DESOI Ram Injection Lances

Injections into the subsoil

TECHNICAL OPINION

Description and methodology
Basics for planning and execution

In cooperation with Geotechnik Dr. Nottrodt Weimar GmbH

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Technical Opinion
DESOI Ram Injection Lances

Contents

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 by 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 Soil stabilisation with carbamide resins (Lauton) *[5]

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

1953 Schachtbau Nordhausen - Former mining official 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]

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

*[1-9] Page 11: Specialist literature and sources

2. The subsoil consists of two basic types of rock

Hard rock ↔ Loose rock

- The subsoil is a system made up of three substances:
  - Solids (mineral grains / rock)
  - Liquid (mostly water)
  - Gas (mostly air)
- Liquid and gas fill the fissures (rock) or the pore space (soil)
- If the fissures or pores are expanded due to processes (e. g. leaching out, washing out, etc) or are unnaturally enlarged, then we are dealing with cavities in the ground
- The formation or presence of cavities can usually only be seen due to effects on the earth's surface (sinkholes, depressions, etc.) 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

The first successful method for sealing and stabilising the subsoil is the **Joosten method** (patented on 15 August 1926 in Germany)

- Water glass and calcium chloride successively pressed together (gelling)
- The reaction occurs abruptly

2.2 Types of injection

Filling Injection

- Injection for filling existing fissure and pore systems
  - Sealing
  - Stabilising solid and loose rock (formation of coherent grout)

Important: Continuous flow of the filler, pressure 5 – 10 bar

Compaction groutingw

- Injection to fill an artificially created cavity
- The cavity is filled with grout and compacted

Goal

- Increasing the load capacity of loose rock
- No connected injection objects

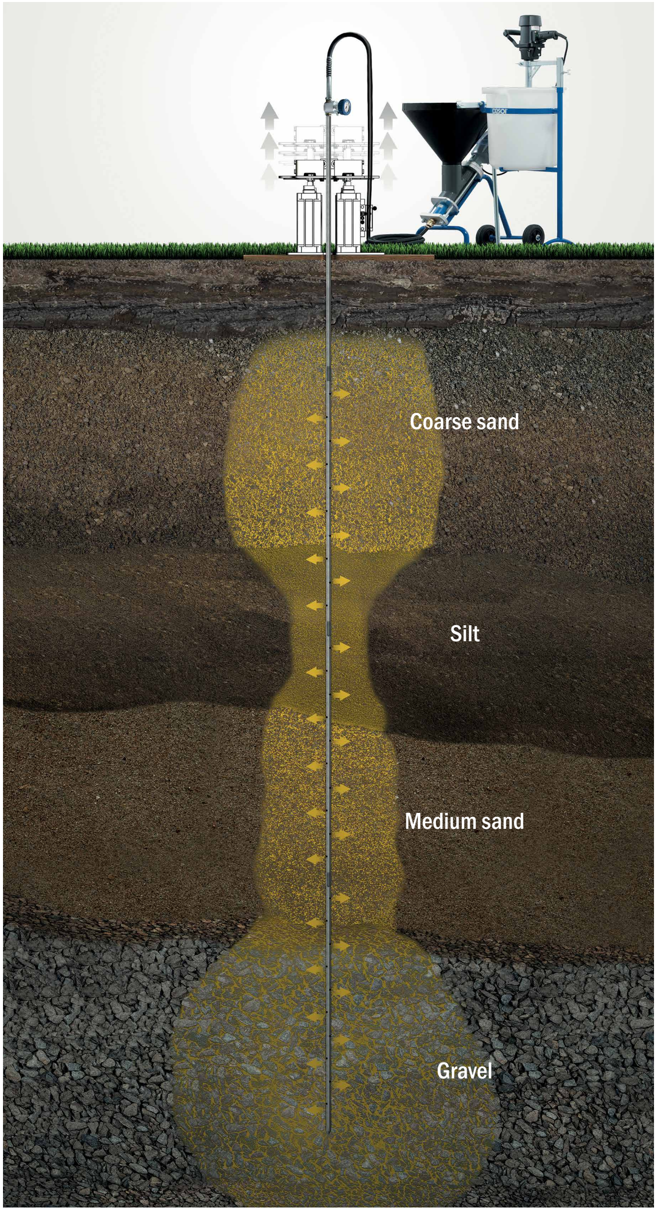
Pressure: up to 2 MN/m² – 20 bar

2.3 Use of the process with ram injection lances

- Soils consisting of fine sands and silty fine sands
- Grout: cement suspension, acrylic gel
- With compaction grouting, the cement objects do **not** need to touch
- Ram injection lance distance: 0.5 – 1 m
- In compression zones
  Pressure: approx. 0.5 MN/m² – 5 bar
  Injection rates: 2 – 3 l/min at the beginning
  1 – 1.5 l/min at the end

