DESOI Ram Injection Lances

Injections into the subsoil

TECHNICAL OPINION

Description and methodology
Basics and recommendations for planning and execution

In cooperation with Geotechnik Dr. Nottrodt Weimar GmbH

1. Historical outline "More than 200 years of injection procedures"

The first mineral injection into subsoil took place over 200 years ago:

- In 1802, the Frenchman Charles Bérigny injected a suspension of water and cement in order to fill, solidify and seal scouring (washout) in the subsoil of a sluice. The **injection method** originates with him.
- In the US, mineral injection into the subsoil has been used since the 40s (compaction grouting), in Russia since the 50s ...

1802 First mineral injection into the soil „Hafenschleuse Dieppe", Engineer/Architect Charles Bérigny, France *[1]

1843 Development of Portland cement as an injection mortar by the Englishman Joseph Aspdin

1871 Royal Württemberg Building Inspector Rudolf Daser, Injection of cement paste to stop water entering tunnel * [2]

1882 Sealing of a dry dock in the port of Greenock, Scotland *[1]

1886 First patent application on soil stabilisation in Germany (Ing. Ezersky) *[5]

1906 Patent on soil stabilisation with injection of lime mortar (Ing. Mechner) *[5]

1910 Securing a bridge, the stability of which was endangered by cracks and cavities - Author: August Wolfsholz *[3]

1914 „Injection History" (supplemented by Dr. Kutzner) - In the first two decades of the 20th century: High-pressure pumps with steam / first forerunner of today's packers / pressure recorder diagram for assessing the injection process World War 1914: 53 m high Brüx dam near Teplitz (Czech Republic) sealed on gneiss at a depth of 30 m (cement injection)

1926 Use of silicates with two-component solutions in Germany (JOOSTEN method / Dr.-Ing. Hugo Joosten) / Reichspatent Sealing alkali inflows in potash shafts *[7]

1929 – 1932 Renovation works at the Johanneskirche in Ellrich / Nordhausen Cathedral (recipes by Otto Rüth) / mineral fillers *[4]

1931 „Vorläufige Anweisung für Abdichtungen von Ingenieurbauten (AIB)" (Guideline on the sealing of buildings) of the Deutsche Reichsbahn *[6]

1944 Stabilisation of the sand near the coast during the Allies' landing in Normandy *[5]

1946 Patent on acrylic resin preparation in the USA (Hauser, Danenberg) *[5]

1947 Bodenverfestigung mit Karbamidharzen (Lauton) *[5]

1951 Soil stabilisation with calcium acrylate (Lemb) *[5]

1953 Schachtbau Nordhausen - Former mining official a. D. Hans Jähde publishes the textbook „Injektionen zur Verbesserung von Baugrund und Bauwerk" (Injections for improving subsoil and building structure) (son-in-law of Dr. Hugo Joosten) *[8]

1967 France: Publication of the work of Kambefor „Principles and Methods of Soil Injection" *[5]

1988 Additional technical regulations and guidelines for filling cracks in concrete components, ZTV-RISS 88

1991 Textbook: „Injektionen im Baugrund" [Injections in subsoil], author Christian Kutzner, 1991 edition

2006 DIN V 18028 „Crack filling compounds according to DIN EN 1504-5: 2005-03 with special properties"

2009 Harmonised product standards of DIN EN 1504 (10 main standards)

2014 Sealing of buildings by injection: ABI leaflet, 3rd Edition, Publisher: Studiengemeinschaft für unterirdische Verkehrsanlagen e. V. (STUVA) *[9]

ZTV-ING: Additional contractual conditions and guidelines for engineering buildings Status 2014/12 - BAST

2018 Comprehensive compilation of the state of scientific knowledge on injections in the [Grundbautaschenbuch, 21 + 22]

2019 Definition of the contractual framework conditions for Pile driving, vibrating and pressing work and grouting work in DIN18304 and 18309 VOB/C

*[1-9, 12, 13, 21, 22] Page 21: Specialist literature and sources

2. Subsoil and Injection

Hard rock ↔ Loose rock

- General distinction in loose rock (soil) or solid rock (rock) with different transition areas (e.g. rock decay zone)
- The subsoil is a system made up of three substances:
  - Solids (mineral grains/rock)
  - Liquid (mostly water)
  - Gas (mostly air)
- Liquid and gas fill fissures (rock) or pore space (soil)
- Cavities = fissures or pores expanded or unnaturally enlarged due to processes (e.g. leaching out, rinsing ...)
- Formation or presence of cavities can usually only be seen due to effects on the earth's surface (sinkholes, depressions ...) or altered groundwater conditions (higher groundwater levels, greater groundwater flow etc.)

2.1 What do we mean by injection into the subsoil?

- Injecting a grout for the purpose of sealing or tightening in cavities, fissures, pores
- The permeability and firmness of the injected solid and loose rocks are crucial
- All injection grouts are fluid and penetrate into fissures and pores

However,

- Many processes in the subsoil remain unknown during injection
- The theoretical considerations are limited
- The "right solution" therefore is:
  If the purpose of the injection operation is achieved with acceptable technical
  and economic expenditure

2.2 Types of injection

Filling Injection / Pore Space Injection

- Injection for filling existing fissure and pore systems (pressure lower than so-called tear-open pressure)
- Sealing and strengthening of solid and loose rock (formation of coherent grout)
- Important: Continuous flow of the filler, pressure > 10 bar

Compaction grouting

- Injection with stiff injection material for pressing artificially created cavities (pressure lower than so-called tear-open pressure)
- Displacement and compaction of the soil without penetrating into the pore space

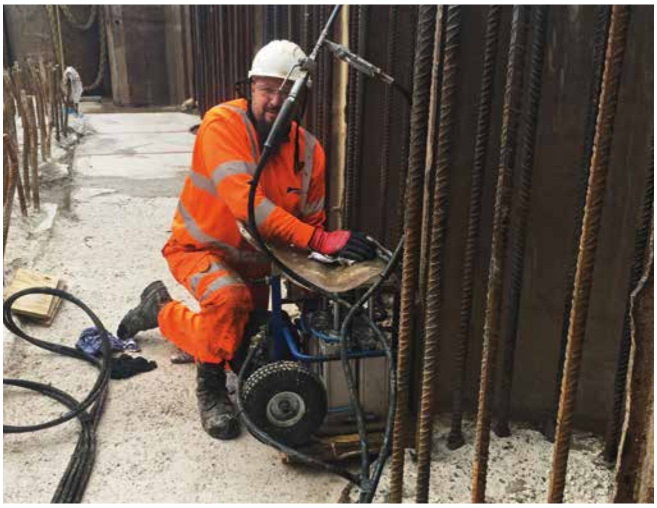
Soil Fracturing Injection

- Injection for targeted splitting of the soil (pressure greater than so-called tear-open pressure) with subsequent pressing
- Reinforcement and consolidation of the soil mass
- Compaction or consolidation of the soil between the cement-filled cracks

