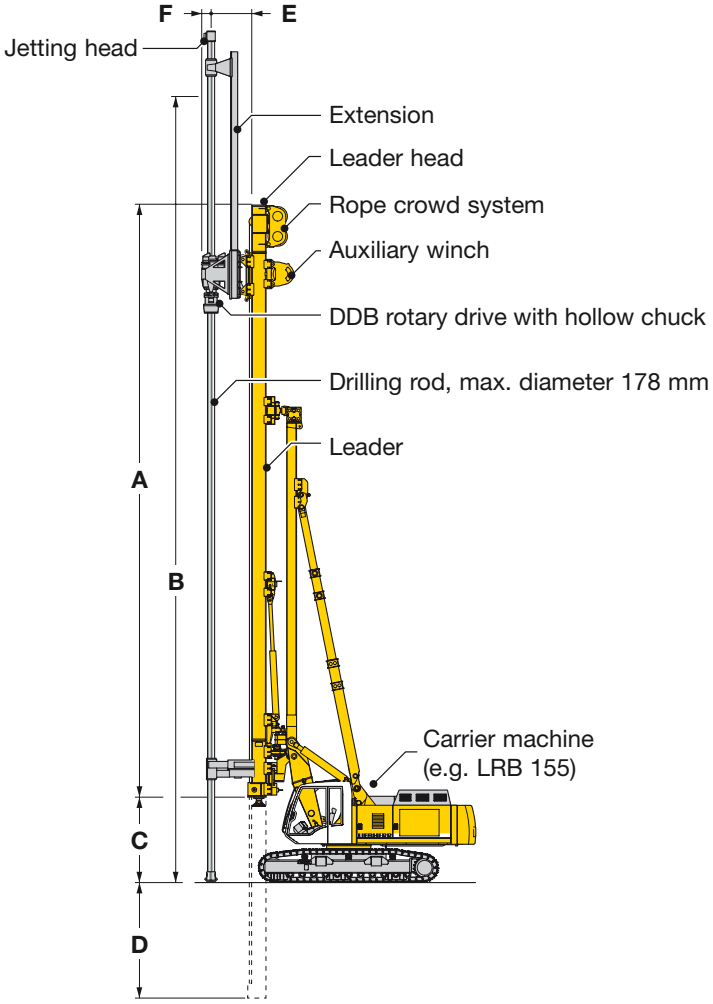
5.1 Double rotary equipment



Dimensions for applications with a double rotary drive (DBA)

Machine	Leader length (mm) **A** =	Max. effective length (mm) **B** = from the ground	Leader height adjustment (mm) **C** = above ground	**D** = below ground	Drilling axis spacing (mm) **E** = to front edge of leader	**F** = to front edge of DBA
LRB 125 with DBA 80	12800	15500	max. 5000	An adjustment below ground is possible but not standard.	790	225
LRB 155 with DBA 200	18200 (21200) [24200]	18000 (21000) [24000]	max. 3000		1250	300
LRB 255 with DBA 250	21200 (24200) [27200] {30200}	21000 (24000) [27000] {30000}	max. 3000		1250	300

5.2 Rotary equipment with hollow chuck



Dimensions for applications with a rotary drive with hollow chuck

Machine	Leader length (mm) **A** =	Max. effective length (mm) **B** = from the ground	Leader height adjustment (mm) **C** = above ground	**D** = below ground	Drilling axis spacing (mm) **E** = to front edge of leader	**F** = to front edge of DBA
LRB 125	12800	Variable, possible beyond leader top	max. 5000	An adjustment below ground is possible but not standard.	900	300
LRB 155	18200 (21200) [24200]		max. 3000		900	300
LRB 255	21200 (24200) [27200] {30200}		max. 3000		900	300

6 Quality assurance

Soil cementation with the jet grouting method is one of the most complex and demanding special deep foundation methods. A large amount of specialist knowledge and experience is required in order to practise this method.

Quality assurance cannot be limited to the performance of the building work alone, but must also include all activities ranging from the planning to the work preparations, the actual production stage to the checking of the finished reinforced ground structure.

Before the actual jet grouting is performed, detailed ground inspections are required, suitability tests need to be performed, materials need to be chosen and the variation of the method to be used needs to be decided upon. It may also be necessary to produce test columns. The production parameters are chosen according to empirical data.

The following production parameters need to be monitored and recorded on data recording systems throughout the entire production process:

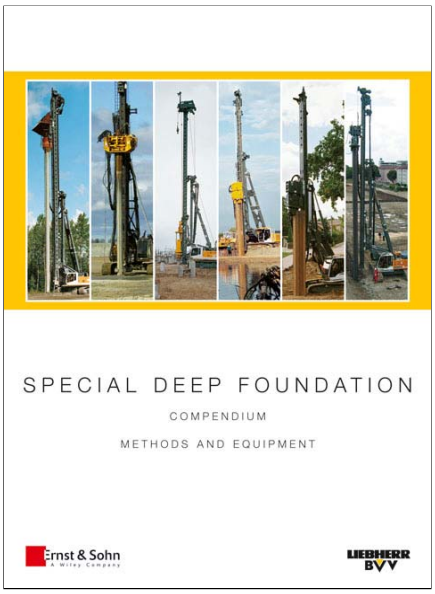
- For the drilling part: the drilling depth, the drilling speed, the jetting pressure and the amount of jetted material;
- For the jetting part: the rotational speed, the extraction speed, the current nozzle depth, the pressure of the concrete suspension (water pressure, air pressure) and the quantity of concrete suspension (water quantity)
- The composition of the fresh suspension and the returned suspension (material checks).

Furthermore, the compliance of the boreholes with the plans in terms of location and inclination need to be checked. In the case of deep drillings (e.g. for horizontal sealing slabs) and in the case of sealing wall columns or fins, the required drilling accuracy is checked by means of inclinometry measurements in the drilling rod.

During and after production, tests must be carried out to measure the movements of existing buildings (height measurement).

After the reinforced ground structure has been produced, it should be checked for compliance with the target dimensions (check bores) and in terms of its strength (test specimen).

Book Recommendation



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Special Deep Foundation

Compendium Methods and Equipment

The methods and equipment technology employed in the deep foundation industry have improved rapidly in recent years. The ingenuity of civil engineers, the results of new scientific research and the ongoing and new developments in machine technology have all led to the acceleration of this process. Applying technologies that have become very complex, and selecting the suitable machinery and equipment, demand ever more specialized knowledge and practical experience. It has become very difficult for users and manufacturers of special deep foundation machinery to maintain an overview of the level of technology in the sector. This compendium provides a comprehensive overview of the special deep foundation applications and processes. It is intended as an aid to planning and implementation, and aims to help practitioners, public authorities, engineering companies and students to broaden and complete their level of knowledge. It is targeted primarily at occupational engineers and applications in the field. The individual chapters discuss manufacturing techniques and potential applications, along with the associated machine components. The specifics of each method and machine technology are examined in detail. This special deep foundation compendium is the result of intensive collaboration between engineers, technicians, practitioners, machine manufacturers and users.
Approx 370 pages with approx 300 figures 300 in color. Hardcover. Published)

From the contents:

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Augered piles, Partial and full displacement augered piles
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