Note

- Too high pressure splits the environment (the granular structure of the soil)
- Material escapes from the annular gap when the pressure is too high



3. Theory of injection into the subsoil

Prerequisites

- Cavities are filled with grout
- Complete filling is possible if the cavities are interconnected
- Grout penetrates from the drill holes into the fissure and pore system
- The grout keeps flowing due to the injection pressure.
  "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 = elevations on the surface or shifts. The material escapes from the annular gap.

3.1 Flow and solidification behaviour of the grout

Flow and solidification behaviour of all grouts are characterised by **viscosity** and **flow limit** , e.g. Marsh funnel.

1 litre of cement suspension: approx. 25 – 30 seconds
(water: 20 – 25 seconds)

3.2 Injection pressure recommendations

Goal

Merging or overlap of adjacent injection regions

Recommended injection pressure and injection speed

- Maximum allowable pressure which must not be exceeded
- Depends on the injection range
- Increase pressure slowly
- Maintain pressure for several minutes (absorption capacity of the fissures and pores)

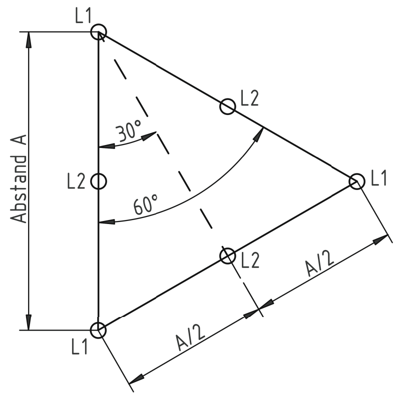
3.3 Trial injections

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

Objective of the trial injection

- Investigating technical details
- Defining piling procedure / piling technique
- Determining and documenting the injectability of the subsoil
- Recording the findings in the preliminary remarks of the service specifications / contract conditions

Arrangement of ram injection lances for a trial injection



*Based on Kutzner *[21]*

- Possible water testing
- Then fill the ram injection lances with cement suspension
- Test with core drillings

Findings from the trial injection

- Basic suitability of the method
- Appropriate clearance for the ram injection lances
- Determine draw-up pressure and appropriate injection pressure
- Determine the injection material absorption and possible relation to the water absorption

3.4 Injection time

Is linked to viscosity development of the grout,

- to injection pressure,
- to the desired or achievable range

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
- 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 (and 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 at least for the following parameters:
  - local designation
  - grain size distribution
  - mass fraction of stones and blocks
  - water content
  - plasticity number
  - consistency number
  - storage density
  - soil group
  - possibly also pore fraction and permeability coefficient

→ Environmental chemistry investigation of the soil and water, depending on the intended grouting

→ If necessary also using geophysical methods for the spatial cavity search

“Savings” in subsoil investigations have
quite often led to

- Construction complications
- Cost overruns
- Accidents
- Abandoning the construction work (H. Jähde 1953) * [22]

Note

Soil and rock classes as per VOB/contracting rules for award of public works (2012 and earlier) are invalid.

4.3 Notes on homogeneous areas (from ATV DIN 18304 - 2015)

“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.”

Spread of grout

5. Planning of injection work (subsoil injection)

Goal

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

  -**Sealing loose rock**

  - Producing a grouted bottom
    - Producing a grout curtain
    - Special solutions, such as sealing a trench bottom for laying pipelines

-**Stabilising or improving loose rock**

- Underpinning constructions or components
- Stabilising or improving subsoil (increasing subsoil load-bearing capacity before the construction or in the context of renovation)
- This calls for break-up injections due to the high pressures required (to offset subsidence)