Special applications:

Sealing Injection

- Coupling of sheet pile wall to bored pile wall
- Sealing of individual sheet pile locks or drilling pile sections
- Coupling of sheet pile or bored pile wall to HDI undercuts



Sealing injection with ram injection lances between bored pile and sheet pile wall

Filling of dryness-related cavities and cracks

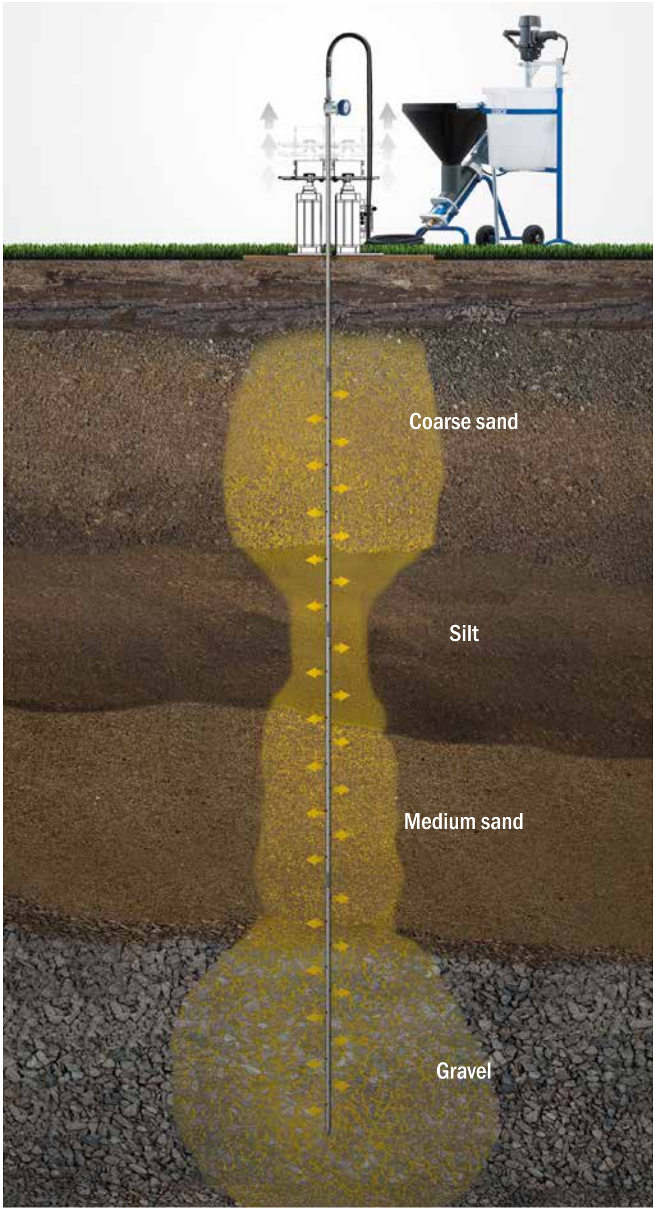
- Extrusionof the upper soil zone (2 m to 3 m below ground level) to avoid settling
- Normally non-injectable clays lose volume due to shrinkage due to drying out, resulting in (hair)cracks

2.3 Use of the process with ram injection lances

- Use in soils consisting of sands and silty fine sands
- Injection material: cement suspension, acrylic gel, polyurethane and polyurea silicate
- No contact with the cement bodies necessary for compaction injection
- Ram injection lance distance: 0.5 – 1 m
- Injection pressure depends on the subsoil and the injection material
- Injection pressure and injection rates are determined by the expert planner after preliminary tests and should only be as high as absolutely necessary

Note

- Too high pressure splits the environment (the granular structure of the soil)
- Material exits from the annular gap with excessive pressure



3. Theory of foundation injection

Procedure

- Grout penetrates from the drill holes into the fissure and pore system
- Cavities are filled with grout (depending on the type of injection – exception = compaction injection, here compaction by displacement of the soil, see Chap. 2.2)
- Complete filling possible if cavities are interconnected
- Injection pressure keeps the grout in flow → control over DESOI w.i.l.m.a. (see Chap. 5.5) or inspection
- "Range" = Distance between the injection source and the point toward which the grout is advancing.

Note

The injection pressure and the range must always be limited. Excessive pressure leads to elevations on the surface or shifts and the material escapes from the annular gap.

3.1 Injectability of the subsoil

- Injectability (with common cement-based injectables) depending on grain distribution

Initial assessment – injection criterion according to Mitchell

- Comparison of the grain size distributions subsoil / binder
  $N = D_{15} / d_{85}$ with D_{15} = mass percent at 15 % sieve passage of the subsoil
  d_{85} = Percentage by mass at 85 % sieve passage of the binder
- If $N < 11$ → subsoil not injectable
- If N = 11 ... 24 → possibilities to be checked by injection attempts
- If $N > 24$ → subsoil injectable