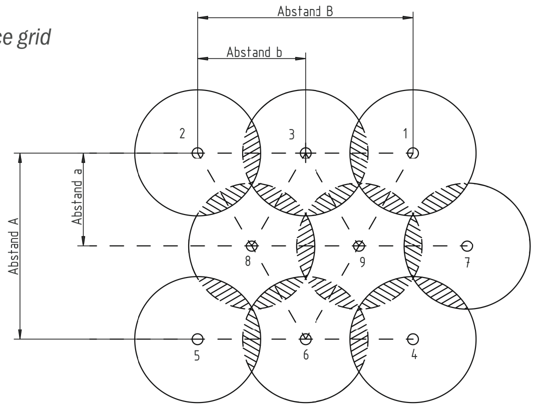
5.1 Recommended arrangement of ram injection lances

- 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 m for shallow injection holes
- Adjacent rows are to be staggered

Lance grid



Suggested arrangement of ram injection lances

5.2 Notes on carrying out injection work

Basics

- Introducing the ram injection lances
- Producing the injection body

The advantage of ram injection lances:

Costs for piling are significantly lower than for the drilling. Ram injection lances can be used repeatedly (several times).

5.3 Notes on the procedure for using ram injection lances

Ascending injection "from the bottom up"

- Advance the lance to the target depth
- Carry out injections from the bottom up for each section
- With lost tip

Selecting the method based on geological conditions.

5.4 Instructions for grout / injection substances

The goal of subsoil injections

- Sealing
- Stabilising / improving

injection grout

- **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 – 100µm, e.g. suspensions of water and cement/ aggregates, such as binders
- **Emulsions**
  - Mixtures of two or more liquids with different properties 1 – 10 µm, e.g. emulsions of bitumen and water / resin and rubber emulsions

Grout selection → depends on the size and volume of the pores and fissures.

Note:

Generally finer grouts that fit into the pores and fissures

Injection mortar

Cement suspension plus sand additive for large cavities or fissures.

Suspensions based on cement

- Crucial:
  - High grinding fineness
  - Grain size distribution max. 0.1 mm, 90 % of cement grains smaller than 0.05 mm
- Squeeze out excess water
- Flow properties are crucial
- Take into account sediment behaviour

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

Long-term tests positive since 1937 - in Nordhausen [7] or [8] no fatigue or solidification in a selected object, tested again in 1956

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

- The injection body is always below the ground surface
- DESOI w.i.l.m.a.
  -Data on the quantity of injection material constantly documented
  -Permanent control during production!

Advantages for designers and builders

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 corresponding machine technology is reliable, robust, tried and tested in practice and provides a high degree of design reliability.
On request, the system can be equipped on a project- and use-related basis.

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

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

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
- The injection body's environment is checked and documented

6. Notes on environmental compatibility

- Investigations since 1981, see pp. 272/273 in Kutzner [21]
- Structures investigated
  - Berlin subway H 110
  - Mendelsohn Bau Berlin
  - Hamburg Allermöhe
  - Vienna subway 3/5

6.1. Current regulations in Germany

DIBt Section II 6

Requirements for construction works with regard to the effects on soil and water (ABuG), version 16.12.15

Water Resources Act (WHG)

§ 9 (1) 4 Uses

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

§ 49 Soil exploration

- The water authority or environment agency must be notified of planned subsoil injection works about a month before they begin.

§ 62 Principle of Prevention

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

Construction contract and tendering

The tender is the foundation and eventually the main component of a construction contract.

VOB standards that must be observed (amended version 2015) for injections with ram injection lances

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

7. Conditions for the object description / tender

- The prospective construction must be described in a way that the provider 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 currently not sufficiently known

7.1 Tendering injection work

- Service and construction description
- General contractual conditions
- Technical implementation provisions
- Service specifications

7.2 Recommendations for service description

- Work to be carried out must be described in full
- Include results from completed subsoil investigations
- Evaluate geological, rock, and soil-mechanical reports
- Results of field and laboratory tests and conclusions
- Climate, rainfall, temperatures in the construction area / construction time
- Identify access routes and their status
- Water and energy supply of the construction site
- Disposal conditions for all substances being used
- Groundwater conditions / design water level
- Vegetation and provisions for its protection
  - regional characteristics, location and nature of the building
  - potentially keeping records and documentation
  - document notes and agreements with the builders
  - removal of ram injection lances / hydraulic lance lifters

Recommendation

Do a site inspection in advance with the builders / planners

Suggested priorities for the service description

Injection work in the subsoil

1. Construction site equipment
   - preparation of all drilling/ injection sites
   - office containers, accommodation, toilets, energy supply, etc.