More detailed procedure – Pore narrowing procedure

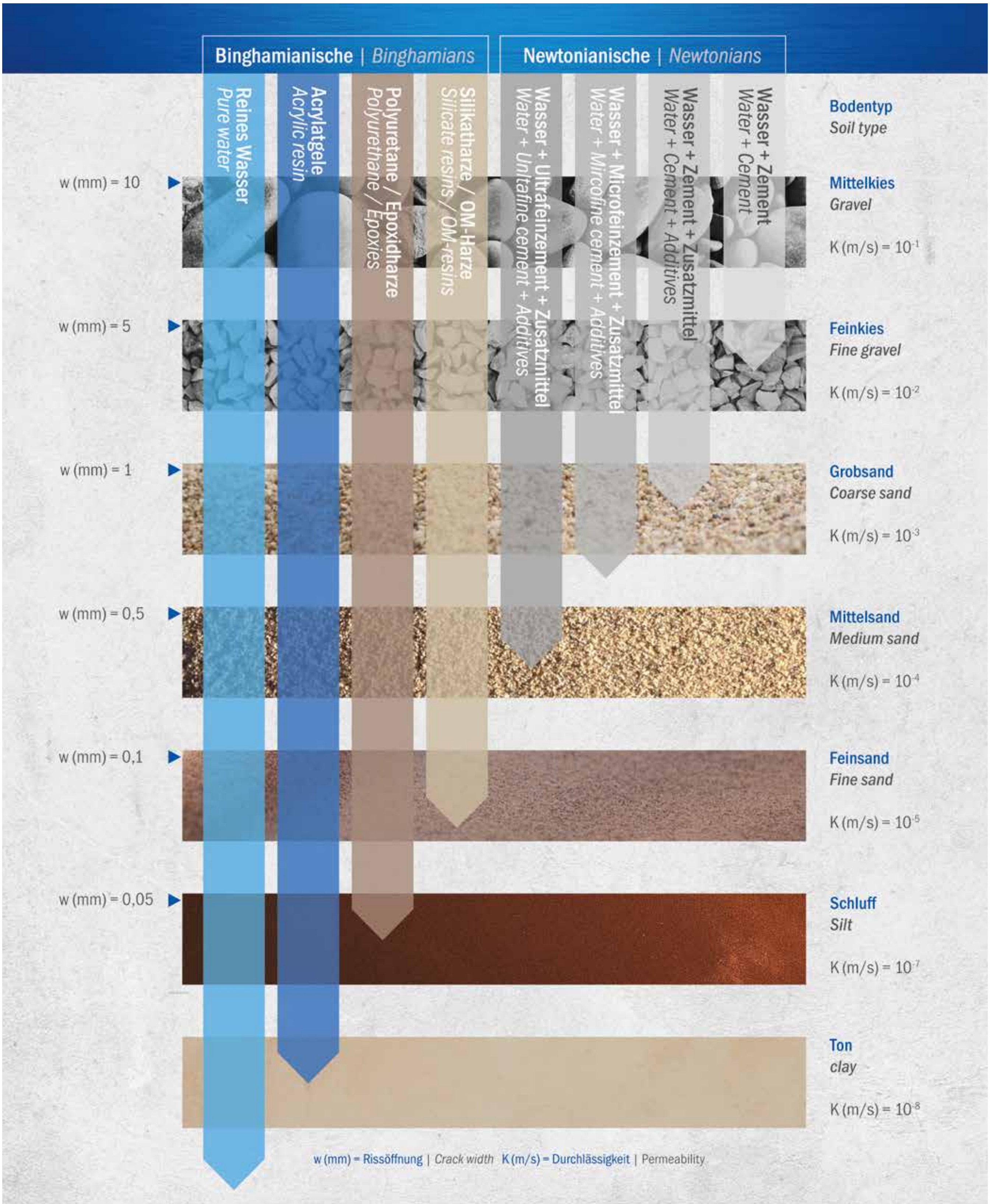
- Comparison of smallest pore of the subsoil and largest grain of the binder
  $p_0 / d_{100} \geq 2$ with p_0 = smallest pore of the subsoil
  d_{100} = Largest grain of the binder
- If the criterion is met, → subsoil injectable

Important

- Numerous other injection criteria available
- Reliance on parameters alone is uncertain
- Especially in the absence of practical experience with the existing subsoil, injection attempts are mandatory

For the use of polymer injection materials, see illustration on page 6 and notes in section 5.4.

Criterion for pre-selection of the injection material depending on the ground permeability



3.2 Flow and solidification behaviour of the injection material

Flow and solidification behaviour of all grouts are characterised by viscosity and flow limit, determined, for example, by Marsh funnel in the case of cementitious grouts. Orientation / guideline: 1 litre of cement suspension: approx. 25 – 30 seconds (water: 20 – 25 seconds) flow time

3.3 Injection pressure recommendations

Goal

- Merging or overlap of adjacent injection regions

Recommendations for injection pressure and injection speed

- Injection pressure is to be determined by trial injections, see also Chapter 3.4
- Specification of a maximum permissible pressure in consultation with geotechnical engineer
- Depends on the injection range
- Increase pressure slowly
- Maintain pressure for several minutes (absorption capacity of the fissures and pores)

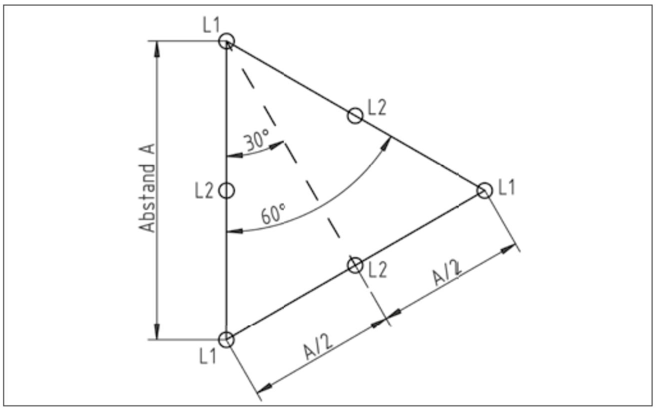
3.4 Trial injections

- Ideally carried out before the tender (trial injections are dependent on the building, but are always recommended)

Objective of the trial injection

- Exploration of technical conditions
- Defining piling procedures / piling engineering
- Determining and documenting the injectability of the foundation soil
- Recording the findings in the preliminary remarks of the service specifications / contract conditions

Arrangement of ram injection lances for a trial injection



*Top view based on Kutzner *[19]*

- If necessary, carrying out water pressure tests
- Pressing the ram injection lances
- Testing by means of core drilling and, if possible, with mining

Criterion for preselection of the injection material *(see page 6)*

Findings from the trial injection

- Basic suitability of the method
- Appropriate clearance for the ram injection lances
- Determining the pressing pressure and suitable pressing pressures
- Determination of the injection material absorption and possible relation to water absorption

3.5 Injection time

Is linked to

- Viscosity development of the grout
- Injection pressure
- Desired or achievable range
- Soil condition

The aforementioned parameters are very individual for each construction task, which means that
no empirical values for injection times can be specified.
The injection times are to be determined by trial tests.

4. Subsoil investigations

4.1 Need for subsoil investigations

The following general
parameters of a subsoil injection must be established in advance:

- Thickness of the subsoil layer(s) to be injected / improved
- Proportion of water or gas-filled pores and cavities
- Physical and chemical properties of the soil and groundwater (Important: occurrence of gypsum / anhydride)
- Groundwater flow direction and - speed
- Rammability of the subsoil: Is it "rammable"? Is it feasible to use ram injection lances?

4.2 Subsoil investigation in loose rock

- Selective explorations in the form of core drillings, drill probes or excavations
- Ideally carry out supplementary field trials, particularly pumping and/or injection trials (particularly the assessment of trial injections)
- Pressure or driving probes for determining bulk density and rammability
- Removal of undisturbed and disturbed soil samples, environment and water samples
- Investigations in the earthworks laboratory according to Section 4.3
- Environmental chemical investigation of the soil and water, depending on the intended grouting
- If necessary also using geophysical methods for the spatial cavity search
- As a result of the subsoil investigation, the injectability with solid suspensions is to be evaluated (e.g. injection criterion according to Mitchell or pore constriction procedure [21])

"Savings" in subsoil investigations have quite often led to

- Construction delays and complications
- Cost overruns
- Accidents
- Abandoning the construction work [20]

Note

Soil and rock classes according to VOB/C (2012 and earlier) are contractually ineffective and are still often used in the private construction sector for "reasons of simplification and custom".

4.3 Notes on homogeneous areas (from ATV DIN 18304 - 2019)

When using ram injection lances, the subsoil must be described in accordance with DIN 18304 from VOB/C 2019.

"Soil and rock are to be classified into homogeneous areas in accordance with their state before the piling, vibrating, or pressing work. The homogeneous region is a limited area consisting of single or multiple soil or rock layers having comparable properties for piling, vibrating or pressing work.

If environmental ingredients need to be taken into account, these must be considered in the classification into homogeneous areas."

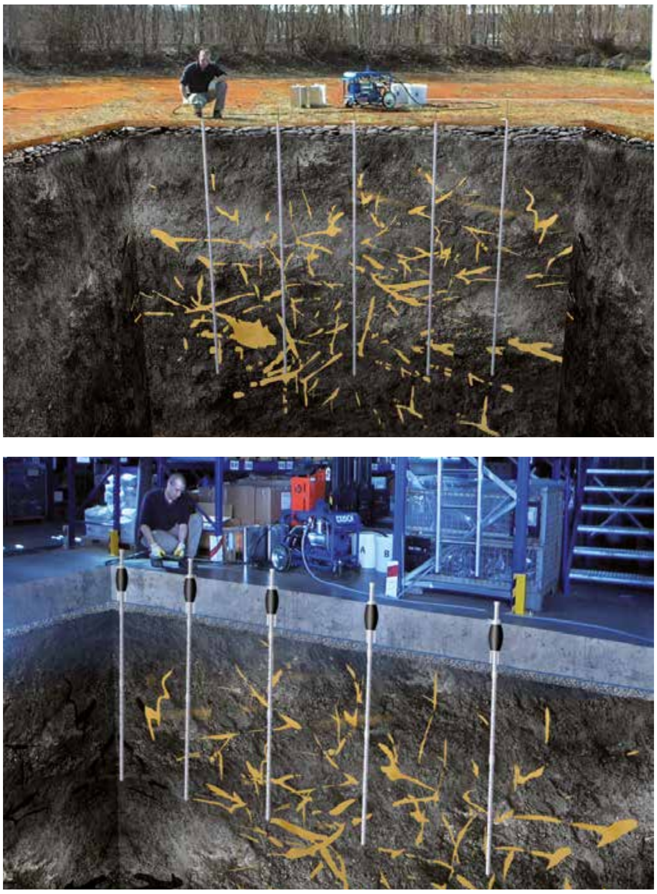
For a professional subsoil classification and thus tendering, at least the following parameters must be specified for this trade:

for soils

- Local name
- Particle-size distribution
- Mass fraction of stones and blocks
- Water content
- Plasticity number
- Consistency number
- State of compaction
- Soil group
- As far as possible, pore proportion, degree of saturation and horizontal and vertical permeability coefficient

For "rock" (if it can be rammed)

- Local name
- Naming of rock
- Compressive strength
- Of course, additional information on separation areas and fissures, so that the mountain permeability can be estimated



Spreading injection agent, working in open terrain and under existing floor slabs

5. Planning of low-pressure injections using RVL

Goal

- Planning for filling injection involves arranging the ram injection lances in such a way that the improved subsoil zones overlap as far as possible.
- An interconnected, closed injection object (soil grains and injection material) should be the result (DIN 4093)

- **Sealing loose rock**
    - Production of a grouted bottom
    - Creation of a vertical injection curtain
    - Special solutions, such as sealing a trench bottom before laying pipelines or sealing between components (transition from sheet pile wall to bored pile wall)
    - Stabilising or improving loose rock
    - Underpinning constructions or components
    - Foundation soil consolidation or improvement (increasing construction sustainability before the construction or in the context of renovation)
    - As a rule, no break-up injections (e.g. for settlement compensation) due to the high pressures required

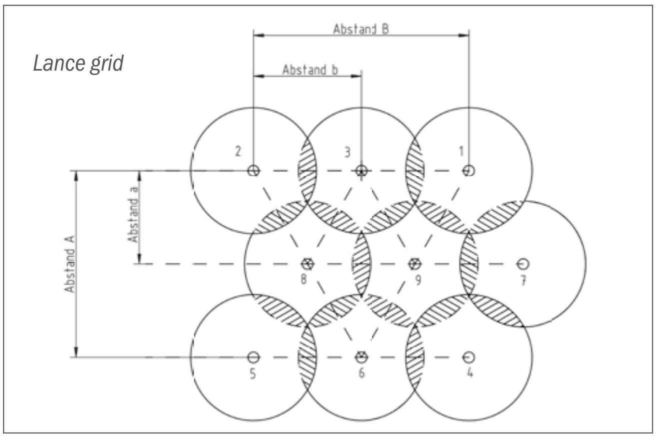
- **Stabilising or improving loose rock**
    - Underpinning constructions or components
    - Foundation soil consolidation or improvement (increasing construction sustainability before the construction or in the context of renovation)
    - This calls for break-up injections due to the high pressures required (to offset subsidence)

5.1 Recommended arrangement of ram injection lances

- Arrange them in such a way that an interconnected, closed injection body is formed
- The clearance for the ram injection lances depends on the range of the injection substance

Typical clearances

- 0.25 – 0.5 m within a row
- 0.25 – 0.5 m for deep injections (Curtain)
- 0.5 – 1.0 m for shallow injection holes
- Adjacent rows are to be staggered



Suggested arrangement of ram injection lances

5.2 Notes on preparing injection work

Essential points

- Carrying out and evaluating trial injections in advance
- Selecting injection agents in consultation with the planner and geotechnical engineer
- Determining the injection range
- Creating puncture plans for the RVL

The advantage of ram injection lances

Costs for piling are significantly lower than for the drilling.
Ramming lances can be reused (several times).

5.3 Notes on the procedure for using ram injection lances

As a rule: Ascending injection "from the bottom up"

- Advancing the lance with the lost tip to the target depth
- Placing the material hose
- Gradually pulling up and pressing in or injecting

Alternative: Multi-range injections

- Using lances with lateral openings
- No use in sandy soils, otherwise side holes will clog

Selecting the method based on geological conditions and structural requirements.

For the ram injection lances, injection and compression equipment and accessories available, see www.desoi.de

5.4 Instructions for injection materials

The goal of subsoil injections

- Sealing
- Stabilising / improving
- Void filling
- Raising (in the presence of optimal boundary conditions)

Grouts / fillers

- **Solutions**
  - Chemical compounds of liquid, solid and gaseous substances
  - Fully mixed, e. g., gels / liquid plastics / resins
- **Suspensions**
  - Mixtures made of liquid and solids
  - Diameter: 1 – 100 µm, e. g., suspensions of water and cement / aggregates, such as binders
- **Emulsions**
  - Mixtures, e. g., of bitumen and water / resin only for special applications, usually not suitable for RVL

Grout selection depends on the size and volume of the pores and fissures (topic: injectability / preliminary tests; see Chapters 3.1 and 3.3).

Note

Use finer grouts that fit into fissures and pores.

Injection mortar

- Cement suspension plus sand additive for large cavities or fissures.