2. Compliance with the requirements of environmental protection / WHG

3. Provision of all equipment, machinery, devices, material, ram injection lances

4. Test drillings for injection purposes at an angle of degree – total depth
   Price per m ______

5. Setting the ram injection lances
   Depth
   ______ Piece Price per piece ______

6. Water pressure tests (contingent position)
   Number
   ______ Price per test

7. Delivery, storage
   Injection material
   ______ kg / t Price per kg ______

8. Preparing and injecting
   ______ kg / t Price per kg ______

9. Waiting times due to
   - Arrangement of ram injection lances, possible obstacles
   - Due to reaction / setting behaviour of the injection substance
     Time / hour Cost per hour

10. Hourly wage
    for specially arranged services
    Time / hour ______

11. Quality control to detect the quantities injected, injection pressure, injection time

Note

Property-dependent elevation measurements

7.3. Invoicing basis

- Construction site equipment / flat-rate billing
- Site clearance
- Provision of devices, technology in accordance with time/ days
- Drilling and pile driving work by metres, piece
- Possible packer placement, billing per piece
- Possibly necessary water testing / water pressure testing as per time expenditure/piece
- Injection, invoicing according to injection hours and by weight or volume of the injected materials
- Removal of the ram injection lances
- Reports, DESOI w.i.l.m.a. - Diagrams

7.4. 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; do this selectively on vulnerable parts of the structure (e. g plug gauges, horizontal inclinometers) or continuously, e.g. in the injection area using fibre optic sensors, for instance; possibly measure at trial injections

9. Specialist literature and sources

In the specialist literature in Germany, practical knowledge and experience have been documented for over 70/50 years as "injections in the subsoil" (e.g. Jähde / Kutzner) [21] and [22]:

- 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

[1] Maus, H.: Über die Anfänge der Technik des Verpressens von Zement bei Mauerwerksbauten. In: SFB Jahrbuch 1987, S. 101 – 104

[2] Blum, H.: Die Trockenlegung nasser Tunnelgewölbe und Widerlager. In: Centralblatt der Bauverwaltung, 1890,10

[3] Wolfsholz, A.: Wiederherstellung der gewölbten Eisenbahnbrücken über den Mittel- und Südkanal in Hamburg mittels Zementeinpressung. In: Zentralblatt der Bauverwaltung 30 Jg. (1910), S. 359 – 360

[4] Rüth, G.: Wiederherstellung und Sicherungsmaßnahmen am Dom in Nordhausen. In: Die Denkmalpflege. München 1931, Nr. 2/3, S. 76 – 83

[5] Dr. Rgjanitsyn B. A.: Die chemische Befestigung des Bodens im Bau", Bauverlag Moskau, 1986

[6] Deutsche Reichsbahn: Abdichtung von Ingenieurbauwerken AIB, erschienen: 15.07.1931 Deutsche Bundesbahn – Nachdruck November 1949 – mit Berichtigungsblättern

[7] Fachbuch „Schachtbau Nordhausen - Firmengeschichte Band 1, 2003 - S. 22

[8] Fachbuch „Schachtbau Nordhausen - Firmengeschichte Band 1, 2003 - S. 67

[9] STUVA: Abdichten von Bauwerken durch Injektion - Fraunhofer IRB Verlag Oktober 2014

[10] Idel: Injektionsverfahren – Kap. 2.2 in GRUNDBAUTASCHENBUCH, T.2 Ernst & Sohn 1991

[11] Bachelorarbeit FH Erfurt, eingereicht von Steffen Graf „Baugrunduntersuchungen für die Anwendungspraxis von Bodeninjektionen" (Rammverpresslanzen), 28.01.2013

[12] DIN EN 12715:2000-10 (Deutsche Fassung) Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Injektionen

[13] VOB Teil C Beuth Verlag: Allgemeine Technische Vertragsbedingungen für Bauleistungen (ATV) Einpressarbeiten – DIN 18309:2015-08

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[15] Prof. Dr.-Ing. Sylvia Stürmer, B + B, 5.2014, S. 25, Verbinden, was auseinander strebt

[16] Prof. Dr.-Ing. Carsten Schlötzer, Der Bausachverständige, Injektionen im Baugrund zur Sanierung und Bestandsicherung, Detmold 2007