Suspensions based on cement

Decisive for selection is:

- High grinding fineness
- Maximum grain size distribution 0.1 mm, adapted to our DESOI superfine cement VP1

Notes:

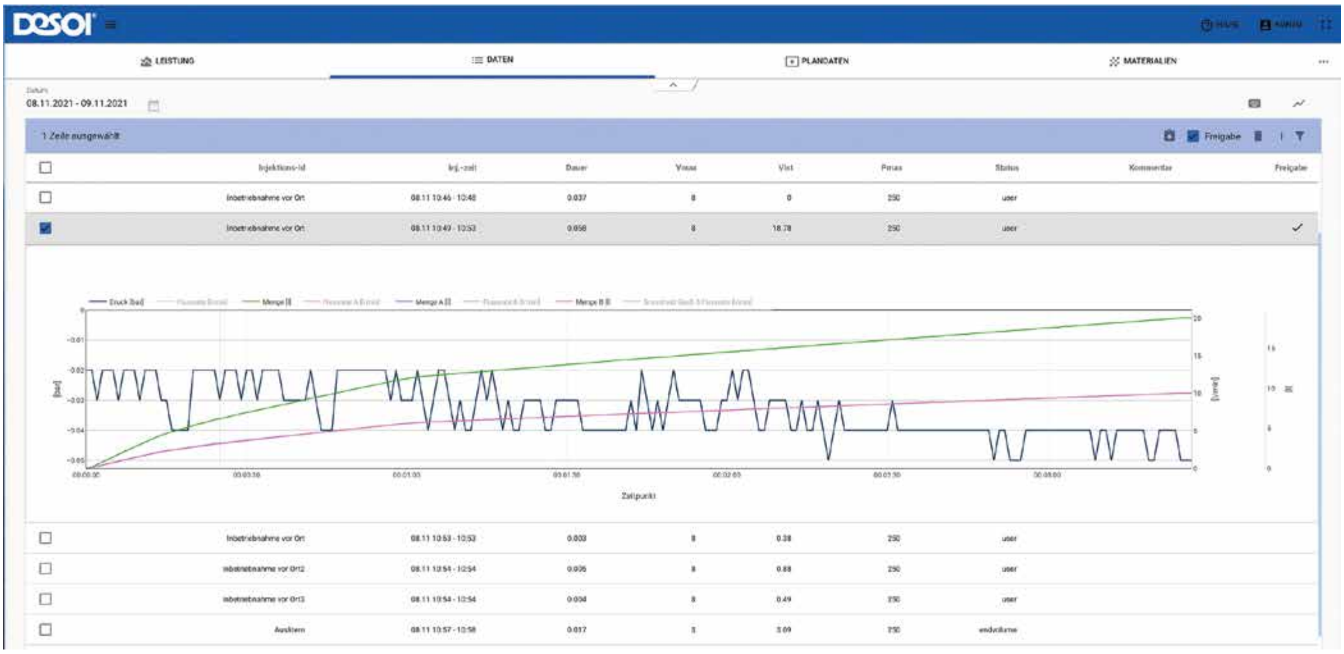
- Pore water must be squeezed out
- Flow properties are relevant
- Take into account the sediment behaviour of the suspension

(see also figure on page 7 "Permeability of soil types")

Silicate gels

- Raw material: water glass mixed with inorganic or organic hardener
- This gel is injected into soils similar to sandstone
- A certain tensile strength
- Low compressive strength
- "Ecological oils" for use in drinking water protection areas
- Long-term stability of the gels is generally considered to be ensured

5.5 Checking the production of the injection body with the DESOI w.i.l.m.a recording and documentation device



Example of a protocol printout from DESOI w.i.l.m.a.

- The injection body is always below the ground surface
- DESOI w.i.l.m.a. = wireless injection logging monitoring assistant
- Continuously documents injection data
- Permanent control of the injection via display possible

Advantages for designers and clients

DESOI w.i.l.m.a. devices guarantee that planned consumption rates and prescribed technical parameters are constantly monitored and maintained, e. g. mixing ratio and injection pressure. The machine technology designed for this purpose is reliable, robust, tried and tested, and enables high implementation safety.

On request the system can be customised for a project or application.

You can find the technical brochure at **www.desoi.co.uk** or request it from us!

Experience

- Constantly increasing pressure with an injection rate that is constantly falling at the same time indicates that there are no breakages in the injection site
- For pore injections into loose rock: Monitor the injection rate for each injection lance / bore hole section This is an indication that the grout has been produced as planned.
- Records also provide a calculation basis for the work being done
- Testing and documenting the injection body‘s environment

DESOI w.i.l.m.a. - Display

6. Environmental compatibility and sustainability

6.1 Current regulations on environmental compatibility in Germany (Extract)

The safety of the technology with regard to environmental compatibility has proven itself in practice over the past 3 decades and has been confirmed several times by studies

DIBt Unit II 6 – German Institute for Civil Engineering, Unit II 6 – Environmental Protection, Sustainability

Model administrative regulation for technical building regulations (MVV TB), Annex 10 (version 08/2020): Requirements for construction works with regard to the effects on soil and water (ABuG)

- Ingredients of a construction product must not exceed specified limit values for individual concentrations of carcinogenic, mutagenic and reprotoxic substances; for limit values, see Regulation (EC) No 1271/2008
- Recycled or industrially produced aggregates must not be used in grouts made from binder suspensions or injection mortars that are in direct contact with groundwater
- Grouts with the component or the reaction product acrylamide must not be used
- When using silicon-rich fly ash in grouts, upper limits must be observed; see MVV TB Table A-4

Water Resources Act (WHG of 31/07/2009)

§ 9 (1) 4. Uses

Introducing/discharging substances into bodies of water requires an official permit or licence.

§ 49 Soil profile pits

The competent water authority or environment agency must be notified of planned foundation soil injection works a month before they begin.

§ 62 Requirements for the handling of substances hazardous to water (principle of precaution)

Equipment must be acquired, maintained and operated in a way that it does not cause any adverse changes to the water that require action

§ 89 Liability for changes in water quality

Anyone who adversely changes the water quality is obliged to compensate for any damage.

DVGW - German Gas and Water Engineers' Association

Worksheet W 347 (version 05/2006):

Hygienic requirements for cement-bound materials in the drinking water sector – testing and evaluation

- When installing cement-bound materials with drinking water contact, these and their source materials (e. g., organic and inorganic additives, additives, aggregates, pigments, etc.) must be tested for suitability for use in the drinking water sector

Tests per requirement

- Recipe test: comparison of individual components with the positive list of the DVGW worksheet
- Migration test: test for the release of certain substances from the material (e. g., TOC, arsenic, lead, cadmium, chromium, lithium, nickel)
- Microbiological test: only if organic components are present; testing according to DVWG W 270 (A) – formation of a biofilm after water storage

Law on Life-Cycle Management,

§ 45 (2) sentence 1

The federal authorities [...] have [...] in the design of work processes, in the procurement or use of materials and consumer goods, in construction projects [...] given preference to products that have been produced in resource-conserving, energy-saving, water-saving, low-pollutant or low-waste production processes.
→ "Obligation to give preference"

6.2 Sustainability

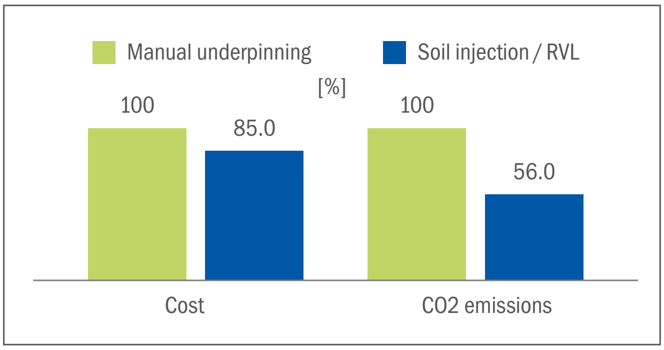
DGNB – Deutsche Gesellschaft für Nachhaltiges Bauen – German Sustainable Building Council

"Sustainable building is about getting the most out of the existing possibilities in terms of holistic quality."

The 3 pillars of sustainability → Ecology, economy, social issues

Pillars of sustainability			
	Ecology	Economics	Social
Objectives (among others)	- Minimisation of energy and resource consumption - Low impact on the natural environment	- Optimisation of total costs	- Consideration of socio-cultural effects, e.g., aspects of monument preservation
RVL contribution	- Resource-saving technology - Use of equipment with low energy consumption, in part Electric drive technology	- Construction site equipment manageable (low transport costs, no silos and concrete pumps required) - Use of equipment with low energy consumption	- When used for subsequent foundation reinforcement / underpinning, existing foundations are hardly weakened (existing substance is essentially retained) - Protection of the subsoil / existing structures through the use of light equipment - Healthy work process (gentle on the musculoskeletal system)
Comparison of CO2 emissions and costs based on the New Palace reference project – manual underpinning / Ram Injection Lances (see bar chart)			

Comparison of costs and CO2 emissions



7. Conditions for the object description / tender

- The prospective construction must be described in a way that the bidder has a clear idea of the expected services and supplies
- What technical methods are to be used?
- Description of the individual construction services for a reliable calculation – including partial services
- Include all construction services, even those that are not sufficiently known for the tender
- Notes on trial injections (location, grouting materials, timing, minimum requirements to be achieved, evaluation report...)

7.1 Tendering injection work

- Technical construction description (if possible with injection plans)
- General and special contractual conditions
- In the case of statically effective injections, also a structural design / soil statics
- Technical specifications

VOB standards that must be observed (amended version 2019) for injections with ram injection lances

- ATV DIN 18304: Piling, vibration, and pressing work
- ATV DIN 18309: Grouting

7.2 Recommendations for service description

- Work to be carried out must be described in full
- Include results from completed injection projects in the environment
- Evaluate hydrogeological and geotechnical reports
- Results of field and laboratory tests and conclusions
- Climate, rainfall, temperatures in the construction area/during the construction time
- Identify and describe access routes and their status, as well as working widths and heights in the building if necessary

- Identify construction site equipment and storage areas, water and energy supply of the construction site
- Disposal conditions for all substances being used
- Groundwater conditions/measured water level and any necessary measures for groundwater protection
- Vegetation and provisions for its protection
  - regional characteristics, location and nature of the building
  - possibly keeping records and vibration measurements including their documentation
  - Have notes and agreements with the client documented and confirmed
  - Removal of the ram injection lances (drawing device – pneumatic, hydraulic or manual)

Urgent recommendation:

- Before the start of planning, inspect the site together with the client
- Before the start of construction, carry out a site briefing with the construction company

Suggested priorities for the service description with RVL

1. **Site equipment and evacuation**

   - Preparation of all drilling / injection sites and access routes – office containers, accommodation, toilets, energy supply, etc.
   - If necessary, double construction site equipment also for trial injections

   Price usually as a flat rate (for the planned construction period)

2. **Compliance with the official requirements, including environmental protection /WMA , etc.**

   - Obtaining management information
   - Coordination of the work and substances to be used with the environmental authorities, including processing of the requirements

   Price as a flat rate

3. **Provision of all equipment, machinery, devices, material**

   Ram injection lances

   Price per calendar week provision

4. **Trial injections before the start of construction, preferably as an early batch**

   with description of the lance types, grouting materials, location, length and inclination of the test lances, intervals for grouting pressures; definition of the eventual test holes by individual columns and mines for head exposure, preparation of test report with recommendations for the main injections, price per piece or according to effort

5. **Plan, prepare and carry out measurements during construction**

   Setting up fixed reference points and measuring points on statically relevant components of the structure,
   regular measurements and controls during injection, if necessary with the involvement of a
   surveying office, definition of warning and intervention values
   (Preservation of evidence, ammunition release and vibration measurements are the client's tasks!)

   Price according to effort per calendar week

6. **If necessary:**

   Opening of components such as floor slabs or foundations made of concrete, reinforced concrete, natural stone... by means of core holes or the like; adaptation of the drilling diameter to the diameter of the RVL,
   depth ... cm Price per piece or according to running metre.

7. **Introducing the ram injection lances**

   (length, inclination, diameter, outlet openings, type of tip) incl. later drawing process as well as replacement of no longer usable RVL
   Price per piece or according to running metre.

8. **Delivery and storage of the grouting material**

   (Proof of delivery notes)

   Price per kg

9. **Preparing and injecting**

   Necessary addition of water must be taken into account

   Price per kg (alternatively via injection times)

10. **Waiting times due to**

    - Adaptation of ram injection lances to possible obstacles
    - Due to reaction/setting behaviour of the injection substance price per hour injection column

11. **Hourly wage work**

    For specially arranged additional services

    Price per hour injection column

12. **On the client's request:**

    Final documentation for quality control as well as for the detection of the quantities injected, injection pressures, injection times, mixing ratio, e. g. evaluation of the protocols of DESOI w.i.l.m.a., documentation of the elevation measurements

    Price per piece

7.3. Recommendation for monitoring during construction

- In urban areas, ensure the neighbouring buildings are audited in advance (preferably by a publicly appointed and certified expert)
- Plan and implement a monitoring programme during the injection work; install measuring bolts selectively on vulnerable parts of the structure, for example, and possibly measure them during trial injections
- Depending on the type of building, noise and vibration measurements may also be required by the authorities at the start of construction

8. Reference objects

8.1 Drinking water tank

"Schwarze Pumpe Industrial Estate" – injection with ram injection lances

Drinking water tanks 1 and 2 on the area of the "Schwarze Pumpe Industrial Estate" each have a storage space of 2800 cubic metres.
They were built in the period from 1989 to 1991 as standardised projects ("PROWA" series).