[17] Dr.-Ing. Vladimir Kozlovskii, St. Petersburg State Transport University, 190031 St. Petersburg - Fachvorträge

[18] DIBt Bekanntmachung des Entwurfs der „Anforderungen an baulichen Anlagen bezüglich der Auswirkungen auf Boden und Gewässer" (ABuG) Entwurf 16.12.2015

[19] DESOI GmbH, Kalbach, Fachprospekt „Bodeninjektion mit Rammverpresslanzen", 2018

[20] DESOI GmbH, Kalbach, Fachprospekt „DESOI W.I.L.M.A. - Aufzeichnung und Dokumentation von Injektions- und Dosierprozessen", 2022

[21] Verlag Enke, Christian Kutzner „Injektionen im Baugrund"

[22] VEB Verlag Technik Berlin, H. Jähde „Injektionenen zur Verbesserung von Baugrund und Bauwerk"

9. Reference object

9.1 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 (series "PROWA").

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 bottom of the container is about 1.50 metres above the ground. 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 Märtin, 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

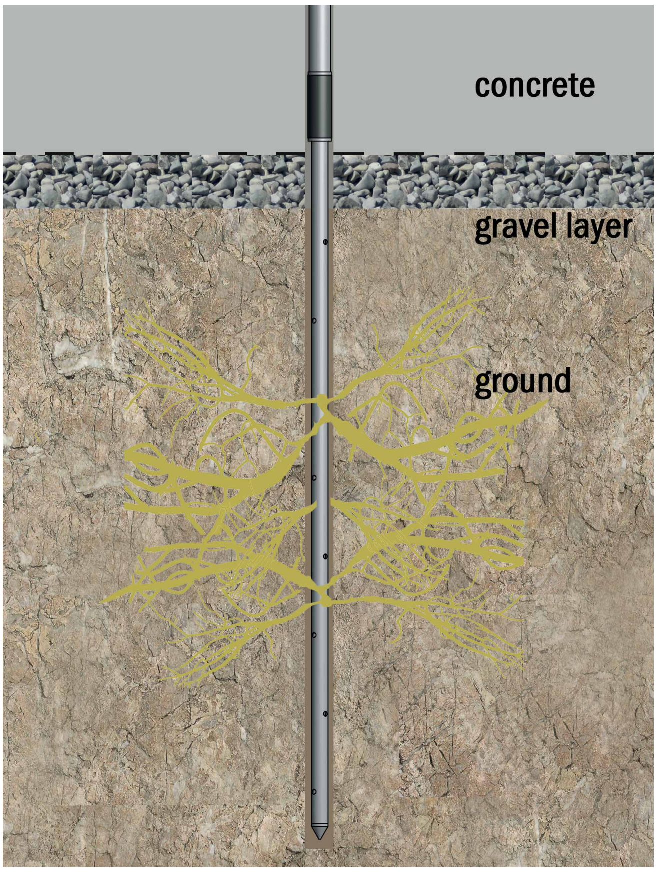
Following the acceptance of the construction work with a positive leakage test after filling the tank, the restructuring measures, incl. ground stabilisation by means of the ram injection lance, were completed successfully.

Reference object

Drinking water tank “Industriepark Schwarze Pumpe” – injection with ram injection lances

Drinking water tank “Schwarze Pumpe”

Drinking water tank "Schwarze Pumpe”



Use of ram injection lances (Photo: Desoi)

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9.2 Gas pipeline construction

Anklam / Groß Polzin 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 the Peene, near the nature reserve in Groß Polzin. The geological structure included on 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 of the Peene. 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 balanced out by a greater amount of supporting fluid with higher pressure at the same time. 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 crater was neither pressure-tight nor was it able to hold the supporting slurry fluid. It had to be sealed and solidfied using an additional measure on the ground in front of the tunnel face. A particular challenge in finding solutions was the lack of logistics and the requirement to use neither large appliances nor environmentally unfriendly injectables. 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 (DESOI PN-1412-3K) 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 (DESOI PN-2036-2K), out of the tunneling 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 slurry pressure could be increased once again and the machine could continue its work.

Reference object

Gas pipeline construction in the Anklam / Groß Polzin nature reserve - backfill sealed with injections via ram injection lances

Groß Polzin Nature Reserve

Installation of ram injection lances

Introduction of the ram injection lances with the ram hammer (photos: Desoi)

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