Building construction

The overhead tanks are free-standing round containers with an outer diameter of 25.88 metres and a ceiling height of 6.00 metres. They were manufactured in a mixed structure, usually as a reinforced concrete structure. Monolithic construction: ring container foundations, lower foundations, container floor with a berm formation in the wall area. Erection of buildings: container wall, supports and upper sealing construction. The container floors were constructed from in-situ concrete (B 20) with a soft steel reinforcement. The entire floor plate area was thus formed with both radial and diagonal joints (transverse joints). The container bottom is ca. 1.50 metres above ground level. This means that the plate surface was refilled during the construction phase.

Structural damages

After water leaked from the drinking water tank 1 to the outer area, an internal investigation was carried out following the emptying of the tank with the following results: permeable joints were found in parts of the container edge areas between the berm and the foundation ring. A ground subsidence was found in the berm plate area next to an obviously crumbling transverse joint, due to erosion/flushing in the floor area below the tank bottom as a result of permeable joints.

Restructuring planning

The required restructuring planning was implemented by Kiwa MPA Bautest GmbH, Lausitz Service Centre. Prior to the renovation of the crumbling joint, the lowered underground in the berm plate area needed to be solidified in order to avoid further sinking of the ground in this area.
The subsoil is backfill or refill material (certainly gravel mixture).

The following steps were planned for this process:

1. Drilling of injection ports for the intended ram injection lance at intervals of about 50 cm x 50 cm vertically through the concrete floor slab.
2. Following the vacuuming of debris and dust from the injection channels, the injection lances are driven in.
3. Product: ram injection lances by DESOI GmbH, type: BP complete, diameter 25 mm x 1200 mm.
4. Sealing and solidifying ground injection by injecting a low viscosity polyurethane-based duromer resin manufactured by MC-Bauchemie with a 2-component injection pump over the previously introduced ram injection lance.
5. After the injection material has hardened, the steel packer is removed and the concrete surface is repaired.

Construction

The construction work was carried out by the company M.B.S. MAERTIN, Bausanierung Spremberg GmbH. The construction work was carried out professionally in accordance with the restructuring plan incl. specifications. In addition to the ground stabilization, this naturally included the general restructuring/ repair of all crumbling joint areas. The implementation of the construction was thereby monitored on site by the planner and the client.

Conclusion

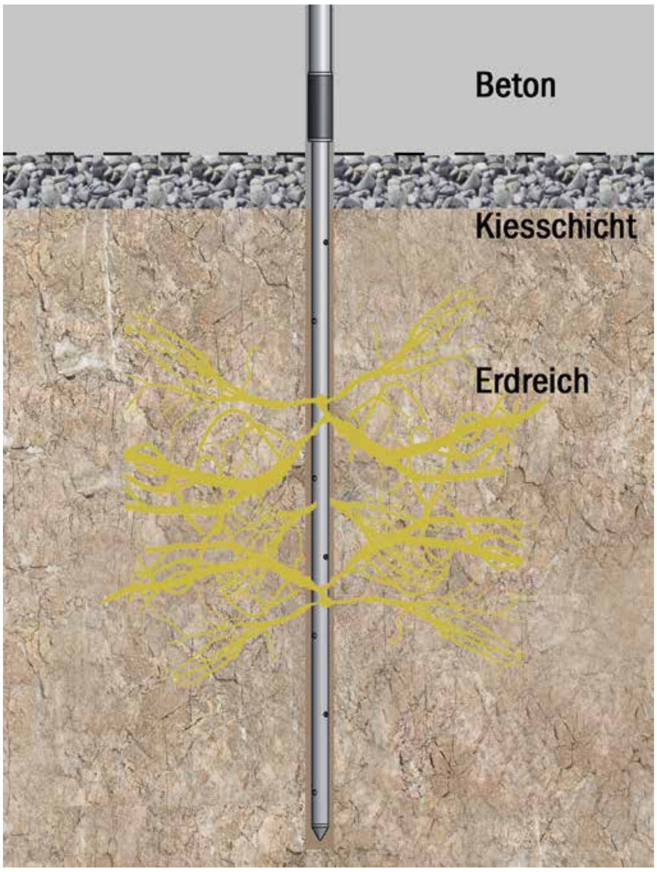
Following the acceptance of the construction work with a positive leakage test after filling the tank, the restructuring measures, incl. ground stabilisation by means of the ram injection lance, were completed successfully.

Reference object

Drinking water tank "Industriepark Schwarze Pumpe" – injection with ram injection lances

Drinking water tank "Schwarze Pumpe"

Set ram injection lances – drinking water tank "Schwarze Pumpe"



Use of ram injection lances (Photo: Desoi)

8.2 Gas pipeline construction

Nature reserve – backfill sealed with injections via ram injection lances

Creating a micro tunnel for the gas pipeline

During construction of the gas pipeline, a microtunnel had to be created about 20 m under a river near the nature reserve. The geological structure included on the one hand a sandy gravel floor and on the other hand a layer of solidified peat close to the surface. Despite the dry ground, water was found under the riverbed. A tunnel boring machine (TBM) with an external diameter of 3 m was selected which was suitable for cohesive ground.

Specifics during transit

After the first half of the tunneling route posed no problems, a boulder was identified in front of the machine. A plan was made to destroy the stone by driving through it. Since the cutting tool of the machine, however, was designed for soft floors, this could not be achieved despite several attempts. The strong forces placed on the stone during the attempts to destroy it resulted in cavities appearing around the boulder and the machine. This had to be compensated for by a larger amount of supporting fluid and simultaneously increased pressure. The ground coverage over the microtunnelling machine could not, however, withstand the pressure of more than 2.5 bar of supporting pressure, therefore the stone had to be blown up. All attempts to fill the resulting crater by using liquid soil and then solidify it thus failed: the support pressure could not be started up again. The filled funnel was neither pressure-tight nor could it hold the supporting liquid. It had to be sealed and solidified using an additional measure on the ground in front of the tunnel face. A particular challenge in finding a solution was the lack of logistics and the requirement not to use large equipment or environmentally harmful injection agents. The tight time frame for the completion of the work also had to be taken into account.

Sealing via ram injection lances

TPH, a company involved in the project, suggested stabilising and sealing the backfill soil by injection. In addition, an injection by the tunneling machine should fill in and compress the blasted boulder which was checked previously. As no machine movement was allowed in this nature reserve, conventional methods such as cement injection or freezing were out of the question. Injection by means of a Desoi ram injection lance was therefore selected. The ram injection lances are of modular design and can be adapted with different technical properties according to on-site conditions. In this case, at up to 17.5 m, they were driven into the ground with a light pile hammer and could thus be placed in very close proximity to the machine.

Injection work procedure

The injection device DESOI AirPower M25-3C presses acrylate gel in over the lances and the soil is compacted. All of the equipment could be transported without machinery and the acrylate gel was approved for use by the local water authority on the basis of the DIBt certification. A total of 56 ram injection lances were used and ca. 2,400 l gel was introduced. The basically dense backfill soil was consistently permeated and solidified only by the use of very low viscose acrylate gels, where a combination of solidification and sealing had to be achieved. The ram injection lances enabled the required targeted injection. The cavities which had been created in the ground by the boulder blast were filled with a silicate foam by a further injection device, DESOI AirPower L36-2C, out of the tunnelling machine. The benefit of silicate foam is that it provides a very good adhesion to siliceous substrates due to the high water glass content, but it also passes through easily from the machine.

Conclusion

Within 3 days, the problem was solved. The pressure of the support fluid could be increased once again and the machine could continue its work.

Reference object

Gas pipeline construction in the nature reserve – backfill sealed with injections via ram injection lances

Nature reserve

Installation of ram injection lances

Introduction of the ram injection lances (photos: Desoi)

8.3 New Palace, Potsdam

Construction of an excavation pit shoring by means of grouting under existing foundations

Redesign of the visitor reception at the New Palace in Potsdam

As part of the redesign of the visitor reception area in the New Palace in Potsdam, the floor in a section of the basement is to be lowered and a lift installed in the same area. The floors should be lowered by approx. 0.90 m to allow for a greater room height. The underpass of the lift is approx. 1.55 m lower than the previous floor level. The excavation pits required for the construction of the underpass and the lowering of the floors are therefore approx. 1.45 m to 2.20 m below the previous level and thus partly below the groundwater level.

The excavation levels required for this work are lower than the foundations of the neighbouring foundations, the lower edge of which is generally 1.40 m below the current upper edge of the floor. As a result, it was necessary to shore up the excavation pit to secure the groundwater level.

Construction pit installation by means of injections via ram injection lances

Due to the cramped conditions with room heights of between approx. 1.50 and 1.80 metres and the listed context of the New Palace, conventional construction methods such as the jet grouting method or the use of nailed shotcrete shells were out of the question. These technologies either introduce excessive vibrations and movements (e.g., due to process-related subsidence) into the structure or require the use of large equipment.

In order to be able to select a suitable method for excavation support, the geometric boundary conditions (existing working space), the building structure to be protected and the subsoil and groundwater conditions had to be determined and taken into account. In the present project, this consists of valley sands in the relevant foundation area. Groundwater is approx. 2.20 m below the existing floor.

As a result of the requirements to be complied with in the construction process, the geotechnical expert and later specialist planner (GNW) recommended the consolidation of the soil below the foundation horizon of the foundations by means of a low-pressure injection, which would then act as excavation support. The valley sands in the injection area have sufficient pore space and are therefore suitable for this method. The requirements for injections in drinking water protection areas can be complied with.

Injection work planning and trial injections

The planning of the injection work is divided into various work steps that build on each other. In the first step, the required injection body under the foundation must be dimensioned and statically verified. An insertion plan is then drawn up on the basis of the cross-sections determined, see diagrams below. The targeted arrangement of the injection columns is intended to cover the entire transverse profile of the injection body. For this planning step, it is necessary to assume a producible column radius and a necessary overlap between the columns.

For the present project, a diameter of 0.75 m and an overlap of 0.65 m were set.

The planned injection bodies resemble a trapezoid in cross-section and have dimensions of 0.90 m to 3.50 m at the base. The very wide foundations (up to 3.20 m) and the fact that the foundations to be secured could only be accessed from one side in some areas posed a planning challenge. As a result, the grouting work can only be carried out as planned under inclination and in some cases only after the foundations have first been penetrated by means of core drilling.

An important step in the planning process is the implementation of the trial injections. This is the only way to check the column radius assumed in the planning. Only then is the previous planning confirmed or revised. The trial injection is also indispensable for checking the compressive strength of the injection body. Depending on the load from the building, there are requirements for a minimum value. The compressive strength can be controlled by the choice of the cement suspension used and the addition of water and is determined on core samples obtained from the sample injection body.

A third important aspect is the injectability of the subsoil. This criterion can also only be assessed theoretically in the planning process, generally on the basis of the grain distribution of the soil and the binder. Only by trial injections can it be established and proven in a well-founded manner which binder, in combination with the existing subsoil, meets the requirements (diameter, strength, etc.).

In order to be able to draw reliable conclusions from the trial injections, their execution with different grid spacings and injection pressures as well as the use of a cement suspension previously assessed as (theoretically) suitable is planned.

Execution of the injection work

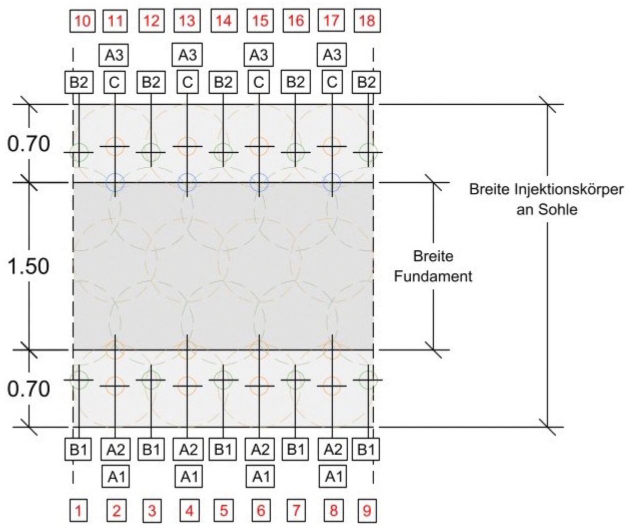
At the time of editing this brochure, the building project in the New Palace was still undergoing the planning and tendering process. The trial injections are currently planned for July 2024. We will keep you informed about further developments and construction site findings.

Reference object

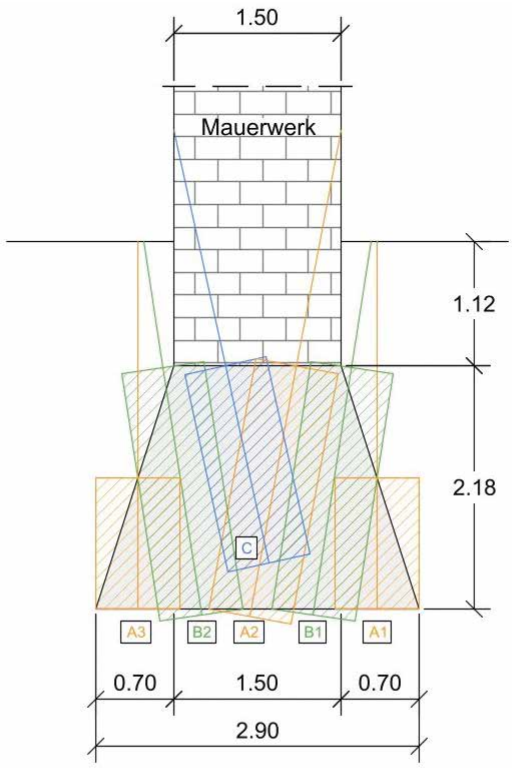
New Palace, Potsdam, construction of an excavation pit shoring by means of grouting under existing foundations

New Palace, Potsdam

Top view



Transverse profile



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